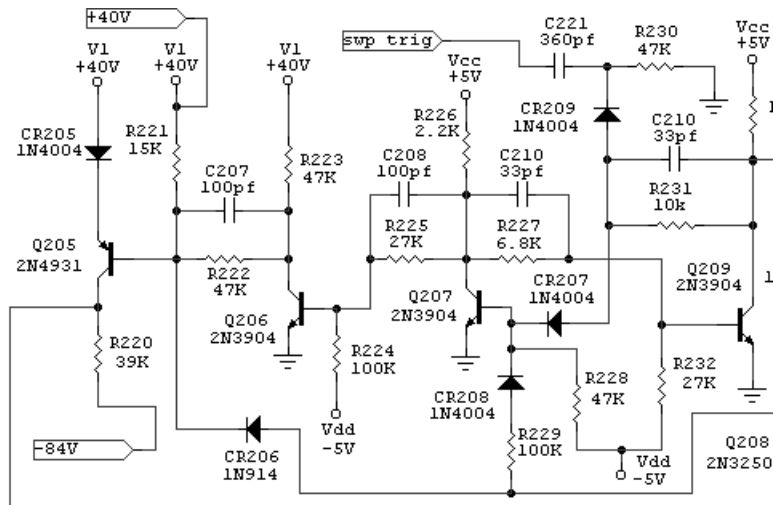


CircuitMaker[®] *for Windows*

**Integrated Schematic Capture
and Circuit Simulation**



User Manual

**CircuitMaker 6
CircuitMaker PRO**

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CHAPTER 1

Welcome to CircuitMaker

Introduction

Welcome to CircuitMaker, the most powerful, easy-to-use schematic capture and simulation tool in its class! Thank you for joining thousands of users who have discovered that CircuitMaker provides the features of "high-end" design software at a *fraction* of the cost.

Using CircuitMaker's advanced schematic capabilities, you can design electronic circuits and output netlists for TraxMaker and other PCB design tools and autorouters. You can also perform fast, accurate simulations of digital, analog and mixed analog/digital circuits using CircuitMaker's Berkeley SPICE3f5/XSpice-based simulator.

Required User Background

With just a minimum of electronics theory, you can successfully use CircuitMaker to design and simulate circuits. For beginners, CircuitMaker is perfect for learning and experimenting with electronics and circuit design. For advanced users, CircuitMaker's powerful analyses provide a sophisticated environment for testing and trying all the "what if" scenarios for your design. Best of all, you can accomplish more in less time than traditional prototyping methods.

Required Hardware/Software

- IBM® compatible 486 or higher PC with a hard disk drive and a 3½" high density disk drive.
- Math coprocessor recommended (for analog simulation).
- 8M RAM, 15M hard disk space (20M during installation).
- Mouse or other pointing device.
- VGA (or higher) resolution monitor (color preferred).

- Microsoft® Windows 95, Windows NT 4.0 or greater or Windows 3.1x (requires Win32s, a set of operating system extensions which allows some 32-bit applications to run under the 16-bit operating system).

Installing CircuitMaker

- 1 Start your Windows operating system.
- 2 If you are installing from the CircuitMaker CD, insert it into the CD drive and skip to Step 5.

OR

If you are installing with floppy disks, insert Disk 1 into drive A: and continue with Step 3.

- 3 If using Windows 95 or NT4, choose **Start > Run** from the Taskbar.

OR

If using Windows 3.1x, choose **File > Run** from Program Manager.

- 4 Type **a:setup** and press **Enter**.
- 5 Follow the installation instructions.

Warning: If you are reinstalling or upgrading CircuitMaker be sure to install in a different directory to avoid writing over some of your existing work.

If you are installing under Windows 3.1x, you will be prompted to install the Win32s operating system extensions.

- 6 Double-click the CircuitMaker icon to launch the program.
- 7 If you are upgrading from an earlier version of CircuitMaker, see the next section *Updating from a Previous Version*.

Installing the Hardware (HW) Keys

Most copies of CircuitMaker sold internationally (outside the US and Canada) come with a Hardware (HW) key for copy protection. If your copy includes a HW key, this key must be attached to the parallel port of your computer in

order to run the software. If you have any questions, please call MicroCode Engineering Technical Support.

Updating from a Previous Version

While upgrading from a previous version of CircuitMaker is a relatively painless process, you should take care when converting custom macro libraries and simulating existing circuits. When you load a pre-4.0 circuit file (identified by the .CIR extension), it will automatically be converted to the newer ASCII file format (which uses the .CKT extension).

If you have not added components to the library, simply follow the instructions above in *Installing CircuitMaker*. The new version will be installed in a new directory and you can delete the previous directory.

If you have added new device symbols to the macro library, see *Updating 32-bit Macro Libraries* or *Updating 16-bit Macro Libraries* below.

If you have added new SPICE models, see *Updating Model Libraries* below.

Warning: Be careful not to discard or overwrite your previous work.

Updating 32-Bit Macro Libraries

If you are upgrading from a 32-bit version of CircuitMaker and have created your own macro devices or symbols, follow these steps:

- 1 Install the new version of CircuitMaker as described earlier. Remember to install the new version in a different directory to avoid writing over your existing work. Run CircuitMaker.
- 2 Select **Macros > Macro Copier**.
- 3 Open the old USER.LIB file as the *Copy From* file. When asked if you want to list only the user defined devices, click Yes.
- 4 Open the USER.LIB file from your new CircuitMaker directory as the *Copy To* file.
- 5 Select the first device that you have created and click on the Copy button. Repeat for each additional device that

you have created. Each device copied will be placed in the new USER.LIB file. You may be prompted for information regarding the simulation mode for which a device is intended. If the device can be used in digital simulations, check the Digital box; if it can be used in analog simulations, check the Analog box. If it can be used in either simulation mode, check both boxes.

Updating 16-Bit Macro Libraries

If you are upgrading from a 16-bit version of CircuitMaker and have created your own macro devices or symbols, follow these steps:

- 1** Install the new version of CircuitMaker as described earlier. Be sure to install the new version into a different directory to avoid writing over your existing work.
- 2** Run the BTOA file conversion utility.
- 3** Select **File > Convert Library**. Open the USER.LIB file from your previous CircuitMaker directory. Save the new file as USERLIB.ASC.
- 4** Run CircuitMaker.
- 5** Select **Macros > Convert ASCII Library**. Load the file USERLIB.ASC that you just created. Save the new file as NEWUSER.LIB.
- 6** Select **Macros > Macro Copier**.
- 7** Open the NEWUSER.LIB file as the *Copy From* file. When asked if you want to list only the user defined devices, click Yes.
- 8** Open the USER.LIB file from your new CircuitMaker directory as the *Copy To* file.
- 9** Select the first device that you created and click on the Copy button. Repeat for each additional device that you have created. Each device copied will be placed in the new USER.LIB file. You may be prompted for information regarding the simulation mode for which a device is intended. If the device can be used in digital simulations, check the Digital box; if it can be used in analog simulations, check the Analog box. If it can be used in either simulation mode, check both boxes.

Note: Importing of bitmaps and unconverted metafiles is no longer supported for creating devices in CircuitMaker. If you have created devices of this type, the symbol will not be available in CircuitMaker 6 or PRO (the symbol will be replaced by a rectangle). These symbols may be redrawn with the Symbol Editor.

Updating Model Libraries

If you have added or modified any of the .MOD, .SUB or .LIB files from a previous version, you must make these same additions or modifications to the files in the new Models directory. *Since many of these .MOD, .SUB and .LIB files in CircuitMaker 6/PRO contain new information added by MicroCode Engineering, it is recommended that any changes you made previously be done manually (don't just copy your old file over the top of the new one), to avoid any possible loss of data.*

If you have created any user-defined symbols to which SPICE models have been linked, you must remember that each of these user-defined symbols has a corresponding .MOD or .SUB file. Be sure to copy these files into the new Models directory.

If you have used CircuitMaker's automatic linking feature (accessed through the Model Data button in Macro Utilities dialog box) to link a symbol to a user-added SPICE model in a .LIB file, you must do one of two things:

- 1 Reenter the information using the Macro Utilities dialog box just like before.

OR

- 2 Copy the linking information that was automatically placed in the .MOD or .SUB files into the new files. This information would usually be located at the end of the .MOD or .SUB file that corresponds to the symbol.

Updating Pre-5.0 Digital Circuits for Analog Simulation

Digital circuits created in pre-5.0 versions of CircuitMaker will still run in Digital Logic Simulation mode. However, if you want to run them in Analog Simulation mode, you should be aware of the following:

- Analog is not a free-running simulation mode.
- Analog simulations require proper use of Vcc and Ground connections to digital devices.
- Analog simulations require designations of all devices.
- The digital devices saved in old circuits do not contain SPICE data for simulation. These must be replaced by new digital SimCode devices. To do this, delete the existing devices and replace them with new devices from the current library.
- The Pulser is a digital only device. It must be replaced by a Data Sequencer or a Signal Generator.
- Devices which are animated in Digital Logic Simulation mode are not animated in Analog Simulation mode.

Multi-User (Project) Installations

You can configure CircuitMaker to support “Projects” for multiple users, each user having access to separate libraries and preferences. Project installations are possible whether on a network or on a stand-alone system. Each user must be assigned a separate directory from which the CircuitMaker preferences, libraries and circuit files can be accessed. This same method may be used by a single user who needs to access multiple projects, each with separate libraries and preferences.

Note: A site license is required for network installation.

Setting Up Multiple Projects

- 1 Install and run CircuitMaker as described above to initialize the default file paths, then exit.
- 2 Create a separate directory for each user or project.
- 3 Place a copy of the Cirmaker.dat file in each user’s project directory. This file contains the Preferences data which allows each user to specify their own circuit and library paths and other circuit and program preferences.
- 4 If a user will need to make modifications or additions to the Macros library (changes that must not affect other users), place a copy of the USER.LIB, DEVICEDB.DAT, SYMBOLDB.DAT and HOTKEYSDB.DAT files into that user’s project directory. The DEVICEDB.DAT,

SYMBOLDB.DAT and HOTKEYSDB.DAT files must always be placed in the same directory as USER.LIB.

- 5 If a user will need to make modifications or additions to the SPICE models or subcircuits, place a copy of the entire Models directory into that user's project directory.
- 6 If accidental modification of files which are common to multiple users is a concern, see your network administrator for details on how to protect these files from modification.
- 7 In Windows 95/NT4, Right-click the Start button and select **Open**. Browse to the CircuitMaker icon, right-click it, and Select **Properties**. Click the Shortcut tab.

OR

From the Windows 3.1x Program Manager, click once on the CircuitMaker icon to select it. In Program Manager, select **File > Properties**.

- 8 Add the word "PROJECT" onto the string in the Target edit field. For example:

```
"c:\...\cirmaker.exe" project
```

then click OK. This enables the Select Project dialog box (explained later in this section).

- 9 Run CircuitMaker.
- 10 The Select Project dialog box appears, allowing you to find the individual project directories. Browse the directories to find one individual's Cirmaker.dat file and click OK.
- 11 When CircuitMaker has loaded, select **File > Preferences**, then click **Directories and Files**.
- 12 Change the Circuit Directory path to that of the project directory. This is where that individual's circuit files (*.CKT) will be stored.
- 13 If there is a copy of the User.lib file in the project directory, change the User Library File path to that of the individual's directory. This allows the individual to make changes/additions to the Macros library.

- 14 If there is a copy of the Models directory in the project directory, change the Model Directory path to that of the individual's directory. This allows the individual to make changes/additions to the SPICE models and subcircuits.
- 15 Click OK to exit the Directories and Files dialog box; then click OK in the Preferences dialog box to save these changes.
- 16 Exit CircuitMaker.
- 17 CircuitMaker is now completely configured for one user. Repeat steps 9-16 to configure CircuitMaker for each individual user.

Accessing a Project

- 1 Run CircuitMaker.
- 2 The Select Project dialog box appears, allowing you to find your personal project directory. Browse the directories to find your CIRMAKER.DAT file and click on the OK button.

Technical Support

MicroCode Engineering, Inc. is dedicated to producing only the finest quality software and supporting customers after the initial purchase. If you encounter problems while using CircuitMaker or just need general help, contact us via phone, FAX, electronic mail or US Mail and we'll provide prompt and courteous support.

NOTE: Please be prepared to provide your name and registration number (found on the back of the User Manual, Disk 1, or the CD jacket) when contacting us.

Telephone:	(801) 226-4470
FAX:	(801) 226-6532
Internet:	http://www.microcode.com
Email:	support@microcode.com

US Mail: MicroCode Engineering, Inc.
927 West Center
Orem, UT 84057 USA

Future versions of CircuitMaker are planned so please feel free to write and let us know what features or additions you would like to see. Our goal is to provide a product that will meet your needs and expectations, so feedback from you the end user is essential!

About the Documentation

CircuitMaker comes with two manuals, a *User Manual* and a *Device Library Guide*. This *User Manual* has been designed to guide you through CircuitMaker's many features and simplify the retrieval of specific information once you have a working knowledge of the product. The separate *Device Library Guide* outlines the symbols and device models that are included with CircuitMaker.

The manual assumes that you are familiar with the Windows desktop (3.1x, 95, and NT) and its use of icons, menus, windows and the mouse. It also assumes a basic understanding about how Windows manages applications (programs and utilities) and documents (data files) to perform routine tasks such as starting applications, opening documents and saving your work.

Manual Conventions

The following conventions are used to identify information needed to perform CircuitMaker tasks:

CircuitMaker PRO only

Note that this manual contains information for both CircuitMaker Version 6 and CircuitMaker PRO. Those features described in this manual which are only available in CircuitMaker PRO are highlighted by the banner at the left.

Step-by-step instructions for performing an operation are generally numbered as in the following examples:

- 1 Choose **File** > **Save**.

This means "choose the **File** menu, then choose **Save**."

- 2 Select the **Arrow Tool** on the Toolbar.

Notes, Hints and Tips are written in the margins for better visibility.

Menu names, menu commands, and Toolbar options usually appear in bold type as are text strings to be typed:

3 Type the Label-Value: **220K**.

This manual also includes some special terminology—words that are either unique to schematic capture and circuit simulation or have some specific meaning within CircuitMaker. Such terms are italicized when first introduced.

Using On-line Help

You can access CircuitMaker's on-line Help file (CIRMAKER.HLP) in several ways.

From the Help Menu

To access Help from the Help menu,

- 1** Choose **Help > CircuitMaker Help Topics**.
- 2** Choose the **Contents** tab to see an overview of all Help topics arranged hierarchically.

OR

Choose the **Index** tab, then enter a keyword to look up a specific Help topic.

OR

Choose the **Find** tab to find Help topics that contain the word you are looking for.

From a Dialog Box

To access context-sensitive Help,

- 1** Open a dialog box, then press **F1** to display Help specifically tailored for that dialog box.

From the Toolbar

To get context-sensitive Help about a particular device or item you have placed in the work space,

- 1** Click the **Help** button on the Toolbar.
- 2** Click the item.

From the Help File Directly

Even when CircuitMaker is not running, you can view the Help file by double-clicking its icon in the CircuitMaker program group.

Watching the On-line Tutorial

For a quick overview of CircuitMaker, double-click the CM Tutorial icon. The ScreenCam demonstrations illustrate the major areas of schematic drawing and simulation.

Where to Go from Here

Once you have mastered a few Windows basics, you'll be ready to learn CircuitMaker. Use the following table to help you get around this User Manual.

Topic	Where to Go
CircuitMaker Basics	Chapters 2, 3
Drawing and Editing Schematics	Chapter 4
Simulation	Chapters 5, 6
Exporting Files	Chapter 7
Fault Simulation	Chapter 8
CircuitMaker Menus	Chapters 9–14
Advance SPICE Tips	Chapter 15
Creating New Devices	Chapter 16
SimCode	Chapter 17

CHAPTER 2

Getting Started

CircuitMaker Basics

This chapter gives you an overview of the CircuitMaker workspace, conventions, preferences, shortcuts, and HotKeys. It's a great place to start if you need some guidance before using CircuitMaker to draw, edit, test, and simulate electronic circuits.

Starting CircuitMaker

If you have installed CircuitMaker on your hard disk, you're ready to run the program.

- 1 Open the **Start** menu.
- 2 Choose **Programs > CircuitMaker 6 or CircuitMaker PRO**.
- 3 Choose the **CircuitMaker** program.

You can also create a shortcut for CircuitMaker and have the icon display on your desktop all the time.

CircuitMaker Workspace

When you start CircuitMaker, the blank workspace appears. This is where you place devices that represent real life components such as resistors, transistors, power supplies, etc. The CircuitMaker workspace also includes the Toolbar, Menu Bar, and special windows for circuit simulation and testing purposes.

After placing devices exactly where you want, you simply wire them together. The wiring lines you draw form intelligent links between devices, which then allow the circuit to be simulated, tested, and analyzed using CircuitMaker's powerful simulator. Figure 2.1 shows the CircuitMaker workspace filled in with the Drawing Window and several analysis windows.

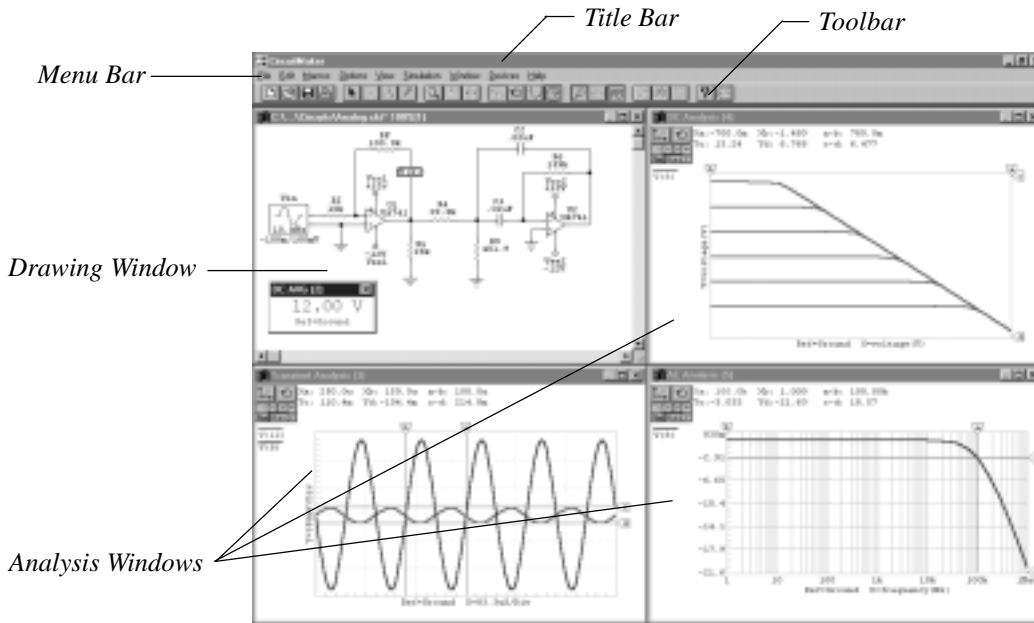


Figure 2.1. The CircuitMaker workspace.

Connectivity

An important feature of CircuitMaker is the way electrical connections between the elements in your design are recognized.

The concept of *connectivity* is the key to using CircuitMaker to draw and simulate electronic circuits. The program stores connection information for simulation, and it is also used for creating and exporting *netlists* into TraxMaker or other pcb layout programs to create a working printed circuit board (PCB).

About CircuitMaker Windows

In addition to the Drawing window, CircuitMaker offers several other windows, most of which display information and waveforms for analog and digital simulations. During simulation, the windows for the selected analyses appear, showing waveforms and simulation data. Multiple analysis windows can be open simultaneously; however, only one window of each of analysis type can be open at a time.

Anatomy of a Schematic Drawing

Figure 2.2 shows a basic schematic, including device symbols, label-values and designations, wires, and pin dots.

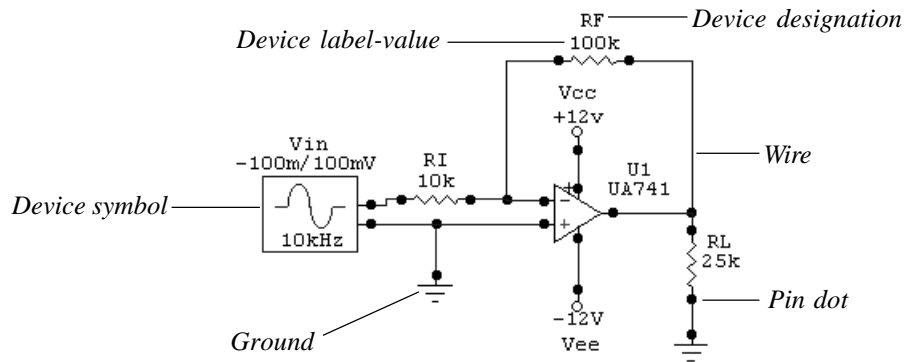


Figure 2.2. CircuitMaker's straightforward approach makes it easy to identify each part of a schematic drawing.

CircuitMaker Conventions

If you are experienced with Windows applications, you already know how to start and quit CircuitMaker, select menus using the mouse, save your work, and locate and organize your documents. On the other hand, CircuitMaker has special features that are not common to other Windows applications. These options let CircuitMaker perform some of the special tasks unique to circuit design.

CircuitMaker Files

CircuitMaker includes a number of special purpose files in addition to the CircuitMaker application. The following table lists the various types of files you will use by file extension.

.CKT	Schematic (or Circuit) files
.DAT	Data files (HotKeys; device library classifications)
.LIB	Device library files
.SRP	Script files
.MOD	Model files
.SUB	Subcircuit files
.RAW	Simulation data files

Accessing Tools and Features

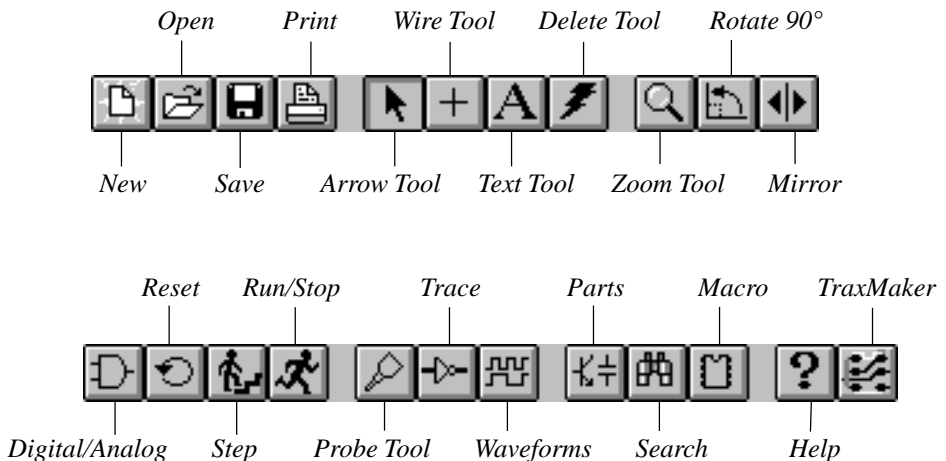
This section shows you the fundamental tools and processes used to draw schematics.

Task Overview

Using CircuitMaker involves six basic procedures: 1) *placing* devices (such as resistors, transistors, power supplies, and grounds) in the workspace; 2) *repositioning* devices; 3) *editing* devices with precise values and parameters; 4) *deleting* devices (if necessary); 5) wiring devices together; 6) *simulating* and *testing* the circuit.

Using the Toolbar

You can perform most CircuitMaker tasks using the buttons on the Toolbar, which is conveniently located at the top of the workspace.



The table on the following page briefly describes each button and tool on the Toolbar. Generally, a Tool lets you apply a specific action, whereas a Button performs a general function. For more details about the drawing and editing tools, see *Chapter 4: Drawing and Editing Schematics*. For more information about the simulation tools, see *Chapters 5: Digital Logic Simulation* and *Chapter 6: Analog/Mixed Signal Simulation*.

Tool or Button	Lets You
Arrow Tool	Select, move and edit devices, wires and text. Also used to place wires (when Arrow/Wire option is checked).
Wire Tool	Place wires to connect devices in the circuit (+Shift to place bus wires).
Text Tool	Add text to the circuit.
Delete Tool	Delete devices, wires and text (+Shift to snip wires).
Zoom Tool	Magnify and reduce the circuit (+Shift to reduce).
Rotate 90°	Rotate one or more selected devices.
Mirror	Mirror one or more selected devices.
Digital/Analog	Toggle between Digital or Analog simulation mode (AND Gate = Digital, Transistor = Analog).
Reset	Initialize analog and digital simulations.
Step	Single-step digital simulations (Setup in Digital Options).
Run/Stop	Run and stop simulations.
Probe Tool	Observe/plot data at any point(s) in the circuit (context-sensitive).
Trace	Interactively see the logic state of all nodes in Digital simulation mode.
Waveforms	Show digital waveforms (in Digital simulation mode).
Parts	Display and select devices from the graphical parts browser.
Search	Search for devices in the library by name/number.
Macro	Create a new macro or expand a selected macro.

Help Tool	Display information on devices and wires.
TraxMaker	Automatically create a PCB netlist and launch TraxMaker.

Using the Mouse

As in other Windows applications, CircuitMaker uses the mouse for clicking, selecting and dragging. When moving the mouse, a corresponding selection tool (or cursor) movement occurs on the screen.

The familiar “pointer” **Arrow Tool** is used for standard Windows operations, such as choosing from menus and dialog boxes.

You can return to the standard **Arrow Tool** at any time by selecting the tool from the Toolbar, or right-clicking on the schematic background and selecting **Arrow**.

Right-Click Pop-Up Menus

You can right-click (click with the right mouse button) in different areas of the CircuitMaker workspace to open various pop-up menus (see Figure 2.3). The items listed in the pop-up menu vary depending on where you right-click. The following locations and circumstances will each access a different pop-up menu:

- Schematic background
- Device
- Wire
- Text object created with the Text Tool.
- Group of selected items (pop-up menu depends on types of items that you select)
- Waveform label
- Anywhere else in Waveform window

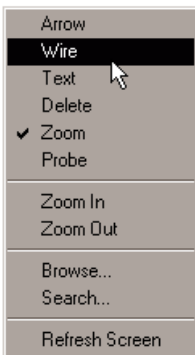


Figure 2.3. Right-click the mouse on different areas to access many CircuitMaker features.

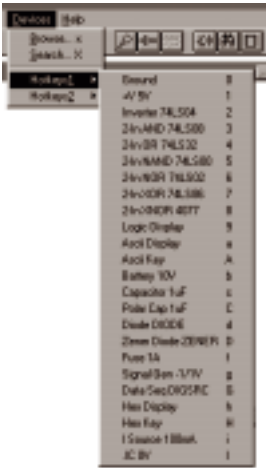


Figure 2.4. Use HotKeys to quickly select devices. You can customize HotKeys to fit your needs.

HotKeys

For quick and easy device placement, CircuitMaker offers up to sixty user-definable HotKeys that let you place commonly-used devices with a single keystroke.

For example, press the **r** key (lowercase “r”) to get a 1K resistor. Or press **b** for a 10V battery. These assignments can be changed and customized so that the parts you use most are right at your fingertips. See *Chapter 4: Drawing and Editing Schematics* to learn how to customize HotKeys.

For a list of all default HotKeys, choose **Devices > HotKeys1** or **HotKeys2**. Figure 2.4 shows the default HotKeys1 list.

Shortcut Keys

Command key or “shortcut” keys let you select menu commands directly. The following table lists the available short cut keys in CircuitMaker.

Keystroke	What it Does
Ctrl+N	Starts a new CKT file.
Ctrl+O	Lets you choose a file to open.
Ctrl+S	Saves the current file.
Ctrl+P	Prints/plots the current file.
Shift+Space	Opens the Script Functions dialog box.
Ctrl+Z	Undo (reverse) an action.
Ctrl+X	Cuts the currently selected item or group of items to the Clipboard.
Ctrl+C	Copies the currently selected item or group of items to the Clipboard.
Ctrl+V	Pastes the currently selected item or group of items from the Clipboard.
Shift+Insert	Moves the currently selected group of items.
Ctrl+D	Duplicates the currently selected item or group of items.
Ctrl+F or End	Refreshes the screen.

Esc	Aborts the current operation.
Page Up	Enlarges the display (zooms in).
Page Down	Reduces the display (zooms out).
Delete	Deletes the current selection.
Home	Centers the screen around the cursor
Tab	Skips to next input item in dialog boxes.
Arrow Keys	Nudges a selected device (by pressing the Left, Right, Up, or Down Arrow keys).

CircuitMaker Preferences

CircuitMaker stores many settings such as program and circuit defaults. You specify preference settings using the Preferences dialog box (choose **File > Preferences**) as shown in Figure 2.5. You can use different Preference settings or reload the factory defaults. See *Chapter 9: File Menu* for more information.

Changing Preferences

- 1 Choose **File > Preferences**.
- 2 Make the desired changes then choose OK.

Restoring Factory Defaults

If your Preferences settings have become confused, you can restore them to the way they were when you first started CircuitMaker.

- 1 Choose **File > Preferences**.
- 2 Choose **Factory Settings** then choose OK.

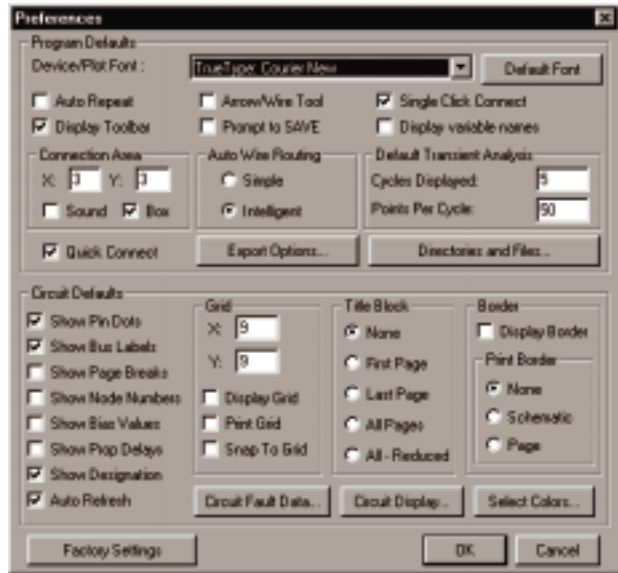


Figure 2.5. Use the Preferences dialog box to manage CircuitMaker settings.

Basic .CKT File Management

This section explains the basic CircuitMaker file management procedures.

Starting, Saving & Closing a .CKT File

The features you will use most often are New, Save, and Save As.

- 1 Choose **File > New** to start a new file.
- 2 Choose **File > Save** if you've already established a filename.

Or

Choose **File > Save As** to give the file a filename. This is the way to copy a .CKT file.

- 3 Choose **File > Close > Yes** to save and exit a .CKT file without exiting CircuitMaker.

OR

Choose **File > Exit > Yes** to exit CircuitMaker and save your work.

Opening and Re-Opening a .CKT File

- 1 Choose **File > Open**.
- 2 Select the file with .CKT extension that you want to open, then choose **Open**.

You can open any of the last 8 .CKT files you've had open.

- 1 Choose **File>Reopen**.
- 2 Select the file you want to reopen.

Reverting to Previously Saved File

If you made changes to a .CKT file that you don't wish to save, you may "revert" to the last version of the .CKT file you saved under the same filename.

To revert to the previously saved file,

- 1 Choose **File > Revert**.

CHAPTER 3

Tutorials

This chapter covers step-by-step processes in the order you would normally perform them. Working through the following examples will provide a general understanding of the way CircuitMaker works and will illustrate that there is often more than one way of doing a task.

Tutorial 1: Drawing a Schematic

This tutorial covers the following topics:

- Using the Device Selection dialog box
- Selecting a transistor
- Selecting resistors
- Selecting a +V and ground device
- Changing resistor and transistor label values
- Wiring the circuit

Using the Device Selection Dialog Box

Drawing a schematic is as easy as pointing and clicking with the mouse. Let's walk through a simple example by constructing the circuit shown in Figure 3.1.

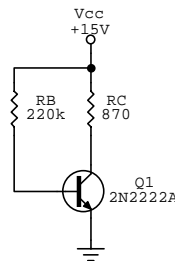


Figure 3.1. This is a very simple circuit that consists of one transistor, two resistors, a power source, and a ground.

New Button



Parts Button



Parts Search Button

- 1 Begin by starting the CircuitMaker program and, if necessary, clearing the workspace by choosing **File > New** or clicking the **New** button on the Toolbar.
- 2 Choose **Devices > Browse** or click the **Parts** button on the Toolbar to display the Device Selection dialog box, pictured in Figure 3.2.

Note: Throughout this tutorial, the location of a device in the library is indicated by its major and minor class and its default HotKey (if applicable) using this format:

[major device class/minor device class] (default HotKey)

For example, a battery is found at [Analog/Power] (b). You can also find devices through hotkeys in the **Devices > HotKeys1** and **HotKeys2** menus. By simply pressing a HotKey (for example, the letter “b”) you can quickly select and insert a device into the workspace.

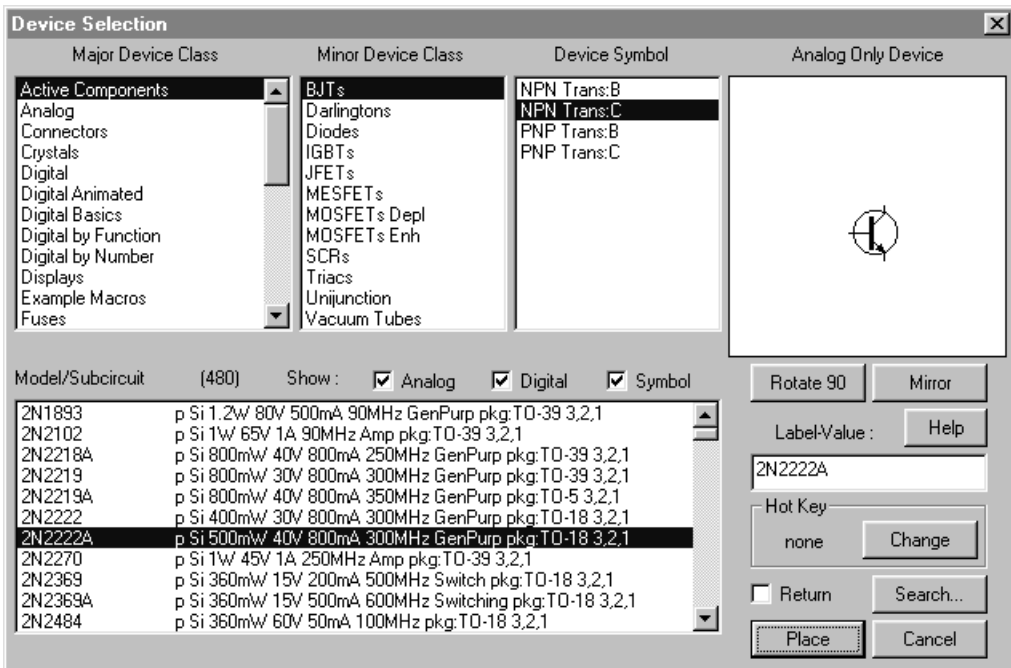
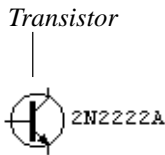


Figure 3.2. Use the Device Selection dialog box to pick a device from a large library of devices. Notice that, in this example, the 2N2222A transistor is selected.

Selecting a Transistor

Begin the circuit by selecting the 2N2222A transistor [Active Components/BJTs].



- 1 Select **Active Components** in the Major Device Class list, **BJTs** in the Minor Device Class list, and **NPN Trans:C** in the Device Symbol list. Select the **2N2222A** transistor in the Model/Subcircuit list.

- 2 Click **Place** to select this device from the library.

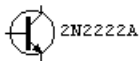
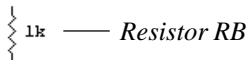
You can also click the **Search** button on the Toolbar, type **2n2222a**, and click **Find** to quickly find the part.

- 3 Position the transistor at about mid-screen and then click the left mouse button once.

Notice that the transistor is placed on the workspace and no longer follows the mouse (see picture at left).

Selecting the Resistors

The next procedure involves placing two resistors.



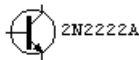
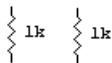
- 1 Choose **Options > Auto Repeat** (make sure the feature has a check mark next to it) or press **Ctrl+R**.
- 2 Select a **Resistor** [Passive Components/Resistors] (r) by pressing the letter **r** on the keyboard. Notice that the resistor is oriented horizontally.
- 3 Press the **r** key again (or click the **Right** mouse button) to rotate the device 90°.

- 4 Drag the resistor above and to the left of the transistor and click the **Left** mouse button once.

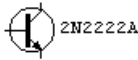
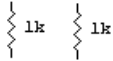
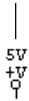
This will be resistor RB. Don't worry about the value yet. Since you enabled the Repeat On feature, another resistor will appear with the same orientation as the previous one.

- 5 Place the next resistor directly above the transistor. This will be resistor RC.
- 6 Another resistor appears. Press any key on the keyboard (except R or M) to delete it.
- 7 Choose **Options > Auto Repeat** and uncheck the Auto Repeat feature or press **Ctrl+R**.

Resistor RC



Voltage device



Selecting +V and Ground Devices

Now you'll place a voltage source and change its settings.

- 1 Select a **+V** [Analog/Power] (1) by pressing the **1** (number one) key. Place it above resistor RC.
- 2 Select a **Ground** [Analog/Power] (0) by pressing the **0** (zero) key. Place it below the transistor.
- 3 Double-click the **+V** device using the **Left** mouse button to open the Edit Device Data dialog box, pictured in Figure 3.3.

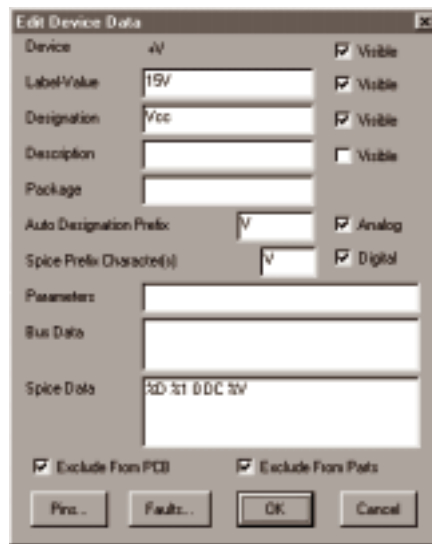
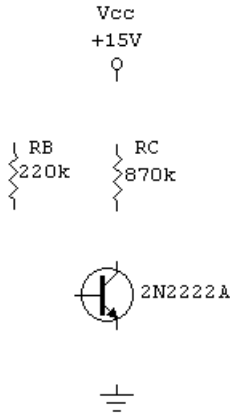


Figure 3.3. The Edit Device Data dialog box lets you change a wide range of device settings.

- 4 Change the Label-Value field to read **+15V**.
- 5 Click once on the **Visible** check box next to the Label-Value field to change the black check mark to a grayed-out check mark. This causes **+15V** to replace the **+V** on the schematic.
- 6 Enter **Vcc** in the **Designation** field and click once in the Visible check box next to it so that there is a black check mark in it. Click OK.

Changing Resistor/Transistor Label-Values

Now try the same editing procedure on the transistor and resistors.



- 1 Double-click resistor RB.
- 2 Change the Label-Value field to read **220k**, enter **RB** in the **Designation** field, make it visible and click OK.
- 3 Double-click resistor RC.
- 4 Change the Label-Value field to read **870k**, enter **RC** in the **Designation** field, make it visible then click OK.
- 5 Double-click the transistor to display the Model Selection dialog box.

Since you have already selected the model that you want to display (2N2222A), just click on the Netlist button to open the Edit Device Data dialog box.

- 6 Enter **Q1** in the **Designation** field and make it visible. Click OK, and then click Exit to return to the schematic.
- 7 If necessary, drag the devices and labels around with the mouse to place them in convenient locations.

Wiring the Circuit Together

Now it's time to hook up these devices into a working circuit by wiring them together.

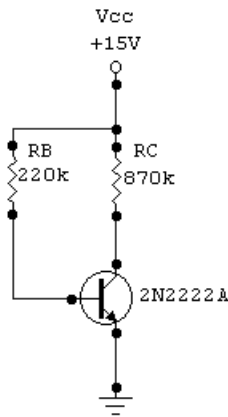


Wire Tool

- 1 Select the **Wire Tool** from the Toolbar (or use the **Arrow Tool** if the Arrow/Wire option is enabled).
- 2 Place the cursor on the emitter pin (the pin with the arrow) of the transistor.

When the cursor gets close to the pin, a small rectangle appears.
- 3 Click and hold the left mouse button, then drag the wire to the pin of the Ground symbol.
- 4 Release the mouse button to make the connection.

If **Options > Show Pin Dots** is enabled, a small dot will be placed at each connection point to verify the connection (see circuit example on the following page).



The completed schematic

- 5 Place the cursor on the bottom pin of RC, and then click and hold the mouse button to start a new wire.
- 6 Drag the end of the wire to the collector pin of the transistor and release the mouse button.
- 7 Connect a wire from the top pin of RC to Vcc.
- 8 Connect another wire from the bottom pin of RB to the base of the transistor.
- 9 Finally, connect a wire from the top pin of RB to the middle of the wire which connects Vcc to RC.

You can move device and wire positions by dragging them with the mouse.

Tutorial 2: Simulating a Digital Circuit

The best way to see how the digital simulation works is to load an example circuit and try some commands.

Open Button



- 1 Click the **Open** button in the Toolbar.
- 2 Select the SIM.CKT file from the list of available circuits.

The SIM.CKT circuit contains several mini-circuits and is useful for demonstrating CircuitMaker's digital simulation features.


- 3 Click the **Run Tool** on the Toolbar to start simulation.


You know that simulation is running when you see a Hex Display showing a count sequence.


- 4 Select the **Probe Tool** from the Toolbar and touch its tip to the wire just to the left of the label "Probe Wire to the Left".

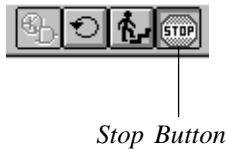
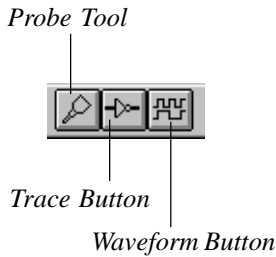
The following illustration describes the meaning of the letters that might appear in the Probe Tool, depending on what part of the schematic you touch with the tool.

 *High State*

 *Pulse (between High and Low States)*

 *Low State*

 *Unknown or Tristate*



- 5 Move the tip of the **Probe Tool** to the Logic Switch labeled “Toggle Switch” and click near its center. The Logic Display connected to the output of this mini-circuit should then start to toggle on and off rapidly.
- 6 Click the **Waveforms Tool** button on the Toolbar to open the digital Waveforms window. Each node in the circuit that has a SCOPE attached is charted in this window.
- 7 Select **Simulation > Scope Probe**.

A new waveform called Probe displays in the Waveforms window. Watch what happens to this waveform as you move the Probe Tool around the circuit.
- 8 Click the **Trace** button in the Toolbar to see the state of every wire in the circuit as the state changes.
- 9 Click the **Stop** button in the Toolbar to stop simulation.

Tutorial 3: Analog Analysis

The best way to get acquainted with CircuitMaker’s analog simulation is to build a few simple circuits, set up the analyses, and run the simulations. This tutorial covers:

- Simple circuit analysis
- Simulating a simple AC circuit
- More circuit simulation
- Setting up the analyses
- Running the simulation
- Mixed-mode simulation

New Button



Digital Simulation



Analog Simulation

Simple Circuit Analysis

Let's begin with a simple DC circuit:

- 1 Click the **New** button on the Toolbar.

This opens an untitled circuit window.

- 2 Click the **Digital/Analog Simulation** mode toggle button.

You know CircuitMaker is in Analog mode when the transistor icon, not the AND gate icon, is visible on the Toolbar (see pictures at left). If the AND gate icon is displayed (Digital mode), click the button to switch.

- 3 Draw the circuit as shown in Figure 3.4, using the following devices:

- 1 Battery [Analog/Power] (b)
- 1 Ground [Analog/Power] (0 (zero))
- 2 Resistors [Passive Components/Resistors] (r)

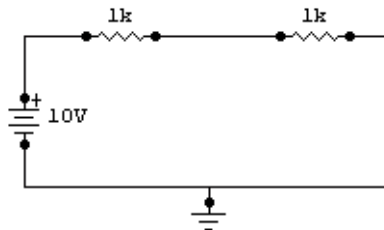


Figure 3.4. A quick way to access the devices for this circuit is to use the HotKey shortcuts (explained in Chapter 2) and type the keys for the corresponding devices.

Note: Every analog circuit must have a Ground and every node in the circuit must have a DC path to ground.

- 4 Use the **Wire Tool** to wire the circuit together (or the **Arrow Tool** when the Arrow/Wire option is enabled).
- 5 Choose **Simulation > Analyses Setup** then click the **Analog Options** button to display the dialog box shown in Figure 3.5.

Wire Tool



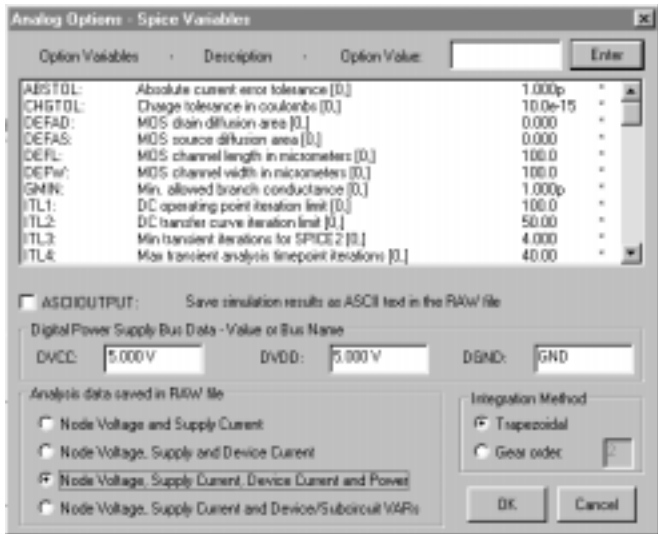


Figure 3.5. The third option (selected) lets you measure voltage, current, and power with the Probe Tool.

- 6 From the **Analysis data saved in RAW file** group box, select the third option, **Node Voltage, Supply Current, Device Current and Power** then click OK to exit Analog Options.

This option lets you to take current and power measurements with the Probe Tool.

- 7 Click the **Run Analyses** button to start the simulation.

OR

Click **Exit** and click the **Run Tool** on the Toolbar.

An interactive SPICE simulation window appears during the SPICE data collection process showing the progress of the simulation. When the SPICE data collection process is completed, the Multimeter Window appears.

Probe Tool



- 8 Click the wire connected to the + terminal of the battery with the tip of the **Probe Tool**. Notice that the letter **V** appears on the Probe Tool when you move it over a wire.

The DC voltage at that node (+10V) appears in the Multimeter Window.

- 9 Click the wire connected between the two resistors.

The DC voltage at that node (+5V) appears in the Multimeter Window. SPICE data is not collected for the Ground node in the circuit; it is always at zero volts.

- 10 Click the + pin of the battery or one of the resistor pins. Notice that an “I” displays on the Probe Tool when it is over a device pin.

The current through that device (5mA) appears in the Multimeter Window.

- 11 Click directly on one of the resistors. Notice that a “P” displays on the Probe Tool when over a device.

The power dissipated by that resistor (25mW) appears in the Value Window.

- 12 Click the **Stop** button on the Toolbar to stop the simulation and return to editing mode.



Stop Button

Creating a Simple RC Circuit

Now let's replace one of the resistors with a capacitor to create a simple RC circuit where you can see the charging of the capacitor. Transient Analysis begins its simulation in a stable DC condition where the capacitors are already charged. Since you want to see the capacitor charging from time zero, you must set the initial condition of the capacitor to 0V.



Delete Tool

- 1 Using the **Delete Tool** on the Toolbar, delete the second resistor (the one connected to ground) and the wire leading to it.
- 2 Replace the resistor with a Capacitor [Passive Components/Capacitors] (c).
- 3 Select an .IC device [Analog/SPICE Controls] (I) and connect it to the wire between the resistor and capacitor.

This will set an initial condition of 0V on the capacitor for the analysis. Your circuit should now look like the one pictured in Figure 3.6.

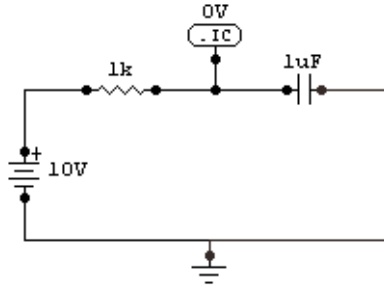


Figure 3.6. By replacing the resistor with the capacitor, you can create a simple RC circuit to see the charging of the capacitor.

- 4 Run the simulation again by clicking the **Run** button on the Toolbar.

This time the Transient Analysis window (similar to an oscilloscope) appears.

- 5 Click the Transient Analysis window to select it, and then click with the tip of the **Probe Tool** between the resistor and capacitor.

Notice a diagonal line across the scope. This is actually the beginning of the charge curve for the capacitor. Your view of the curve is limited by start and stop times of the Transient Analysis that were selected by default. You now have the option of changing the Transient Analysis settings to increase the size of the time segment that you can view with the scope, or you can reduce the component values so the capacitor will charge quicker. For this example, you will change the component values.

- 6 Stop the simulation by clicking the **Stop** button.
- 7 Double-click the Resistor to display the Edit Device Data dialog box.
- 8 Change the Label-Value from 1k to 100, and then click OK.
- 9 Double-click the Capacitor, change the Label-Value from 1uF to .001uF, and then click OK. Compare your schematic with Figure 3.7.

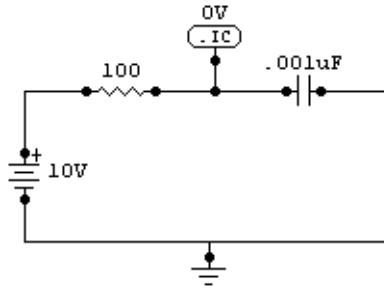


Figure 3.7. Notice that the resistor and capacitor now have different label-values.

10 Run the simulation again.

This time you will see the charge curve of the capacitor.

Simulating a Simple AC Circuit

Now let's create a simple AC circuit using a Signal Generator and two Resistors:

- 1 Click the **New** button on the Toolbar.
- 2 Draw the circuit as shown in Figure 3.8, using the following devices:
 - 1 Signal Gen [Analog/Instruments] (g)
 - 1 Ground [Analog/Power] (0 (zero))
 - 2 Resistors [Passive Components/Resistors] (r)

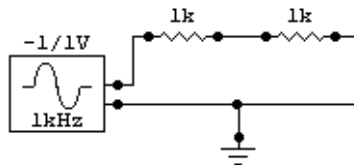


Figure 3.8. A simple AC circuit with a Signal Generator and two Resistors.

- 3 Use the **Wire Tool** to wire the circuit together (or the **Arrow Tool** when the Arrow/Wire option is enabled).

- 4 Make sure you are in Analog simulation mode (the transistor icon is showing on the simulation mode button), then run the simulation.
- 5 Click the Transient Analysis window to select it, then click the wire connected to the output of the Signal Generator.

The sine wave appears on the scope.

- 6 Hold down the **Shift** key and click the wire connected between the two resistors.

A second waveform appears on the scope.

- 7 Stop the simulation.

Tutorial 4: More Circuit Simulation

The next example demonstrates how to use all of the analyses and how to take simple measurements using the cursors in the analysis windows. Let's create a basic 10X amplifier circuit using a μ A741 Op Amp in this configuration:

$$\text{voltage gain} = R_F/R_I$$

- 1 Choose **File > New**.
- 2 Make sure that Analog simulation mode is selected.
- 3 Draw the circuit as shown in Figure 3.9 using the following devices:
 - 1 Signal Gen [Analog/Instruments] (g) for Vin on the schematic
 - 2 +V devices [Analog/Power] (1) for Vcc and Vee
 - 2 Grounds [Analog/Power] (0 (zero))
 - 3 Resistors [Passive Components/Resistors] (r) for RI, RF and RL
 - 1 Op-Amp5 [Linear ICs/OPAMPs] for U1

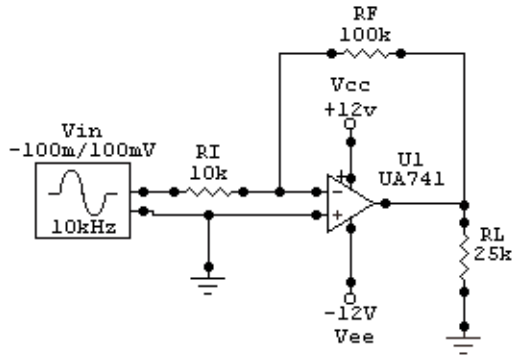


Figure 3.9. A 10X Amplifier Circuit.

- 4 Select the **Rotate 90** button on the Toolbar, which lets you rotate devices in 90° increments.
- 5 Using the **Rotate 90** button, rotate RL and the -12V supply.
- 6 Use the **Wire Tool** to wire the circuit together.
- 7 Use the **Arrow Tool** to drag the devices, wires and labels to make the circuit look clean.
- 8 Select the **Arrow Tool** and double-click the **Op Amp**.
- 9 Select **UA741** from the list of available subcircuits (located near the bottom of the list; see Figure 3.10) and click the **Select** button.
- 10 Click the **Netlist** button.
- 11 Set the Designation field to **U1**, set it to be visible, and then click OK.
- 12 Double-click the top +V device.
- 13 Set the **Label-Value** field to **+12V** and visible; set the **Designation** field to **Vcc** and visible; set the **Device** field to NOT visible then click OK.
- 14 Double-click the bottom +V device.



Figure 3.10. Use the Subcircuit Selections dialog box to select a specific model, such as the UA741.

- 15 Set the **Label-Value** field to **-12V** and visible; set the **Designation** field to **Vee** and visible; set the **Device** field to NOT visible then click OK.
- 16 Click and drag the labels so they are positioned as shown on the schematic in Figure 3.9.
- 17 Double-click each resistor to change both its Label-Value and its Designation and make them visible. Set them up as follows:

Resistor	Label-Value	Designation
Input	10k	RI
Feedback	100k	RF
Load	25k	RL
- 18 Double-click the **Signal Generator**.
- 19 Set **Peak Amplitude** to 0.1V and the frequency to 10kHz.
- 20 Click the **Wave** button in the Signal Generator.
- 21 Enable the **Source** check box for **AC Analysis**; set **Magnitude** to -0.1V and **Phase** to 0, and then click OK.

You can now use the Signal Generator as a reference for the AC analysis.

- 22 Click the **Netlist** button.
- 23 Set **Designation** to **Vin**, Visible, and then click OK.

Note: The Label-Value field contains **-1/1V** which represents the minimum and maximum programmed voltage swings before you double-clicked on the Signal Generator.

Setting Up the Analysis

Now that you have created the circuit, you will set up the analyses. When you run the simulation, the results are based on the conditions you set up.

- 1 Select **Simulation > Analyses Setup**.
- 2 Uncheck the **Always Set Defaults for Transient and Operating Point Analyses** option so it is cleared.

By unchecking this option, you can access the Transient and Multimeter (Operating Point) Analysis setups. When checked, defaults are used for the simulation.

- 3 Click the **Transient/Fourier** button.
- 4 Click the **Set Defaults** button for default Transient Analysis setups and click OK.

This provides simulation for 5 cycles of the input signal with 200 data points. For best reliability, Max Step should be the same size as Step Time. More data points require longer simulation time.

- 5 Click the **Multimeter** button.
- 6 Select the **DC (Operating Point)** option in the Display group box and click OK. This sets the initial display mode of the Value Window to DC.

Note: You must enable Transient Analysis in order to obtain DC AVG or AC RMS values. Multimeter must be enabled in order to use the Multimeter Window.

- 7 Click the **DC...** button.
- 8 Select the **Enabled** and **Enable Secondary** options in the DC Analysis Setup dialog box. When you are finished entering the following settings into the appropriate fields, choose OK.

	Primary	Secondary
Source Name	V _{in}	V _{cc}
Start	-1.5V	10V
Stop	-.7V	14V
Step	0.01V	1V

This setup lets you sweep the voltage of V_{in} over the specified range at each of 5 different V_{cc} levels.

- 9 Click the **AC...** button.
- 10 Select the **Enabled** option in the AC Analysis Setup dialog box and enter the following settings into the appropriate fields:

Start Frequency	1 Hz
Stop Frequency	1MHz
Test Points	10
Sweep	Decade

This setup lets you plot the frequency response of the circuit. Click OK to save the settings. Click Exit to return to the circuit.

- 11 Select **File > Save As** and save the circuit as MYAMP.CKT (analyses setups are saved with the circuit).

Running the Simulation

When you run the simulation, an interactive XSpice window appears showing the progress of the simulation. By placing Run-Time Test Points in your circuit beforehand, you can monitor the results as XSpice collects the data (for more information about Test Points, see *Chapter 6: Analog/Mixed-Signal Simulation*).

If you don't place any Run-Time Test Points, you will see only a bar graph showing the progress of the simulation. The amount of time it takes to finish is based on the analyses you have enabled, the amount of data you're collecting, the complexity of the circuit, and the speed of your computer.

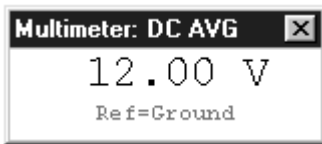
- 1 Select the **Probe Tool** on the Toolbar.
- 2 Using the left mouse button, click the wire connected to the output of the Op-Amp with the tip of the Probe Tool.

CircuitMaker places a Run-Time Test Point on that node and displays a dialog box.

- 3 Enable the **AC**, **DC** and **TRAN** check boxes, change the Max. Scale of the DC graph to 15, and then click OK.
- 4 Click the **Run** button on the Toolbar to start the simulation.

The interactive XSpice simulation window displays showing the waveforms as the data is collected. When the data collection process has completed, CircuitMaker displays the analyses windows.

- 5 Select **View > Fit Circuit to Window** (or press F4) to make the entire circuit visible.



- 6 Click the Multimeter window to select it (it's in the upper left hand corner of the screen and should say **DC** in the title bar).

- 7 Click on any wire in the circuit (except a wire connected to ground) with the tip of the **Probe Tool**. Notice that the letter **V** displays on the Probe Tool when it's over a wire.

The DC voltage at that node will be displayed in the Value window.

- 8 Click the pin of the +12V power supply.

The DC current through that supply appears in the Value window. Notice that the letter **I** appears on the Probe Tool when it's over a pin.

You can also measure current and power on other devices, but only if you have enabled corresponding Test Points (see the information about Test Points later in this tutorial).

Note: SPICE sees the current flowing *into* the positive terminal of a power supply, Multimeter or Signal Generator as positive current.

- 9 Double-click the Multimeter window, change the setting to AC RMS then click OK.



Now when you click the wires in the circuit the AC voltage or current appears.

- 10 Click in the Transient Analysis window to select it, and then click the wire connected to the output of the Signal Generator with the tip of the **Probe Tool**.

A green waveform appears in the Transient Analysis window, similar to what would be seen on an oscilloscope.

- 11 Hold down the **Shift** key and click on the wire connected to the output of the Op Amp.

A second (yellow) waveform appears in the Transient Analysis window. A quick comparison of the two waveforms confirms that the amplitude at the output of the amplifier is much greater than the amplitude at the input.

- 12 Click the **c** cursor at the far right of the Transient Analysis window and drag it to the top peak of the output waveform (the yellow one).

- 13 Click the **d** cursor and drag it to the top peak of the input waveform (the green one).

The actual peak voltages appear at the top of the graph as **Yc** and **Yd**. As you can see from the **Yc** and **Yd** values, the peak voltage at the output of the amplifier is 10 times the peak voltage at the input of the amplifier. The difference between the two Y cursors is shown as **c-d**.

- 14 Click the **b** cursor at the top of the Transient Analysis graph and drag it to the top peak of the first cycle of the output waveform.

- 15 Click the **a** cursor and drag it to the top peak of the second cycle of the output waveform.

The period (period = 1/frequency) of the signal is shown as the difference between the two X cursors **a-b**. The frequency also appears directly.

- 16 Draw a selection rectangle around a portion of the waveforms in the Transient Analysis window that is of interest to you. Do this by clicking the mouse once and holding the mouse while you draw a box.

Reset Button



Notice that when you release the mouse button, the view zooms in on the portion of the waveform that you selected. To restore the original view, click the **Reset** button in the graph window.

- 17 Click the DC Analysis window to select it, then click on any wire in the circuit.

A DC analysis waveform displays in the window, similar to what would be seen on a curve tracer. Use the cursors to get measurements from the waveforms.

- 18 Click the AC Analysis window to select it, and then click the wire at the output of the Op Amp.

An AC analysis waveform displays in the window.

- 19 Click the **Setup** button (the left button) in the upper left hand corner of the AC Analysis window.

- 20 Select **Log** scale for the X Grid; select **Decibels** for the Y Axis, click the **Show Wave Grid** check box then click OK.

The waveform now shows the response of the circuit over the specified frequency. Use the cursors to get measurements from the waveforms.

- 21 Click the **Stop** button on the Toolbar to stop the simulation and return to editing mode.

Mixed-Mode Simulation Example

The following BCD counter circuit demonstrates how digital SimCode devices can be used in analog simulation mode.

- 1 Choose **File > New**.
- 2 Make sure that Analog simulation mode is selected.
- 3 Draw the circuit shown in Figure 3.11 using the following devices:
 - Data Sequencer [Analog/Instruments]
 - 74LS168A Counter [Digital by Number/741xx]
 - +V [Analog/Power] (1)
 - Ground [Analog/Power] (0 (zero))

- Logic Switch [Switches/Digital] (s)
 - Logic Display [Displays/Digital] (9)
 - Hex Display [Displays/Digital] (h).
- 4 Double-click the +V and enter **DVCC**; (including the semicolon) in the Bus Data field to connect this device to the Vcc pin of the 74LS168A.
 - 5 Double-click the **Data Sequencer**.
 - 6 Click the **Pattern** button.

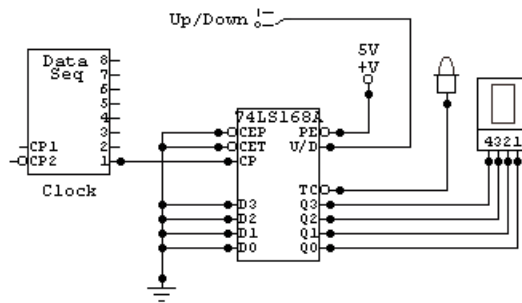


Figure 3.11. BCD Counter Circuit.

- 7 Select **Count Up** and click OK.
- 8 Enter **20** in the Stop Address field, and then click OK.
- 9 Choose **Simulation > Analyses Setup** and make sure the **Always Set Defaults** check box at the bottom of the dialog box is checked, and then choose OK.
- 10 Select the **Probe Tool** on the Toolbar.
- 11 Using the **Left** mouse button, click on the wire connected to the output of the Data Sequencer with the tip of the **Probe Tool**.

CircuitMaker places a Run-Time Test Point on that node and a dialog box appears.

- 12 Enable the **TRAN** check box and the **Combine Plots** check box.

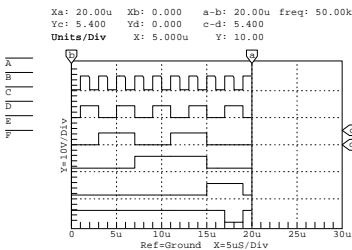
- 13 Set the **Max. Scale** of the **TRAN** graph to 20, and then click OK.
- 14 Hold down the **Shift** key and click the wire connected to the TC (terminal count) output of the **74LS168A**.

CircuitMaker places a second Run-Time Test Point on that node and a dialog box appears.

- 15 Again, enable the **TRAN** and **Combine Plots** check boxes.
- 16 The **Max. Scale** should already be set to 20. Set the **Vert. Offset** to 6, and then click OK.
- 17 Click the **Run** button on the Toolbar to start the simulation.

The interactive SPICE window appears, showing waveforms as the data is being collected. When the SPICE data collection process is completed, the Transient Analysis window appears.

- 18 Click the output of the Data Sequencer to view the clock signal in the Transient Analysis window.
- 19 Click the **Man** button in the corner of the Transient Analysis window to switch to manual scaling mode.



- 20 Click the **Up** scale button to change the vertical scale to **10V/Div**.
- 21 Click the green waveform label along the left-hand edge of the Transient Analysis window to select the waveform.
- 22 Press the **Up Arrow** key briefly to change the vertical position of the waveform, moving the waveform near the top of the graph.
- 23 While holding down the **Shift** key, click the **Q0** output of the **74LS168A**.

A yellow waveform appears near the center of the graph.

- 24 Click the corresponding yellow label along the left-hand edge of the Transient Analysis window to select this waveform.

- 25** Press the **Up Arrow** key to change the vertical position of the waveform, moving it near the green waveform.
- 26** Repeat this procedure for each output of the 74LS168A. The resulting graph should appear similar to the one shown at the left.

You can run this same circuit in Digital Logic simulation mode. To try it, stop the simulation, switch to digital and run simulation. In Digital Logic simulation mode, the displays will be animated to show the correct output.

CHAPTER 4

Drawing and Editing Schematics

Using CircuitMaker's robust set of drawing and editing tools, you can create simple to complex schematics quickly and easily. This chapter covers schematic drawing and editing tools and features.

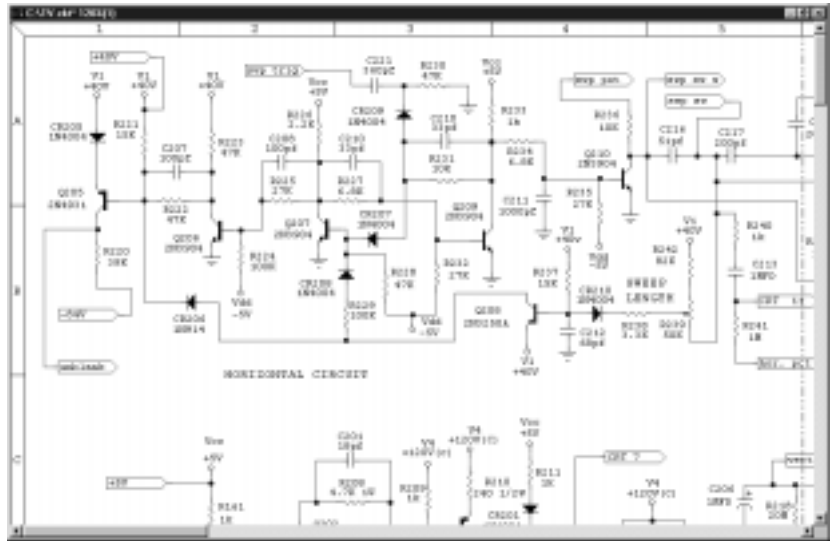
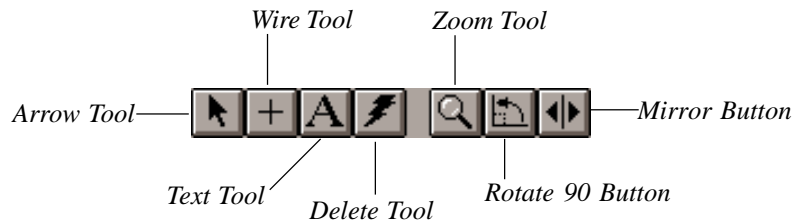
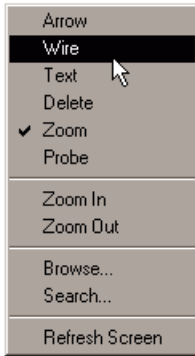


Figure 4.1. CircuitMaker lets you search a library of devices, place them, wire them together, and edit the schematic drawing exactly to your specifications.

Drawing & Editing Tools

This section describes the buttons on the Toolbar that you will use when placing and wiring components.

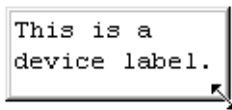




Tip: Right-click with the mouse to access helpful pop-up menus. Contents of the pop-up menu will vary depending on where you click.



Tip: Hold down the **Alt** key while using the Wire Tool to draw a dashed line, for example, around a section of circuitry to show that it is a logical block.



Tip: Using the Text Tool, you can add text anywhere in the schematic drawing.

Arrow Tool

Use the **Arrow Tool** to select items, move items, flip switches, select tools from the Toolbar, etc. You can double-click items with the Arrow Tool to perform many functions, such as editing specific devices. You can also activate the Arrow Tool by pressing **Alt+A** or right-clicking the mouse in the schematic background and choosing **Arrow** from the pop-up menu. If you choose **Options > Arrow/Wire**, you can use the Arrow Tool to place a wire by clicking on a device pin.

Wire Tool

Use the **Wire Tool** to place wires in the work area. Draw bus wires by holding down the **Shift** key when starting to draw the wire. Refer to the sections *Wiring the Circuit* and *Working with Bus Wires* later in this chapter for more information. Draw a dashed line by holding down the **Alt** key while drawing a wire. Dashed lines act just like regular wires, but if they are not connected to anything, they will not be included in a netlist. You can also activate the Wire Tool by pressing **Alt+W** or by right-clicking the mouse in the schematic background and choosing **Wire** from the pop-up menu.

Text Tool

Use the **Text Tool** to place text in the circuit. Select the tool, click in the work area and type the text. Choose **Edit > Font** to stylize the text or choose **View > Colors** to assign a different color to text. You can alter the way multi-line text wraps by clicking it with the Text Tool and resizing its enclosing rectangle. You can also select the Text Tool by pressing **Alt+T** or by right-clicking in the schematic background and choosing **Text** from the pop-up menu.

Delete Tool

Use the **Delete Tool** to selectively delete items. Select the **Delete Tool**, click on the item you want to delete, and the item is immediately deleted, *except in the case of wires*: If you click and hold on a wire with the **Delete Tool**, the wire is highlighted but not deleted until you release the mouse button. If you hold down the mouse button and move the **Delete Tool** away from the wire, the wire is not deleted. This allows you to see the complete extent of the wire that will be deleted, before you actually delete it. To delete just a

segment of wire, right-click on a wire with the **Delete Tool** and choose "Delete Wire Segment", and only the segment between the nearest corners or connections will be deleted.

Cut (or divide) a wire in two by holding down the **Shift** key and clicking the wire with the Delete Tool. The wire is separated at the contact point.

You can also select the **Delete Tool** by pressing **Alt+D** or by right-clicking in the schematic background the mouse and choosing **Delete** from the pop-up menu. Or select an item and press the **Delete** key on the keyboard to delete that item.

Zoom Tool

Use the **Zoom Tool** to magnify (zoom in) and reduce (zoom out) your circuit. To zoom in, select the Zoom Tool and position it over the area that you want to enlarge. Click the left mouse button to magnify the circuit by the selected Scale Step size. To zoom out, select the Zoom Tool and position it over the area you want to reduce. Hold down the **Shift** key and click the left mouse button to reduce the circuit by the selected Scale Step Size.

You can also activate the Zoom Tool by pressing **Alt+Z** or by right-clicking the mouse in the schematic background and choosing **Zoom** from the pop-up menu.

Another zooming method is to press the **Page Up** key on the keyboard to zoom in or the **Page Down** key to zoom out at any time, without using the Zoom Tool. In this case, the zoom is centered on the position of the mouse cursor. See also *Display Scale, Normal Size/Position* and *Fit Circuit to Window* in *Chapter 13: View & Window Menus*.

Rotate 90 Button

Use the **Rotate 90 Button** to rotate the selected device in 90° increments.

You can also rotate a device as you select it from the library by pressing the **r** key on the keyboard or by clicking the **Right** mouse button before placing the device in the circuit. You can also select the Rotate 90 Button by choosing **Edit > Rotate 90** or by pressing **Alt+R**.

Note: When you rotate a device, pin names and numbers and label values remain readable, that is, they won't be upside down.



Use the Rotate 90 Button to rotate a selected device in increments of 90°. Notice that the Label-Value remains readable as the device rotates.

Mirror Button

Use the **Mirror Button** to flip the device horizontally. You can also mirror a device as you select it from the library by pressing the **m** key on the keyboard before placing the device in the circuit. You can also select the Mirror Button by choosing **Edit > Mirror** or by pressing **Alt+M**.

Grid, Title Block and Borders

CircuitMaker gives you many advanced schematic features to enhance your schematic, and make precise placement easier.

Grid

Use the Grid option to turn the alignment grid of the circuit window on or off (see Figures 4.1a and b). The grid is useful as an aid in precisely aligning objects. Use Snap To Grid to place new devices (devices not already in a circuit) according to the specified grid. It also lets you move old devices (devices already in the circuit) according to the selected grid, relative to their original position.

Note: When you place a device exactly on the grid, it always remains on the grid regardless of scroll position. However, Snap To Grid does not guarantee alignment of component pins.

Choose **Options > Grid** to access the Grid Setup dialog box.

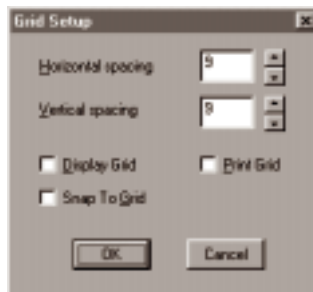
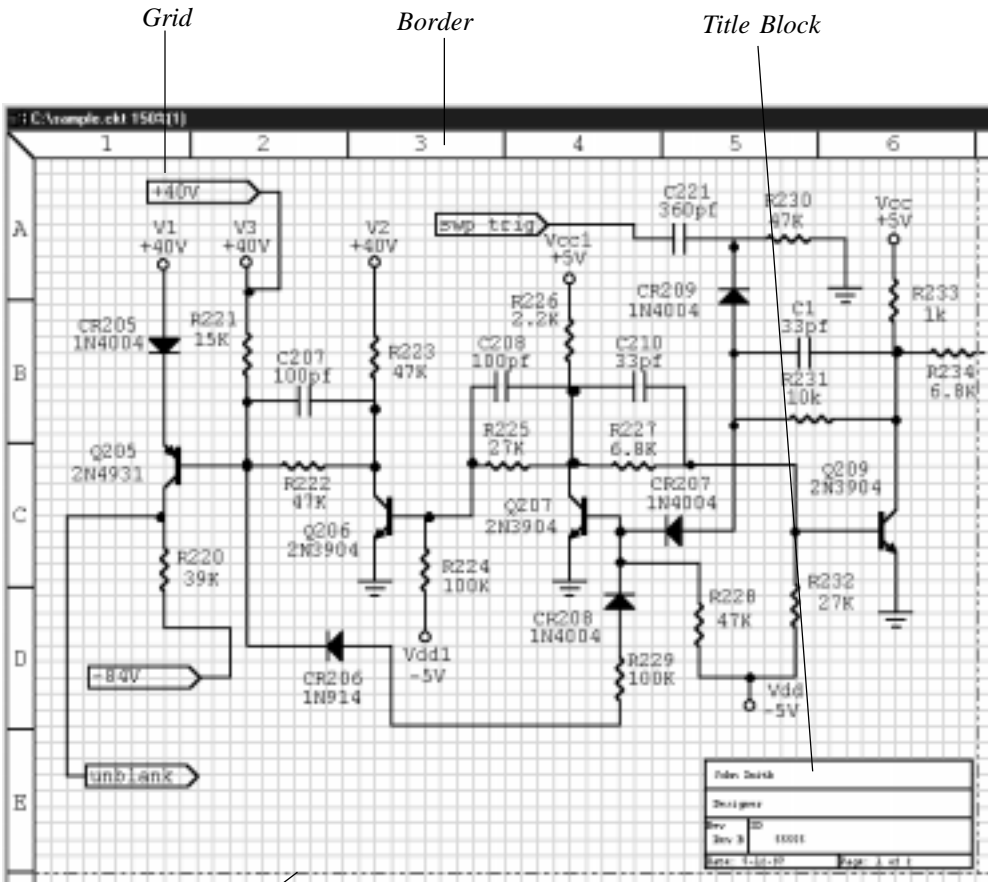


Figure 4.1a. Use the Grid Setup dialog box to turn the alignment grid on or off.



Moveable Page Breaks

Figure 4.1b. Use the Border, Grid, Title Block options to enhance the appearance of your schematic.

Title Block

Use the Title Block option (see Figure 4.1b for an example) to add a title box to the lower right corner of the page. The title block contains the following fields: Name, Title, Revision, ID, Date, and Page. The Name and Title fields expand in height to handle multiple rows of text. If you leave the Name or Title fields blank, CircuitMaker excludes them from the title block. The title block also expands in width according to the amount of text that you enter. You can print the title block on

the first page, on the last page, or on all pages. Additionally, you can print the full title block on the first page and a reduced title block (that is, one that does not include the Name and Title fields) on subsequent pages.

Choose **Options > Title Block** to access the Title Block setup options.

Borders

Use this option to quickly locate devices by displaying a coordinate grid system around your schematic (see Figure 4.1b for an example). For example, suppose you want to find a device that you know is located in the B-5 grid square. By drawing an imaginary line from the letter B and the number 5 on the margins of the schematic; the intersection of these lines locates the grid square containing the device.

To add a border to your schematic drawing,

- 1 Choose **Options > Border** to display the Border dialog box.
- 2 Select **Display Border On Screen** to display a border that outlines the total allowed schematic area.
- 3 Select **Do Not Print** if you don't want to print the border.

OR

Select **Print Around Entire Schematic** to print the border so that it is only on the outside edges of the outside pages, making a border around the entire schematic when the pages are arranged together.

OR

Select **Print Around Each Page** to print the complete border on each page of your schematic.

Listing and Selecting Devices

CircuitMaker comes with a library of several thousand devices (see the Device Library book for a complete list of the devices and instruments). You can select devices (or parts) from the library using the graphical parts browser (see Figure 4.2), HotKey shortcuts or the Device Search feature.

The Graphical Parts Browser

You can graphically browse through the parts in CircuitMaker from the Device Selection dialog box. The parts are listed by Major Device Class, Minor Device Class, Device Symbol and Model/Subcircuit.



Figure 4.2. The Device Selection dialog box lets you graphically browse and select from a library of several thousand devices.

To list and select a device,

- 1 Click the **Parts Button** on the Toolbar.

OR

Select **Devices > Browse**.

OR

Press the **x** key on the keyboard.

- 2 Locate the device you want to place by first selecting a **Major Device Class**, a **Minor Device Class**, a **Device Symbol**, and if applicable, a specific model or subcircuit.

In this manual, device location is indicated as [major class/minor class]. For example, a 2N3904 could be found at [Active Components/BJTs].

Notice that the schematic symbol for the part you select is shown. Use the **Rotate 90** and **Mirror** buttons in the dialog box to view each device in other orientations.

- 3 Select the **Return** check box if you want to return to the Device Selection dialog box after placing a device.
- 4 Click **Place** to select the device for placement in your circuit (or just double-click the item to be selected in the Device Symbol list or the Model/Subcircuit list).

Notice that the device follows the mouse around the screen until you click the **Left** mouse button.

Filtering Devices in the Parts Browser

The **Show Analog**, **Digital**, and **Symbol** check boxes in the Device Selection dialog box (see Figure 4.2) let you filter the devices shown to reduce the number of parts to search through.

- Check **Analog** to display the devices which function in CircuitMaker's Analog simulation mode.
- Check **Digital** to display the devices which function in CircuitMaker's Digital Logic simulation mode.
- Check **Symbol** to display the nonfunctional schematic symbols.

For example, if you are looking for digital devices to use in Analog simulation mode, you could uncheck both **Digital** and **Symbol** to hide all the devices which will not run in Analog simulation mode. At least one of the three boxes must be checked at all times.

Note that above the picture of the device symbol are the words **Digital Only Device**, **Analog Only Device**, **Analog/Digital Device**, or **Schematic Only Device**. This indicates the simulation mode for which the currently displayed device will function properly.

HotKeys

You can also select devices by pressing a predefined HotKey on the keyboard. The Devices menu lists all predefined HotKey assignments, and you can reassign HotKeys to different devices as needed.

Assigning New HotKeys

You can assign sixty of your most commonly used devices to HotKeys. This lets you quickly select these devices by pressing the HotKey on the keyboard or by selecting the item from the HotKey sub-menus on the Devices menus.

To assign a HotKey to a specific device,

- 1 In the Device Selection dialog box (Figure 4.2), display the device for which you want to assign a HotKey.
- 2 Click **Change** to display the dialog box in Figure 4.3.

HotKeys are listed alphabetically along with the devices that are currently assigned to them.

- 3 Scroll through the list to find the HotKey that you want to assign to your selected device, and then click the **Assign** button.



Figure 4.3. Use this dialog box to assign or reassign HotKeys to devices.

Unassigning a HotKey

To remove a HotKey assignment from the list,

- 1 Follow Steps 1-3 from the previous section.
- 2 Assign a new device in its place.

OR

Assign **none** (at the top of the list) as the HotKey.

Searching for Devices

Click the **Device Search** button on the Toolbar to display the Device Search dialog box (Figure 4.4), which lets you find all devices that match the part number or description that you enter. A match is found any time the search text you enter is contained in a device's major class name, minor class name, symbol name, or model description. However, only the symbol name and model description appear in the match list.

Note: The Device Search feature is not case sensitive.

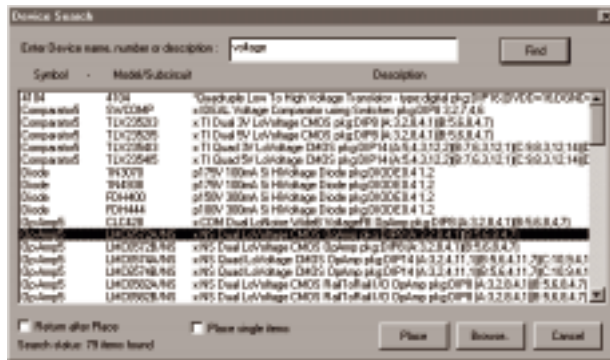


Figure 4.4. This example shows the found set after typing the word “voltage” in the Device Search dialog box.

If a search produces items that don't seem to match the search text you entered, it might be because the match occurred with the major or minor class names, which are not displayed.

The Device Search feature accepts partial words to match devices. For example, a search text of **op** would find **Op-Amp** or **loop**. You can also use an asterisk as a “wild card.” For

example, entering **74*8** matches **748, 7408, 74LS08, 74138, 74285**, and so on. If you enter multiple words as the search text, a match for each word is found, though not in the order you enter them. For example, typing **741 op-amp** and **op-amp 741** would both give the same results.

To search for a device,

1 Click the **Device Search** button on the Toolbar.

OR

Select **Devices > Search** or press **Shift+X**.

2 Type a device name, number, or description in the text box, then choose **Find**.

3 Use the scroll bar (if necessary) to scroll through the list. When you find the device, click it to highlight it.

4 Select **Return after Place** to return to the Device Search dialog box after placing an item.

5 To eliminate the need to click the **Place** button when a single match is found, select **Place Single Items** to automatically place an item if it is the only match found.

6 Double-click the device or click **Place** to place the highlighted device in the workspace.

OR

Click **Browse** to display the selected part in the Device Selection dialog box.

The Browse button is useful to see what the device symbol looks like and also to find other similar devices.

Note: If you modify the User Library (USER.LIB) file, expect a slight delay the next time you search for devices in the Device Search dialog box. The delay is caused as CircuitMaker builds a new SEARCHDB.DAT search list file. If for any reason the search list seems incorrect or out of date, you can create a new search list file by choosing **Macros > Update Search List**.

Placing Devices

After you have searched and found a device, you can place the device or reselect it using a number of different options illustrated in this section.

To place a device,

- 1 Select it using one of the methods discussed in the previous section.
- 2 Press the **r** key or **Right**-click the mouse to rotate the device into the position you want.
- 3 Press the **m** key to mirror the device.
- 4 Left-click the mouse to place the device in the workspace.

Note: To repeatedly place identical devices, choose **Options > Auto Repeat** or **Ctrl+R**.

Selecting Devices

Use the **Arrow Tool** to select and move devices around the workspace. There are four different ways of selecting items in the circuit window:

Selecting a Single Item

To select a single item, click it with the **Arrow Tool**. Click anywhere else in the work area to deselect the item.

Selecting Multiple Items

To select multiple items, hold down the **Shift** key and click on one or more items with the Arrow Tool. To deselect any single item click on it a second time while still holding down the **Shift** key. To deselect all items, release the **Shift** key and click somewhere in the work area away from all items.

You can also select multiple items by holding down the mouse button and dragging a selection rectangle around the desired items. This method works especially well for selecting switches, because clicking on a switch will not always select it (unless you click on the outer edge of the switch). To deselect any single item from a group of selected items, **Shift-click** on it. To deselect all items, click in the workspace away from all items.

***Note:** If the **Quick Connect** feature is enabled and an unconnected device pin is placed so that it touches a wire or other device pin, **CircuitMaker** will automatically make the connection. See the **Wiring** section in this chapter for details.*

Selecting All Items

To quickly select all items, choose **Edit > Select All**.

Nudging Devices

To slightly “nudge” a device in any direction, select a single device and then press the **Left Arrow**, **Right Arrow**, **Up Arrow**, or **Down Arrow** key (as illustrated in Figure 4.5). A single nudge shifts the device one pixel, whether or not **Snap-to-Grid** is enabled.

Note: The nudge feature does not work if you have selected wires or multiple devices. It only works with a single device.

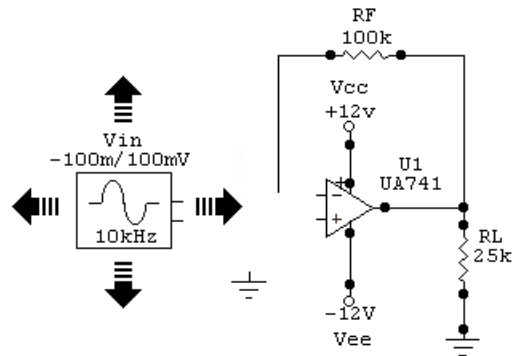


Figure 4.5. Use the Left, Right, Up, or Down Arrow key to “nudge” a selected device more precisely.

Wiring the Circuit

To simulate and generate PCB netlists properly, the components in your circuit must be correctly wired together. CircuitMaker's Auto Routing, Manual Routing and Quick Connect methods are fully integrated and automatic, so you don't have to choose or switch between wiring modes. A "valid connection point" for wiring is any device pin or wire.

Wiring Method

How to Use

Auto Wire Routing

Click and drag with the Wire Tool from any valid connection point to another connection point, then release.

Manual Wire Routing

Click with Wire Tool to start wire, single-click to change directions, then single-click on a connection point or double-click to end wire.

Quick Connect

Place or move a device with the Arrow Tool so that unconnected pins touch a wire or other device pins.

The SmartWires™ Advantage

Regardless of the method of wiring you use, CircuitMaker's SmartWires™ feature lets you connect a wire to a device pin or another wire without being in exactly the right place. This ensures perfect connections every time, and eliminates any guesswork. A user-definable connection area exists around each valid connection point. When you place the Wire Tool in a connection area, a rectangle appears highlighting the connection point. Use the Preferences dialog box to set the size of the connection area and whether or not to display the rectangle. For more information, see *Connection Area* in *Chapter 9: File Menu*.



Wire Tool

Tip: You can also draw wires with the Arrow Tool if you have enabled the Arrow/Wire option on the Options menu.

Auto Routing

To quickly and easily Auto Route wires,

- 1 Select the **Wire Tool** from the Toolbar.
- 2 Move the tool over a valid connection point.

Note: A valid connection point is any device pin or wire.

- 3 Click and hold the left mouse button.
- 4 Drag the mouse to another valid connection point and release the mouse button.

The wire automatically routes between the two points.

Auto routing requires two valid connection points. You cannot draw a wire with auto routing that does not connect to something on both ends. Also, you cannot draw bus wires with the auto routing method.

The auto routing can be either Simple or Intelligent, depending on what you have selected in the Preferences dialog box. Simple routing draws only one or two wire segments, horizontal and/or vertical, making the shortest path without regard for devices that might be in the way. Intelligent routing tries to find a path which does not cross directly over any devices. If no reasonable path can be found, the simple method is used.

Manual Routing

Manual routing lets you freely place wires exactly where you want them. It also lets you place “free wires” in your circuit that are not connected to anything.

Note: To draw bus wires, use the manual routing method.

To route wires manually,

- 1 Select the **Wire Tool** from the Toolbar.
- 2 Move the tool to the position where you want to start the wire.
- 3 Click and release the left mouse button.

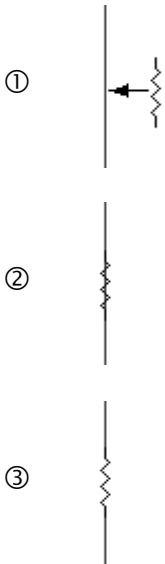
The Wire Tool cursor disappears and is replaced with an extended wiring cursor. The extended cursor simplifies the task of precisely aligning wires with other objects.

- 4 Click once with the left mouse button to turn 90° or double-click to end the wire.
- 5 Single-click the mouse to terminate the wire when it is at a valid connection point (if you have enabled the **Single Click Connect** option in the Preferences dialog box).

- 6 To cancel a wire at any time while you are drawing it, press any key or right-click with the mouse.

Quick Connect Wiring

One of the easiest methods for wiring is to use the Quick Connect wiring method. This feature allows you to simply touch unconnected device pins to wires or other unconnected device pins, and the connections are made automatically.



To wire using Quick Connect,

- 1 Choose a new device from the library

OR

Nudge or click and drag an existing device with the Arrow Tool.

- 2 Move the device so that the end of the unconnected pin(s) touches a wire or other device pin(s).
- 3 Once placed, CircuitMaker will connect the device to the wire or pin it is touching.

NOTE: Placing a device so that two pins are parallel over a wire will automatically connect both ends and “insert” that device into the wire segment (as in illustration 3 at left).

The same connection area size used by SmartWires (described previously) is used by the Quick Connect feature. This connection area determines how close you must be to a wire or pin before CircuitMaker will automatically make the connection, and can be altered in the Preferences dialog box.

By default, the Quick Connect option is always active. To turn off Quick Connect, go to **File > Preferences** or **Options > Quick Connect** to uncheck and deactivate the Quick Connect option.

Extending, Joining, and Cutting Wires

Wires are fully editable and can be extended, joined, and cut.

To extend a wire,

- 1 Select the **Wire Tool** from the Toolbar.
- 2 Place it over the end of the wire and start a new wire to extend the existing one.

To join two wires together,

- 1 Draw a wire from the end of the first wire to the end of the second wire.

Notice that they become the same wire.

To cut a single wire into two or more separate wires,

- 1 Select the **Delete Tool** from the Toolbar.
- 2 Place it over the point(s) where you want to cut the wire.
- 3 Hold down the Shift key.
- 4 Click the left mouse button to cut the wire. The wire is divided into multiple wires.

Moving Devices with Connected Wires

You can move a device that has wires connected to it without disturbing the connection. When you select and drag a device with the Arrow Tool, the wires undergo a “rubberband” effect, meaning that they stretch (extend) but remain connected to the device.

Working with Bus Wires

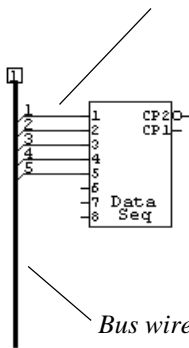
Bus wires are a special type of wire that contain multiple individual wires. Each bus wire is identified by a number and each individual wire within a bus also has a number. Bus wires can be easily identified in a circuit because they are drawn thicker than regular wires.

To draw a bus wire,

- 1 Hold down the **Shift** key.
- 2 Draw a regular wire using the manual routing method (see *Manual Routing* earlier in this chapter).

Note: You must hold down the Shift key before you start a wire but you can release the key before the wire is finished.

Bus connection wires



After you draw the bus wire, a dialog box (shown in Figure 4.6) prompts you for a bus number.

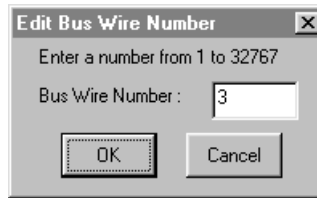


Figure 4.6. Each bus must have a different bus number.

- 3 Enter a unique bus number.

Note: If two separate buses are given the same number, they are considered to be the same bus, even though they are not physically connected on the screen.

You can extend, join, or cut bus wires just like regular wires. However, you don't need to hold down the **Shift** key when extending bus wires.

Working with Bus Connection Wires

Regular wires that are connected to a bus wire are called “bus connection wires.” These wires connect to the individual wires within the bus.

To create bus connection wires,

- 1 Select the **Wire Tool** from the Toolbar.
- 2 Move the tool over a valid connection point.
Note: A valid connection point is any device pin or wire (including a bus wire). At least one end of the bus connection wire must be connected to a bus.
- 3 Click and hold the left mouse button.
- 4 Drag the mouse to another valid connection point and release the mouse button.

When you make the connection, a dialog box appears asking you to assign a bus connection wire number.

- 5 Specify a bus connection wire number.

- 6 Choose **Angle Connection to Top/Left** if you want to change the angle of the connection.

To edit a bus wire or bus connection wire number, double-click it with the **Arrow Tool** and change the number.

CircuitMaker displays bus and bus connection labels by default, but you can disable them by unchecking **Options > Show Bus Labels**.

Wiring Bus Connection Wires Together

If you assign two bus connection wires the same number and you connect them to the same bus wire (or to different bus wires with the same bus wire number), they function as though they were connected together.

“Wiring” with Connectors

CircuitMaker has Input, Output, and Terminal connectors [Connectors/Misc] that allow you to connect points together without using direct wires. All Input, Output, and Terminal connectors that have the same name will operate as though they were wired together. Double-click one of these devices to edit its name.

Input and Output Connectors

The Input and Output connectors have different symbols but they are functionally identical. These connectors are sometimes a useful alternative to direct wires. The following two examples are functionally equivalent. The second example uses Input and Output connectors instead of direct wires to connect the inverter outputs to the AND gate inputs.



Figure 4.6a: Connections using standard wiring techniques.



Figure 4.6b: The equivalent connections of Figure 4.6a, using Input and Output connectors.

Terminal Device Power Connections

The Terminal connector (also called the Terminal device) can function like the Input and Output connectors as described previously. Additionally, the Terminal device can be used to connect to a power bus.

For example, suppose you have several op-amps that you want to connect to VCC in a single net, but you do not want to run wires everywhere. In this case you can use one normal +V device and multiple terminal devices. Wire the +V device to one op-amp, and wire a Terminal device to the each of the other op-amps. Enter **VCC**; in the Bus Data field of the +V device's Edit Device Data dialog box (see *Bus Data* in the *Edit Device* section later in this chapter). Enter **VCC** (not VCC;) in the Terminal Name field for each of the Terminal devices. This use of terminal devices instead of multiple +V devices gives you a single net for the netlist (SPICE or PCB).

You can double click on a Terminal device to edit its name. When you click the OK button, CircuitMaker automatically copies the Terminal Name field to the Terminal's Bus Data field (in the Edit Device Data dialog box) and appends a semicolon. The Terminal Name field is also copied to the Label-Value field.. If for some reason you want to edit the Bus Data field or Label-Value field directly, click the Netlist button, make the desired changes, click OK, and then click Cancel on the Edit Terminal Name dialog box. Normally, entering the Terminal name in the Edit Terminal Name dialog box should suffice.

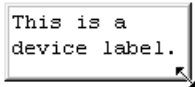
Labeling the Circuit

CircuitMaker offers several methods of labeling the circuit, including the Text Tool and editing the device itself.

Using the Text Tool to Label

To label the circuit using the Text Tool,

- 1 Select the **Text Tool**.
- 2 Click in the workspace where you want to place text.
- 3 Resize the text box as necessary (see picture at left).
- 4 Type the text.



Text can be multi-lined and fully stylized. Always visible, text may be repositioned at any time.

Changing Device Labels

Don't confuse a device designation with a device label-value. Figure 4.7 illustrates the difference.

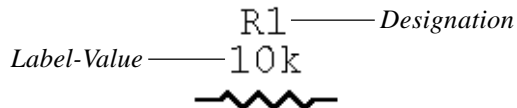


Figure 4.7. A Label-Value is information about a device whereas a Designation identifies the device in the circuit.

To label devices using the Edit Device Data dialog box,

- 1 Double-click the device.
- 2 If a dialog box other than the Edit Device Data dialog box appears, click the **Netlist** button.
- 3 Type the appropriate text in the Label-Value, Designation, or Description text box.
- 4 Make the text visible on the schematic by selecting its Visible check box.

You can reposition label-values, designations and descriptions anywhere around the device by dragging them with the Arrow Tool. Even if you reposition a label around a device, it remains attached to the device when the device is moved around the workspace. For a detailed description of these labels, refer to the following section, *Editing Devices*.

Editing Devices

You can easily edit a wide range of device information related to schematic, simulation, pcb netlists and other purposes.

To edit a device,

- 1 Double-click on a device to display the Edit Device Data dialog box shown in Figure 4.8.

Note: A different dialog box will appear when you double-click on certain devices, so click the **Netlist** button to get to the Edit Device Data dialog box.

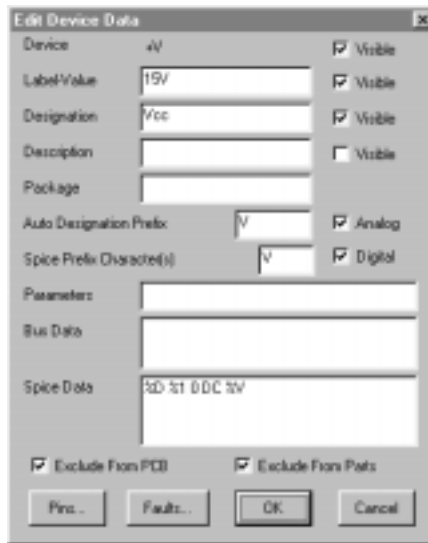
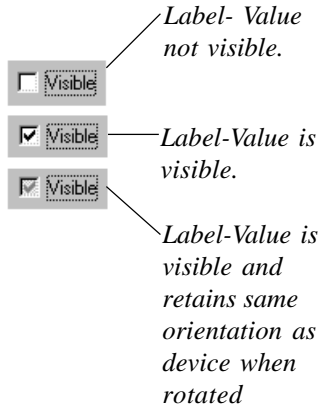


Figure 4.8. Use the Edit Device Data dialog box to enter or change a variety of device information.

Device

This non-editable field shows the device name as it appears in the library menus. Use the Visible check box to show or hide the name in the schematic. If visible, the device name retains the same orientation as the device when you rotate it. The label-value, designation and description, however, will remain right-side up no matter how the device is rotated.

The Label-Value field has a tri-state Visible check box:



Note that some device names, such as “Resistor”, cannot be made visible.

Label-Value

Use this field to enter information about the device such as its label (1N914, 2N3904, etc.) or its value (47K, 100U, etc.), or to replace the existing Device name (that is, make the Device not visible and the Label visible). The Label-Value can be dragged around the device on the schematic with the mouse and will remain attached to the device when the device is moved.

If you set the Visible check box to gray (see diagram at left), the Label replaces the Device name and retains the same orientation as the device when rotated. Otherwise, the label-value will remain right-side up no matter how the device is rotated.

Designation

Use this field to identify the device in the circuit such as U3, CR7, RLOAD, etc. You can also make this field visible with the Visible check box. This field must contain the device designation in order for simulation and pcb netlists to work properly. The Designation label may also be dragged around on the schematic with the mouse. It will remain right-side up no matter how the device is rotated.

This field is filled in automatically when you place the device. See *Auto Designation Prefix* later in this section for more information. See also *Set Designations* in *Chapter 10: Edit Menu* and *Device Designations* in *Chapter 12: Options Menu* for other features that affect device designations.

Important: Individual parts of multipart packages must be grouped properly. CircuitMaker takes care of this automatically if you use devices as they are from the library. However, if you have altered multipart packages, they must be grouped using the **Edit > Group Items** command. Just changing the Designation field is not sufficient. Each individual part must be identified as PART A, PART B, etc., from the Edit Device Pin Data dialog box. See *Pins* later in this chapter.

Description

Use this field for schematic reference only. You can use it to display additional information such as custom part numbers, tolerances, etc. This field does not affect simulation. Use the Visible check box to make the field visible or not. You can also drag the Description label around on the schematic with the mouse. The Description label will remain right-side up no matter how the device is rotated.

Package

Use this field to identify the type of physical package (footprint) the device is in (DIP14, TO-92B, etc.). When you are creating pcb netlists for TraxMaker or other pcb layout programs, make sure the Package name you enter *exactly* matches the name of the corresponding component footprint in your pcb layout program's library.

Auto Designation Prefix

This is the prefix used when CircuitMaker automatically assigns a device's designation (whenever you place a device or select **Edit > Set Designations**). The prefix may be up to 4 characters in length.

Spice Prefix Character(s)

This is the SPICE prefix used in conjunction with the %D and %M flags described later under *Spice Data*. You would normally use this field when linking the macro symbols you define to the proper model selections when creating new devices (see *Chapter 16 Creating New Devices* for more information). Valid prefixes are:

Prefix Meaning

A	XSpice Model
BV	Nonlinear Dependent Voltage Sources
BI	Nonlinear Dependent Current Sources
C	Capacitors
D	Junction Diodes
DZ	Zener Diodes
E	Linear Voltage-Controlled Voltage Sources
F	Linear Current-Controlled Current Sources
G	Linear Voltage-Controlled Current Sources
H	Linear Current-Controlled Voltage Sources
I	Independent Current Sources

JN	JFETs (N-channel)
JP	JFETs (P-channel)
K	Coupled (Mutual) Inductors
L	Inductors
MN	MOSFETs (N-channel)
MP	MOSFETs (P-channel)
O	Lossy Transmission Lines
QN	Bipolar Junction Transistors (NPN)
QP	Bipolar Junction Transistors (PNP)
R	Resistors
S	Voltage Controlled Switches
T	Lossless Transmission Lines
U	Uniform Distributed RC Lines (Lossy)
V	Independent Voltage Sources
W	Current Controlled Switches
X	Subcircuits
ZN	MESFETs (N-channel) (GaAs FETs)
ZP	MESFETs (P-channel) (GaAs FETs)

Analog

This check box identifies this as a device that can be used in CircuitMaker's Analog simulation mode. The analog simulator can only simulate a device if there is SPICE simulation data for that device. If you attempt to run an Analog simulation using a device that does not have the Analog check box checked, CircuitMaker displays a warning message and that device will be ignored in the simulation. When creating your own device, this box should be checked only if you have supplied SPICE data for the device or if the device is a macro circuit containing other analog devices (see *Chapter 16: Creating New Devices* for more information on new device creation).

Digital

This check box identifies this as a device that can be used in CircuitMaker's Digital simulation mode. The digital simulator can only simulate a device if there is digital SimCode for that device. If you attempt to run a digital simulation using a device that does not have the Digital check box checked, CircuitMaker displays a warning message and that device will be ignored in the simulation. When creating your own device, select this box only if the device is a macro circuit

containing other digital devices or was created using digital SimCode (see *Chapter 17: Digital SimCode* for more on digital device creation).

Parameters

This field stores information that affects the simulation of certain devices. For digital SimCode devices, this field would contain **type:digital**. It could then be followed by a list of parameters which are generally set in the Digital Model Parameters dialog box.

Some generic device models can be redefined by passing parameters as an alias to describe a specific device. For example, the parameter field of a crystal would contain **alias:XCRYSTAL** and could be followed by a list of databook parameters that define that specific crystal. Generally, you enter these parameters in the Subcircuit Parameters dialog box. See *Chapter 16: Creating New Devices* for more information on parameter passing.

Bus Data

Use this field to specify which pins on the device are connected to the power or ground buses, since these pins are not shown on the predefined device packages. This field holds up to 2048 characters, which is helpful when creating devices with many power and ground pins. The general format for this data is:

```
busnam[=pinnum[,pinnum,...]];[busnam=pinnum[,pinnum,...];...]
```

For example, on a 74LS83 the Bus Data is:

```
DVCC=5;DGND=12;
```

This means that the Vcc bus is connected to pin 5 and the Ground bus is connected to pin 12. The bus data for a 74AC11190 would look like:

```
DVCC=15,16; DGND=4,5,6,7;
```

The order in which the buses are listed is not important.

To connect these bus pins for Analog simulation or for creating a PCB netlist to export into TraxMaker or other PCB layout program, each bus must be defined. There are three devices that can be used for this purpose: +V, Ground and Terminal. The Bus Data format for these devices is simply:

busnam;

where busnam identifies the specific bus. For example, each Ground device, by default, contains the Bus Data **GND**; which causes all of the Ground symbols to be tied together in a single node or net.

Note: For simulation purposes, the Ground device *always* equates to Spice node 0, even if the Bus Data changes.

A +V device does not contain any default Bus Data. This is because each +V device may represent a different supply voltage. However, the Bus Data field can also be used on these devices to identify it as the voltage source for the digital devices. For this example, set the Bus Data to **DVCC**; or **DVDD**;

In some cases it may be necessary to connect a different voltage source (such as the output of a voltage regulator) to the digital devices. In such cases, connect a Terminal device to the power source and enter **DVCC** in its Terminal Name field. CircuitMaker will make a connection between the Terminal device and any bus that has the same name. CircuitMaker will also make a connection between the Terminal and any Input or Output connector that has the same name. Do not use a semicolon in the Terminal Name field. For example, **DVCC** is correct, but **DVCC;** is incorrect for the Terminal Name field. Note: CircuitMaker automatically copies what you enter in Terminal Name field to the Terminal's Bus Data field and appends a semicolon.

You can short multiple +V and Terminal devices together by Bus Data for the +V device and Terminal Name for the Terminal device. If you short two +V devices together, you will receive an XSpice error when you run the simulation. To avoid this problem, remove the Spice Data and Spice Prefix Character from all but one of the shorted +V devices.

See also *Vcc and Ground* in *Chapter 6: Analog/Mixed-Signal Simulation*.

Spice Data

This field is used to specify the SPICE simulation data for the device. The analog devices provided with CircuitMaker already have default SPICE data included. If you create your own devices to use with the analog simulation, you will need to fill in this field yourself. You can enter SPICE data into this field directly, or you can reference it to the other fields in the dialog box. The percent sign (%) is used as a flag to tell CircuitMaker to reference the already defined fields. Their meanings are:

Name (%N)

Inserts the Device Name into the SPICE data string. This is the name found in the library menus.

Label (%L)

Inserts the Label-Value into the SPICE data string. This requires the first character in the Label-Value string to be an alpha character. The label may not exceed 8 characters.

Value (%V)

Inserts the Label-Value into the SPICE data string. This requires the first character in the Label-Value string to be numeric. The value may be an integer (12, -44), a floating point number (3.14159), either an integer or floating point number followed by an integer exponent (1e-14, 2.65e3), or an integer or floating point number followed by one of the following multipliers:

T	= 10 ¹²	u	= 10 ⁻⁶
G	= 10 ⁹	n	= 10 ⁻⁹
Meg	= 10 ⁶	p	= 10 ⁻¹²
K	= 10 ³	f	= 10 ⁻¹⁵
m	= 10 ⁻³		

If multipliers are used, they must immediately follow the number with no spaces. Letters that are not multipliers immediately following a number are ignored, and letters immediately following a multiplier are ignored. For example, 10, 10V, 10Volts, and 10Hz all represent the same number and M, MA, Msec, and MMhos all represent the same multiplier. Note that 1000, 1000.0, 1000Hz, 1e3, 1.0e3, 1KHz, and 1K all represent the same number.

Model (%M)

Inserts the Label-Value into the SPICE data string. If the first character of the Spice Prefix Character(s) does not match the first character in the label, then it inserts the first character of the prefix at the beginning of the string. The %M is also required in order to guarantee that the .MODEL data for this device will be included in the SPICE netlist file for simulation. The Label (including prefix) may not exceed 8 characters.

Subcircuit (%S)

Inserts the Label-Value into the SPICE data string. If the first character in the label is not an **X**, then it inserts an **X** at the beginning of the string. The %S is also required to ensure that the .SUBCKT data for this device will be included in the SPICE netlist file for simulation. The Label (including the **X**) may not exceed 8 characters.

Designation (%D)

Inserts the Designation label into the SPICE data string. If the first character of the Spice Prefix Character(s) does not match the first character in the designation, then it inserts the first character of the prefix at the beginning of the string.

Description (%I)

Inserts the Description field into the SPICE data string.

Package (%P)

Inserts the Package label into the SPICE data string.

Bus Data (%B)

Inserts the entire Bus Data field into the SPICE data string.

Named Subcircuit (%X)

Inserts the specified subcircuit into the SPICE data string. If the subcircuit resides in a .SUB file other than the one associated with the symbol name of the current device, the .SUB file name where the subcircuit is located must also be specified. For example: %XUA741 or %XUA741:OPAMP5.

Include File (%= "*pathfilename.ext*")

Inserts the ASCII text file *filename* into the SPICE data string by using SPICE's .INCLUDE command. Path is the same as the current circuit unless enclosed in quote marks (" ").

Node (%*number*)

Inserts the node number for the specified pin into the SPICE data string. *Number* refers to the position of the pin in the Edit Device Pin Data dialog box. For example, the pin at the top of the list is represented by %1, the next pin down is %2, etc. See *Pins* later in this section.

Analysis Probe Name (%[*]*)

Inserts the output node number associated with an Analysis Probe. For example, %[TP1] or %[+TP1] inserts the node number associated with the + pin of the Analysis Probe that has the name TP1. %[-TP1] inserts the node number associated with the - pin.

Example of Using SPICE Data

The following examples show how you can use the SPICE Data field when creating custom devices.

Example 1

If resistor R3 has a value of 27 ohms and is connected between node 5 and ground, the SPICE data for R3 could be written as:

```
R3 5 0 27ohms
```

However, by using a generalized form of the SPICE data, it can be updated automatically if items such as designations or node numbers change. For example, the items in the above example can be substituted accordingly:

Value	Description	Substitution
R3	Designation	%D
5	First pin node number	%1
0	Second pin node number	%2
27ohms	Label-Value	%V

Using these substitutions, the generalized form of the SPICE Data becomes:

```
%D %1 %2 %V
```


Example 2

If transistor Q2 is a 2N3904 with its collector connected to node 7, its base to node 4 and its emitter to node 12, the SPICE data may be written as:

```
Q2 7 4 12 Q2N3904
```

However, you may need to enter SPICE model data into the netlist manually. A more universal method would be to enter the following string:

```
%D %1 %2 %3 %M
```

Example 3

If op amp U4 is an LM741 where the +input is connected to node 3, the -input is connected to node 1, the +V pin to node 5, the -V pin to node 12 and the output to node 9, the SPICE data may be written as:

```
XU4 3 1 5 12 9 XLM741
```

But again, a more universal method would be to enter the following string:

```
%D %1 %2 %3 %4 %5 %S
```

Exclude From PCB

Use this check box to exclude a device from the PCB netlist. Typically, devices used for simulation purposes only (external inputs like a signal generator, for example) would be excluded from the PCB netlist.

Exclude From Bill of Materials

Use this check box to exclude a device from the Bill of Materials. See *Exporting a Bill of Materials* in *Chapter 7: Exporting Files* for more information on generating a Bill of Materials.

Pins

Click the **Pins** button on the Edit Device Data dialog box to display the dialog box shown in Figure 4.9. This dialog box lets you edit the pin designations of the package for the selected device and determine whether the pin designations will be shown on the schematic.

You can specify pin numbers using up to five alphanumeric characters. Not only can you use standard pin numbers such as 1, 2, 3, but you can also use pin numbers such as A1, B1, C1, A2, B2, C2.

Some device packages actually contain more than one of the same device. For example, a 7400 Quad 2-Input NAND gate actually has 4 gates in the same package. The pin numbers are different for each gate. CircuitMaker groups together the individual gates to indicate which gates go in which package. As you place each gate in the circuit, the next available gate is used from the previous package. If no gates are available in the previous package, a new package is used. You can regroup the gates as needed using the **Edit > Group Items** option. Each gate in the package is assigned a letter (A, B, C, etc.) and the pin numbers for that gate correspond to that assignment. You can manually reassign the pins used for a particular gate by selecting the appropriate letter (PART A, PART B, etc.) for that gate with the **Up** and **Down Arrows** in the dialog box.



Figure 4.9. Use this dialog box as a reference for pin SPICE information.

Default pin data has already been entered for the predefined devices. Clicking the **Default Designations** button restores the pin numbers to their original default values. You can add default pin numbers to a macro device by editing the pin numbers while the macro is expanded and while saving the macro.

To edit macro pin names and designations,

- 1 Double-click them in the Symbol Editor (see *Chapter 16: Creating New Devices* for more information).

The order in which the pins appear in the list is determined by the order in which you placed pins on the device.

To edit pin designations for a specific part,

- 1 Double-click them in this dialog box. This does not change the pin designations in the library.

Faults

Clicking the **Faults** button on the Edit Device Data dialog box displays the Device Faults dialog box, which lets you add fault data to the device. If the fault data has been password protected, the Access Faults dialog box appears. See *Chapter 8: Fault Simulation* for details.

Printing and Exporting Circuits

When you have finished designing your circuit, you can print it on any Windows-selectable printer or plotter, or export the circuit to a file and use it in documentation, presentations, etc.

Printing Circuits

To print a circuit, choose **File > Print**.

If your design is larger than a single sheet of paper it will automatically be printed on multiple sheets of paper. To see where page breaks occur, choose **Options > Show Page Breaks**.

Adjusting Print Size

There are various ways to adjust the print size of your schematic in CircuitMaker.

- Choose **File > Print Setup** and select **Fit to Page** and the schematic will be automatically be scaled to fit in a single page, or choose **Scale** and enter the percentage you would like the circuit scaled to.

OR

- Choose **Options > Show Page Breaks** and click and drag one of the page breaks, until the circuit fits in the page as you want it to print.

Other print options are also available, including color printing. See *Print Setup* in *Chapter 9: File Menu*. You can also print digital timing diagrams, analog waveforms, title blocks, borders, and grids. See *Chapter 12: Options Menu* for more information.

Exporting Circuits as Graphics

You can export CircuitMaker circuit schematics and use them in documentation, presentations, etc. You can either save the circuit as a graphic file, or copy and paste the circuit directly into another software program.

Use the Export Circuit as Graphic option to save the circuit to disk as a Windows Metafile, Device Independent Bitmap or Device Dependent Bitmap. Use the Export Options dialog box, described earlier, to choose the format.

To export the circuit as a graphic,

- 1 Choose **File > Export > Circuit as Graphic**. Select the name of the file where you want to save the circuit graphic, then choose **Save**.

OR

Choose **Edit > Copy to Clipboard > Circuit**, then open another Windows program and Paste the circuit directly into your document. See also *Chapter 7: Exporting Files*.

CHAPTER 5

Digital Logic Simulation

One of CircuitMaker's most powerful features is circuit simulation, allowing you to try variations in a design and troubleshoot it before you invest time and money in hardware prototypes.

CircuitMaker's Simulation Modes

CircuitMaker is one of the few simulation programs that offers 2 distinct modes of simulation: Analog mode and Digital mode. This gives you greater flexibility and control over how your circuit is simulated, and each mode has advantages depending on the type of simulations you need.

Analog Mode is the accurate, "real-world" simulation mode you can use for analog, digital and mixed-signal circuits. This mode will give you results like you would get from an actual breadboard. In Analog mode, the devices function just like real-world parts, and each individual model functions like its real-world counterpart. For example, digital ICs have accurate propagation delays, setup and hold times, etc. Outputs of the devices see the effect of loading on them, and nearly all the parameters of the real world are taken into account. See *Chapter 6: Analog/Mixed-Signal Simulation* for more on this mode.

Digital Mode, on the other hand, is designed for purely digital logic simulation. This mode is only used for digital circuits, and depends solely on the logic states of the devices that make up the circuit. Digital mode simulation still takes into account propagation delays, but they are unit delays instead of actual propagation delays. No power supply is required, and the digital device output levels are constant in this mode.

Digital electronics is the world of the computer. The binary 1's and 0's of the computer are actually the high and low voltage levels of tiny electronic devices known as integrated

circuits. Digital logic simulation, then, becomes a relatively simple task because of the limited number of digital states that must be represented. CircuitMaker's digital logic simulator is very fast and fully interactive, meaning you can flip switches and alter the circuit while the simulation is running and immediately see the response.

Devices and Simulation

CircuitMaker provides four types of devices, which can be used in different simulation modes.

Device Type	Will Function In
Digital Only device	Digital simulation mode only
Analog Only device	Analog simulation mode only
Analog/Digital device	Analog or Digital mode
Schematic Symbol only	No functionality

So any **Digital Only** and **Analog/Digital** devices will function properly in the Digital mode. To find out the intended simulation mode for a device, read the words above the symbol pictured in the Device Selection dialog box. Or, refer to the Device Library book for a description of each device and the simulation mode for which it is intended.

If you attempt to simulate a device using a simulation mode for which the device is not intended, CircuitMaker displays a warning message and that device is ignored, producing an open circuit where that device is located.

Using the Digital Logic Simulator

Digital simulation is completely interactive, meaning that the circuit responds immediately to changes from input stimulus, and the operation of the circuit is shown in real time as it happens on the screen. You can observe the operation of the circuit in the following ways:

- Enable CircuitMaker's exclusive **Trace** feature to show the state of every node in the circuit simultaneously as the simulation runs. In this mode, wires at a logic one are shown as red, wires at a logic zero as blue, and wires at an unknown or tristate as green (these colors may be changed by choosing **View > Colors**).

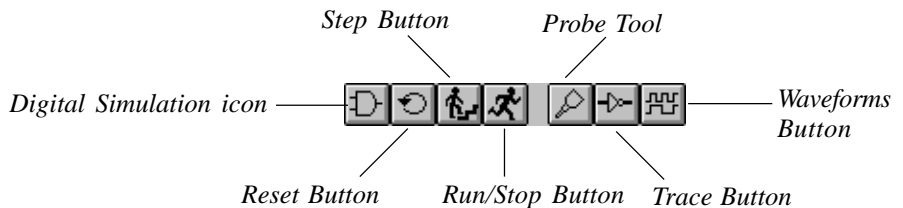
TP1

- Connect any number of SCOPE probes to any nodes in the circuit, so that the timing diagrams for those nodes are shown in a separate digital Waveforms window. The timing information is updated continuously to show changes as they happen in real time.
- Connect any of a variety of displays and note the conditions shown on them.
- Use the **Probe Tool** to probe any wire in the circuit either during simulation or after you have stopped it. The logic states seen by the Probe Tool can also be charted in the Waveforms window.

Digital Logic Simulation Tools

Several buttons in the Toolbar are used specifically for simulation. This section describes these tools.

Note: The functionality of these buttons is somewhat different in CircuitMaker's Analog mode. See *Chapter 6: Analog/Mixed-Signal Simulation* for more information.



Digital/Analog Button

Click the **Digital/Analog** button to choose the simulation mode you want to use. When the AND gate icon is displayed, you are in Digital simulation mode; when the transistor icon is displayed, you are in Analog mode.

Reset Button

Click the **Reset** button to restart the simulation. You can also reset by choosing **Simulation > Reset** or by pressing **Ctrl+Q**.

Step Button

Click the **Step** button to run the simulation for one step or simulation “tick”. You can also choose **Simulation > Step** or press **F9**. Use the **Simulation > Digital Setup** feature (see Figure 5.1) to control the size of a step. When you click this tool, the simulation runs for one step and then stops. This command is handy for debugging a circuit, especially when used in conjunction with the **Trace** button.



Figure 5.1. Use the Digital Options dialog box to specify the size of a step and other digital simulation options.

Run/Stop Button

Click the **Run** button to start the simulation. The icon will change to a Stop Sign. Click the **Stop Sign** icon to stop the simulation (You can also choose **Simulation > Run and Stop** or press **F10**). When the simulation is running you can't perform edit operations such as move and delete (if you try, CircuitMaker will signal a warning beep). You can flip switches with the **Arrow** or **Probe Tool**, and view or toggle the state of a wire with the **Probe Tool**.

Probe Tool

Use the **Probe Tool** to monitor the state of any node in the circuit or to inject a state into a node. You can also activate the Probe Tool by pressing **Alt+P** or right-clicking the mouse and choosing **Probe** from the pop-up menu.

To see the state of a node, either while the simulation is running or after it has stopped, touch the Probe Tool's tip on a wire or device pin. The tool displays one of four messages: H, L, P, or no letter at all. The meanings of these letters are



High State



Low State



Pulse (between High and Low States)



Unknown or Tristate

illustrated at left. Choose **Simulation > Scope Probe** beforehand to have CircuitMaker chart the waveforms you see with the Probe Tool in the Waveforms window.

To inject a state into a node,

- 1 Touch the tip of the **Probe Tool** on a wire or device pin.
- 2 Click the left mouse button.

The state of that node changes to be opposite of what it was (a one becomes a zero and a zero becomes a one).

To inject a tristate signal,

- 1 Hold down the **Shift** key and click.

Note: In both cases, if the node is driven by some other device, the state change is immediately overridden because the device drives the node back to its original state.

You can also use the Probe Tool to flip switches while the simulation is running.

Trace Button

Click the **Trace** button (or press **F11**) to turn the trace feature on or off. Use Trace to debug your circuit or to simply provide a convenient way of observing operation of the circuit. Trace shows the state of all nodes within the circuit as it runs by drawing the wires in different colors to show the logic state of each wire. A wire at a high state is red, a wire at a low state is blue, and a tristate wire is green.

Note: Because the wires in the circuit will be redrawn each time they change states, turning this option on may slow down the simulation speed.

Waveforms Button

In digital mode, clicking on the Waveforms button will open or close the digital Waveforms window. You can also choose **Simulation > Display Waveforms** or press **F12**. Waveforms are described in detail later in this chapter.

Propagation Delays

The delay of a device determines how many simulation ticks it takes for a signal to propagate from the input to the output of the device. The default delay for all devices is 1, but you can change this to any value from 1 to 14. You determine the real-time value of each tick. The concept is that if one device has a delay of one and another a delay of three, then in the real world the second device would have a propagation delay three times larger than the first device.

To change the delay of one or more devices,

- 1 Select the device(s).
- 2 Select the **Edit > Set Prop Delays** to display the dialog box shown in Figure 5.2.
- 3 Enter a new value for the delay and choose OK.

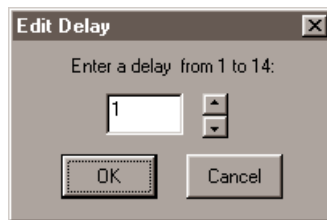


Figure 5.2. Use this dialog box to change the propagation delay of one or more devices.

Choose **Options > Show Prop Delays** to display the propagation delay of all devices in the circuit. The delay values are shown within a rounded rectangle located near the center of each device. Some devices (Pulsers, Logic Displays, macro devices, etc.) do not have a delay, so no value will be shown. In the case of macro devices, the delay is determined by the individual delay setting of each device within the macro.

Digital Waveforms

By attaching SCOPes [Digital/Instrument] (t) to points of interest in the circuit, you can graph the states of these nodes over time as the simulation runs. Choose **Simulation > Display Waveforms** or click the **Waveforms** button in the Toolbar to display or hide the digital Waveforms window. An example of the waveforms window is shown in Figure 5.3.

Breakpoint check boxes



Figure 5.3. The Waveforms window lets you graph the states of nodes over time as the simulation runs.

Before you can view timing waveforms for any node in your circuit, you must connect a SCOPE to each node you want to monitor, or choose **Simulation > Scope Probe** to monitor the states of the Probe Tool in the Waveforms window.

Changing Waveform Order

To change the order of waveforms,

- 1 Point the mouse at any of the scope labels in the waveform window.
- 2 Press and continue to hold down the left mouse button.
- 3 Move the rectangle to the desired position.
- 4 Release the mouse button.

Notice that the waveforms are automatically reordered in the window. Repeat this process as often as desired in order to position the waveforms in any order. When you save a circuit to disk, CircuitMaker also saves the order of the waveforms.

Digital Options

Use the Digital Options dialog box to control the size of a step when running the simulation in single step mode, to set the conditions for break points and to set the simulation speed. Choose **Simulation > Digital** to display the dialog box shown in Figure 5.4.



Figure 5.4. Use the Digital Options dialog box to control the size of a step and other digital simulation options.

You can define the **Step Size** in either ticks or cycles. A cycle always consists of 10 ticks. A tick is the smallest unit of delay for the digital simulator. It takes one tick to perform a single step of the simulation for all devices.

Adjust **X Magnification** to view a larger or smaller section of the waveforms in the digital Waveforms window. By default, the magnification is set to 8. A smaller value zooms out, a greater value zooms in.

Use **Simulation Speed** to control how fast the simulation runs. This could be useful, for example, if the simulation is running too fast to view the states of a seven-segment display. Setting this field to a lower number slows down the simulation so you can view the changes of the display. Another method of slowing the simulation would be to run it in single step mode or set breakpoints.

Use the **Breakpoint** and **Conditions** options in conjunction with the waveforms window to set breakpoints. The following table illustrates the results of various combinations of settings.

Combination	Result
Level-And	All break conditions must be met before the simulation stops.
Level-Or	Any one of the break conditions stops the simulation.
Edge-And	The simulation stops when the proper edge occurs on all of the specified waveforms.
Edge-Or	The simulation stops if a transition to any of the specified conditions occurs.

Setting Breakpoints in a Circuit

Use the breakpoint check boxes in the digital Waveforms window (see Figure 5.3) to set breakpoints in a circuit.

To set a breakpoint,

- 1** Click once in the small breakpoint check box to the left of a SCOPE's label in the Waveforms window to fill the bottom portion of the square indicating a break on zero condition.
- 2** Click a second time to fill the top portion of the square indicating a break on one condition.
- 3** Click a third time to return the square to its empty state indicating no break condition.

Digital Instruments

This section introduces two digital instruments: the Pulser and the Data Sequencer.

Pulser

The Pulser [Instruments/Digital] (p) is a digital pulse generator which provides a continuous stream of highs and lows. In the pulse format, time high, time low, and trigger mode are individually programmable for each Pulser in the circuit.



To edit the Pulser settings,

- 1 Double-click the Pulser with the **Arrow Tool** to display the dialog box shown in Figure 5.5.
- 2 Change the number of simulation ticks for which the pulse will stay high and low, the format of the pulse (normal or inverted), and whether the pulser is in free run or external trigger mode.

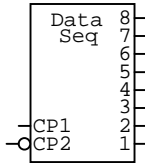


Figure 5.5. Use the Edit Pulser dialog box to change pulse ticks and set free run or external trigger mode.

- 3 Select **External Trigger** to use the Pulser as a programmable one-shot.

In the External Trigger mode, the CP1 and CP2 inputs serve as rising and falling edge trigger inputs, respectively. If either pin receives a trigger pulse then the outputs of the Pulser will go active on the next simulation tick and remain active for Pulse High ticks. You can retrigger the Pulser in this mode so additional trigger pulses occurring before the completion of the cycle will cause the active time to be extended for another cycle.

Data Sequencer



You can use the Data Sequencer [Instruments/Analog] (G) device in both digital and analog simulation modes. Also known as a Data or Word Generator, it allows you to specify up to 32767 8-bit words which can be output in a defined sequence. Since there is no limit to the number of Data Sequencers that you can use in a circuit, you could place several in parallel to create a data stream of any width. Double-click the **Data Sequencer** with the Arrow Tool to display the dialog box pictured in Figure 5.6.

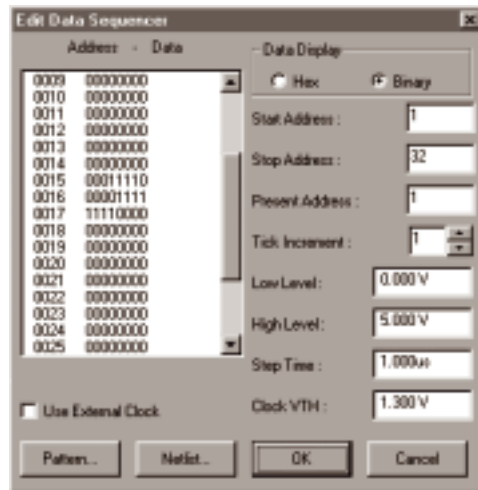


Figure 5.6. Use the Edit Data Sequencer dialog box to edit stimulus for your circuits.

Start Address is the address of the data that outputs first when the simulation begins. **Stop Address** is the address of the data that outputs last before the sequence repeats. Use **Use External Clock** to make the CP1 and CP2 inputs rising and falling edge clock inputs, respectively. If pins are clocked, the Data Sequencer advances to the next address.

Digital Simulation Mode Only

The **Present Address** option indicates the address of the data that is output next if the circuit is not reset or modified. The **Tick Increment** specifies how many simulation ticks occur before the output is advanced to the next address when the external clock is disabled.

Analog Simulation Mode Only

Low Level and **High Level** indicate the output voltage levels. **Step Time** is the length of time that the outputs remain at each address when the external clock is disabled. **Clock VTH** is the voltage threshold level at which the external clock pins cause the outputs to advance to the next address.

Pattern Editor

You can type data directly into the Data list box in the Data Sequencer dialog box. However, when creating a large pattern this method becomes time consuming. Choose the **Pattern** button on the Data Sequencer dialog box to display the dialog box shown in Figure 5.7. The Pattern Editor helps you to create large, complex patterns quickly.

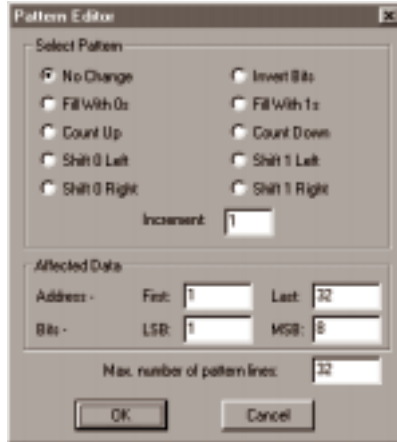


Figure 5.7. Use the Pattern Editor to help you quickly create large, complex patterns.

The Pattern Editor not only lets you to enter predefined pattern sequences, it also lets you specify which rows (addresses) and columns (bits) are affected. For example, you could fill just one column with a count up sequence to produce a stream of ones and zeros on a single output. Or you could fill rows 23-67 with ones in just 5 columns and fill the same rows with a repeating Shift 0 Left in the other 3 columns.

The **Increment** field indicates how many rows will contain the same data before the next change in pattern. For example, with an increment of 3, a **Shift 1 Left** pattern shifts on every third pattern row.

You can set the maximum pattern size for each Data Sequencer. This lets you create small patterns for several Data Sequencers without allocating large amounts of memory or creating large circuit files. The **Max. number of pattern lines**, by default, is set to 32, but can be increased as needed to as many as 32767. It can never be smaller than the Stop Address. When you *increase* the maximum number of pattern rows, the new rows are filled with zeros. If you *decrease* the maximum number of pattern rows, any pattern data that was stored in the upper addresses is lost permanently.

CHAPTER 6

Analog/Mixed-Signal Simulation

One of CircuitMaker's most powerful features is circuit simulation, allowing you to try variations in a design and troubleshoot it before you invest time and money in hardware prototypes.

CircuitMaker's Simulation Modes

CircuitMaker is one of the few simulation programs that offers 2 distinct modes of simulation: Analog mode and Digital mode. This gives you greater flexibility and control over how your circuit is simulated, and each mode has advantages depending on the type of simulations you need.


Analog Mode is the accurate, "real-world" simulation mode you can use for analog, digital and mixed-signal circuits. This mode will give you results like you would get from an actual breadboard. In Analog mode, the devices function just like real-world parts, and each individual model functions like its real-world counterpart. For example, digital ICs have accurate propagation delays, setup and hold times, etc. Outputs of the devices see the effect of loading on them, and nearly all the parameters of the real world are taken into account.


Analog is the classic world of electronics. Unlike digital electronics, there are no logic state restrictions; the voltage level of any given circuit node is not limited to a high or low. Analog simulation, therefore, is much more complex. CircuitMaker's analog/mixed-mode simulation uses an enhanced version of Berkeley SPICE3f5/XSpice, allowing you to accurately simulate any combination of analog and digital devices without manually inserting D/A or A/D converters. This "mixed-signal" or "mixed-mode" simulation is possible because CircuitMaker includes accurate, event-driven behavioral models for its digital devices, including TTL and CMOS digital devices.

SPICE:
Simulation
Program with
Integrated
Circuit
Emphasis

In Analog mode, there are also a wide variety of analyses that can be used in Analog mode to test and analyze various aspects of your design.

Digital Mode, on the other hand, is designed for purely digital logic simulation. This mode is only used for digital circuits, and depends solely on the logic states of the devices that make up the circuit. Digital mode simulation still takes into account propagation delays, but they are unit delays instead of actual propagation delays. No power supply is required, and the digital device output levels are constant in this mode. See *Chapter 5: Digital Logic Simulation* for more on this mode.

 *Digital Mode*

 *Analog Mode*

Devices and Simulation

CircuitMaker provides four types of devices, which can be used in different simulation modes.

Device Type	Will Function In
Digital Only device	Digital simulation mode only
Analog Only device	Analog simulation mode only
Analog/Digital device	Analog or Digital mode
Schematic Symbol only	No functionality

So any **Analog Only** and **Analog/Digital** devices will function properly in Analog mode. To find out the intended simulation mode for a device, read the words above the symbol pictured in the Device Selection dialog box. Or, refer to the Device Library book for a description of each device and the simulation mode for which it is intended.

Overview of Analog Simulation

This section explains the basic concepts for simulation in CircuitMaker's analog mode.

Before You Use the Analog Simulator

To do analog simulation, you must ensure there is SPICE information for each device in the circuit. Only those devices listed as Analog or Analog/Digital in the Device Library

book have SPICE data associated with them. You can use other devices in the circuit as long as you provide the SPICE information for those devices. See *Chapter 16: Creating New Devices* for more information.

The **Analog** check box in the Edit Device Data dialog box indicates whether or not that device will function in Analog simulation mode (meaning there is SPICE simulation data available for the device). If the **Analog** check box is not checked and you use the device in analog simulation, a warning appears and that device is ignored, leaving an open circuit where that device is located.

Setting Up Analog Analyses

You set up analog analyses using the Analyses Setup dialog box described later in this chapter. By default, whenever you create a new circuit, the **Always Set Defaults** option is enabled for the analog analyses. This means that Operating Point Analysis (the Multimeter) is enabled for simple DC circuits. For more complex circuits, Transient Analysis (the oscilloscope) is enabled and set to its default conditions. Under normal conditions, you probably won't need to change these settings.

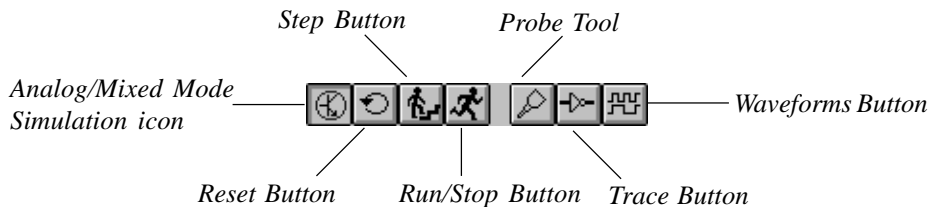
Selecting Analog Simulation Mode

You know Analog simulation mode is selected when the transistor icon is displayed on the Digital/Analog button on the Toolbar.

Analog Simulation Tools

Several buttons in the Toolbar are used specifically for simulation. This section describes these tools.

Note: The functionality of these buttons is somewhat different in Digital logic mode. See *Chapter 5: Digital Logic Simulation* for more information.



Digital/Analog Button

Click the **Digital/Analog** button to choose which simulation mode you want to operate in. When the AND gate icon is displayed, you are in CircuitMaker's Digital mode; when the transistor icon is displayed, you are in Analog mode. See the *CircuitMaker's Simulation Modes* earlier in this chapter for an explanation of the differences between Analog and Digital mode.

Reset Button

In Analog mode, clicking the **Reset** button generates the node numbers for the circuit without running the simulation. This is important if you want to save a SPICE netlist file or view the node numbers on the schematic, but not run the simulation. You can also reset the simulation by choosing **Simulation > Reset** or by pressing **Ctrl+Q**.

Step Button

The **Step** button is used in Digital mode only. Refer to *Step Button* in *Chapter 5: Digital Logic Simulation*.

Run/Stop Button

Click the **Run** button to start the simulation. The icon will change to a Stop Sign. Click the **Stop Sign** icon to stop the simulation (you can also choose **Simulation > Run and Stop** or press **F10**). An interactive XSPICE simulation window appears showing the progress of the simulation (see *Using XSpice for Windows* later in this chapter). The amount of time it takes to complete the simulation is based on the analyses you have enabled, the amount of data you are collecting, the complexity of the circuit, and the speed of your computer. When the simulation has completed, an analysis window appears for each of the selected analyses you have run.

Note: If no changes have been made since the last simulation was run, clicking the Run button will not rerun the simulation, but will immediately load the previous simulation data.

The Stop icon replaces the Run icon when the Run button is pressed. Once the data collection sequence has ended and the analysis windows are displayed, pressing the Stop button will stop the simulation, closing all analysis windows, and returning to schematic editing mode.

Probe Tool

The context-sensitive **Probe Tool**, which you can also select by pressing **Alt+P**, allows you to quickly probe any point(s) in the circuit during simulation and see the resulting waveform or data in the selected analysis window. Note that the Probe Tool is used differently in Analog mode than it is in Digital mode.

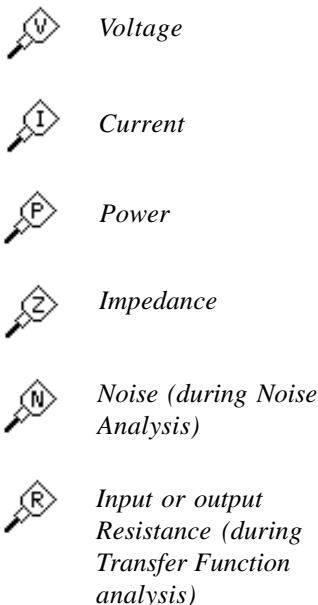
Before running a simulation, you can left-click the Probe tool in the circuit to add or remove Run-Time Test Points. Or, by left-clicking while holding down the **Ctrl** key you can add or remove Exclusive Test Points in the circuit. Note, however, that you **do not** have to pre-define test points before running a simulation in CircuitMaker. See *Working with Test Points* later in this chapter for more information on using test points.

During simulation, touch the tip of the Probe Tool to a wire, device pin or device body to observe or plot data at that point. The tool displays one of six letters: V, I, P, Z, N, or R. The meanings of these letters are illustrated at left.

Click the left mouse button while the Probe Tool is at the point in the circuit you wish to probe, and a value or waveform appears instantly in the current (active) analysis window. *To see multiple waveforms*, simply Shift-click with the Probe Tool on as many points as you wish and the corresponding waveforms “stack” in the current analysis window.

Note: If CircuitMaker indicates that current or power data is not available, then go to **Simulation > Analyses Setup > Analog Options...** and select the **Node Voltage, Supply Current, Device Current and Power** radio button in the lower right-hand corner of the dialog box.

Ctrl-clicking with the Probe Tool sets a new voltage reference point (the default voltage reference is ground) for the current (active) analysis window.



Trace Button

The Trace button is only used in Digital mode. Refer to the *Digital Logic Simulation Tools* section of *Chapter 5: Digital Logic Simulation*.

Waveforms Button

In analog mode, click the **Waveforms** button (or press **F12**) to open all analysis windows for which there is data in the .RAW file for this circuit. This allows you to view the graphs for this circuit without rerunning the simulation (this is only available if the circuit has not been modified since the .RAW file was created). Clicking the button again closes all waveform analysis windows, which also stops the simulation (just like clicking the **Stop** button) and lets you edit the circuit. You can open the analysis windows individually from the Windows menu.

Vcc and Ground

CircuitMaker's digital devices do not include Vcc and ground pins. However, to properly simulate these devices in Analog simulation mode, Vcc and ground connections are required. You can include them by placing entries in the Bus Data field of each digital device which references specific power and ground buses.

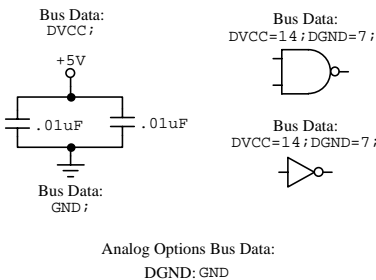


Figure 6.1. Analog Options Bus Data: DGND; GND

Create a power supply bus by placing a +V device in the circuit with a bus identifier (such as **DVCC**; or **DVDD**;) in its Bus Data field. A ground bus is already defined by the Ground symbol which contains **GND**; in its Bus Data field. If no bus is placed directly in the circuit, the default values for **DVCC**, **DVDD** and **DGND** are used. These default values are specified in the Analog Options-Spice Variables dialog box. See *Setting Up Analog Analyses* later in this chapter for more information.

The Bus Data fields are predefined in CircuitMaker's digital devices with values such as **DVCC=16; DGND=8**; which also identify the specific pin numbers on the package that are connected to the buses.

In the example in Figure 6.1, both the NAND gate and the inverter are connected to +5V and ground, along with two bypass capacitors. The DGND on the devices is connected to the GND bus through the Analog Options dialog box.

This is the same procedure used to connect the Vcc and ground pins in a PCB netlist for export to TraxMaker. See *Chapter 4: Drawing and Editing Schematics*.

Note: You can tie together Multiple +Vs by using one normal +V to supply power and multiple +Vs with the SPICE data field deleted. You can also use one normal +V to supply power and multiple terminal devices [Connectors/Misc]. Connect these together using the Bus Data field of the +V device and the Terminal Name field of the Terminal device. Using the terminal devices instead of additional +V devices eliminates the step of deleting the SPICE Data field. CircuitMaker will make a connection between the Terminal device and any bus that has the same name. CircuitMaker will also make a connection between the Terminal device and any Input or Output connector that has the same name. Do not use a semicolon in the Terminal Name field. For example, to connect a Terminal device to the VEE bus, enter **VEE** (not **VEE;**) in the Terminal Name field. CircuitMaker automatically copies what you enter in Terminal Name field to the Terminal's Bus Data field and appends a semicolon.

*Note: You **do not** have to set test points before running a simulation. CircuitMaker does it automatically according to the chosen analyses.*

Working with Test Points

Test Points are set in a circuit to tell CircuitMaker where to collect simulation data. Note that you **do not** have to set test points before running a simulation (CircuitMaker does it automatically). Test Points determine how much data is actually stored in the .RAW file, and they determine which variables are displayed in the analysis windows when the simulation runs. As a result, more test points require a longer simulation time.

Test Point Types

There three types of Test Points used in CircuitMaker:

Test Point Type	How Used
Default Test Points	CircuitMaker automatically places Default Test Points in the circuit, according to the Analog Options settings. These are not displayed on the circuit.
Exclusive Test Points	These are test points you place in the circuit to measure voltage, current or power. When placed, exclusive test points disable the default test points, and data is only collected for each exclusive test point.
Run-Time Test Points	These are test points you place in the circuit to graph data at a specific point.

Default Test Points

CircuitMaker automatically places Default Test Points in the circuit, allowing you to click with the Probe Tool on almost any wire, pin, or device to measure voltage, current, or power (respectively). The Default Test Points are set based on the Analog Options settings. See *Setting Up Analog Analyses* later in this chapter for more information.

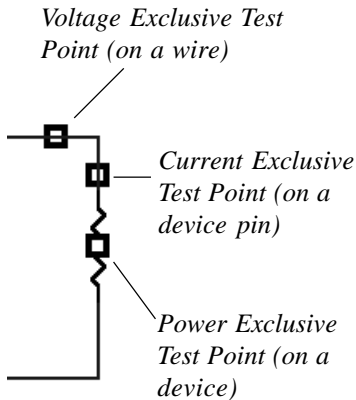
When you place Exclusive Test Points, the Default Test Points are automatically disabled and data is only collected for the points that you define. Note that Default Test Points are not displayed on the circuit.

Exclusive Test Points

These are test points you place manually in the circuit to measure voltage, current or power. When placed, exclusive test points disable the default test points, and data is only collected for each exclusive test point.

To place Exclusive Test Points in the circuit,

- 1 Make sure the simulation is stopped.
- 2 Select the **Probe Tool** from the Toolbar.



To add an Exclusive Test Point, **Right-click** the Probe Tool

- 3 Hold the **Ctrl** key and left-click the appropriate locations in the circuit.

Placing Multiple Exclusive Test Points

To place multiple Exclusive Test Points,

- 1 Hold the **Shift** and **Ctrl** key while left-clicking.

You can place Exclusive Test Points on wires to measure node voltages, on device pins to measure current, or on devices themselves to measure power dissipation. Data is not collected for devices containing subcircuits.

Removing Exclusive Test Points

To remove all Exclusive Test Points from the circuit,

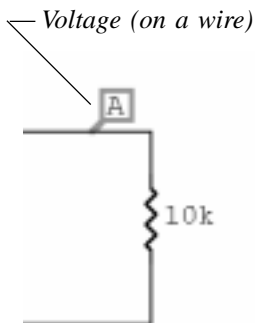
- 1 Hold the **Ctrl** key and left-click the **Probe Tool** in any blank area of the circuit window.

Note that when you remove all Exclusive Test Points, the Default Test Points become active again.

Run-Time Test Points

Run-Time Test Points are locations you can define in the circuit where CircuitMaker will automatically display graphical data that is collected during simulation. Like regular Exclusive Test Points, Run-Time Test Points can measure voltage, current, or power dissipation. *Note that you can also plot waveforms by simply clicking with the Probe Tool after the simulation is complete.*

You can place Run-Time Test Points on wires to measure node voltages, on device pins to measure current, or on devices themselves to measure power dissipation. CircuitMaker displays waveforms only if it actually collects data by default or by the Test Points you define. CircuitMaker does not display waveforms for some devices, such as those containing subcircuits.



To add a Run-Time Test Point, **Left-click** the Probe Tool.

To place Run-Time Test Points in the circuit,

- 1 Stop the simulation.
- 2 Select the **Probe Tool** from the Toolbar.
- 3 Click the appropriate locations in the circuit using the left mouse button to display the Run Time Test Point dialog box pictured in Figure 6.2.



Figure 6.2. Use the Run-Time Test Point dialog box to choose the type of analysis data you want to see.

- 4 Specify which type of analysis data you want to see by checking the applicable check box: AC, AC in decibels, DC or Transient.
- 5 If you like, you can specify the minimum and maximum Y-scale values that will be used on each graph. This is optional.
- 6 Place a check in the **Combine Plots With Same Analysis and Scale** check box for each Run-Time Test Point that you want to combine for displaying multiple waveforms on the same graph during simulation.
- 7 Choose OK.

When combining Run-Time Test Points on a single plot, it is sometimes useful to change the DC offset of each waveform so they do not overlap. To do so, just enter a different offset value in the **Vert. Offset** field for each Run-Time Test Point. You can also choose to pause when the simulation is complete, before returning to CircuitMaker.

To edit an existing Run-Time Test Point, double-click it with the **Arrow Tool**.

Adding Multiple Run-Time Test Points

To add multiple Run-Time Test Points,

- 1 Hold down the **Shift** key while clicking with the Probe Tool.

Removing All Run-Time Test Points

To remove all Run-Time Test Points from the circuit,

- 1 **Left**-click with the **Probe Tool** in any blank area of the circuit window.



Run Button

Running the Simulation

Once you have created the circuit, you can run the simulation by simply clicking the Run button on the Toolbar. One aspect that sets CircuitMaker apart from other SPICE-based simulators is the seamless integration between the schematic design and simulation process. There are no complex data fields to enter, and everything is done quickly and efficiently from the same workspace.

CircuitMaker displays an interactive XSpice simulation window during the SPICE data collection process, showing the progress of the simulation. When the simulation has completed, an analysis window appears for each of the selected analyses you have run.

Using the Analysis Windows

CircuitMaker displays data and waveforms using Analysis windows, which allow you to quickly and easily test, analyze and probe your circuits during simulation. Many attributes of the Analysis windows can be changed, to customize your view of the waveforms. There are also features within the Analysis windows that allow you to precisely measure the waveforms you are viewing.

When you run a simulation, CircuitMaker displays a separate analysis window for each of the following types of analyses that you enable:

- DC (curve tracer)
- AC (Bode plotter)
- Transient (oscilloscope)
- Fourier (spectrum analyzer)
- Operating Point (multimeter)
- Transfer Function
- Noise

For more information on these analyses, see *Setting Up Analog Analyses* later in this chapter. Figure 6.3 shows an example of an analysis window.

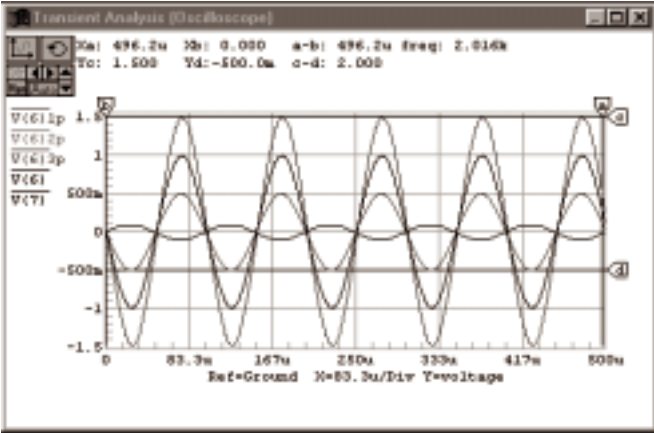


Figure 6.3. The Transient Analysis window.

Displaying Waveforms

Once you have run a simulation, you can quickly view data (waveforms) at any point(s) in the circuit using CircuitMaker's context-sensitive **Probe Tool**.

To plot data (waveforms) in an analysis window, first choose the appropriate analysis window by clicking somewhere in it so that it is "active", then:

- 1 Click any valid point in the circuit with the tip of the **Probe Tool**. See the *Probe Tool* section earlier in this chapter for information on some of the other types of data that can be plotted with the Probe Tool.
 - Click on a **wire** to measure voltage
 - Click on a **device pin** to measure current
 - Click on a **device body** to measure power

If CircuitMaker indicates that current or power data is not available, then go to **Simulation > Analyses Setup >**

Tip: You can “nudge” waveforms and cursors around the analysis window by selecting a waveform or cursor and using the arrow keys on the keyboard.

Analog Options... and select the **Node Voltage, Supply Current, Device Current and Power** radio button in the lower right-hand corner of the dialog box.

- 2 Hold down the **Shift** key and click to plot or “stack” multiple waveforms simultaneously in the analysis window. Note that clicking on another point in the circuit *without* holding the **Shift** key will replace the previous waveform with a new one.
- 3 Hold down the **Ctrl** key and click to set a new voltage reference for the active analysis window (the default reference is ground).

Plotting Subcircuit Internal Variables

By default, CircuitMaker doesn’t collect simulation data for any subcircuit’s internal variables.

To plot a subcircuit’s internal variables,

- 1 Choose **Simulation > Analyses Setup**.
- 2 Click **Analog Options**.
- 3 Click the radio button titled **Node Voltage, Supply Current and Device/Subcircuit VARs** then choose OK.
- 4 Run the simulation.
- 5 Click the subcircuit device with the tip of the **Probe Tool** and select the variable from the list.

Scaling Waveforms

You can view waveforms in the analysis windows in either Auto scale or Manual scale mode.

- Select the **Man** (Manual) button to set the window to manual scale mode.
- Select the **Auto** button to set the window to auto scale mode.



Waveform Scaling and Editing Controls

The manual scale controls allow you to specify the units per division for both the X and Y scales, using the arrow keys in corner of the analysis window. Auto scale mode will automatically scale the analysis window so that the selected waveform(s) are completely viewable within the window.

To scale a waveform in Manual Scale mode,

- 1 Select a waveform by clicking its label in the list on the left-hand side of the graph window. For example, click A, or V(8) if you have enabled the **Simulation > Display Variable Names** option.

If no waveform is selected, all waveforms will be scaled simultaneously.

- 2 Use the **Up** and **Down** arrow buttons to change the **Y** scale for the selected waveform(s).
- 3 Use the **Left** and **Right** arrow buttons to change the **X** scale for the selected waveform(s).

Note: You can adjust only linear scales; manual scaling has no effect on log scales.

In Auto Scale mode, CircuitMaker displays all waveforms at the same scale. The graph is automatically scaled so that the waveforms fill almost the entire graph.

You can click and drag a selection rectangle around a portion of the graph, then release the mouse to zoom in on that portion of the analysis window. See Figure 6.4.

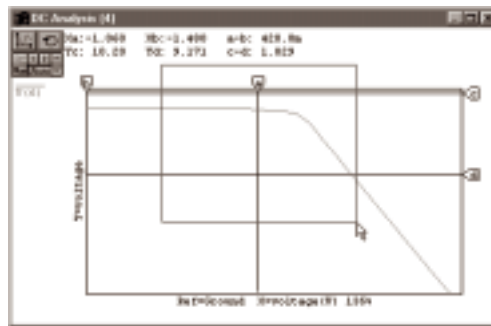


Figure 6.4. Click and drag a rectangle around any portion of the window to zoom in on that area.

Offsetting Waveforms

To reposition the waveform on the graph, alter its X and Y offsets:

- 1 Select a waveform by clicking on its name in the variable list on the left-hand side of the graph window.
- 2 Click and drag the waveform itself with the mouse or press the arrow keys on the keyboard to change both the X and Y offsets.
- 3 Select the **Off** button to display the offset values for the selected waveform (the values are shown near the top of the analysis window).

Using Measurement Cursors

Four measurement cursors let you precisely measure values in the waveform analysis windows such as amplitude and period. There are two cursors on the x axis and two on the y axis.

To use the measurement cursors,

- 1 Turn the cursors ON or OFF by double-clicking the tab at the end of the cursor.
- 2 Reposition a cursor by dragging the tab or by selecting it and pressing the arrow keys on the keyboard.

If no cursor is selected, pressing the arrow keys will move the selected waveform. The value at each cursor's position is displayed at the top of the graph window as well as the difference in value for each pair of cursors.

In manual scale mode, cursor values correspond to the selected waveform only. In auto scale mode, cursor values correspond to all waveforms, assuming there are no offsets.

Setup Button

The Setup button displays the Settings dialog box pictured in Figure 6.5, which lets you control the X (horizontal) and Y (vertical) axes of the graph, allows you to store and recall waveforms, and lets you control many visual aspects of the analysis windows. Note that you can also access many of the analysis window settings through the right-click pop-up menu that appears when you right-click anywhere inside an analysis window.

Tip: You can “nudge” waveforms and cursors around the analysis window by selecting a waveform or cursor and using the arrow keys on the keyboard.

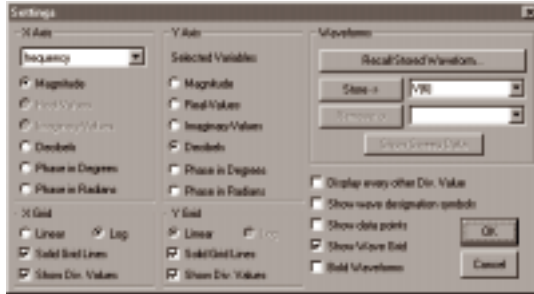


Figure 6.5. Use the Settings dialog box to control the X and Y axes of the graph, to store and recall waveforms and to alter the visual aspects of the analysis window.

Storing Waveform for Future Reference

To store the currently displayed waveform for future reference,

- 1 Select the waveform in the Store list box, then click the **Store** button.
- 2 Specify the name of the file in which to save the waveform. Each waveform is stored in a separate file.

Working with a Stored Waveform

To recall a stored waveform and place it on the graph,

- 1 Click the Recall Stored Waveform button.
- 2 Select the appropriate waveform file from the File Selection dialog box and choose **Open** to display the dialog box shown in Figure 6.6.

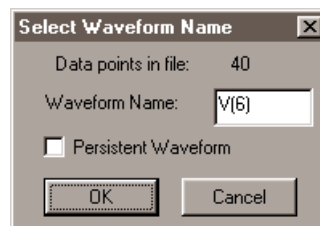


Figure 6.6. This dialog box indicates the number of data points in the file.

- 3 To rename the waveform to avoid naming conflicts with other waveforms, type a new name in the Waveform Name text box.
- 4 Select the **Persistent Waveform** check box to keep the waveform displayed on the graph no matter where else you click on the circuit.

A persistent waveform has an asterisk (*) placed in front of the name.

- 5 Deselect the **Persistent Waveform** check box to display the waveform only when you click the corresponding point in the circuit (it will be displayed together with the waveform for the loaded circuit).
- 6 To remove a persistent stored waveform, select it in the Remove list box and click the **Remove** button.

OR

Select the waveform by clicking its label on the left side of the graph then press the **Delete** key on the keyboard.

You can display multiple waveforms for the same point in a circuit by naming the waveforms the same up to the) or] character in the name. By adding different characters after the) or] you can plot multiple waveforms for the same point in the circuit.

For example, suppose you name one recalled waveform **v(4)1** and another **v(4)2**. This causes both waveforms to display simultaneously along with the current **v(4)** waveform when you click on node 4 in the circuit.

Reset Button

Click the **Reset** button in the analysis window to return all of the waveform offsets to zero and restore the graph to its unzoomed state. The axes will remain unchanged.

Setting Up Analog Analyses

CircuitMaker's powerful simulation capability includes a wide variety of standard and advanced analyses. Choose **Simulation > Analyses Setup** to display the Analyses Setup dialog box pictured in Figure 6.7.



Figure 6.7. Use the Analog Analyses Setup dialog box to setup the various analyses.

CircuitMaker offers the following standard and advanced analyses:

- DC Analysis
- AC Analysis
- DC Operating Point
- Transient
- Parameter Sweep
- Fourier
- Transfer Function (CircuitMaker PRO only)
- Noise (CircuitMaker PRO only)
- Temperature Sweep (CircuitMaker PRO only)
- Monte Carlo (CircuitMaker PRO only)
- Impedance Plots (CircuitMaker PRO only)

Always Set Defaults

You can use the **Always Set Defaults for Transient and Operating Points Analyses** check box to simplify the task of setting up the Transient and Operating Point analyses. It is primarily for the beginning user who does not completely understand or does not want to be concerned with all of the

settings in the Analog Analyses dialog box. When this box is checked, the Set Defaults button is pressed automatically every time the simulation is run. For simple DC circuits (those that contain no Signal Generators or reactive devices), only Operating Point Analysis is enabled. For more complex circuits, Transient Analysis is also enabled and the default start, stop and step settings are used.

DC Analysis (DC Sweep)

The DC Analysis generates output like that of a curve tracer. It performs an Operating Point Analysis at each of a series of steps defining a DC transfer curve. Source Name is the name of an independent power source (either a fixed voltage or current supply or a Signal Generator) that is to be stepped in the circuit. The start, stop and step values define the sweep range and resolution. The primary source is required while the secondary source is optional. If a secondary source is specified, the primary source is stepped over its entire range for each value of the secondary source.

To set up and run a DC Analysis,

- 1 Choose **Simulation > Analyses Setup**.
- 2 Click the **DC...** button to display the dialog box pictured in Figure 6.8.

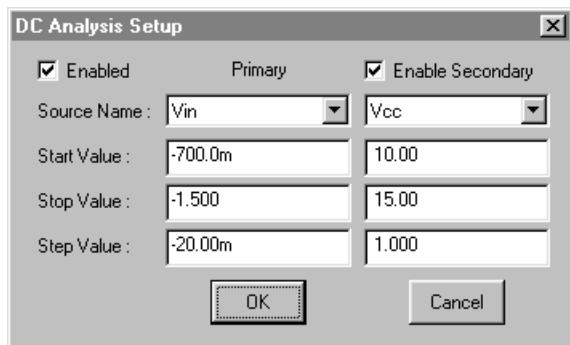


Figure 6.8. The DC Analysis Setup dialog box.

- 3 Specify the settings you want, select the Enabled check box, and then choose OK.
- 4 Run the simulation.

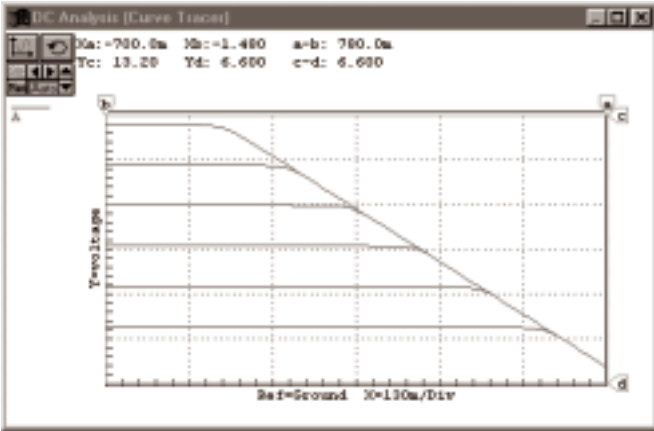


Figure 6.9. A DC Analysis waveform.

The waveform in Figure 6.9 was generated by simulating the ANALOG.CKT circuit using the values shown in Figure 6.8. Notice that the x axis represents the voltage of the primary source, and the y axis is the voltage at the output of the circuit. The waveforms correspond with each step of the secondary source. See *Using the Analysis Windows* earlier in this chapter for more information about manipulating the waveforms.

AC Analysis (AC Sweep)

AC Analysis generates output like that of a Bode plotter, computing the small-signal AC output variables as a function of frequency. It performs an Operating Point Analysis to determine the DC bias of the circuit, replaces the signal source with a fixed amplitude sine wave generator, and analyzes the circuit over the frequency range you specify. The desired output of an AC small-signal analysis is usually a transfer function (voltage gain, transimpedance, etc.).

To set up and run an AC Analysis,

- 1 Connect at least one Signal Generator to the circuit and enable it as an AC Analysis source.

Do this by double-clicking the Signal Generator, clicking **Wave**, and setting up the AC Analysis Source options.

- 2 Choose **Simulation > Analyses Setup**.
- 3 Click the **AC Sweep** button to display the dialog box pictured in Figure 6.10.

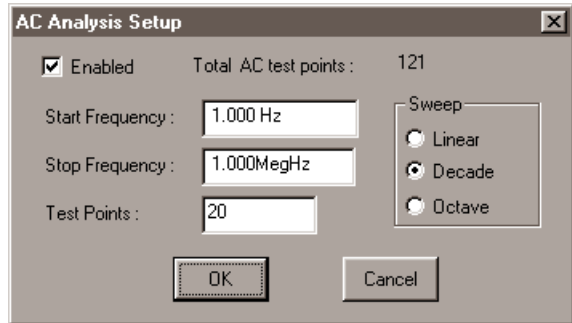


Figure 6.10. Use this dialog box to set up an AC Analysis (AC sweep).

- 4 Enter the AC Analysis settings you want (see the following table), select the Enabled check box, and then choose OK.

Sweep Option	What it Means
Linear	Total number of Test Points in the sweep.
Decade	Number of Test Points per decade in the sweep.
Octave	Number of Test Points per octave in the sweep.

- 5 Run the simulation.

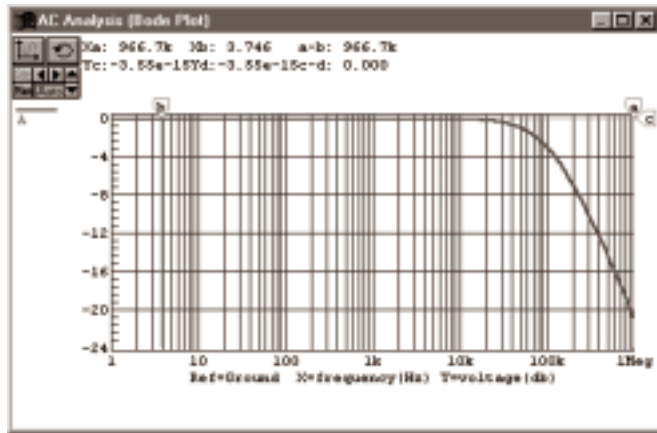


Figure 6.11. An AC Analysis waveform.

The waveform in Figure 6.11 was generated by simulating the ANALOG.CKT circuit using the values shown in Figure 6.10. Notice that the x axis represents frequency in a log scale. The waveform represents the magnitude of the circuit's output voltage in decibels (db). See *Using the Analysis Windows* earlier in this chapter for more information about manipulating the waveforms.

DC Operating Point Analysis

Operating Point Analysis generates data similar to the readings of a DC multimeter. It determines the DC bias of the entire circuit with inductors shorted and capacitors opened, and determines linearized, small-signal models for all of the nonlinear devices in the circuit. It does not take into account the existence of any AC source.

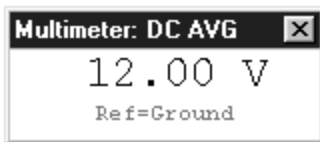


Figure 6.12. The Multimeter showing the DC operating point of a point in the circuit.

Operating Point Analysis is generally performed automatically before each of the other analyses, even if it has been disabled in the Analog Analyses dialog box. However, you must enable it if you want to use the Probe Tool as a multimeter to view the DC, DC AVG or AC RMS values of current, voltage or power. (Viewing the DC AVG or AC RMS values also requires that you enable Transient Analysis). See *Probe Tool* earlier in this chapter.

To set up and run DC Operating Point Analysis,

- 1 Choose **Simulation > Analyses Setup**.
- 2 Click the **Multimeter** button to display the dialog box pictured in Figure 6.13.

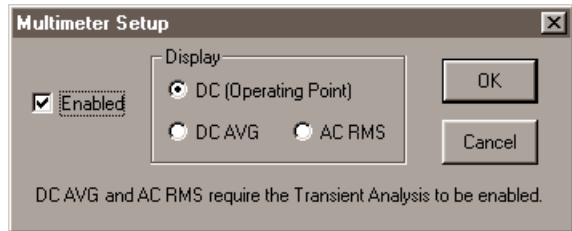


Figure 6.13. Use this dialog box to set up DC Operating Point Analysis.

- 3 Select **DC (Operating Point)**.
- 4 Select **Enabled** and choose OK.
- 5 Run the simulation.
- 6 Click the **Probe Tool** on the point of the circuit where you want to analyze the DC operating point (see Figure 6.12).

Transient Analysis

A Transient Analysis generates output like that of an oscilloscope, computing the transient output variables (voltage or current) as a function of time over the user-specified time interval.

A Transient Analysis first performs an Operating Point Analysis to determine the DC bias of the circuit, always beginning at time zero. In the time interval between zero and **Start Time**, XSpice analyzes but does not display the circuit. In the time interval between **Start Time** and **Stop Time**, XSpice both analyzes and displays the circuit. **Step Time** is the suggested computing increment, but the timestep will be varied automatically by XSpice in order to properly converge. **Max. Step** limits the varying size of the timestep that XSpice can use when calculating the transient data; by default, the program chooses either **Step Time** or $(\text{Stop Time} - \text{Start Time})/50$, whichever is smaller. Typically, **Step Time**

and **Max. Step** would be the same value. If you enable the **UIC** (Use Initial Conditions) option, the Transient Analysis begins from an initial condition, bypassing the Operating Point Analysis. This is useful for viewing the charging of capacitors, etc.

To set up and run a Transient Analysis,

- 1 Choose **Simulation > Analyses Setup**.
- 2 Click the **Transient/Fourier** button to display the dialog box pictured in Figure 6.14.

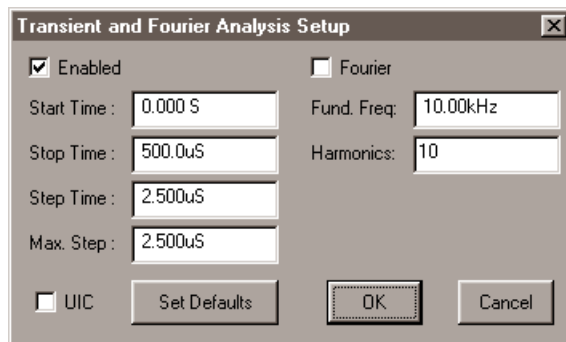


Figure 6.14. Use this dialog box to set up Transient and Fourier Analyses.

- 3 Enter the analysis settings and choose OK.
- 4 Run the simulation.
- 5 Assuming you have enabled the appropriate Test Points, you can view and measure voltage, current and power dissipation waveforms of the circuit in the analysis window that is displayed.

Set Defaults

Use the **Set Defaults** button to set up the default parameters of the Transient Analysis. Start Time is set to zero and **Stop Time**, **Step Time** and **Max. Step** are set to display 5 cycles of the *lowest* frequency Signal Generator in the circuit with a resolution of 200 data points. You can define these default values in the Preferences dialog box. If the Always Set Defaults check box is checked, CircuitMaker acts as if this button is pressed before each simulation.

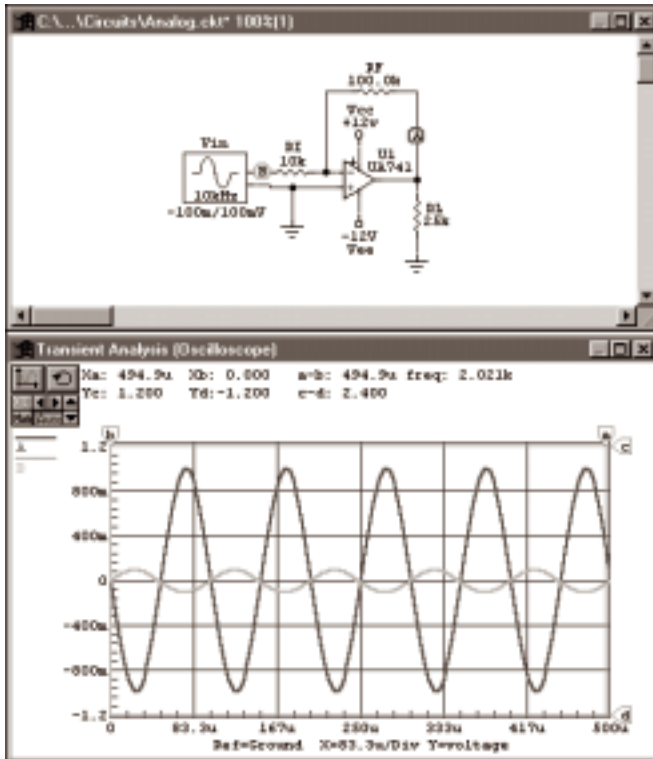


Figure 6.15. The circuit ANALOG.CKT, and the Transient Analysis window.

The waveform in Figure 6.15 was generated by simulating the ANALOG.CKT circuit using the values shown in Figure 6.14. This analysis shows the voltage at the test points during the time frame specified in the **Start** and **Stop** fields. Notice that the x axis shows the time in seconds, and the y axis is voltage. The larger waveform represents the voltage at the circuit output, while the smaller waveform is voltage at the source (signal generator) or input. See *Using the Analysis Windows* earlier in this chapter for more information about manipulating the waveforms.

Parameter Sweep

Use a Parameter Sweep for two variables including transistor parameters. You can vary only basic components and models; subcircuit data is not varied during the analysis.

You can use the Parameter Sweep feature only when you have enabled one or more of the standard analyses (AC, DC, or Transient). Furthermore, data is only saved for nodes that have a Run-Time Test Point attached. The parameter sweep requires the following data: **Parameter**, **Start Value**, **Stop Value**, and **Step Value**. The parameter can be a single designation or a designation with a device parameter in brackets. The following are valid examples:

Example	What it Varies
RF	Resistor with designation RF
Q3[bf]	Beta forward on transistor Q3
R3[r]	Resistance of potentiometer R3
R3[position]	Position of potentiometer R3
option[temp]	Temperature (CircuitMaker PRO only)
U5[tp_val]	Propagation delays of digital device U5

Normally you would use a Temperature Sweep to vary the temperature for simulation; however, temperature can also be varied in the Parameter Sweep (useful if you want to vary the temperature as either the primary or secondary parameter in a two-parameter sweep).

To set up and run a Parameter Sweep Analysis,

- 1 Choose **Simulation > Analyses Setup**.
- 2 Click the **Parameter Sweep** button to display the dialog box pictured in Figure 6.16.
- 3 Make the desired settings, select **Enabled**, and then choose OK.
- 4 Place Run-Time Test Points at the nodes you want to observe.
- 5 Run the simulation.
- 6 View the resulting waveforms in the analysis window, such as the one in Figure 6.17.



Figure 6.16. Use this dialog box to set up a Parameter Sweep Analysis.

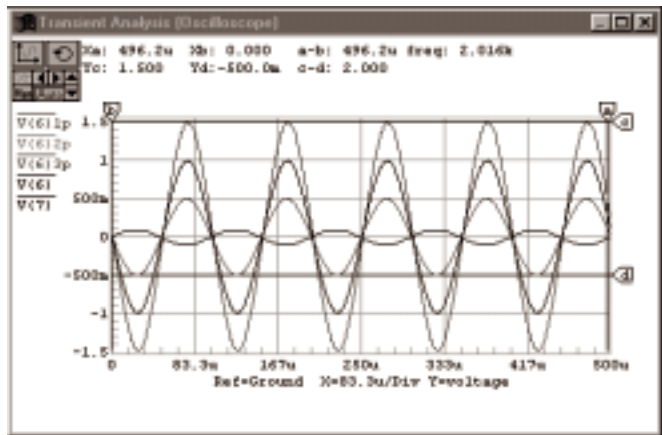


Figure 6.17. Parameter Sweep sweeps a selected component (in this example, a resistor) over a defined range in defined steps and plots the output voltage of the circuit at each of those steps.

The waveform in Figure 6.17 was generated by simulating the ANALOG.CKT circuit using the values shown in Figure 6.16. Notice that it also plots the input and output voltages for the nominal run (meaning all values as they are shown in the schematic).

Relative Values Option

If you enable the **Use Relative Values** option on the Parameter Sweep Setup dialog box, the values entered in the **Start Value**, **Stop Value**, and **Step Value** fields are added to the parameter's default value. For example, suppose you do a Parameter Sweep with the following conditions:

- The parameter is a 1kohm resistor.
- The **Start**, **Stop**, and **Step** fields are -50, 50, and 20, respectively.
- You enable **Use Relative Values**.

The following resistor values would be used in the simulation runs: 950, 970, 990, 1010, 1030, and 1050.

CircuitMaker displays the results of the Parameter Sweep in the AC, DC, or Transient Analysis window(s), depending on which analyses you enabled.

Sweep Trace Labels

For the Monte Carlo, Temperature Sweep, and Parameter Sweep analyses, CircuitMaker gives a unique label to each trace or waveform generated. When you enable **Simulation > Display Variable Names**, CircuitMaker displays the trace names from each sweep run in the analysis window, with a special character appended to the trace name. For example, the appended characters are **m** for Monte Carlo, **t** for Temperature Sweep, and **p** for Parameter Sweep. There is also a trace for the simulation run which was done with the nominal circuit values. This trace will not have a character appended to its trace label. The following are some example trace labels with explanations:

V(6)1p	Voltage at node 6 for Parameter Sweep run 1
V(6)2p	Voltage at node 6 for Parameter Sweep run 2
V(6)3p	Voltage at node 6 for Parameter Sweep run 3
V(6)	Voltage at node 6 for nominal run
V(6)1m	Voltage at node 6 for Monte Carlo run 1
V(6)1t	Voltage at node 6 for Temperature Sweep run 1

You can double-click on a trace label to display details about the device values used in that simulation run.

Fourier Analysis

Fourier Analysis setup is included with the Transient Analysis setup. You must enable the Transient Analysis in order to do the Fourier Analysis. When the simulation is completed, the Fourier Analysis is displayed in a separate window. The Fourier Analysis is based on the last cycle of transient data. For example, if the fundamental frequency is 1.0kHz, then the transient data from the last 1ms cycle would be used for the Fourier analysis.

To set up and run a Fourier Analysis,

- 1 Choose **Simulation > Analyses Setup**.
- 2 Click the **Transient/Fourier** button to display the dialog box pictured in Figure 6.18.



Figure 6.18. Use this dialog box to set up a Fourier Analysis.

- 3 Enter the analysis settings and choose OK.
- 4 Run the simulation.
- 5 Assuming you have enabled the appropriate Test Points, view and measure voltage, current and power dissipation waveforms of the circuit in the analysis window that CircuitMaker displays.

The waveform in Figure 6.19 was generated by simulating the BANDPASS.CKT circuit using the values shown in Figure 6.18. This analysis shows the frequency spectrum of the square wave from the signal generator. The first peak in the waveform is the amplitude of the component at the fundamental frequency. Amplitudes at various harmonics within the specified range are also shown. See *Using the Analysis Windows* earlier in this chapter for more information about manipulating the waveforms.

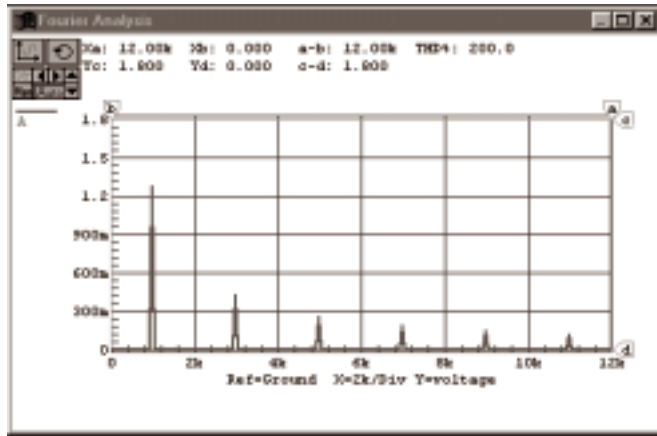


Figure 6.19. A Fourier Analysis waveform.

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Transfer Function Analysis

The Transfer Function analysis calculates the DC input resistance, DC output resistance, and DC gain.

To set up and run a Transfer Function Analysis,

- 1 Choose **Simulation > Analyses Setup**.
- 2 Click the **Transfer** button to display the dialog box pictured in Figure 6.20.

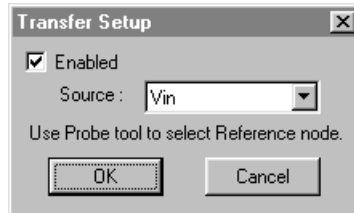


Figure 6.20. Use this dialog box to set up a Transfer Function Analysis.

- 3 Select the input source you want to consider from the **Source** drop-down list.
- 4 Select the **Enabled** check box and choose OK.

Note: You do not need to specify the output node ahead of time. However, to specify a reference other than ground, click a point in the schematic with the **Probe Tool**, and check the **TRANSFER Reference** check box in the Run-Time Test Point dialog box before you run the simulation.

- 5 Run the simulation.
- 6 Click the **Transfer Function** window, and then click on any node in the circuit to see the Transfer Function data for that node.
- 7 To display the Transfer Function data for multiple nodes, hold down the Shift key when you click to display.

The data that appears indicates the transfer function from the input to the specified node.

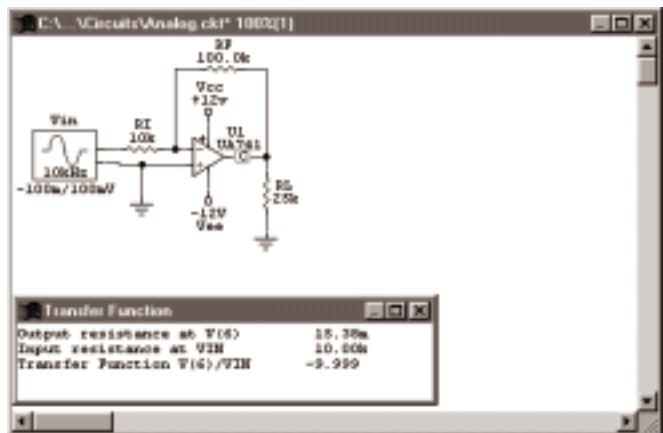


Figure 6.21. Transfer Function Analysis data.

The waveform data in Figure 6.21 was generated by simulating the ANALOG.CKT circuit using the values shown in Figure 6.20. This analysis shows the gain from the specified source to the output (the point you click with the Probe Tool). Notice that it shows DC resistance seen by the source and the DC resistance seen by the output load.

Noise Analysis

Noise Analysis lets you measure the noise in your circuit due to noise contributions of resistors and semiconductor devices. CircuitMaker can plot the Noise Spectral Density, which is the noise measured in Volts squared per Hertz (V^2/Hz). Capacitors, inductors, and controlled sources are treated as noise free. The following noise measurements can be made in CircuitMaker:

Measurement	Description
Output Noise	The noise measured at a specified output node.
Input Noise	The amount of noise that, if injected at the input, would cause the calculated noise at the output. For example, if the output noise is 10p, and the circuit has a gain of 10, then it would take 1p of noise at the input to measure 10p of noise at the output. Thus the equivalent input noise is 1p.
Component Noise	The output noise contribution of each component in the circuit. The total output noise is the sum of individual noise contributions of resistors and semiconductor devices. Each of these components contributes a certain amount of noise, which is multiplied by the gain from that component's position to the circuit's output. Thus the same component can contribute different amounts of noise to the output, depending on its location in the circuit.

To set up and run a Noise Analysis,

- 1 Select the output node by clicking the output node of the circuit with the **Probe Tool**.

This places a Run-Time Test Point and displays the dialog box shown in Figure 6.22 In the dialog box that appears, check the **Enable Noise** checkbox, and make sure **Out** is selected.



Figure 6.22. Use this dialog box to set up Run-Time Test Points for a Noise Analysis.

- 2 Choose **Simulation > Analyses Setup**.
- 3 Click the **Noise** button to display the dialog box pictured in Figure 6.23.

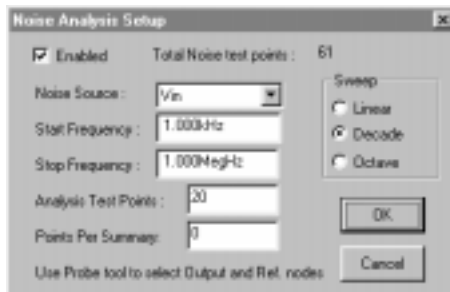


Figure 6.23. Use this dialog box to set up Noise Analysis.

- 4 Specify the analysis information in the Noise Analysis dialog box.

If you want to measure the noise contribution of each component, enter 1 in the Points Per Summary field. If you only want to measure input and output noise, enter 0 in this field.

- 5 Run the simulation.
- 6 View the input and output noise results.

7 Click the Noise analysis window, then click on the noise output node.

8 Choose **Simulation > Display Variable Names**.

This labels the input noise waveform as **NI**, and the output noise waveform **NO**. For example, if the specified noise output node is node **6**, then the output noise waveform would be labeled **NO(6)**, and the input noise waveform would be labeled **NI(6)**.

9 Click a component to measure the output noise contribution of that component. If the component you click on is a subcircuit, then you may select from a list of contributing noise sources within the subcircuit. Note that component noise data is *not* available if 0 (zero) was entered in the Points Per Summary field in the Noise Analysis Setup dialog box.

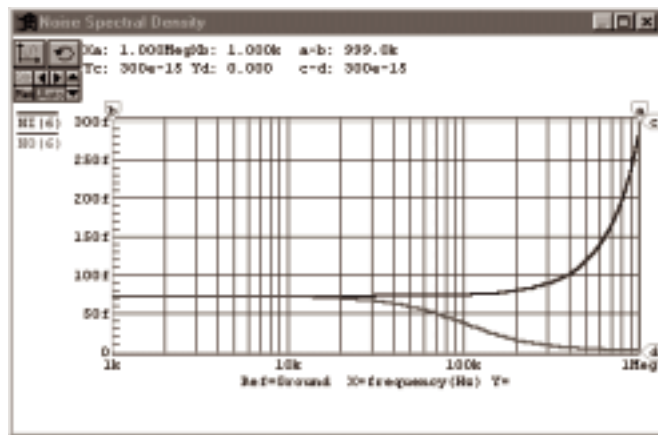


Figure 6.24. This Noise Analysis waveform shows noise at the output and the equivalent input noise at the specified source over a specified frequency range.

The waveform in Figure 6.24 was generated by simulating the ANALOG.CKT circuit using the values shown in Figures 6.22 and 6.23. See *Using the Analysis Windows* earlier in this chapter for more information about manipulating the waveforms.

Temperature Sweep

You can use a Temperature Sweep only when you have enabled one or more of the standard analyses (AC, DC, or Transient). Furthermore, CircuitMaker data is only saved for nodes that have a Run-Time Test Point attached.

To set up and run a Temperature Sweep Analysis,

- 1 Select **Simulation > Analyses Setup**.
- 2 Click **Temperature Sweep** to display the dialog box shown in Figure 6.25.

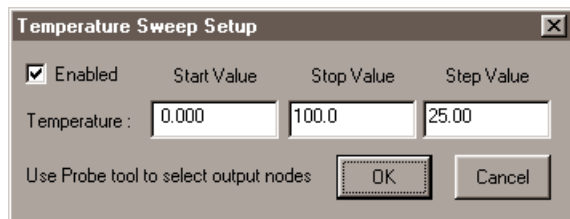


Figure 6.25. Use this dialog box to set up a Temperature Sweep Analysis.

- 3 Enter the temperature range you want to sweep.
- 4 Select the **Enabled** check box.
- 5 Set up one or more standard analysis so that each analysis is performed at the indicated temperatures.
- 6 Place Run-Time Test Points at the nodes you want to observe, by left-clicking with the Probe Tool on a point in the circuit.

CircuitMaker displays the results of a Temperature Sweep in the AC, DC, or Transient Analysis window(s), depending on which analyses you enabled.

The waveform in Figure 6.26 was generated by simulating the ANALOG.CKT circuit using the values shown in Figure 6.25. Notice that the analysis sweeps the temperature of the circuit in specified steps, between the start and stop temperature values. The waveforms in this example represent the magnitude of the circuit output voltage (in db) for each temperature step. See *Using the Analysis Windows* earlier in this chapter for more information about manipulating the waveforms.

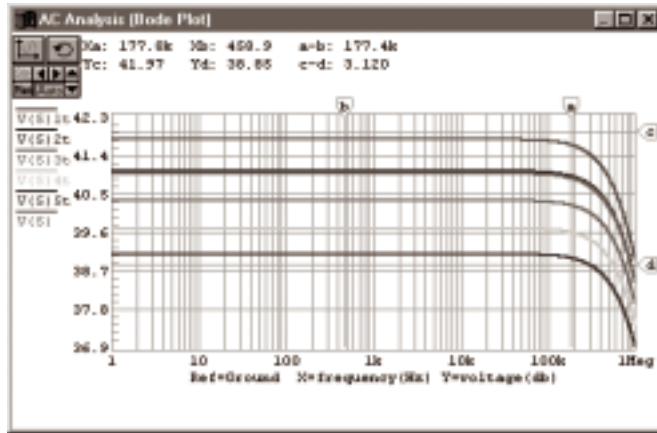


Figure 6.26. Temperature Sweep Analysis waveforms.

Monte Carlo Analysis

Monte Carlo Analysis lets you do multiple simulation runs with device values randomly varied according to specified tolerances. You can use this feature only when you have enabled one or more of the standard analyses (AC, DC, or Transient). Furthermore, CircuitMaker saves data only for nodes that have a Run-Time Test Point. Subcircuit data is not varied during the Monte Carlo Analysis. Only basic components and models can be varied.

The items in the Monte Carlo Setup dialog box are as follows:

Option	Description
Simulation Runs	Enter the number of simulation runs you want CircuitMaker to perform. For example, if you enter 10, then CircuitMaker will run 10 simulation runs, with different device values on each run, within the specified tolerances.

Seed

CircuitMaker uses the specified seed to generate random numbers for the Monte Carlo runs. The default seed value is -1 . If you want to run a simulation with a different series of random numbers, then you must change the seed value to another number.

Distribution

You can choose from the following three distributions for random number generation in the Monte Carlo Analysis:

Uniform distribution

Values are uniformly distributed over the specified tolerance range. Suppose you have a 1K resistor with a tolerance of 10 percent. There is an equal chance of the generated value being anywhere from 900 ohms to 1100 ohms. It is a flat distribution.

Gaussian distribution

Values are distributed according to a gaussian (bell-shaped) curve with the center at the nominal value and the specified tolerance at ± 3 standard deviations. Given a 1K, 10 percent resistor, the center of the distribution would be at 1000 ohms, $+ 3$ standard deviations at 1100 ohms, and -3 standard deviations at 990 ohms.

Worst Case distribution

This is the same as the uniform distribution, but only the end points (worst case) of the range are used. Given a 1K, 10 percent resistor, the value used would be randomly chosen from the two worst case values of 990 ohms and 1100 ohms. On any one simulation run, there is an equal chance that the high-end worst case value (1100) or low-end worst case value (990) will be used.

To set up and run a Monte Carlo Analysis,

- 1 Choose **Simulation > Analyses Setup**.
- 2 Click the **Monte Carlo** button to display the dialog box pictured in Figure 6.27.

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- 3 Enter tolerances as actual values or as percentages for the six general categories of devices then choose OK (see *Specifying Default Tolerances* later in this section).
- 4 Place Run-Time Test Points at the nodes you want to observe as in Figure 6.28.
- 5 Run the simulation.
- 6 View the data as it appears in Figure 6.32.



Figure 6.27. Use this dialog box to set up Monte Carlo Analysis.

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Figure 6.28. Use this dialog box to set up Run-Time Test Points for the nodes you want to observe (right-click with the Probe Tool on a point in the circuit).

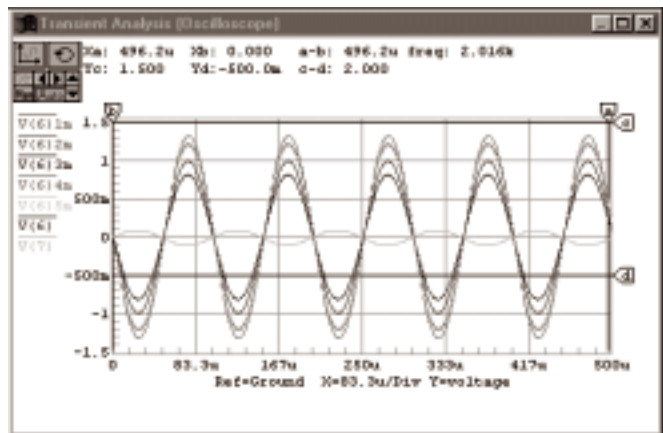


Figure 6.29. Waveforms for the Monte Carlo Analysis.

The waveform in Figure 6.29 was generated by simulating the ANALOG.CKT circuit using the values shown in Figures 6.27 and 6.28. Notice that this analysis randomly varies the component values within the specified tolerances, and then plots the output voltage of the five simulation runs, including the input and output voltages for the nominal run. See *Using the Analysis Windows* earlier in this chapter for more information about manipulating the waveforms.

Specifying Default Tolerances

You can specify default tolerances for six general categories of devices: resistor, capacitor, inductor, DC source, transistor (beta forward), and digital TP (propagation delay for digital devices). You can enter tolerances as actual values or as percentages.

For example, you can enter a resistor tolerance as **10** or **10%**. If a 1kohm resistor has a tolerance of 10, it varies between 990 and 1010 ohms. With a tolerance of 10%, a 1kohm resistor varies between 900 and 1100 ohms. Each device is randomly varied independent of the other devices. For example, if a circuit has two 10kohm resistors, and the default tolerance is set to 10%, then during the first pass of the simulation, one resistor might have a value of 953 ohms, and the other one could be 1022 ohms. CircuitMaker uses a separate and independent random number to generate the value for each device.

Overriding with Specific Tolerances

To override the default tolerance value with specific tolerance values for specific devices,

- 1 Click **Add** in the Monte Carlo Setup dialog box.
- 2 Enter the appropriate information in the various fields (see Figure 6.30).



Figure 6.30. Use this dialog box to enter device and lot tolerances.

For basic components like resistors, capacitors, and inductors, leave the **Device Parameter** field blank because there are no parameters besides the device value. Both device and

lot tolerances are allowed, but only one or the other is required. CircuitMaker calculates device and lot tolerances independently (using different random numbers) and then adds them together. The example in Figure 6.30 has a device tolerance of 5% and a lot tolerance of 10%, and thus a total variation of up to 15%. In general, component values in the analysis vary independently, unless a tracking number is assigned. If you give two devices the same device tolerance tracking number and distribution, then the same random number is used for both devices when the device values for a simulation run are calculated. The same holds true for lot tolerances. However, device tracking and lot tracking are independent of each other. In other words, device tracking #1 and lot tracking #1 are unrelated.

To edit an item in the **Specific Tolerances** list in the Monte Carlo Setup dialog box,

- 1 Select the item you want to change.
- 2 Click **Edit** or click **Delete** to delete the item.

Impedance Plot Analysis

An Impedance Plot Analysis shows the impedance seen by any two-terminal source. Normally plotted in the AC Analysis window, an Impedance Plot does not have a separate setup dialog box.

To run an Impedance Plot Analysis, run a standard simulation, then click the source's negative terminal with the **Probe Tool**. An impedance plot appears in the selected analysis window. This is especially useful to measure input and output impedance versus frequency in the AC Analysis window. The impedance measurement is calculated from the voltage at the supply's positive terminal divided by the current out of that same terminal (see Figure 6.31). Clicking the positive terminal of a supply is already defined as an operation to plot current, thus the negative terminal must be clicked on for impedance.

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To measure input impedance,

- 1 Run the desired simulation (usually AC analysis).
- 2 Select the desired analysis window and then click on the negative terminal of the input source.

To measure output impedance,

- 1 Remove the source from the input.
- 2 Ground the circuit's inputs where the input supply was connected.
- 3 Remove any load connected to the circuit.
- 4 Connect a two-terminal source to the output, with the source's positive terminal connected to the output and the source's negative terminal connected to ground.
- 5 Run the desired simulation.
- 6 Select the desired analysis window and then click on the negative terminal of the source with the **Probe Tool**.

This causes an impedance plot to appear in the selected analysis window as in Figure 6.32.



Figure 6.31. For Impedance Plots, you would normally change the Y axis to Magnitude. Click the Settings button in the analysis window to change X and Y axes for that window.

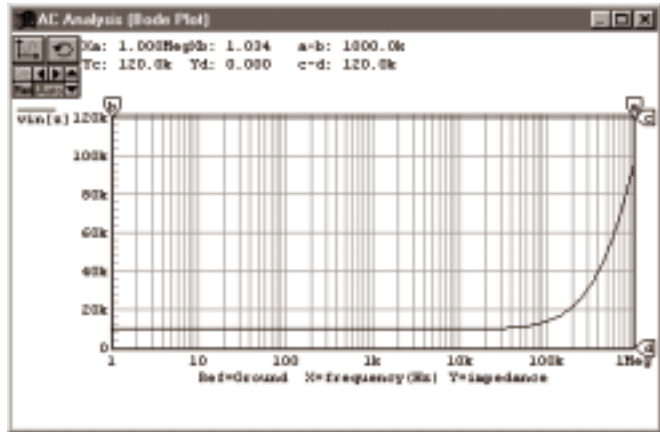


Figure 6.32. This Impedance Plot shows impedance seen by a two-terminal source over frequency.

The waveform in Figure 6.32 was generated by simulating the ANALOG.CKT circuit, and making an adjustment to the AC Analysis window as shown in Figure 6.31. See *Using the Analysis Windows* earlier in this chapter for more information about manipulating the waveforms.

Using XSpice for Windows

This section provides an in-depth look at CircuitMaker's XSpice for Windows, how to see the information it displays more closely, and the errors and warning messages associated with it.

To view the information in XSpice for Windows,

- 1 Click the **Run** button to start the simulation.

Notice the Run icon is replaced by a Stop Sign, and the interactive XSpice simulation window appears showing the progress of the simulation.

If you have added Run-Time Test Points to the circuit, the corresponding waveforms are displayed as the data is collected, otherwise the progress of the simulation is presented as a simple bar graph.

Figure 6.33 shows an example of an XSpice simulation window where both Transient and AC analyses are enabled, but only AC Analysis has a corresponding Run-Time Test Point.



Figure 6.33. The XSpice window shows the progress of the simulation.

- 2 Select the **Stop When Simulation Is Complete** check box if you want XSpice to pause before returning to the CircuitMaker workspace.
- 3 If you have chosen the **Stop When Simulation Is Complete** option, then a dialog box will appear when the simulation is complete, asking if you wish to exit XSPICE. Click **Yes** to exit and return to the CircuitMaker analysis windows, which let you analyze the simulation data, or click **No** to remain in XSpice for Windows (exit later by clicking **Quit**).
- 4 If you clicked **No** in Step 3 and are remaining in the XSPICE area, click **Rescale All** (in the XSpice menu) to rescale all of the plots to fit the Min. and Max. data that has been collected.

You can do this even if the simulation is still running.
- 5 While the XSpice window is displayed, you can change the scale for a single plot window by clicking the window to pause the simulation and display the dialog box shown in Figure 6.34.
- 6 Enter the desired scale limits (or click the **Auto** button to scale to the data that is already in the window) then choose **OK**.

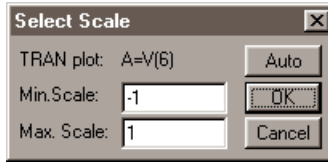


Figure 6.34. Use this dialog box to enter new scale limits for the XSPICE plots.

- 7 Use the **Up** and **Down** options in the XSpice menu to move the graphs into view if there are more graphs to be displayed than can be shown on your monitor.
- 8 Click **Quit** in the XSpice menu to stop at any time.

When you click **Quit**, the dialog box pictured in Figure 6.35 appears asking if you want to save the simulation data collected. This option is very useful if you have been waiting for a long simulation and want to analyze the data which has been collected so far, but don't want to wait for the simulation to complete.



Figure 6.35. Use **Quit** to stop long simulations.

- 9 Click **Yes** to display the graphics windows, which let you analyze the simulation data that has been collected.

OR

Click **No** to discard the simulation data. Click **Cancel** to continue the simulation.

Note: the simulation cannot always be stopped at a location where the data will be available for display.

.NET and .RAW File Output

While the interactive XSpice simulation window is displayed, CircuitMaker generates a SPICE netlist to disk in a temporary file called *filename*.NET where *filename* is the name of the circuit file. XSpice for Windows analyzes the netlist file and stores the simulation results in a file called

filename.RAW. The amount of time it takes to complete the simulation is based on the analyses that are enabled, their sweep ranges, the complexity of the circuit, and the speed of your computer. The .RAW file can become very large for a complex simulation and is deleted when changes are made to the circuit. You can greatly reduce the size of the .RAW file by reducing the number of Test Points in the circuit and by disabling the ASCIIOUTPUT option in the Analog Options dialog box. See the *Test Point Types* section earlier in this chapter for more information.

Warning Messages vs. Error Messages

Sometimes CircuitMaker displays warning or error messages during circuit simulation. These messages are saved in a text file called ***filename.ERR***. CircuitMaker prompts you to view these messages, displaying them in the Windows Notepad editor. The following distinguishes the two messages.

Warning Messages

Warning messages are not fatal to the simulation. They generally provide information about changes that SPICE had to make to the circuit in order to complete the simulation. These include invalid or missing parameters, etc.

Note: Normally, valid simulation results are generated even if warning messages are reported.

SimCode warnings may include information such as timing violations (tsetup, thold, trec, tw, etc.) or significant drops in power supply voltage on digital components.

Error Messages

Error messages provide information about problems that SPICE could not resolve and were fatal to the simulation. Error messages indicate that simulation results could not be generated, so they must be corrected before you will be able to analyze the circuit. If you need help troubleshooting SPICE simulation errors, refer to *Chapter 15: SPICE: Beyond the Basics*.

Setting Up Analog/SPICE Variables

SPICE allows you to control certain aspects of its simulation such as iteration limits, temperature, etc. Choose **Simulation > Analyses Setup > Analog Options** to display the dialog box pictured in Figure 6.36.

To learn more about the option variables listed in this dialog box, and how to change their values, turn to *SPICE Option Variables* in *Chapter 15: SPICE: Beyond the Basics*.

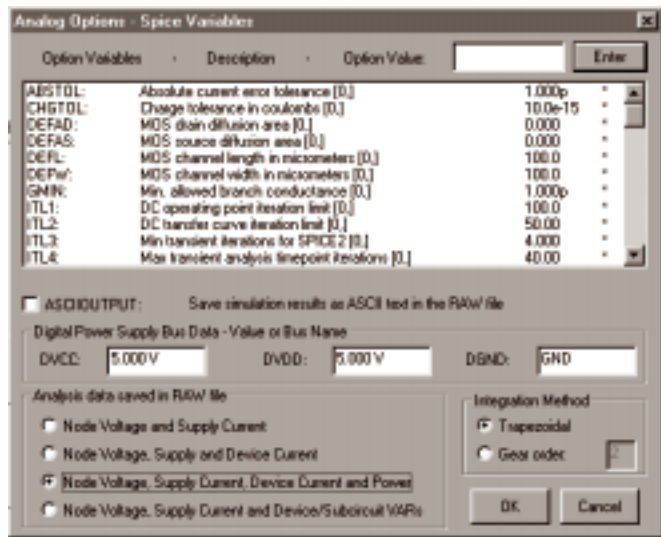


Figure 6.36. Use this dialog box to control certain aspects of the SPICE simulation.

ASCIIOUTPUT Check Box

By default, the simulation data is saved in the .RAW file in binary format, creating smaller .RAW files. Use this check box to have SPICE save the simulation data in ASCII format, which lets you to read the data directly or load it into other applications. Default= binary format.

DVCC, DVDD and DGND

These are default values of the Vcc, Vdd and ground buses for the digital devices. If these buses are not specified in the circuit, the default values will be used. If a bus name is entered instead of a value, that bus will be connected to the devices. By default, **DVCC** and **DVDD**=+5V, **DGND**="GND".

Integration Method

Choose which numerical integration method you want to use with XSpice. The *trapezoidal* method is relatively fast and accurate, but tends to oscillate under certain conditions. The *gear* method requires longer simulation times, but tends to be more stable. The gear order must be a value between 2 and 6. Using a higher gear order theoretically leads to more accurate results, but increases simulation time.

Default=Trapezoidal.

Analysis Data Saved in .RAW File

Use the four radio buttons (see Figure 6.36) to select the default level at which variables are saved in the .RAW file. This determines how much data is actually stored in the .RAW file and which variables can be plotted in the analysis windows when the simulation is run.

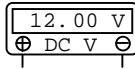
- Select the top button to store only the node voltages and supply currents.
- Select the second button to store node voltages, supply currents and device pin currents.
- Select the third button to store node voltages, supply currents, device pin currents and device power dissipation.
- Select the bottom button to store node voltages, supply currents, device pin variables and subcircuit internal variables.

If you have added any Exclusive Test Points to the circuit, data will be saved only for each Exclusive Test Point and these radio buttons will be disabled.

Analog/Mixed-Signal Instruments

Following is a description of instruments found in CircuitMaker's device library that are most commonly used in analog and mixed-signal circuits.

Multimeter



In addition to the Multimeter/Operating Point analysis window, CircuitMaker includes a multimeter instrument for measuring resistance, DC, DC AVG or AC RMS voltage or current. You may place as many multimeters into your circuit as you like. When you run the simulation, the measured value is then displayed on the meter. Remember, when measuring voltage, connect the meter in parallel with the circuit; when measuring current, connect it in series. When measuring resistance, be sure to remove any power sources from the circuit and beware of dangling devices that may cause XSpice errors. Also, since the multimeter forces a current through the circuit to measure ohms, make sure you have only one multimeter set to ohms in the circuit at a time. XSpice sees the current flowing into the positive terminal of a power supply, Multimeter or Signal Generator as positive current.

When you place a Multimeter [Analog/Instruments] in your circuit, the dialog box shown in Figure 6.37 appears showing the settings of the multimeter.

Note: To measure DC AVG or AC RMS values, Transient Analysis must be enabled and must simulate enough cycles of transient data to make the measurements meaningful. Likewise, Operating Point Analysis (multimeter) must be enabled in order to obtain resistance and DC values.

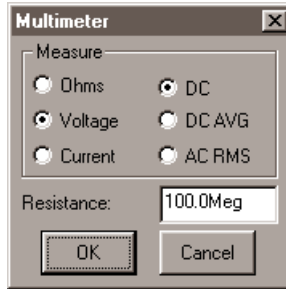
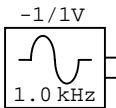


Figure 6.37. This dialog box appears when you place a multimeter in your circuit.

The resistance of a voltmeter is high and the resistance of an ammeter is low, so it will have little effect on the circuit it is measuring. When measuring voltage on a high resistance circuit it may be desirable to increase the resistance of the voltmeter. When measuring current through a low resistance circuit it may be desirable to decrease the resistance of the ammeter. When measuring pin junction resistance, it may be desirable to increase the forcing current of the ohmmeter.

Multifunction Signal Generator

You can place as many of CircuitMaker's multifunction signal generators in your circuit as you like. Waveform functions include:



- Sinusoidal
- Single-Frequency AM
- Single-Frequency FM
- Exponential
- Pulse (including Triangle and Sawtooth)
- Piece-Wise Linear

The settings for each of these functions are edited through separate dialog boxes, which are described in the following sections.

Accessing the Signal Generator Editor

After placing a Signal Gen [Analog/Instruments] (g) in your circuit, double-click it with the **Arrow Tool** to display the dialog box pictured in Figure 6.38.



Figure 6.38. This dialog box shows the settings for the currently selected waveform function.

All of the waveform dialog boxes have the following items in common:

Volts/Amps

Allows you to select whether this is a voltage or current source.

Netlist Button

Displays the Edit Device Data dialog box described in *Editing Devices* in *Chapter 4: Drawing and Editing Schematics*.

Wave Button

Displays the dialog box pictured in Figure 6.39, allowing you to change waveform functions for this generator. To change waveform functions, click one of the function buttons and specify this generator's effect when running AC Analysis. AC Analysis temporarily replaces each AC source with a sinusoidal wave of a fixed magnitude and phase. The Source check box allows you to specify whether this generator will be used as an AC source in the AC Analysis. The Magnitude and Phase edit fields allow you to specify the fixed values that will be used.

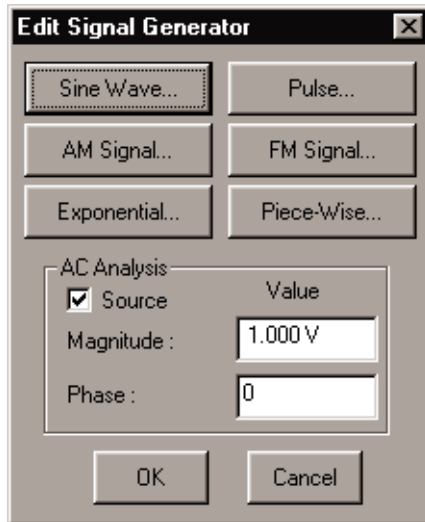
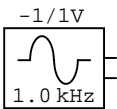


Figure 6.39. Use the Edit Signal Generator dialog box to select the waveform you want to edit.

Editing Sine Wave Data

Click the **Sine Wave** button to display the dialog box pictured in Figure 6.40. Use this dialog box to set the parameters of the sinusoidal waveform.



The waveform, beginning at Start Delay, is described by the following formula where t = instance of time:

$$V(t_0 \text{ to } t_{SD}) = VO$$

$$V(t_{SD} \text{ to } t_{STOP}) = VO + VA \sin(2\pi F (t-SD)) e^{-(t-SD)THETA}$$



Figure 6.40. Use this dialog box to edit sine wave data.

DC Offset (VO)

Used to adjust the DC bias of the signal generator with respect to the negative terminal (usually ground), measured in volts or amps.

Peak Amplitude (VA)

Maximum amplitude of the output swing, excluding the DC Offset, measured in volts or amps.

Frequency (F)

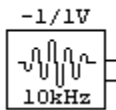
Frequency of the output in hertz.

Start Delay (SD)

Provides a phase shift of the output by delaying the start of the sine wave.

Damping Factor (THETA)

A positive value results in an exponentially decreasing amplitude; a negative value results in an exponentially increasing amplitude.



Editing AM Signal Data

Click the **AM Signal** button to display the dialog box pictured in Figure 6.41a. Use this dialog box to set the parameters of the single-frequency AM waveform.

DC Offset (VO)

Adjust the DC bias of the signal generator with respect to the negative terminal (usually ground), measured in volts or amps.

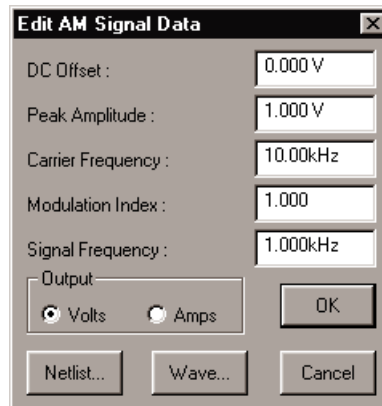


Figure 6.41a. Use this dialog box to edit an AM signal.

Peak Amplitude (VA)

Maximum amplitude of the output swing, excluding the DC Offset, measured in volts or amps.

Carrier Frequency (F_c)

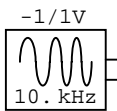
Frequency of the unmodulated output in hertz.

Modulation Index (MDI)

Value corresponding to the percentage of amplitude modulation. 1 = 100%, 0.5 = 50%, etc.

Signal Frequency (F_s)

Frequency of the modulating signal in hertz.



Editing FM Signal Data

Click the **FM Signal** button to display the dialog box pictured in Figure 6.41b. Use this dialog box to set the parameters of the single-frequency FM waveform.

The waveform is described by the following formula where t = instance of time:

$$V(t) = V_O + V_A \sin(2\pi F_c t + M D I \sin(2\pi F_s t))$$

DC Offset (V_O)

Adjust the DC bias of the signal generator with respect to the negative terminal (usually ground), measured in volts or amps.

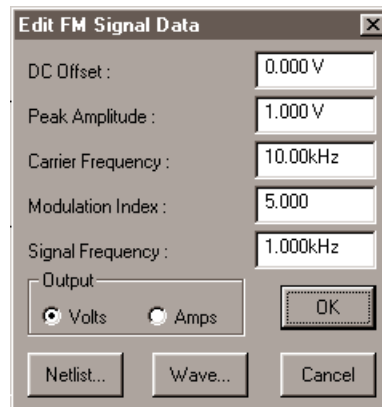


Figure 6.41b. Use this dialog box to edit an FM signal.

Peak Amplitude (V_A)

Maximum amplitude of the output swing, excluding the DC Offset, measured in volts or amps.

Carrier Frequency (F_c)

Frequency of the unmodulated output in hertz.

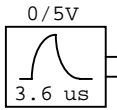
Modulation Index (MDI)

Value corresponding to a function of amplitude of the modulating signal indicating the level of modulation.

$$MDI = (\text{frequency deviation}) / F_s$$

Signal Frequency (F_s)

Frequency of the modulating signal in hertz.



Editing Exponential Data

Use the dialog box in Figure 6.42 to set the parameters of the exponential waveform. The waveform is described by the following formulas where t = instance of time:

$$\begin{aligned}
 V(t_0 \text{ to } t_{RD}) &= VI \\
 V(t_{RD} \text{ to } t_{FD}) &= VI + (VP - VI) (1 - e^{-(t-t_{RD})/tRT}) \\
 V(t_{FD} \text{ to } t_{STOP}) &= VI + (VP - VI) (-e^{-(t-t_{RD})/tRT}) + \\
 &\quad (VI - VP) (1 - e^{-(t-t_{FD})/tFT})
 \end{aligned}$$

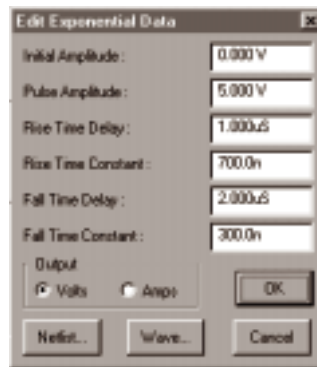


Figure 6.42. Use this dialog box to edit exponential wave data.

Initial Amplitude (VI)

Initial amplitude of the output with respect to the negative terminal (usually ground), measured in volts or amps.

Pulse Amplitude (VP)

Max. amplitude of output swing, measured in volts or amps.

Rise Time Delay (RD)

The point in time, from t_0 , when the output begins to rise. This provides a phase shift of the output by delaying the start of the exponential waveform.

Rise Time Constant (RT)

Standard RC charging time constant.

Fall Time Delay (FD)

The point in time, from t_0 , when the output begins to fall.

Fall Time Constant (FT)

Standard RC discharging time constant.

Editing Pulse Data

To set the parameters of the pulse waveform, click **Pulse/Triangle/Sawtooth** to display the dialog box in Figure 6.43.

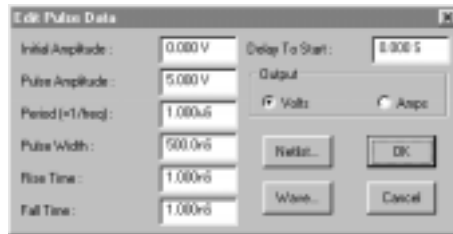
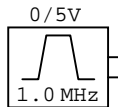


Figure 6.43. Use this dialog box to edit pulse data.

The waveform is described as follows where t = instance of time. Intermediate points are set by linear interpolation:

$$\begin{aligned}V(t_0) &= VI \\V(t_{SD}) &= VI \\V(t_{SD} + t_{TR}) &= VP \\V(t_{SD} + t_{TR} + t_{PW}) &= VP \\V(t_{SD} + t_{TR} + t_{PW} + t_{TF}) &= VI \\V(t_{STOP}) &= VI\end{aligned}$$

Initial Amplitude (VI)

Initial amplitude of the output with respect to the negative terminal (usually ground), measured in volts or amps.

Pulse Amplitude (VP)

Maximum amplitude of output swing, in volts or amps.

Period (=1/freq)

Duration of one complete cycle of the output.

Pulse Width (PW)

Duration output remains at VP before ramping toward VI.

Rise Time (TR)

Duration of the ramp from VI to VP.

Fall Time (TF)

Duration of the ramp from VP to VI.

Delay to Start (SD)

Duration that the output remains at VI before beginning to ramp toward VP the first time.

Editing Piece-Wise Data

Click the Piece-Wise button to set the parameters of the piecewise linear waveform as pictured in Figure 6.44.

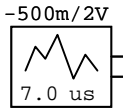


Figure 6.44. Use this dialog box to set the parameters of the piecewise linear waveform.

Piecewise linear data must come from one of two sources:

- You can describe the waveform with a set of up to 8 points that you enter directly into this dialog box. The time specified for each successive point must be more positive than its predecessor. If it is not, the cycle will end, excluding that and all successive points.
- You can define the waveform in an ASCII text file containing an indefinite number of points. Values must be entered in pairs and each pair must include a time position followed by an amplitude. The first character of each data line must be a plus sign (+) and each line may contain up to a maximum of 255 characters. Values must be separated by one or more spaces or tabs. Values may be entered in either scientific or engineering notation. Comments may be added to the file by making the first character of the line an asterisk (*). For example:

```
* Random Noise Data
+ 0.00000e-3 0.6667 0.00781e-3 0.6372 0.01563e-3 -0.1177
+ 0.02344e-3 -0.6058 0.03125e-3 0.2386 0.03906e-3 -1.1258
+ 0.04688e-3 1.6164 0.05469e-3 -0.3136 0.06250e-3 -1.0934
+ 0.07031e-3 -0.1087 0.07813e-3 -0.1990 0.08594e-3 -1.1168
+ 0.09375e-3 1.4890 0.10156e-3 -0.2169 0.10938e-3 -1.4915
+ 0.11719e-3 1.4914 0.12500e-3 0.1486
```

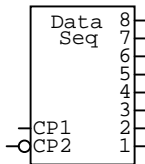
Intermediate points are determined by linear interpolation. If **Max. Amp** is specified in the dialog box, the data in the file will be scaled vertically so that the peak-to-peak amplitude

of the waveform is equal to the specified **Max. Amp** and is centered around zero. If an **Offset** is specified, the waveform will be offset vertically by the specified amount. If a **Max. Time** is specified, the waveform will be scaled horizontally to fit the specified **Max. Time**. Example circuit: PWL.CKT.

Note: The .PWL file must be located in the same directory as the circuit you are simulating.

Data Sequencer

You can use this device in both digital and analog simulation modes. Also known as a Data or Word Generator, it allows you to specify up to 32767 8-bit words which can be output in a defined sequence. Since there is no limit to the number of Data Sequencers that you can use in a circuit, you could place several in parallel to create a data stream of any width. For a complete description of the data sequencer, refer to *Data Sequencer* in *Chapter 5: Digital Logic Simulation*



CHAPTER 7

Exporting Files

CircuitMaker offers several powerful export options, letting you export your circuit data to any of the following output types:

- Bill of Materials
- Waveforms as graphic files
- Circuits as graphic files
- SPICE Netlists
- SPICE Subcircuits
- PCB Netlists

This level of flexibility lets you easily integrate the work you do in CircuitMaker with a wide variety of other schematic capture, simulation, and printed circuit board layout programs.

CircuitMaker works seamlessly with TraxMaker, meaning that you can export to the TraxMaker PCB netlist format and also configure and launch TraxMaker directly from CircuitMaker.

This chapter defines the different types of output files and provides step-by-step procedures for them.

Bill of Materials

Formerly known as a Parts List, a Bill of Materials is a file that contains information about how many and which kinds of parts are used in your circuit. You can export a Bill of Materials to a text file.

To access the Bill of Materials feature,

- 1 Choose **File > Bill of Materials** to display the dialog box pictured in Figure 7.1.
- 2 See the following sections for more information.

You can save a Bill of Materials in one of two formats: Single Item per line or Multiple items per line.



Figure 7.1. You can save, display, or print a Bill of Materials in one of two formats.

Single Item Per Line

This format puts each component on a separate line in the Bill of Materials. Items are listed in order according to the device designation. The columns are tab delimited. This format can easily be loaded into a spreadsheet and then sorted and arranged to your liking. The following is an example of the single item per line format:

Bill of Materials for:
C:\CM\Circuits\Diffamp.BOM

Item	Label-Value	Attributes	Designation
1	1N914	DIODE0.4	D1
2	1N914	DIODE0.4	D2
3	2N2222A	TO-92	Q1
4	2N2222A	TO-92	Q2
5	2N2222A	TO-92	Q3
6	3.2k	AXIAL0.4	R1
7	1.5k	AXIAL0.4	R2
8	50	AXIAL0.4	RB1
9	50	AXIAL0.4	RB2
10	7.75k	AXIAL0.4	RC1

Multiple Items Per Line

This Bill of Materials format lists components on the same line if the label-value, description and package fields match. Columns are tab delimited. The following is an example of the multiple items format:

Bill of Materials for:

C:\CM\Circuits\Diffamp.BOM

Item	Quantity	Label-Value	Attributes	Designations
1	2	1N914	DIODE0.4	D1,D2
2	3	2N2222A	TO-92	Q1,Q2,Q3
3	1	3.2k	AXIAL0.4	R1
4	1	1.5k	AXIAL0.4	R2
5	2	50	AXIAL0.4	RB1,RB2
6	2	7.75k	AXIAL0.4	RC1,RC2
7	1	2.5k	AXIAL0.4	RE

As you can see in the examples, the three main things listed for each item are Label-Value, Attributes, and Designation. The default attributes are package and description, which can be set for each device in the Edit Device Data dialog box. Notice that none of the items in the list had a description, so only the package is listed. If multiple attributes are present for devices, then additional lines are added to list those attributes. For example, a group of items that has both a package and a description would require a second line to list the second attribute (description):

5	2	50	AXIAL0.4	RB1,RB2
			5% Resistor	

Saving, Displaying, and Printing the Bill of Materials

To save the Bill of Materials to a file,

- 1 Enter the desired output file path and name in the Bill of Materials dialog box.
- 2 Click the **Save** button.

To display the Bill of Materials,

- 1 Click the **Display** button.

The Bill of Materials appears in the Notepad editor.

- 2 Choose **File > Print** in the Notepad editor to print the Bill of Materials.

Including Attributes

Use the **Include Attributes** field in the Bill of Materials dialog box to enter items that you want to appear in the attribute column of the Bill of Materials. These items must be separated by commas, and should be listed in the order that you want them to appear in the Bill of Materials. There are two predefined attributes: package and description. These are listed as the default attributes in the **Include Attributes** field. Deleting an item from the **Include Attributes** field excludes that attribute from the Bill of Materials. You can enter other attributes in the **Include Attributes** field if they are defined an attribute file as described below.

Creating an Attribute File

You can create an attribute file to define additional attributes.

To use an attribute file,

- 1 Create an attribute file.
- 2 Select the attribute file in the **Attribute File** field of the Bill of Materials dialog box by typing the full path and naming the file, or by clicking the **Attribute File** button to find and select the file.
- 3 Define the attributes in the attribute file and enter the names of the attributes in the **Include Attributes** field of the Bill of Materials dialog box.

If you use an attribute file, devices that match an entry in the attribute file will have the defined attributes listed in the attribute column in the Bill of Materials. An entry in an attribute file must have one of the following two comma delimited formats:

Format 1

[Label-Value], [Package], [Description], [Attribute Name],
[Attribute Data]

This format is used for all devices except for resistors, capacitors, and inductors.

Example:

```
ua741 , DIP8 , * , MFG , FairChild
```

Format 2

[Spice Prefix (R, C, or L)], [Package], [Description],
[Attribute Name], [Attribute Data]

This format is used for resistors, capacitors, and inductors.

Example:

```
c , CAP0.2 , * , MFG , Mallory
```

A device is considered to match an entry in the attribute file if the label-value (or spice prefix), package, and description of the device match those of the entry in the attribute file. The matching is case insensitive. You can use an asterisk (wild-card) to indicate that a match for a particular item is not required. In the Format 1 ua741 example, only the Label-Value and the package must match. The description does not need to match because of the asterisk.

A single line in the attribute file can only contain one attribute. Additional attributes for the same device type can be listed by using the plus (+) character. The plus character means that the Label-Value, package, and description for the new line are the same as the line above. This means that only the new attribute name and attribute data are listed. Here is the above ua741 example restated, with additional attributes:

```
ua741 , DIP8 , * , MFG , FairChild
```

```
+ , COST , $0.25
```

```
+ , MFGID , UA741N
```

The information in the **Include Attributes** field of the Bill of Materials dialog box could be as follows:

```
Package,Description,MFG,MFGID,cost
```

A corresponding entry in a Bill of Materials would then be:

```
24      3      UA741      DIP8      U1,U2,U3
          Fairchild
          UA741N
          $0.25
```

Even though Description is listed in the **Include Attributes** field, a description does not appear in the Bill of Materials because the **Description** field in the Edit Device Data dialog is blank for this device. Note that the order of the attributes in the Bill of Materials depends on the order in the **Include Attributes** field, not the order in the attribute file. The following are examples of additional entries from an attribute file:

```
LM741,DIP8,* ,MFG,National
+,COST,$0.26
+,MFGID,LM741N
```

```
r,AXIAL0.4,* ,MFG,TRW
+,COST,$0.05
```

```
LF411,CAN8,* ,MFG,National
+,COST,$0.26
+,MFGID,LM741N
```

```
c,CAP0.2,* ,MFG,Mallory
```

Setting Up Export Options

Use the Export Options dialog box to specify the format used when transferring graphics to the clipboard or when exporting a graphic to a file.

To setup export options,

- 1 Choose **File > Export > Options** to display the dialog box shown in Figure 7.2.
- 2 Choose **On**, **Off**, or **Simulation** for the **Show LED/LAMP Display State** option.
- 3 Choose Color or B/W (Black and White) to specify the output color.

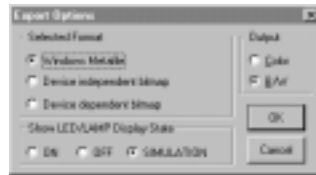


Figure 7.2. The Export Options dialog lets you specify output settings.

- 4 Choose an export format:

Format	Characteristics
Windows Metafile	Windows format for vector graphics.
Device Independent Bitmap	A pixel-by-pixel representation of a graphic that looks good at any resolution.
Device Dependent Bitmap	A pixel-by-pixel representation of a graphic that only looks good at its original resolution.

Exporting Waveforms as Graphics

You can export CircuitMaker waveforms and use them in documentation, presentations, etc. You can either save the waveform as a graphic file, or copy and paste the waveform directly into another software program.

Use the Waveforms as Graphics export option to save the waveforms for the current circuit as a Windows Metafile, Device Independent Bitmap or Device Dependent Bitmap. Use the Export Options dialog box, described earlier, to choose the format.

Note: CircuitMaker saves only the information currently displayed in the active Waveforms or Analysis window.

To save waveforms as graphics,

- 1 Run a simulation so that waveform and analysis windows appear on the screen.
- 2 Click and select the waveform window that you want to export.
- 3 Choose **File > Export > Waveforms as Graphic**. Select the name of the file where you want to save the circuit graphic, then choose **Save**.

OR

Choose **Edit > Copy to Clipboard > Waveforms**, then open another Windows program and Paste the waveform directly into your document.

Exporting Circuits as Graphics

You can export CircuitMaker circuit schematics and use them in documentation, presentations, etc. You can either save the circuit as a graphic file, or copy and paste the circuit directly into another software program.

Use the Export Circuit as Graphic option to save the circuit to disk as a Windows Metafile, Device Independent Bitmap or Device Dependent Bitmap. Use the Export Options dialog box, described earlier, to choose the format.

To export the circuit as a graphic,

- 1 Choose **File > Export > Circuit as Graphic**. Select the name of the file where you want to save the circuit graphic, then choose **Save**.

OR

Choose **Edit > Copy to Clipboard > Circuit**, then open another Windows program and Paste the circuit directly into your document.

Exporting a SPICE Netlist

A SPICE netlist is intended for simulation. For more information, see *Chapter 6: Analog/Mixed-Signal Simulation* and *Chapter 15: SPICE: Beyond the Basics*.

Use the SPICE netlist (.NET) option to create a SPICE compatible text file describing your circuit. You can then import this text file into other Berkeley SPICE3 compatible simulation programs.

- 1 Choose **File > Export > SPICE Netlist**.
- 2 Type the name of the netlist file with a .NET extension, and then choose OK.

Exporting a SPICE Subcircuit

Use the SPICE Subcircuit option to create a .SUB text file describing your circuit. You can then copy the text file into a .SUB file which corresponds to the device symbol you intend to use. Connect SCOPE [Digital/Instrument] (t) devices to your circuit to indicate the connecting nodes of the subcircuit. Label them TP1 (1st node), TP2 (2nd node), etc., or anything that ends with a number (1, 2, 3, etc.) up to a maximum of 64 connecting nodes.

To export a SPICE Subcircuit,

- 1 Choose **File > Export > SPICE Subcircuit**.
- 2 Type the name of the subcircuit file with a .SUB extension, and then choose OK.

Exporting a PCB Netlist

Use the **PCB Netlist** export option to create a PCB netlist file for your circuit. CircuitMaker generates PCB netlists in TraxMaker, Protel, Tango, and many other formats, allowing you to use it with a wide variety of Printed Circuit Board layout programs.

What is a Net?

Each *net* represents one electrical junction point or *node* of a circuit. Numerous device pins may be connected to the same net.

What is a Netlist?

A *netlist* is an ASCII text file listing connections which describe the networks (or nets) of component connections in an electronic circuit. Widely used in electronics CAD packages, netlists let you transfer design details between applications, such as CircuitMaker and TraxMaker. Netlists generally contain two types of information:

- Descriptions of the individual components
- A list of all pin-to-pin connections

PCB Netlists come in various formats but generally carry similar data. They can often be translated into another format using a text editor. The file extension “.NET” is used for MicroCode Engineering netlist files.

As straightforward ASCII text files, netlists are easily viewed, created, and modified using a simple text editor or word processor (such as NotePad).

PCB Netlist Requirements

To create a PCB netlist, your circuit must meet the following requirements:

- Each device in the circuit must have a unique Designation (that is, D1, C3, etc.).
- Each device must have a value or label (that is, 10k, 2N2222A, etc.).
- Each device must have a Package type which should match one of the available Patterns in your PCB Layout program (that is, DIP14, AXIAL0.4, etc.).

- Pin numbers must be assigned for each device in the circuit.
- Designators and Package Descriptions (types) are limited to 12 alphanumeric characters. Net names can be 20 characters. Pin numbers in netlists are limited to 4 alphanumeric characters. No blank spaces may be used within these strings.

If any of these required items is missing, an error message will appear.

Exporting to Popular PCB Netlist Formats

CircuitMaker can export PCB netlists in the following formats, making your design usable in any product that supports these PCB netlist formats:

- TraxMaker
- Protel
- Tango
- Orcad PCB II (CircuitMaker PRO only)
- PADS (CircuitMaker PRO only)
- CadNetix (CircuitMaker PRO only)
- Calay (CircuitMaker PRO only)
- Calay 90 (CircuitMaker PRO only)

Note that package description names and pin numbers for each device in CircuitMaker must have exact matches to the library footprints of the pcb layout program you are using. For example, let's say your schematic contains a resistor, and you want that resistor to use an AXIAL0.4 footprint when the netlist is imported into TraxMaker. You would need to make sure that the name "AXIAL0.4" is in the Package field of that resistor (double-click on a part in CircuitMaker to access the Edit Device Data dialog box, to view and edit the package field).

To export a PCB netlist format other than the TraxMaker format,

- 1 Choose **File > Export > PCB Netlist**.
- 2 Select the appropriate format from the drop-down list such as Orcad PCB II.
- 3 Type the name of the netlist file, and then choose Save.

TraxMaker PCB Netlist Format

TraxMaker is a powerful pcb layout and autorouting program from MicroCode Engineering Inc. It is fully compatible with CircuitMaker, and the products are designed to work together seamlessly, giving you a complete start-to-finish design system.

TraxMaker's netlist format is identical to the Tango and Protel netlist formats, and TraxMaker accepts either a dash (-) or a comma (,) delimiter between the designator and pin number (U1-16 or U1,16). Some netlists, including TraxMaker netlists, provide separate formats for component descriptions and connections. Others combine the two sets of data in a single section. The following describes the TraxMaker pcb netlist format.

Character	What it Does
[Marks the start of each component description.
U8	Labels the Component Designator (Designation field).
DIP16	Indicates the package description, type, or pattern (Package field). An identical description is required in the TraxMaker component library.
74LS138	Shows the component's comment (or value). Compare with Label-Value field.
Blank line	Left blank for future provision. There are usually three blank lines.
]	Marks the end of the component description.
(Marks the start of each net.
NET3	Names the net.
U8-3	Shows the first component (by designator) and pin number. Pin numbers in TraxMaker library components must be an exact match.

J21-1	Indicates the second pin in the net.
U5-5	Indicates another pin.
)	Marks the end of the net.

Note that net descriptions are distinguished from component descriptions by the use of rounded, rather than square brackets.

CircuitMaker to TraxMaker

TraxMaker is a powerful pcb layout and autorouting program from MicroCode Engineering Inc. It is fully compatible with CircuitMaker, and the products are designed to work together seamlessly, giving you a complete start-to-finish design system. Because CircuitMaker and TraxMaker are tightly integrated, you can automatically export a TraxMaker netlists, open TraxMaker, define a keep out area, load the netlist, place and arrange the component footprints all with the **TraxMaker Button** in CircuitMaker.

Export to TraxMaker automatically using the TraxMaker Button.



To take a schematic from CircuitMaker into TraxMaker,

- 1 Choose **File > Export > PCB Netlist** (or click the TraxMaker button on the Toolbar) to display the dialog box pictured in Figure 7.3.



Figure 7.3. Not only can you export a TraxMaker netlist, but you can also launch TraxMaker, load the netlist, and automatically define a keep out area and place the components, all from within CircuitMaker.

- 2 Choose **TraxMaker** from the drop-down list (it is chosen for you by default).
- 3 From the **TraxMaker Options** group box, specify the options as described in the following sections.

Run TraxMaker and Load Netlist

Use this option to export the currently opened .CKT file to netlist (.NET) format, run TraxMaker, and load the netlist. If CircuitMaker can't find the TraxMaker executable file, use the **Find TraxMaker** button to locate it. Once you have located it, you don't have to find it again unless the location changes.

Create Keep-Out Layer

Use this option to define the board size for the TraxMaker AutoPlacement and Autorouting features, both of which attempt to stay within this area when placing and routing netlists. See the *TraxMaker User Manual* for more information.

Board Size in Mils

Use this option to define the size of the Keep Out Layer. See the *TraxMaker User Manual* for more information.

Automatically Place Components

This option activates the TraxMaker AutoPlacement feature, which uses several strategies when placing netlisted components on the Board. AutoPlacement attempts to arrange components by first grouping, then placing the groups using the placement and clearance grids you've specified. See the *TraxMaker User Manual* for more information.

CHAPTER 8

Fault Simulation

An exciting educational feature of CircuitMaker is the ability to place faulty devices in circuits. This lets you, as the instructor, to create troubleshooting exercises for students. For example, you can create a working circuit, then “zap” one or more of the devices by applying shorts, opens or other faults to selected pins on those devices. You can then password protect the fault data and limit the resources available to the student. You can add faults to both digital and analog circuits.

Hints: Create a working circuit before adding fault data. While CircuitMaker’s comprehensive fault simulator lets you create multiple, complex faults, use discretion when adding faults to a circuit. One or two damaged pins on an IC, a burnt resistor, or a shorted capacitor might be enough to challenge the student.

Device Faults

Each device might have multiple faults, but each device pin can have only a single fault. There are 6 basic types of device faults that can be simulated in CircuitMaker:

Pin(s) Stuck High

In Digital Simulation mode the specified pins will be connected to a logic high. In Analog Simulation mode the specified pins will be connected to an invisible, independent voltage source of an instructor-specified value.

Pin(s) Stuck Low

In Digital Simulation mode the specified pins will be connected to a logic low. In Analog Simulation mode the specified pins will be connected to an invisible, independent voltage source of an instructor-specified value.

Pin(s) Open

In Digital Simulation mode the specified pins will be disconnected from the device. In Analog Simulation mode the specified pins will be connected to the device through an invisible resistor of an instructor-specified value.

Pins Shorted Together

In Digital Simulation mode the specified pins will be shorted directly together. In Analog Simulation mode the specified pins will be connected together through a daisy-chain of invisible resistors of an instructor-specified value.

Wrong Value

For Analog Simulation mode only. The Fault Label-Value replaces the Label-Value for the device during simulation.

User Defined

For Analog Simulation mode only. The SPICE model or subcircuit specified in the Label-Value for the device is replaced during simulation by the model or subcircuit specified in the Fault Label-Value. The faulty model or subcircuit may be one that has been modified by the instructor to operate incorrectly.

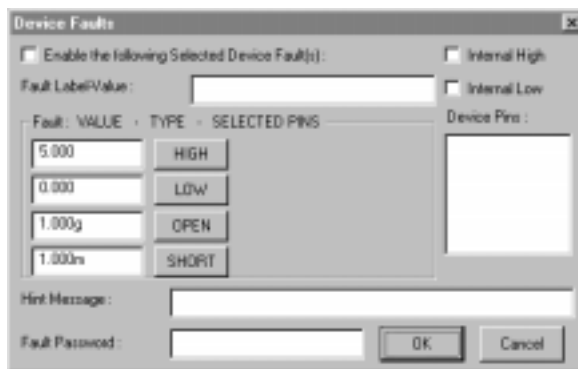


Figure 8.1. Use the Device Faults dialog box, which you access from the Edit Device Data dialog box, to set up faults for the device.

Adding Device Faults

To add faults to a device, follow these steps:

- 1 Double-click the device to display the Edit Device Data dialog box.
- 2 Click **Faults** to display the Device Faults dialog box.

Following is a description of the various items on the Device Faults dialog box (see Figure 8.1).

Enable Device Faults

When checked, the faults specified for this device will be enabled. It is enabled automatically when you edit fault data.

Fault Label-Value

Use this text box to enter the “wrong value” and “user defined” faults mentioned earlier in this chapter. If a value is entered in this field, it will replace the device’s Label-Value when the simulation is run. Faulty SPICE model and subcircuit names may also be entered here. If the field is left blank, the device’s real Label-Value will be used in the simulation.

Faults and Device Pins

Select one or more pins from the **Device Pins** list, then click on one of the fault buttons. The selected pins will be removed from the selection list and placed to the right of the associated fault button. Pressing a fault button again will remove that fault from the pins listed next to it, and place the pins back in the selection list.

Button

HIGH

Used For

The **pin(s) stuck high** fault. In Analog/Mixed mode simulation, the value to the left of the button () indicates the voltage of an invisible voltage source to which the pins are stuck.

LOW

The **pin(s) stuck low** fault. In Analog/Mixed mode simulation, the value to the left of the button () indicates the voltage of an invisible voltage source to which the pins are stuck.

Button	Used For
OPEN	The pin(s) open fault. In Analog/Mixed mode simulation, the value to the left of the button indicates the resistance (very high) between the pin and the device.
SHORT	Used for the pins shorted together fault. In Analog/Mixed mode simulation, the value to the left of the button indicates the value of the resistors (very low) that are daisy-chained between each of the selected pins.

Internal High/Low Check Boxes

Use these options for digital simulation only; they do not affect analog simulation. Stuck high and stuck low faults are assumed, by default, to be external to the device. Due to the nature of the digital simulation, it is desirable to use internal high/low faults on input pins and external high/low faults on output pins. For this reason you should not have an input pin and an output pin both stuck high or both stuck low on the same device.

Hint Message

The instructor can type a brief hint about the nature of the fault in this field that the student can access while troubleshooting the circuit.

Fault Password

The instructor can enter a password in this text box to restrict access to the fault data. If a password is entered here, all fault data will be password protected. If the password is deleted, the fault data will no longer be protected. Passwords are case sensitive and may be up to 15 characters in length. They may include any printable character, excluding Tab or Enter. Password protection:

- Restricts access to the Device Faults dialog box.
- Restricts access to the Circuit Faults dialog box.
- Eliminates fault comments from the SPICE .NET file.

Using the Access Faults Dialog Box

If the fault data has been password protected, the Access Faults dialog box (pictured in Figure 8.2) appears whenever the student:

- Clicks the **Circuit Fault Data** button in the **Preferences** dialog box.
- Clicks the **Faults** button in the **Edit Device Data** dialog box.
- Double-clicks a device (if **Device Data Display** has been checked in the Circuit Faults dialog box).

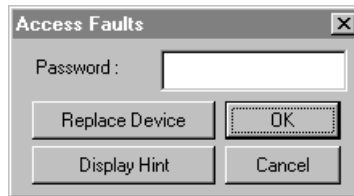


Figure 8.2. The Access Faults dialog box appears whenever a password has been set and the student tries to perform certain actions.

If **Replace Device** has not been disabled (in the Circuit Faults dialog box), the student can click on this button to replace a device. This disables the fault data for the device, but does not actually delete the fault data.

If **Replacement Status** has not been disabled (in the Circuit Faults dialog box), a message will then be displayed indicating whether the replaced device was good or faulty. Disable **Replacement Status** from the Circuit Faults dialog box.

If **Display Hint** has not been disabled (in the Circuit Faults dialog box), the student can click on the **Display Hint** button to view any hint the instructor has provided for that device. The instructor can see how many devices were replaced, and how many hints were displayed, all from the Circuit Faults dialog box. The instructor can also enter the password to gain access to the Device Faults or Circuit Faults dialog box.

Managing Circuit Faults

Use the Circuit Faults dialog box (see Figure 8.3) to control which resources are available to students when faults are enabled. You can also define the default analog fault values. The settings specified in this dialog box are saved with the circuit.

To access the Circuit Faults dialog box,

- 1 Choose **File > Preferences**.
- 2 Click the **Circuit Fault Data** button.

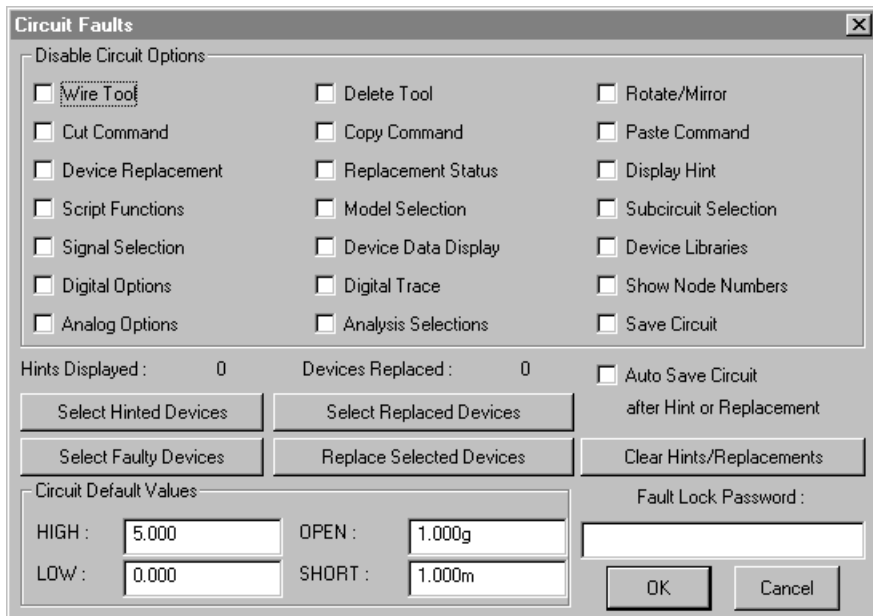


Figure 8.3. Use this dialog box to control which resources are available to students when faults are enabled.

The following information describes the features on the Circuit Faults dialog box.

Disable Circuit Options

Use the options in this group box to limit the features available to the student.

Note: Only the items which are *not checked* are available to the student.

By default, none of the items are checked, meaning that the student has access to all of CircuitMaker's features.

Option	Disables Student's Ability To
Wire Tool	Use the Wire Tool or the Arrow/Wire Tool to modify the circuit.
Delete Tool	Use the Delete Tool or the Delete key to modify the circuit. Note: This does not prevent the student from replacing a device (by clicking on the Replace Device button in the Access Faults dialog box).
Rotate/Mirror	Rotate or mirror devices in the circuit.
Cut Command	Use the Cut and Move commands to modify the circuit.
Copy Command	Use the Copy, Duplicate and Copy Circuit commands. Note: This prevents the student from copying faulty devices into another circuit which is not password protected.
Paste Command	Use the Paste and Duplicate commands to modify the circuit.
Device Replacement	Use the Replace Device button in the Access Faults dialog box. Note: This does not prevent the student from deleting the device or selecting a new device from the device library.
Replacement Status	View a message when a device is replaced. The message indicates whether or not the replaced device was faulty.
Display Hints	View any hint messages.
Script Functions	Run any of the script functions.
Model Selection	Select a new SPICE model for any device.
Subcircuit Selection	Select a new SPICE subcircuit for any device.

Option	Disables Student's Ability To
Signal Selection	Change the settings of the Signal Generators.
Device Data Display	View or edit the device data in the Edit Device Data dialog box, and change the Visible status of the device labels and values.
Device Libraries	Select new devices from the device library. Note: This does not prevent the student from replacing a device by clicking on the Replace Device button in the Access Faults dialog box.
Digital Options	Access the Digital Options dialog box.
Digital Trace	Use the Trace feature. The Trace feature is used in digital simulation to view the logic states of all the wires in the circuit.
Show Node Numbers	View the node numbers for the circuit. Viewing the node numbers could help identify opens and shorts in a circuit.
Analog Options	Access the Analog Options dialog box.
Analysis Selections	Change the enabled/disabled status of the analog analyses, which limits the student to analysis types you specify. The student can, however, change settings of enabled analyses and run modified simulations.
Save Circuit	Save the circuit. This cannot be checked if the Auto Save Circuit after Hint or Replacement option is checked (see <i>Hints and Replacements</i>).

Hints and Replacements

Each time the student presses the **Replace Device** or **Display Hint** button in the Access Faults dialog box, a flag is set for the selected device.

If you check the **Auto Save Circuit after Hint or Replacement** option, the circuit is saved automatically each time the buttons are pressed, preserving the student's work.

Option	Lets Instructor
Hints Displayed	View the number of hints that the student viewed.
Devices Displayed	View the number of devices the student replaced.
Select Replaced Devices	View (or highlight) all devices that were replaced.
Select Hinted Devices	View all devices for which the student viewed a hint.
Select Faulty Devices	View all devices that have fault data in them (whether the faults are enabled for that device or not).
Replace Selected Devices	Disable the fault data for all selected devices; does not delete the fault data.
Clear Hints/Replacements	Clear the flags.

Circuit Default Values

Use the Circuit Default Values group box to set the default values that correspond to the various faults in Analog Simulation mode. These defaults can be overridden for each device individually.

Value	Default Value For the Invisible
HIGH	Voltage source to which the specified pins of a device are connected when a HIGH fault is specified. The factory default is +5V.

Value	Default Value For the Invisible
LOW	Voltage source to which the specified pins of a device are connected when a LOW fault is specified. The factory default is 0V.
OPEN	Resistor placed between the specified pins and the device. The factory default is 1G ohm.
SHORT	Resistors that are daisy-chained between the specified pins of the device. The factory default is 1m ohm.

Fault Lock Password

The instructor might enter a password in this field to restrict access to the fault data. If you enter a password here, all fault data is password protected. If the password is deleted, the fault data will no longer be protected. Passwords are case sensitive and may be up to 15 characters in length. They may include any printable character, excluding Tab or Enter.

Warning: If you forget the password, you will not be able to access the fault data for the circuit.

Creating Black Box Macros

The instructor may lock a macro so that it cannot be expanded by the students, thus creating a “black box” macro.

To create a black box macro,

- 1 Choose **Macros > Expand Macro**.
- 2 Choose **Macros > Macro Lock**.
- 3 Enter any number (up to 4 digits), and then save the macro.

When you attempt to expand the macro again, a display prompt asks you to enter the 4-digit code. A code of 0 (zero) leaves the macro unlocked.

Warning: If you forget the code, you will not be able to expand the macro.

Fault Example

The following step-by-step example illustrates how to use the Circuit Faults dialog box.

- 1 Open the example circuit PS1.CKT.
- 2 Click the **Run** button on the Toolbar to run the simulation.
- 3 Select the Transient Analysis window, and then probe around on the circuit to verify that the circuit is working properly.

If you click on the positive side of the filter capacitor (C1), you should see a ripple on waveform at about 15VDC. If you click on the emitter side of the transistor (Q1), you should see a DC voltage of about 6V.

- 4 Stop the simulation by clicking the **Stop** button on the Toolbar.
- 5 Double-click the filter capacitor (C1) to display the Edit Device Data dialog box then click the **Faults** button.
- 6 Click on device pins 1 and 2 shown in the “Device Pins” list box. Click on the “short” button. This will cause a short to be placed across the capacitor.
- 7 Click on the “Enable the following selected Device Faults” check box to enable the fault.
- 8 Click OK to exit the Device Faults dialog box then click OK to exit the Edit Device Data dialog box.
- 9 Choose **File > Preferences**.
- 10 Click the **Circuit Fault Data** button to display the Circuit Faults dialog box.
- 11 Click **Device Data Display** so it is checked.
- 12 Click the **Clear Hints/Replacements** button to clear these flags.
- 13 Type **xxx** in the **Fault Lock Password** text box.
- 14 Click OK to exit the Circuit Faults dialog box then click OK to exit the Preferences dialog box.

- 15 If you want to save the fault settings for the circuit (not required for this example), you must now save the circuit.
- 16 Click the **Run** button on the Toolbar to restart the simulation.
- 17 Look at the waveform on the positive side of the filter capacitor. You should see a sine wave of very low amplitude (about 80mV peak-to-peak). The student might determine from this measurement that the filter capacitor is shorted and needs to be replaced.
- 18 Stop the simulation by clicking the **Stop** button in the Toolbar.
- 19 Double-click the filter capacitor (C1) to display the Access Faults dialog box then click the **Display Hint** button to view the hint.
- 20 Double-click the filter capacitor again to display the Access Faults dialog box then click the **Replace Device** button to disable the fault data for this device.
- 21 Run the simulation again to see if the problem has been fixed.
- 22 Stop the simulation.
- 23 Choose **File > Preferences**, and then click the **Circuit Fault Data** button to display the Access Faults dialog box.
- 24 Type **xxx** into the **Fault Lock Password** text box then click OK to exit the Circuit Faults dialog box.

Notice that there was one device replaced and one hint displayed.
- 25 On the **File > Preferences > Circuit Faults** dialog box, click the **Device Data Display** check box to remove the check and delete the **xxx** from the **Fault Lock Password** field.
- 26 Click the **Select Replaced Devices** button.
- 27 Click OK to exit the Circuit Faults dialog box then click OK to exit the Preferences dialog box. The device that was replaced (the filter cap) is selected.

CHAPTER 9

File Menu

The File menu contains commands that enable you to open, save and print circuits and waveforms.

New

Select **New** to clear the current circuit from the work area and begin a new circuit. If an unsaved circuit is present in the work area when you select this command, you will be asked if you want to save the current circuit first.

Open

Choose **Open** to abandon the current circuit and load a different circuit into the workspace. If an unsaved circuit is present in the work area, you will be asked if you want to save the current circuit first. A file selector dialog will then be displayed allowing you to choose the circuit to load into the work area. The file extension used by default is .CKT. Circuit files created with older versions of CircuitMaker have the .CIR extension. To open these files, select the .CIR file type. As these files are opened, they will be converted to the new ASCII format and should be saved with the .CKT extension.

Reopen

Use the Reopen command to quickly reopen any of the last 8 circuits that you have used. If changes have been made to the current circuit you will be asked if you want to save the circuit before closing.

Merge

The **Merge** option lets you to add a circuit saved on disk to the circuit in the work area. This command is useful because it lets you save commonly used circuits or portions of circuits to disk then reuse them as often as you need, without having to rebuild them from scratch each time.

Select **Merge** and choose the circuit to be added to the work area. The circuit will be placed starting at the top left corner of the screen, so be sure to position the work area and existing circuit accordingly.

Close

Use **Close** to close the open windows. If changes have been made to the current circuit you will be asked if you want to save the circuit before closing.

Save

Choose **Save** to save the current circuit in the work area to disk using the name shown in the Title Bar. When you save a circuit whose title is UNTITLED.CKT, a file selector dialog box appears, allowing you to save it under a specific name.

Save As

Choose **Save As** to save the current circuit to disk using a file name that is different than the one shown in the Title Bar. CircuitMaker will display a file selector dialog box allowing you to choose the path and a file name of up to eight characters. The circuit is saved in an ASCII format with a default file extension of .CKT.

Revert

Choose **Revert** to abandon any changes made since last saving the circuit to disk and load the last saved version back into the work area. CircuitMaker will then display a dialog box asking you to confirm that you want to revert to the last saved version.

Import > Simulate SPICE Netlist

Use this option to import and simulate a SPICE netlist that you might have created in another simulation program. When you use this feature, CircuitMaker does not display the actual schematic drawing. Instead, it runs the simulation, displays the waveform data, and provides a plot variable which you can use to choose different variables to plot.

To import and simulate a SPICE netlist,

- 1 Choose **Import > Simulate SPICE Netlist**.
- 2 Select a file with a .NET extension and choose **Open**.
- 3 When the simulation is complete, select an analysis window and then click the **Probe Tool** on the plot variable.
- 4 Select a variable from the list that appears, then choose **OK**.

A waveform plots data for the variable you selected.

- 5 To plot multiple variables, hold down the **Shift** key while selecting variables.

Export

CircuitMaker allows you to export a variety of files and formats, including circuit and waveforms, pcb and Spice netlists. See *Chapter 7: Exporting Files* for a complete description of the exporting options.

Bill of Materials

Formerly known as a Parts List, a Bill of Materials is a file that contains information about how many and which kinds of parts are used in your circuit. You can export a Bill of Materials to a text file. See *Exporting a Bill of Materials* in *Chapter 7: Exporting Files* for more information.

Print Setup

The **File > Print Setup** option allows you to scale the output to the printer 10% to 1000%, and choose between black and white, or color. You can also select the desired printer and page orientation by clicking the **Printer** button.

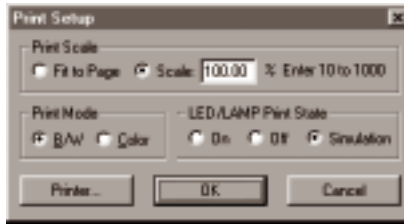


Figure 9.1. The Print Setup dialog box lets you scale the output and set other printing options.

Fit to Page

Use the **Fit to Page** option on the Print Setup dialog box to scale the schematic automatically so that the entire schematic fits on a single printed page.

Print Circuit

Choose **File > Print Circuit** to print the current circuit or to save it to a print file. A Printer dialog box appears, allowing you to select the desired output. If the circuit is too large to fit onto a single page, it will automatically be divided into page-size blocks as it is printed (see *Show Page Breaks* in the View menu). CircuitMaker supports all printers and printer options in the Printer dialog box. Printer setups will vary depending on the device you are printing to, but typically options such as page orientation and reduction factor are available.

Print Waveforms

Choose **File > Print Waveforms** to print the waveforms to a printer or save them to a print file. Only the information currently displayed in the active Waveforms or Analysis window is printed.

Preferences

Choose **Preferences** (Figure 9.2) to change the default settings of CircuitMaker. Preferences are stored in the CIRMAKER.DAT file.



Figure 9.2. The Preferences dialog box lets you change everything from program defaults to circuit defaults.

The options you set in the **Program Defaults** group box remain in effect no matter what circuit is loaded, while the items in the **Circuit Defaults** group box are saved with each individual circuit.

Click **Factory Settings** to reset all the Preferences to their original factory default settings.

Device/Plot Font

This option lets you specify the default font used in CircuitMaker. This font is used on all device labels, wire labels, pin names, key caps, ASCII displays, and plot windows.

Default Font Button

This button sets CircuitMaker's default font to its factory default which is Courier New. This is a TrueType (scalable/rotatable), monospaced font that comes with the Windows operating system.

Auto Repeat

When checked, the Auto Repeat option will be activated by default. Auto Repeat lets you repeatedly place a device, until you either double-click or press any key. This option is also accessible from the Options Menu. See *Auto Repeat* in *Chapter 12: Options Menu*.

Arrow/Wire Tool

When checked, the Arrow/Wire Tool options is activated by default. The Arrow/Wire Tool allows you to initiate a wire by clicking on a device pin with the Arrow Tool. This options is also accessible from the Options Menu. See *Arrow/Wire* in *Chapter 12: Options Menu*.

Single Click Connect

Use this option to manually route wires. When Single Click is enabled, you can terminate a wire by a single mouse click on any valid connection point. You can still terminate a wire at any location with a double-click, even if the end of the wire is not at a valid connection point. When the Single Click option is disabled, you must double-click to end the wire. This double-click mode lets you turn a wire very close to other wires or pins without connecting to them.

Display Toolbar

When checked, the Display Toolbar option will be activated by default. This option is also accessible from the View Menu. See *Toolbar* in *Chapter 13: View and Window Menus*.

Prompt to SAVE

If modifications have been made to the circuit, you may want to save the circuit before you run the simulation. If this box is checked, then each time you run the simulation CircuitMaker will warn you if the circuit has not been saved.

Display Variable Names

When checked, the Display Variable Names option will be activated by default. The Display Variable Names option replaces the A, B, C labels used on the analog analysis windows with the variable names such as V(8), etc. This allows you to identify the various points in the circuit more consistently with those being graphed in analysis windows. This option is also accessible from the *Simulation Menu*. See *Display Variable Names* in *Chapter 14: Simulation Menu*.

Connection Area

The connection area defines a rectangle around valid connection points (a valid connection point is any device pin or wire). The SmartWires™ feature lets you connect a wire to a valid connection point, even if your cursor is not exactly on that point. By setting the “X” and “Y” values, you specify how close (within how many pixels) you must be to the connection point before the wire will snap to that point. By default, the cursor must be within 3 pixels of the connection point. When the **Sound On** option is enabled, the system will beep through the PC’s speaker each time the cursor enters a connection area. When the **Show Box** option is enabled, a rectangle will appear around the connection area each time the cursor enters that area.

Auto Wire Routing

Auto wiring can be simple or intelligent, depending on which check box you select. **Simple** routing draws only one or two wire segments, horizontal and/or vertical, making the shortest path without regard for devices that might be in the way. **Intelligent** routing tries to find a path which does not cross directly over any devices. If no reasonable path can be found, the simple method is used.

Default Transient Analysis

These options allow you to control the parameters supplied to the Transient Analysis when the Default Setups button is pressed in the Analog Analyses dialog box. These values are only used in circuits which contain one or more Signal Generators. **Cycles Displayed** determines the number of cycles of the *lowest* frequency Signal Generator to be analyzed. **Points Per Cycle** determines the resolution of the analysis.

Export Options Button

Click on the Export Options... button to access and modify the export options CircuitMaker will use when exporting circuits and waveforms as graphic files. These export options can also be accessed from File menu directly. See *Chapter 7: Exporting Files* for details on how to export waveform and circuit graphics.

Directories and Files Button

The default directories and files used by CircuitMaker are user definable. Circuit Directory is the path to where CircuitMaker stores your circuit (.CKT) files. Model Directory is the path to where your SPICE model libraries are located. Script Directory is the path to where your script (.SRP) files are located. User Library File is the path and file name of your USER.LIB (Macros) file.

Note: The DEVICEDB.DAT, HOTKEYYDB.DAT and SYMBOLDB.DAT files must be in the same directory as USER.LIB.

Show Pin Dots

When checked, the Show Pin Dots option will be activated by default. The Show Pin Dots option will place a small dot at every connection point in the circuit. This option is also accessible from the Options Menu. See *Show Pin Dots* in *Chapter 12: Options Menu*.

Show Bus Labels

When checked, the Show Bus Labels option will be activated by default. The Show Bus Labels option displays bus labels in the circuit. This option is also accessible from the Options Menu. See *Show Bus Labels* in *Chapter 12: Options Menu*.

Show Page Breaks

When checked, the Show Page Breaks option will be activated by default. The Show Page Breaks option will display the page divisions according to the paper size selected for the printer. This option is also accessible from the Options Menu. See *Show Page Breaks* in *Chapter 12: Options Menu*.

Show Node Numbers

When checked, the Show Node Numbers option will be activated by default. The Show Node Numbers option will display the node number of every node in your circuit. This option is also accessible from the Options Menu. See *Show Node Numbers* in *Chapter 12: Options Menu*.

Show Prop Delays

When checked, the Show Prop Delays option will be activated by default. The Show Prop Delays option will display the propagation delays for all devices in the circuit. This option is also accessible from the Options Menu. See *Show Prop Delays* in *Chapter 12: Options Menu*.

Auto Refresh

When checked, the Auto Refresh option will be activated by default. The Auto Refresh option will automatically refresh the screen as you are editing the circuit. This option is also accessible from the Options Menu. See *Auto Refresh* in *Chapter 12: Options Menu*.

Show Designation

When checked, the Show Designation option will be activated by default. The Show Designation option will display the device designations for all devices in the circuit. This option is also accessible from the Options Menu. See *Device Designation* in *Chapter 12: Options Menu*.

Grid

The Grid options in the Preferences dialog box allow you to set default grid settings that will be used every time you open CircuitMaker. These options include grid size, along with view, print and snap options. This option is also accessible from the Options Menu. See *Grid* in *Chapter 12: Options Menu*.

Title Block

The Title Block options in the Preferences dialog box allow you to set default Title Block settings that will be used every time you open CircuitMaker. This option is also accessible from the Options Menu. See *Title Block* in *Chapter 12: Options Menu*.

Border

The Border options in the Preferences dialog box allow you to set default border settings that will be used every time you open CircuitMaker. These options include view and print preferences. This option is also accessible from the Options Menu. See *Border* in *Chapter 12: Options Menu*.

Circuit Fault Data Button

Click on the Circuit Fault Data button to access and modify the circuit fault options CircuitMaker will use. See *Circuit Faults* in *Chapter 8: Fault Simulation* for more information.

Circuit Display Button

Click on the Circuit Display button to access and modify the default circuit display options CircuitMaker will use. This option is also accessible from the Options Menu. See *Circuit Display Data* in *Chapter 12: Options Menu*.

Select Colors Button

Click on the Select Colors button to access and modify the default color options CircuitMaker will use. This option is also accessible from the View Menu, and from the right-click pop up menu when right-clicking on an analysis window. See *Colors* in *Chapter 13: View and Window Menus*.

Exit

Choose **File > Exit** to exit CircuitMaker and return to Windows. If there are unsaved changes, you will be asked if you want to save them.

CHAPTER 10

Edit Menu

The commands in the Edit menu provide some of the tools necessary to construct and modify circuit diagrams.

Undo

Many of CircuitMaker's editing commands can be undone. Edit operations which can be undone are Cut, Paste, Delete and Move. Only the most recent edit can be undone and many commands are not able to be undone, including Run, Single Step, Reset, Define New Macro, Expand Macro and Delete Macro.

Cut

Use **Cut** to remove all selected items and place them in the paste buffer and on the system clipboard.

Copy

Use **Copy** to place all selected items in the paste buffer and on the system clipboard.


Paste

The **Paste** option displays the contents of the paste buffer in the CircuitMaker workspace and the displayed items follow the mouse around the screen. The cursor is replaced by the paste cursor, indicating the top left corner of the paste area. When the items are positioned at the desired location, click the mouse to finalize the paste. To cancel the paste, press any key or double-click the mouse.

Note: You cannot use Paste to paste items from the system clipboard.

Move

Use the **Move** option to perform both a Cut and a Paste. This provides a quick way to move an entire circuit or portion of a circuit to a new position on the screen. Connections to other portions of the circuit are lost.

 *Normal cursor*

 *Paste cursor*

Delete Items

This feature removes all selected items from the workspace.

Duplicate

Choose **Duplicate** to make a copy of all selected items.

When this command is selected the duplicated items follow the mouse around the screen. The cursor is replaced by the paste cursor, indicating the top left corner of the paste area. When the items are positioned at the desired location, click the mouse to finalize the duplication. To cancel the duplication, press any key or double-click the mouse.

Copy Circuit to Clipboard

Choose **Copy to Clipboard > Circuit** to copy the entire circuit to the system clipboard in one of three formats:

- Windows Metafile
- Device Independent Bitmap
- Device Dependent Bitmap

Choose **File > Export > Options** to select the desired format. This feature enables you to later paste the contents of the clipboard into a graphics program for further manipulation, printout, etc. When this command has been executed, an alert box appears informing you that the circuit has been copied to the clipboard.

Note: You cannot paste items into the CircuitMaker workspace that were copied using this command. It is designed only to copy the circuit to the system clipboard.

Copy Waveforms to Clipboard

Use **Edit > Copy to Clipboard > Copy Waveforms** to copy the contents of the Waveforms window to the system clipboard in one of three formats:

- Windows Metafile
- Device Independent Bitmap
- Device Dependent Bitmap

Choose **File > Export > Options** to select the desired format. When copying waveforms to the clipboard, an alert box appears to inform you that the waveforms have been copied.

Before you can use this feature, at least one Analysis window must be open. You can copy only the information currently visible in the Waveforms window to the clipboard. To ensure that meaningful waveform information is copied, run the simulation prior to using this feature.

Select All

This option selects all items in the work area. This is useful when you want to cut, copy or move the entire circuit.

Find and Select

Use the Find and Select feature (Figure 10.1) to locate a specific device placed on the workspace by Node Number, Designation, Label or Value, or Symbol Name. If CircuitMaker finds a device that matches your description, it is highlighted.

***Note:** To find input/output connectors, put the connector name in the "Label or Value" field of the Find and Select dialog box.*

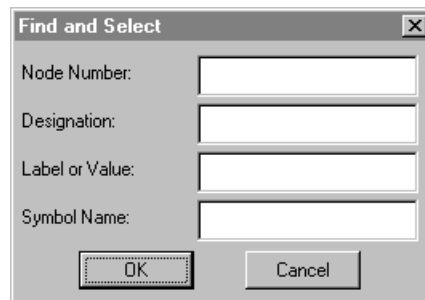


Figure 10.1. Use the Find and Select dialog box to search for devices you have placed in the workspace.

For example, if a SPICE message indicates a problem at node 27 and your schematic is rather complex, this command can help you find the specified node. All wires connected to that node will be selected. You can also search for multiple devices. For example, to select all the transistors, enter **Q*** in the Designation field. All characters after the **Q** will be ignored in the search.

Rotate 90

This is the same as the Rotate 90 button described in *Chapter 4: Drawing and Editing Schematics*.

Mirror

This is the same as the Mirror button described in *Chapter 4: Drawing and Editing Schematics*.

Straighten Wires

When you have wires with multiple bends, sometimes you may want to clean them up a little. This is a quick way of taking out some of the extra “kinks” without having to adjust the wire manually.

To straighten wires,

- 1 Select the wires you want to straighten.
- 2 Choose **Edit > Straighten Wires**.

Place Labels

This option lets you place the labels of all selected devices in their standard positions without rotating or mirroring.

Set Prop Delays

Use **Edit > Set Prop Delays** (for Digital Logic Simulation only) to alter the propagation delay of all selected devices. The delay of a device determines how many simulation ticks it takes for a signal to propagate from the input to the output of the device.

- 1 Select a device then choose **Edit > Set Prop Delay** to display the dialog box pictured in Figure 10.2.
- 2 Enter a new value for the delay then click OK.

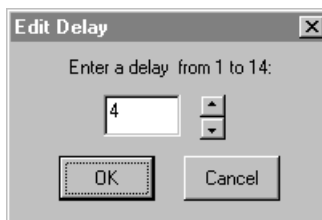


Figure 10.2. Use the Edit Delay dialog box to alter the propagation delay of all selected devices.

The default delay for all devices is one (1), but by using Set Prop Delays, you can change this value to any integer from 1 to 14. The units assigned to delay are arbitrary, and it is left

to you to determine what they are. The concept is that if one device has a delay of one and another a delay of three, then in the real world the second device would have a propagation delay three times larger than the first device.

Set Designations

Choose **Edit > Set Designations** to display the Set Designations dialog box (pictured in Figure 10.3). Use this feature to renumber devices designations of devices you have already placed in the schematic. You can renumber all devices or a group of devices you have selected.



Figure 10.3. Use this dialog box to renumber device designations for all devices or a group of devices.

The Set Designations feature is useful if you want the devices in a schematic, or a particular group of devices, to have designations numbered with a certain range of numbers. For example, you might want to renumber all the resistors in your schematic R40, R41, R42, R43, and so on.

To renumber device designations,

- 1 Unselect all devices (that is, don't select any) devices to renumber all devices on the board.

OR

Select a group of devices by holding the left mouse button while you draw a box around the devices.

OR

Hold down the **Shift** key while clicking the devices you want to select.

- 2 Choose **Edit > Set Designations**.
- 3 Type a number in the **Starting Number** text box.

- 4 Select **All** if you want all devices to be renumbered.

OR

Click **Selected Devices** to renumber only those devices you have selected.

- 5 Select **Show Device Designations** if you want the designations to appear in the schematic.

Designation assignments will start at the stated starting number, and proceed from there, skipping any designations that are already in use.

Note: Set Designations is not the same thing as the Device Designations feature on the Options menu, which numbers newly placed devices with a specified number, or the next available number after the starting number you specify. For more information, see *Device Designations* in *Chapter 12: Options Menu*.

You can set the designation prefix for individual devices using the Edit Device Data dialog box described in *Editing Devices* of *Chapter 4: Drawing and Editing Schematics*. Each device must have a unique designation in order for analog simulation to work.

Edit > Edit Items

While some item parameters can be edited by double-clicking the item, some item parameters cannot. The Edit Items submenu provides editing access to all parameters. The following sections describe the items on this submenu.

Edit Bus Connection

This feature lets you modify the number associated with an existing wire that is connected to a bus wire (see Figure 10.4). It also lets you select the angle on the connecting wire.

- 1 Select the wire (connected to a bus) by clicking it once then choose **Edit > Edit Items > Edit Bus Connection**.

OR

Double-click the wire with the **Arrow Tool**.

- 2 Enter a new number or angle then choose OK.

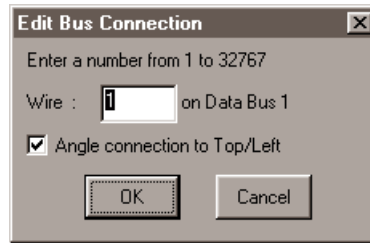


Figure 10.4. Use this dialog box to edit a wire connected to a bus.

Edit Bus Wire Number

This feature lets you change the number associated with an existing bus wire.

- 1 Select the bus wire to be edited by clicking it once, and then choose **Edit > Edit Items > Edit Bus Wire Number**.

OR

Double-click the bus wire with the **Arrow Tool**.

- 2 Enter a new number then choose OK.

Edit Device Data

Choose **Edit > Edit Items > Edit Device Data** to change device labels, values, SPICE data, etc. Refer to *Chapter 4: Drawing and Editing Schematics* for more information.

Edit Digital Params

Choose **Edit > Edit Items > Edit Digital Params** to change digital SimCode device parameters. Refer to *Digital SimCode Devices* in Chapter 16: *Creating New Devices* for details.

Edit Run-Time Test Point

Choose the **Edit > Edit Items > Edit Run-Time Test Point** command to change the setting for the selected Run-Time Test Point. Refer to *Run-Time Test Points* in Chapter 6: *Analog/Mixed-Signal Simulation* for details.

Edit/Select Spice Model

Use the **Edit > Edit Items > Edit/Select Spice Model** option to change the SPICE model for the selected device. Refer to *SPICE Models* in Chapter 16: *Creating New Devices* for details.

Edit PROM/RAM

Use the **Edit > Edit Items > Edit PROM/RAM** option (Figure 10.5) to program the 32 x 8 PROM or the 1k x 8 RAM. Once a PROM is programmed, it retains its contents until reprogrammed. When you save a circuit containing a PROM to disk, the contents of the PROM are also saved. For debugging purposes, the contents of the RAM can be viewed and edited, but the data will not be saved with the circuit.

- 1 Click a single PROM or RAM to select it, and then choose **Edit > Edit Items > Edit PROM/RAM**.

OR

Double-click the device with the **Arrow Tool** to display the dialog box pictured in Figure 10.5.

- 2 Program the device as desired, then choose OK.

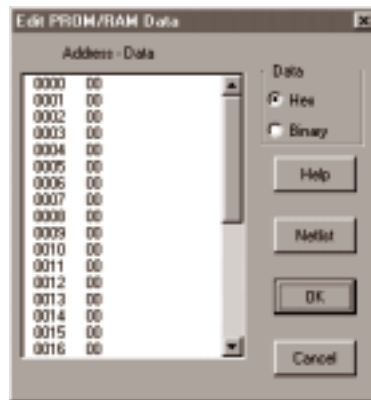


Figure 10.5. Use this dialog box to enter either hexadecimal or binary numbers for the PROM/RAM device.

Edit Pulser

Use **Edit > Edit Items > Edit Pulser** to change the programmed settings of a Pulser. The pulse format, time high, time low, and trigger mode are individually programmable for each Pulser in the circuit. For a complete description of the Pulser, refer to *The Pulser* in *Chapter 5: Digital Logic Simulation*.

Edit Multimeter

This feature allows you to change the function of the selected digital multimeter device (not the Multimeter analysis window).

- 1 Select the Multimeter by clicking it once then choosing **Edit > Edit Items > Edit Multimeter**.

OR

Double-click the device with the **Arrow Tool**.

Refer to *Multimeter* in *Chapter 6: Analog/Mixed-Signal Simulation* for additional information.

Edit Input/Output

This feature (Figure 10.6) lets you change the name associated with an INPUT or OUTPUT device.

- 1 Select the Input (or Output) device by clicking it once then select **Edit > Edit Items > Edit Input/Output**.

OR

Double-click the device with the **Arrow Tool**.

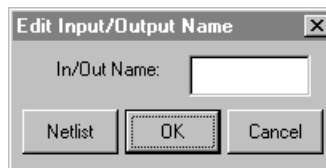


Figure 10.6. Change an Input/Output name.

Edit Data Sequencer

Use the **Edit Data Sequencer** option to change the programmed settings of a Data Sequencer. This device lets you specify up to 32K bytes which can be outputted in a defined sequence.

- 1 Select a Data Sequencer by clicking it once then choosing **Edit > Edit Items > Edit Data Sequencer**.

OR

Double-click the Data Sequencer with the **Arrow Tool**.

For a complete description of the Data Sequencer, refer to *Data Sequencer* in *Chapter 5: Digital Logic Simulation*.

Edit Signal Generator

Use **Edit Signal Generator** to change the programmed settings of the selected multifunction signal generator. For a complete description of the signal generator, refer to *Multifunction Signal Generator* in *Chapter 6: Analog/Mixed-Signal Simulation*.

Edit Scope/Probe Name

This feature (see Figure 10.7) lets you change the name of an existing SCOPE or Analysis Probe.

- 1 Select the scope or probe by clicking it once then choose **Edit > Edit Items > Edit Scope/Probe Name**.

OR

Double-click the scope or probe with the **Arrow Tool**.
- 2 Type a new name.
- 3 Click Netlist to display the Edit Device Data dialog box.

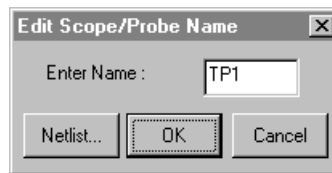


Figure 10.7. This dialog box lets you change the name of an existing SCOPE or Analysis Probe.

Group Items

Use this option to specify the devices that are contained within the same package. For example, a 7400 Quad 2-Input NAND gate actually has 4 gates in the same package. The pin numbers are different for each gate. The individual gates are grouped together automatically as they are placed in the circuit. You could regroup the gates using this feature.

To group items,

- 1 Select the items that you want to group in the same package.
- 2 Choose **Edit > Group Item**.

Font

Choose **Font** (Figure 10.8) to change the font attributes of any selected, free-floating text field, or the default font for new text.

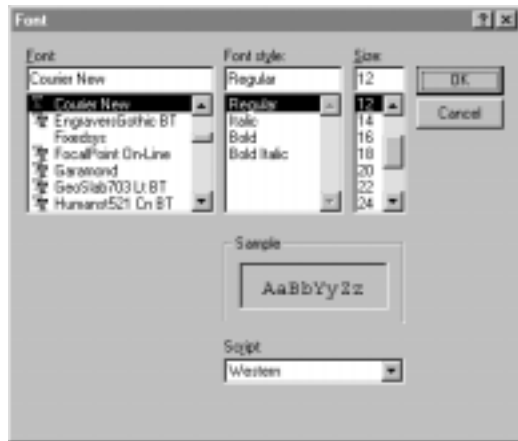


Figure 10.8. Use the Font dialog box to change the font for free-floating text fields or new text.

To change the font,

- 1 Select the text by highlighting it.
- 2 Choose **Edit > Font**.
- 3 Make the desired changes and choose OK.

CHAPTER 11

Macros Menu

Using commands in the Macros menu, you can expand CircuitMaker to meet your exact needs. This chapter describes the options used to create, edit and manipulate macros. Refer to *Chapter 16: Creating New Devices* for a step-by-step tutorial about creating macro devices.

New Macro

Select **New Macro** to create a new schematic symbol to add to the library. If there is a circuit displayed, CircuitMaker asks if you want that circuit included inside the macro for simulation. Macros are saved in a disk file called USER.LIB and once created, are available for use in any circuit or in another macro device.

Edit Macro

To edit a macro, follow these steps:

- 1 Expand the macro by highlighting it and choosing **Macros > Expand Macro**.

Note: When a macro is expanded, the workspace will be cleared. If necessary, save your work beforehand.

- 2 Click the expanded macro's symbol to select it.
- 3 Choose **Macros > Edit Macro** to edit its name, device data or symbol.

You can also double-click the expanded macro's symbol with the Arrow Tool.

If an existing macro is expanded and saved with a new name, it is saved as a new macro and does not overwrite the existing macro. The dialog box shown in Figure 11.1 appears when you use Edit Macro feature.

If no macro (either a newly defined or an expanded one) is present in the work area, the Edit Macro menu item is grayed indicating that it is not available.



Figure 11.1. Use this dialog box to change an existing macro.

You can define a macro as having multiple parts per package; that is, you may specify that there are more than one of these macro circuits, all identical, in a single chip.

Save Macro

Use the **Macros > Save Macro** option to save or resave a macro device. An existing macro saved in this manner will be placed in its original position in the device library. All devices require a Major Device Class designation, so if you use the Save Macro option to save a new macro, CircuitMaker displays the Macro Utilities dialog box allowing you to specify both a major and minor class. To save an existing macro in a new location, refer to the *Macro Utilities* later in this chapter. To save under a different name, refer to *Edit Macro*. Macro devices are stored in the USER.LIB file.

Expand Macro

Use the **Macros > Expand Macro** option to edit a previously saved macro device. Expanding a macro device means that the black box containing the macro's circuitry is opened and all internal circuitry is visible.

Note: Most of the devices included with CircuitMaker are not macro devices and cannot be expanded.

To expand a macro, follow these steps:

- 1 Click a single macro device to select it.
- 2 Choose **Macros > Expand Macro**.

OR

Click the **Macro** button on the Toolbar.

An alert box appears warning that expansion of the macro will clear the work area.

Note: If you haven't saved your work, click the Cancel button to abort the expansion, save the current workspace, and then reselect **Expand Macro**. If you don't need to save the work area, click OK to complete the expansion of the macro.

- 3 Make changes to an expanded macro using any of the available editing commands.
- 4 When you have finished making changes to the macro, choose **Macros > Save Macro**.

Macro Lock

An instructor may want to lock a macro so that it cannot be expanded by the students, thus creating a “black box.”

To lock a macro, follow these steps:

- 1 Expand the macro.
- 2 Click the expanded macro's symbol to select it.
- 3 Choose **Macros > Macro Lock** to display the dialog box pictured in Figure 11.2.

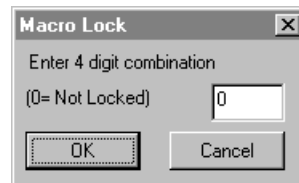


Figure 11.2. Use the Macro Lock feature to lock a macro as a “black box.”

Enter any number (up to 4 digits), then save the macro. When you attempt to expand the macro again, you will be prompted to enter the 4-digit code. A code of 0 (zero) leaves the macro unlocked.

Warning: If you forget the code, you will be unable to expand the macro.

Macro Utilities

The Macro Utilities option on the Macros menu displays the dialog box pictured in Figure 11.3, which enables you to save, expand or delete a macro. The following sections describe the use of these features.

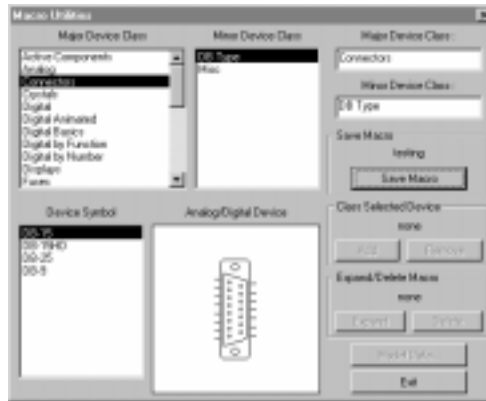


Figure 11.3. The Macro Utilities dialog box lets you save, expand, or delete a macro.

Save Macro

The **Save Macro** button on the Macro Utilities dialog box lets you to save or resave a macro device. If there is no macro (expanded or newly defined) in the work area, this button is grayed. Refer also to the section *Save Macro* described earlier in this chapter.

To save a macro, follow these steps:

- 1 Select both a major and minor device class to indicate where the device is saved in the device library.

Note: You can add new major and minor class names by typing in a new name in the Major Device Class and Minor Device Class text edit fields.

- 2 Click **Save Macro**.

CircuitMaker saves the macro in the USER.LIB file and clears the workspace.

Class Selected Device

Use the Add and Remove buttons in the Class Selected Drive group box to move devices into different major and minor device classes.

To use this group box, follow these steps:

- 1 Select the device in the circuit window.
- 2 Choose **Macros > Macro Utilities**.
- 3 Select the major and minor device classes from the list boxes.
- 4 Click **Add** to add the device to the selected classes.

OR

Click **Remove** to remove the device from the selected classes.

If a device is removed from all classes, it will be inserted in the User Defined major class. To remove a device completely, see *Delete Macro* below.

Expand Macro

Use the Expand button in Expand/Delete Macro group box to perform the same function explained earlier in this chapter. To expand a macro device, select the macro then click the **Expand** button.

Delete Macro

Use the Delete button in the Expand/Delete Macro group box to delete a macro device from the USER.LIB file.

Warning: You cannot open a circuit which uses a macro that has been deleted from the library unless you first create a new macro with the same name.

To delete a macro device, follow these steps:

- 1 Save the workspace if you need to save.
When the macro is deleted the workspace will be cleared.
- 2 Make a backup of the USER.LIB file before you create or delete macros in case something goes wrong and you want to restore the original library.

Note: Most of the devices listed in the Macro Utilities dialog box are actually in the DEVICE.LIB file and cannot be deleted.

- 3 Select the macro.
- 4 Click **Delete Macro**.

Model Data

Use the Model Data button on the Macro Utilities dialog box to add new SPICE models to CircuitMaker's library. This button displays a dialog box that lets you place new references into the linking file for selected symbol. Refer to *Model and Subcircuit Linking Files* in *Chapter 16: Creating New Devices*.

Macro Copier

The following steps illustrate how you can use the Macro Copier to copy your macros into a new version of USER.LIB.

- 1 Choose **Macros > Macro Copier** to display the dialog box pictured in Figure 11.4.



Figure 11.4. Use this dialog box to copy macros from one macro library to another.

- 2 Click lower left **Open** button to display the Open dialog box.

CircuitMaker asks you if you want to list only the user defined devices.

- 3 If you are copying devices that you have created, click **Yes**.
- 4 Select the file *from which* macros will be copied.
This is the library file which has your macros in it (probably USER.LIB in your old CircuitMaker directory).
- 5 Click the lower right **Open** or **New** button to display either the Open or the Save As dialog box.
- 6 Select the file *to which* macros will be copied.
This is usually the USER.LIB file in your new CircuitMaker directory.
- 7 Select a macro to copy from the left hand file list. If a macro already exists with the same name, CircuitMaker will delete the existing macro.
- 8 Click the >>>**Copy**>>> button.
CircuitMaker might prompt you for information regarding the simulation mode for which the device is intended. If the device can be used in digital simulations, check the **Digital** box; if it can be used in analog simulations, check the **Analog** box. If it can be used in either simulation mode, check both boxes.

Save ASCII Library

Use **Save ASCII Library** to write the currently loaded USER.LIB file to an ASCII file. CircuitMaker displays a file selector dialog box asking for the name of the ASCII file. In this format, user defined symbols which have been saved in Windows metafile or bitmap format will be lost and replaced by a simple rectangle. The pins, however, remain intact. The ASCII format is used for conversion between 16- and 32-bit systems. This library may be converted back to binary format by choosing **Macros > Convert ASCII Library**.

Convert ASCII Library

Use **Convert ASCII Library** to convert an ASCII user library file (created with the **Save ASCII Library** option) to binary format. CircuitMaker displays a file selector dialog box asking for the name of the ASCII user library file to be converted. Then a second file selector dialog appears,

asking for the name of the new binary file. This option is provided for compatibility between 16- and 32-bit systems.

Update Search List

Use this feature to “refresh” the SEARCHDB.DAT file. Normally, the SEARCHDB.DAT file is updated automatically when necessary. If for any reason the Device Search list seems incorrect or out of date, you can create a new search list file by choosing **Macros > Update Search List**.

CHAPTER 12

Options Menu

The Options menu contains commands which enable you to control various display, editing and simulation options.

Auto Repeat

This option lets you control how devices are selected from the library. If **Auto Repeat** is checked, as soon as a device is selected from the library and placed, another identical device is automatically selected and made ready for placement. This repeat placement process continues until you cancel it by pressing any key on the keyboard or by double-clicking the mouse. If **Auto Repeat** is not checked, you must select and place each device separately.

Auto Refresh

This option lets you control the refresh mode. When Auto Refresh is on, the screen refreshes automatically as the circuit is edited. When it is disabled, the screen must be refreshed manually while editing (see the Refresh Screen option in the Edit menu). Disabling this option lets you work more quickly on a slower computer system.

Quick Connect

This option allows you to simply place a device pin on a wire or other device pin, and CircuitMaker will automatically wire the parts together for you. By default, Quick Connect is enabled when you start CircuitMaker. See *Wiring in Chapter 4: Drawing and Editing Schematics* for more details.

Device Designations

CircuitMaker automatically assigns a designation to each device when it is placed. Use the Device Designations dialog box (pictured in Figure 12.1) to specify certain designation options.



Figure 12.1. Use this dialog box to specify designation options for new devices you place in the schematic.

Compare the Device Designations feature with the Set Designations feature, which rennumbers the designations of *already* placed devices.

To change device designation options,

- 1 Choose **Options > Device Designations**.
- 2 Select **Show Designation For New Devices** to show the designation for all new devices that you place.
- 3 Type a number in the **Starting Designation Number** text box.

The devices that you place hereafter use the number you specified as the starting number, or the next available number after the specified starting number. For example, if the starting number is 10, and the schematic contains resistors R10, R11, and R12, then the next resistor placed would be assigned the designation R13.

Arrow/Wire

This option, when checked, allows you to initiate a wire by clicking once on a device pin with the Arrow Tool. You can only use the Arrow Tool to initiate a wire on a device pin or to extend an existing wire. You cannot initiate a wire from the middle of another wire using the Arrow Tool as you can with the Wire Tool. This option can be used for both auto and manual routing.

Cursor Tools

This submenu provides an alternate method of selecting the Arrow, Wire, Text, Delete, Zoom, Probe and Help Tools.

Show Pin Dots

This option allows you to control how connections between wires and devices are drawn. If **Show Pin Dots** is checked, connections between wires and devices will be shown by a small dot where the connection occurs. If **Show Pin Dots** is not checked, the connecting dots will not be drawn. Dots showing where wires connect to other wires are always displayed.

Show Bus Labels

This option displays bus labels (numbers) by putting a small, numbered box at the end of each bus wire, and also shows the number of each bus connection wire next to the corresponding bus connection.

Show Page Breaks

This option displays the page divisions of a multi-page circuit when it is sent to the printer. The Show Page Breaks option is also useful when positioning a circuit on a single page. The page breaks you see on your screen are based on the printer selection, paper size and scaling factor.

Moveable Page Breaks

Click and drag a page break to move it. When the cursor is over a page break, it will change to a double-ended arrow, indicating which direction you can move the page break (see Figure 12.5 for an example of the double-ended arrow page break cursor). Move a horizontal page break up and down. Move a vertical page break left and right. Moving any page break changes the print scale, both horizontally and vertically. When moving a page break, the print scale is displayed where the schematic window's title usually appears.

Show Node Numbers

This option displays the node number for each node in your circuit. The number is shown at the center of the longest wire segment of each node. The node numbers, which are determined by CircuitMaker, are used for simulation purposes. They correspond to the variable names used in the analog analysis windows, and can be used as a reference when viewing waveforms.

Show Prop Delays

Use **Show Prop Delays** to display the propagation delay of all devices in the circuit. If **Show Prop Delays** is checked, the delay values for each device will be shown within a rounded rectangle located at the center of each device. Some devices (pulsers, LED's, macro devices, etc.) do not have a delay, so no value will be shown on them. In the case of macro devices, the delay is determined by the individual delay setting of each device contained within the macro.

If **Show Prop Delays** is not checked all devices will be drawn in normal form without the delay value being visible. To change the propagation delay of one or more devices select **Edit > Set Prop Delays**.

Device Display Data

This feature (pictured in Figure 12.2) allows you to quickly change the display settings of all selected devices. If the display item is currently visible on some of the selected devices, but not on others, the check box will be gray. Refer to *Editing Devices* in *Chapter 4: Drawing and Editing Schematics* for more information.



Figure 12.2. Use the Device Display Data dialog box to quickly change the display settings of all selected devices.

Circuit Display Data

This feature (as seen in Figure 12.3) allows you to temporarily override the display settings of every device in the entire circuit. The buttons at the top of each column will quickly change the settings for the entire column, or you can change individual items by clicking on the radio buttons. The Default setting tells CircuitMaker to use the Visible settings of each individual device. Refer to *Editing Devices* in *Chapter 4: Drawing and Editing Schematics*.



Figure 12.3. Use the Circuit Display Data dialog box to temporarily override the display settings of every device in the circuit.

Grid

Use the Grid option to turn the alignment grid of the circuit window on or off (see Figures 12.4 and 12.5). The grid is useful as an aid in precisely aligning objects. Use Snap To Grid to place new devices (devices not already in a circuit) according to the specified grid. It also lets you move old devices (devices already in the circuit) according to the selected grid, relative to their original position.

Note: When you place a device exactly on the grid, it always remains on the grid regardless of scroll position. However, Snap To Grid does not guarantee alignment of component pins.

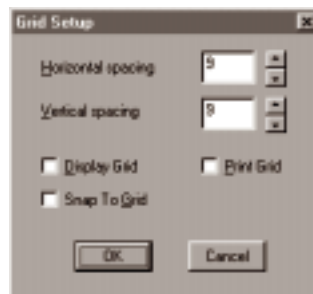
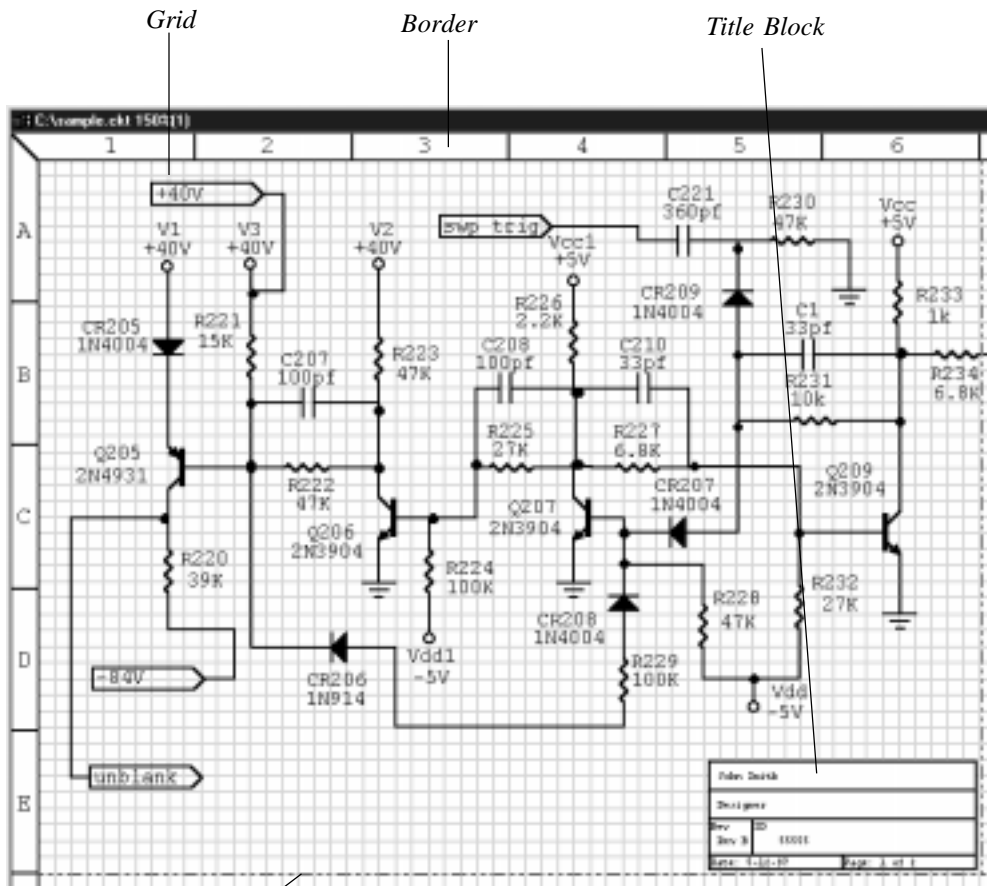


Figure 12.4. Use the Grid Setup dialog box to turn the alignment grid on or off.



Moveable Page Breaks

Figure 12.5. Use the Border, Grid, Title Block options to enhance the appearance of your schematic.

Title Block

Use the Title Block option (see Figure 12.5 for an example) to add a title box to the lower right corner of the page. The title block contains the following fields: Name, Title, Revision, ID, Date, and Page. The Name and Title fields expand in height to handle multiple rows of text. If you leave the Name or Title fields blank, CircuitMaker excludes them from the title block. The title block also expands in width according to the amount of text that you enter. You can print the title block on the first page, on the last page, or on all pages.

Additionally, you can print the full title block on the first page and a reduced title block (that is, one that does not include the Name and Title fields) on subsequent pages.

Border

Use this option to quickly locate devices by displaying a coordinate grid system around your schematic (see Figure 12.5 for an example). For example, suppose you want to find a device that you know is located in the B-5 grid square. By drawing an imaginary line from the letter B and the number 5 on the margins of the schematic; the intersection of these lines locates the grid square containing the device.

To add a border to your schematic drawing,

- 1 Choose **Options > Border** to display the dialog box pictured in Figure 12.6.
- 2 Select **Display Border On Screen** to display a border that outlines the total allowed schematic area.
- 3 Select **Do Not Print** if you don't want to print the border.

OR

Select **Print Around Entire Schematic** to print the border so that it is only on the outside edges of the outside pages, making a border around the entire schematic when the pages are arranged together.

OR

Select **Print Around Each Page** to print the complete border on each page of your schematic.



Figure 12.6. Use the Border feature to add a coordinate system border around your schematic for easily locating devices.

CHAPTER 13

View & Window Menus

The View and Window menus contain features that give you control of various display options and windows. If a check mark is shown beside an item, then the item is currently enabled; if a check mark is not shown beside an item, it is not currently enabled.

The View Menu

Toolbar

Use the Toolbar option to display or hide the Toolbar. For an overview of all Toolbar options, see *Chapter 2: Getting Started* and *Chapter 4: Drawing and Editing Schematics*.

Colors

The Colors feature (Figure 13.1) lets you select the color associated with several functions (low level and high level) and items (Logic Display color, Hex, and ASCII Key Cap color). For example, to change the color of individual LEDs, follow these steps:

- 1 Select one or more LEDs.
- 2 Choose **View > Colors** (or double-click the LED).
- 3 Change color for the Sel-LEDs item.



Figure 13.1. Use the Select Colors dialog box to change the color of different types of items.

The color you select (in this example) becomes the default LED color for all new LEDs. You can change Logic Display colors by double-clicking them. You can also individually select the color of 7-segment displays, analog waveforms, etc.

- 4 Choose **All Items** in the Select Colors dialog box list to set everything (except the background) to the same color.
- 5 Click **Defaults** to restore everything to its original color.
- 6 Click **Save Selections** to save the selected colors even after quitting CircuitMaker.

Display Scale

This feature lets you select the scale at which a circuit is displayed. It also lets you select the Scale Step of the Zoom Tool. See Figure 13.2.



Figure 13.2. This dialog box controls the scale of the displayed circuit and the scale step of the Zoom Tool.

Normal Size/Position

This feature changes the circuit display scale to 100% and moves the horizontal and vertical scroll bars to their home positions.

Fit Circuit to Window

This feature will reduce or enlarge the circuit (by changing the Display Scale and scroll bar positions) so that the entire circuit can be displayed within the circuit window.

Refresh Screen

Choose **Refresh Screen** to redraw the entire circuit. Redrawing may be desirable following a command or operation which causes parts of the screen to become “messy.” Also see *Auto Refresh* in *Chapter 12: Options Menu*.

The Window Menu

Cascade Windows

This command will arrange all open windows in a cascaded (stacked) order.

Tile Windows

This command will arrange all open windows in a tiled (adjacent) order.

Window

Each window that is open (or can be opened with the available simulation data) is listed in this menu. Selecting a window from this menu will open it and bring it to the front.

CHAPTER 14

Simulation Menu

The Simulation menu contains options that let you choose a simulation type and different kinds of analyses.

Digital/Analog Mode

This works just like the **Digital/Analog** button on the Toolbar, which is described in the simulation chapters 5 & 6. The name that is displayed in the menu is the simulation mode that is currently selected.

Analyses Setup

Use the Analyses Setup dialog box to setup the SPICE analyses you want to perform, as well as simulation options such as temperature, tolerances, etc. For more information see *Analyses Setup* and *Analog Options* in *Chapter 6: Analog/Mixed-Signal Simulation*.

Digital Options

Use this dialog box to control the size of a step when running the simulation in single step mode, to set the conditions for break points and to set the simulation speed. Refer to the section *Digital Options* in *Chapter 5: Digital Logic Simulation*.

Check Pin Connections

Use Check Pin Connections to check the entire schematic and be informed of any devices that have unconnected pins.

Reset

This works just like the **Reset** button in the Toolbar, which is described in *Chapter 5: Digital Logic Simulation* and *Chapter 6: Analog/Mixed-Signal Simulation*.

Step

This works just like the **Step** button in the Toolbar, which is described in *Chapter 5: Digital Logic Simulation*.

Run

This works just like the **Run** button in the Toolbar, which is described in *Chapter 5: Digital Logic Simulation* and *Chapter 6: Analog/Mixed-Signal Simulation*.

Trace

This works just like the **Trace** button in the Toolbar, which is described in *Chapter 5: Digital Logic Simulation*.

Display Waveforms

This works just like the Waveforms button in the Toolbar which is described in *Chapter 5: Digital Logic Simulation* and *Chapter 6: Analog/Mixed-Signal Simulation*.

Scope Probe

This option, when checked, causes the logic levels detected by the **Probe** Tool to be displayed in the digital Waveforms window while running digital simulation.

Display Variable Names

The **Display Variable Names** option replaces the A, B, C labels used on the analog analysis graphs with the variable names such as V(8), etc. This allows you to identify the various points in the circuit more consistently with those being graphed in analysis windows.

CHAPTER 15

SPICE: Beyond the Basics

This chapter discusses strategies for troubleshooting SPICE convergence, SPICE option variables, and SPICE's elementary devices. Use this information as a companion and reference as you complete the tasks in *Chapter 6: Analog/Mixed-Signal Simulation*.

Troubleshooting SPICE Convergence

Berkeley SPICE3 uses simultaneous linear equations, expressed in matrix form, to determine the operating point (DC voltages and currents) of a circuit at each step of the simulation. The circuit is reduced to an array of conductances which are placed in the matrix to form the equations ($G * V = I$). When a circuit includes nonlinear elements, SPICE uses multiple iterations of the linear equations to account for the nonlinearities. SPICE makes an initial guess at the node voltages then calculates the branch currents based on the conductances in the circuit. SPICE then uses the branch currents to recalculate the node voltages and the cycle is repeated. This cycle continues until all of the node voltages and branch currents fall within specified tolerances (converge).

However, if the voltages or currents do not converge within a specified number of iterations, SPICE produces error messages (such as “singular matrix”, “Gmin stepping failed”, “source stepping failed” or “iteration limit reached”) and aborts the simulation. SPICE uses the results of each simulation step as the initial guesses for the next step. If you are performing a Transient Analysis (that is, time is being stepped) and SPICE cannot converge on a solution using the specified timestep, the timestep is automatically reduced, and the cycle is repeated. If the timestep is reduced too far, SPICE displays a “Timestep too small” message and aborts the simulation. Use the Analog Options dialog box to specify the tolerances and iteration limits for the various analyses.

SPICE:
Simulation
Program with
Integrated
Circuit
Emphasis

The Operating Point may fail to converge for various reasons. For example, the initial guesses for the node voltages may be too far off, the circuit may be unstable or bistable (there may be more than one solution to the equations), there may be discontinuities in the models, or the circuit may contain unrealistic impedances.

Use the following techniques to solve most convergence problems. When you have a convergence problem, first identify which analysis is causing the problem. Keep in mind that the Operating Point analysis is generally performed automatically before each of the other analyses, even if you have disabled Operating Point Analysis in the Analyses Setup dialog box. Begin with step 1, then consider the recommendations, as needed, to solve the error.

Solving Operating Point Analysis Failures

- 1 Check the circuit topology and connectivity; specifically,
 - Make sure the circuit is correctly wired. Dangling nodes and stray parts are not allowed. The RSHUNT option can be used to overcome these problems.
 - Don't confuse zeros with the letter O.
 - Use proper SPICE multipliers (MEG instead of M for $1\text{E}+6$).
 - Don't put a space between values and multipliers (1.0uF, not 1.0 uF).
 - Every circuit must have a ground node and every node in the circuit must have a DC path to ground. Make sure no sections of your circuit are isolated from ground by transformers, capacitors, etc.
 - Do not use series capacitors or current sources.
 - Do not use parallel inductors or voltage sources.
 - Make sure all devices and sources are set to their proper values.
 - Make sure all dependent source gains are correct.
 - Make sure your models/subcircuits have been correctly entered.

- 2 Increase ITL1 to 300 in the Analog Options dialog box. This will allow the OP Analysis to go through more iterations before giving up.
- 3 Add .NODESET devices. If the initial guess of a node voltage is way off, the .NODESET device can be used to set it to a more realistic value (see *.NODESET* later in this chapter).
- 4 Add resistors and use the OFF keyword. Specify the series resistance parameters of your models and increase the GMIN option by a factor of 10. Specify the initial condition of semiconductor devices, especially diodes, as OFF.
- 5 Use initial conditions. Enable the UIC check box for Transient Analysis in the Analyses Setup dialog box. Place .IC devices in your circuit or set the applicable initial conditions to assist in the initial stages of the Transient Analysis.

Solving DC Analysis Failures

- 1 Check the circuit topology and connectivity. See the common mistakes listed under Step 1 of *Solving Operating Point Analysis Failures* earlier in this chapter.
- 2 Increase ITL2 to 200 in the Analog Options dialog box. This will allow the DC Analysis to go through more iterations for each step before giving up.
- 3 Make the steps in the DC sweep larger or smaller. If discontinuities exist in a device model (perhaps between the linear and saturation regions of the model), increasing the step size may allow the simulation to step over the discontinuity. Making the steps smaller will allow the simulation to resolve rapid voltage-transition discontinuities.
- 4 Do not use DC Analysis. Some problems (such as hysteresis) cannot be resolved by DC Analysis. In such cases, it is more effective to use Transient Analysis, by ramping the appropriate power sources.

Solving Transient Analysis Failures

- 1** Check the circuit topology and connectivity. See the common mistakes listed under Step 1 of *Solving Operating Point Analysis Failures* earlier in this chapter.
- 2** Set RELTOL to 0.01 in the Analog Options dialog box. By increasing the tolerance from 0.001 (0.1% accuracy), fewer iterations will be required to converge on a solution and the simulation will complete much more quickly.
- 3** Increase ITL4 to 100 in the Analog Options dialog box. This will allow the Transient Analysis to go through more iterations for each timestep before giving up.
- 4** Reduce the accuracy of ABSTOL/VNTOL if current/voltage levels allow. Your particular circuit may not require resolutions down to 1uV or 1pA. You should allow at least an order of magnitude below the lowest expected voltage or current levels of your circuit.
- 5** Realistically model your circuit. Add realistic parasitics, especially stray/junction capacitance. Use RC snubbers around diodes. Replace device models with subcircuits, especially for RF and power devices.
- 6** Increase the rise/fall times of the Pulse Generators. Even the best pulse generators cannot switch instantaneously.
- 7** Change the integration method to Gear. Gear integration requires longer simulation time, but is generally more stable than the trapezoidal method. Gear integration may be particularly useful with circuits that oscillate or have feedback paths.

SPICE Option Variables

Use SPICE option variables to control certain aspects of a simulation such as iteration limits, temperature, etc.

To change the value of a SPICE option variable,

- 1 Choose **Simulation > Analyses Setup > Analog Options** to display the Analog Options - Spice Variables dialog box pictured in Figure 15.1.
- 2 Select a variable and type the new value into the Option Value edit field.
- 3 If you want to set a specific option to its default value, type an asterisk in the Value edit field.

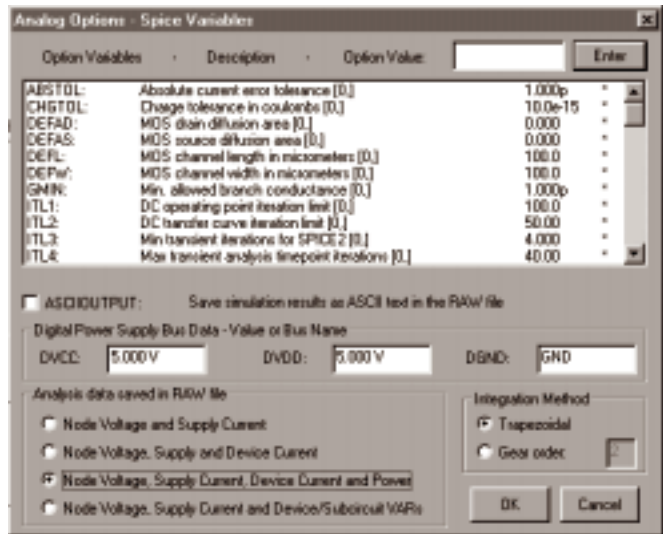


Figure 15.1. This dialog box lists the SPICE option variables, which you can change. An asterisk (*) in the dialog box denotes default values for each option.

Following is a list of the options and their effect on the simulation. See *Setting Up Analog/SPICE Variables* in *Chapter 6: Analog/Mixed-Signal Simulation* for information about the other option in the Analog Options - Spice Variables dialog box.

Option	What it Does
ABSTOL	Sets the absolute current error tolerance of the program. Set $ABSTOL=RELTOL*$ (lowest current magnitude in the circuit). Default=1 picoamp.
CHGTOL	Provides a lower limit on capacitor charge or inductor flux; used in the LTE timestep control algorithm. Default=1.0e-14 coulombs.
DEFAD	Sets the MOS drain diffusion area. Default=0.0 meters ² .
DEFAS	Sets the MOS source diffusion area. Default=0.0 meters ² .
DEFL	Sets the MOS channel length. Default=100.0 micrometer.
DEFW	Sets the MOS channel width. Default=100.0 micrometer.
GMIN	Sets the minimum conductance (maximum resistance) of any device in the circuit. It also sets the value of the conductance that is placed in parallel with each pn junction in the circuit. Default=1.0e-12 mhos. Note: Raising this value may help with simulation convergence in many circuits, but might decrease accuracy.
ITL1	Sets the Operating Point Analysis iteration limit. Default=100 iterations. Note: This may need to be raised as high as 500 for many circuits.
ITL2	Sets the DC Analysis iteration limit. Default=50 iterations. Note: This may need to be raised as high as 200 for some circuits.
ITL3	Sets the lower Transient Analysis iteration limit. Default=4 iterations. Note: This is not implemented in

	SPICE3. It is provided in CircuitMaker for compatibility in creating SPICE2 netlists.
ITL4	Sets the Transient Analysis timepoint iteration limit. Default=10 iterations. Note: Raising this value to 100 or more may help to eliminate “timestep too small” errors improving both convergence and simulation speed.
ITL5	Sets the Transient Analysis total iteration limit. Default=5000 iterations. Note: This is not implemented in SPICE3. It is provided in CircuitMaker for compatibility in creating SPICE2 netlists.
PIVREL	Sets the relative ratio between the largest column entry in the matrix and an acceptable pivot value. The value must be between 0 and 1. Default=1.0e-3. In the numerical pivoting algorithm the allowed minimum pivot is determined by $EPSREL = A_{MAX1}(PIVREL * MAXVAL, PIVTOL)$ where MAXVAL is the maximum element in the column where a pivot is sought (partial pivoting).
PIVTOL	Sets the absolute minimum value for a matrix entry to be accepted as a pivot. Default=1.0e-13.
RELTOL	Sets the relative error tolerance of the program. The value must be between 0 and 1. Default is 0.001 (0.1%). <i>Larger values mean faster simulation time, but less accuracy.</i>
TEMP	Sets the actual operating temperature of the circuit. Any deviation from TNOM will produce a change in the simulation results. Default=27°C. Note: TEMP can be overridden by a temperature specification on any temperature dependent instance.

TNOM	Sets the nominal temperature for which device models are created. Default=27°C. Note: TNOM can be overridden by a specification on any temperature dependent device model.
TRTOL	Used in the LTE timestep control algorithm. This is an estimate of the factor by which SPICE overestimates the actual truncation error. Default=7.0.
VNTOL	Sets the absolute voltage tolerance of the program. Set VNTOL= RELTOL* (lowest voltage magnitude in the circuit). Default=1 microvolt.
BOOLL	Sets the low output level of a boolean expression. Default=0.0V.
BOOLH	Sets the high output level of a boolean expression. Default=4.5V.
BOOLT	Sets the input threshold level of a boolean expression. Default=1.5V.
BADMOS3	Uses the older version of the MOS3 model with the “kappa” discontinuity. Default=NO (don’t use the older version).
KEEPOPINFO	Retains the operating point information when an AC Analysis is run. Note: This is particularly useful if the circuit is large and you do not want to run a redundant Operating Point Analysis. Default=NO (run OP each time).
TRYTOCOMPACT	Applicable to the LTRA model. When specified, the simulator tries to condense LTRA transmission line’s past history of input voltages and currents. Default=NO (don’t compact).
NOOPITER	Skip directly to GMIN stepping algorithm. Default=NO (don’t skip).

GMINSTEP	Sets the number of steps in the GMIN stepping algorithm. When set to 0, GMIN stepping is disabled, making source stepping the simulator's default DC (operating point) convergence algorithm. Default=10 steps.
SRCSTEP	Sets the number of steps in the source stepping algorithm for DC (operating point) convergence. Default=10 steps.
ACCT	Causes accounting and run-time statistics to be displayed. Default=NO (no display).
LIST	Displays a comprehensive list of all elements in the circuit with connectivity and values. Default=NO (no list).
OPTS	Displays a list of all standard SPICE3 Option parameter settings. Default=NO (no list).
BYPASS	Enables the device bypass scheme for nonlinear model evaluation. Default=1 (on).
MINBREAK	Sets the minimum time between breakpoints. Default=0 seconds (sets the time automatically).
MAXOPALTER	Sets the maximum number of analog/event alternations for DC (operating point) convergence. Default=0.
MAXEVTITER	Sets the maximum number of event iterations for DC (operating point) convergence. Default=0.
NOOPALTER	Enables DC (operating point) alternations. Default=NO.
RAMPTIME	Controls turn-on time of independent sources and capacitor and inductor initial conditions from zero to their final value during the time period specified. Default=0.0 seconds.

CONVLIMIT	Disables convergence algorithm used in some built-in component models. Default=NO.
CONVSTEP	Sets the limit of the relative step size in solving for the DC operating point convergence for code model inputs. Default=0.25.
CONVABSSTEP	Sets the limit of the absolute step size in solving for the DC operating point convergence for code model inputs. Default=0.1.
AUTOPARTIAL	Enables the automatic computation of partial derivatives for XSpice code modules. Default=NO.
PROPMNS	Sets scale factor used to determine minimum propagation delay when actual value is not specified in SimCode model. Default=0.5 (50% of typical propagation delay).
PROPMXS	Sets scale factor used to determine maximum propagation delay when actual value is not specified in SimCode model. Default=1.5 (150% of typical propagation delay).
TRANMNS	Sets scale factor used to determine minimum transition time when actual value is not specified in SimCode model. Default=0.5 (50% of typical transition time).
TRANMXS	Sets scale factor used to determine maximum transition time when actual value is not specified in SimCode model. Default=1.5 (150% of typical transition time).
LOADMNS	Sets scale factor used to determine minimum input loading (maximum input resistance) when actual value is not specified in SimCode model.

	Default=1.5 (150% of typical input resistance).
LOADMXS	Sets scale factor used to determine maximum input loading (minimum input resistance) when actual value is not specified in SimCode model. Default=0.5 (50% of typical input resistance).
DRIVEMNS	Sets scale factor used to determine minimum output drive capacity (maximum output resistance) when actual value is not specified in SimCode model. Default=1.5 (150% of typical output resistance).
DRIVEMXS	Sets scale factor used to determine maximum output drive capacity (minimum output resistance) when actual value is not specified in SimCode model. Default=0.5 (50% of typical output resistance).
CURRENTMNS	Sets scale factor used to determine minimum supply current (maximum internal resistance) when actual value is not specified in SimCode model. Default=1.5 (150% of typical internal resistance).
CURRENTMXS	Scale factor used to determine maximum supply current (minimum internal resistance) when actual value is not specified in SimCode model. Default=0.5 (50% of typical internal resistance).
TPMNTYMX	Temporary global override for propagation delay index on SimCode devices (0=default, 1=min, 2=typ, 3=max). Default=0.
TTMNTYMX	Temporary global override for transition time index on SimCode devices (0=default, 1=min, 2=typ, 3=max). Default=0.

LDMNTYMX	Temporary global override for input loading index on SimCode devices (0=default, 1=min, 2=typ, 3=max). Default=0.
DRVMNTYMX	Temporary global override for output drive capacity index on SimCode devices (0=default, 1=min, 2=typ, 3=max). Default=0.
IMNTYMX	Temporary global override for supply current index on SimCode devices (0=default, 1=min, 2=typ, 3=max). Default=0.
SIMWARN	A nonzero value indicates that SimCode warning messages can be displayed during run time. SimCode warnings may include information concerning timing violations (tsetup, thold, trec, tw, etc.) or indicate supply voltage dropping below device specifications. Default=0.
RSHUNT	Value in ohms of resistors added between each circuit node and ground, helping to eliminate problems such as “singular matrix” errors. In general, the value of RSHUNT should be set to a very high resistance (1e+12). Default=0 (no shunt resistors).
ADCSTEP	The minimum step size required to register an event on the input of the internal A/D converters. Default=0.01 volts.

SPICE's Elementary Devices

Each device used in a circuit requires certain information for the SPICE simulation to run. This section describes each type of device and information that each requires. CircuitMaker provides this information to the SPICE netlist provided you properly draw and label the circuit. See *Editing Devices* in *Chapter 4: Drawing and Editing Schematics* for more information.

The information provided here will help you better understand how each of the components affects the simulation of the circuit. Parameters that are enclosed in “<>” symbols are optional. Refer to *Chapter 16: Creating New Devices* for more information about the models mentioned here.

Resistors

General Form

```
RXXXXXXXX N1 N2 VALUE
```

Netlist Example

```
R1 1 2 10K
```

Spice Data Example

```
%D %1 %2 %V
```

N1 and N2 are the two element nodes. Value is the resistance (in ohms) and may be positive or negative, but not zero. If N1 is at a higher voltage than N2, the current flow through the resistor is positive. If N2 is at a higher voltage than N1, the current flow is negative.

See Also

Resistor, Var Resistor (example circuit: ANALOG.CKT)

Semiconductor Resistors

General Form

```
RXXXXXXXX N1 N2 <VALUE> <MNAME> <L=LENGTH> <W=WIDTH> <TEMP=T>
```

Netlist Examples

```
R1 1 2 10K
```

```
R3 5 6 RMODEL L=12u W=1u
```

Spice Data Example

```
%D %1 %2 %M TEMP=100
```

This is the more general form of the resistor. It allows modeling of temperature effects, and calculation of the actual resistance value from strictly geometric information and the specifications of the process. If VALUE is specified, it overrides the geometric information and defines the resistance. If MNAME is specified, then the resistance may be calculated from the process information in the model MNAME and the given LENGTH and WIDTH. If VALUE is not specified, then MNAME and LENGTH must be specified. If WIDTH is not specified, then it is taken from the default width given in the model. The (optional) TEMP value is the temperature at which this device is to operate, and overrides the temperature specification in the Analog Options dialog box.

Capacitors

General Form

```
CXXXXXXXX N+ N- VALUE <IC=INCOND>
```

Netlist Example

```
C2 13 0 0.1UF
```

```
C5 7 0 10UF IC=3V
```

Spice Data Example

```
%D %1 %2 %V IC=12V
```

N+ is the positive node and N- is the negative node. VALUE is the capacitance in Farads. The initial condition is the initial (time-zero) value of the capacitor voltage. Initial conditions only apply if the UIC option is enabled for the Transient Analysis. If N+ is at a higher voltage than N-, the current flow through the capacitor is positive. If N- is at a higher voltage than N+, the current flow is negative.

SPICE uses perfect capacitors, that is, capacitors with no DC leakage. Since all nodes in a circuit must have a DC path to ground, you cannot simulate a circuit with capacitors in series as this would completely isolate the nodes that are between the capacitors. One solution to this problem is to connect a large-value resistor (such as 1-gigaohm) in parallel with each capacitor to account for the leakage resistance of that capacitor.

See Also

Capacitor, Polar Cap, Var Capacitor (example circuit: 555.CKT)

Semiconductor Capacitors

General Form

```
CXXXXXXX N+ N- <VALUE> <MNAME> <L=LENGTH> <W=WIDTH> <IC=INCOND>
```

Netlist Example

```
C2 13 0 0.1UF
```

```
C5 7 0 10UF CMODEL L=12u W=1u
```

Spice Data Example

```
%D %1 %2 %M L=10U
```

This is the general form of the Capacitor and allows calculation of the capacitance value from strictly geometric information and the specifications of the process. If VALUE is specified, it defines the capacitance. If MNAME is specified, then the capacitance is calculated from the process information in the model MNAME and the given LENGTH and WIDTH. If VALUE is not specified, then MNAME and LENGTH must be specified. If WIDTH is not specified, then it is taken from the default width given in the model. Specify VALUE or MNAME, LENGTH, and WIDTH (not both).

Inductors

General Form

```
LYYYYYYY N+ N- VALUE <IC=INCOND>
```

Netlist Example

```
L3 12 9 1UH
```

```
L4 5 0 100UH IC=12.3MA
```

Spice Data Example

```
%D %1 %2 %V IC=5MA
```

N+ is the positive node and N- is the negative node. VALUE is the inductance in Henries. Initial condition (which applies only if UIC is enabled for Transient Analysis) is the initial (time-zero) value of the inductor current. If N+ is at a higher voltage than N-, the current flow through the inductor is positive. If N- is at a higher voltage than N+, the current flow is negative.

Inductors induce voltage across their coils based on the amount of magnetic flux; consider them as voltage sources (and therefore inductors) in SPICE. Don't connect them directly in parallel. Solution: connect a small-value resistor, (such as 0.001 ohms) in series with each inductor to account for the winding resistance of that inductor.

See Also

Inductor, Var Inductor, Coil 3T, Coil 5T (see RESONANT.CKT)

Coupled (Mutual) Inductors

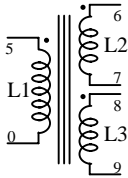
General Form

```
KXXXXXXX LYYYYYYY LZZZZZZZ VALUE
```

Netlist Examples

```
K12 L4 L3 0.999
```

```
KXFRMR L1 L2 0.87
```



Note: A transformer that is simulated in this manner will not reflect the impedance of the secondary winding back into the primary.

Spice Data Example (center-tap inductor)

```
%DA %1 %2 50UH (inductor A)
```

```
%DB %2 %3 50UH (inductor B)
```

```
K%D %DA %DB .85 (inductive coupling)
```

LYYYYYYY and LZZZZZZZ are the names of two coupled inductors, and VALUE is the coefficient of coupling (K), which must be greater than 0 and less than or equal to 1. Using the "dot" convention, place a "dot" on the first node of each inductor, indicating that the voltages at these node are in phase (the voltages go up and down together).

If more than two inductors are being coupled, SPICE data must be provided for each coupling. For example, a transformer with one primary coil (L1) and two secondary coils (L2 and L3) might be expressed as follows:

```
L1 5 0 10MH
L2 6 7 1MH
L3 8 9 1MH
K12 L1 L2 0.93
K13 L1 L3 0.93
K23 L2 L3 0.97
```

The turns ratio for a given pair of windings can be determined by the following formula where LP and LS are the

inductance of the primary and secondary windings, respectively:

Turns Ratio = $\text{sqrt}(LS/LP)$

See Also

Transformers (example circuit: VTPWRAMP.CKT)

Voltage/Current Controlled Switches

General Form

SXXXXXXXX N+ N- NC+ NC- MODEL <ON><OFF>

WXXXXXXXX N+ N- VNAME MODEL <ON><OFF>

Netlist Examples

S1 1 2 3 4 SVS1 (V->Switch)

S2 5 6 3 0 SVS2 ON (V->Switch)

W1 1 2 VS1 WIS1 (I->Switch)

Spice Data Example

%D %1 %2 %3 %4 %M ON

Nodes 1 and 2 are the nodes between which the switch terminals are connected. ON/OFF indicates the initial condition of the switch. For the voltage-controlled switch nodes, 3 and 4 are the positive and negative controlling nodes, respectively. For the current-controlled switch, the controlling current is that through the specified voltage source. The direction of positive controlling current flow is from the positive node, through the source, to the negative node.

See Also

I->Switch, V->Switch (example circuit: SWITCHES.CKT)

Independent Sources

General Form

VXXXXXXXX N+ N- <<DC>> VALUE> <AC> <MAG> <PHASE>>>

IYYYYYYY N+ N- <<DC>> VALUE> <AC> <MAG> <PHASE>>>

Netlist Examples

VCC 10 0 DC 6 (V Source)

ISRC 1 2 AC .3 45 SIN(0 1 1MEG) (Signal Gen)

VMEAS 12 9 (Ammeter)

Spice Data Example

%D %1 %2 DC 0 SIN(0 1 1k 0 0) AC 1 0 (Signal Gen)

N+ is the positive node and N- is the negative node. Voltage sources need not be grounded. Positive current is assumed to flow into the positive node, through the source, and out of the negative node. A current source of positive value forces current to flow into the N+ node, through the source, and out of the N- node. Voltage sources, in addition to being used for circuit excitation, are the ‘ammeters’ for SPICE; that is, zero valued voltage sources may be inserted into the circuit for the purpose of measuring current. They, of course, have no effect on circuit operation since they represent short-circuits.

VALUE is the DC (operating point) value or offset of the source. If the source value is zero it may be omitted. If the source is time-invariant (e.g., a power supply), then the value can be preceded by the letters DC.

The letters AC indicate a small-signal AC source. MAG (AC magnitude) and PHASE (AC phase) are used for AC analysis only. If MAG is omitted following the keyword AC, a value of 1 is assumed. If PHASE is omitted, a value of 0 is assumed.

Any independent source can be assigned a time-dependent value for Transient Analysis. If a source is assigned a time-dependent value, the time-zero value is used for DC (operating point) analysis. There are five independent source functions: pulse, exponential, sinusoidal, piece-wise linear, and single-frequency FM. These are discussed in the *Multifunction Signal Generator* section of this chapter.

Note: For SPICE simulation, voltage sources cannot be placed directly in parallel, and current sources cannot be placed directly in series.

See Also

+V, V Source, I Source, Battery, Signal Gen (example circuit: CEAMP.CKT)

Linear Voltage-Controlled Current Sources

General Form

GXXXXXXX N+ N- NC+ NC- VALUE

Netlist Example

G1 2 0 5 0 0.1MMHO

Spice Data Example

%D %1 %2 %3 %4 %V

N+ is the positive node and N- is the negative node. Current flow is from the positive node, through the source, to the negative node. NC+ is the positive controlling node and NC- is the negative controlling node. VALUE is the transconductance (in mhos).

Note: For SPICE simulation, current sources cannot be placed directly in series.

See Also

V->I Source (example circuit: 741.CKT)

Linear Voltage-Controlled Voltage Sources

General Form

EXXXXXXX N+ N- NC+ NC- VALUE

Netlist Example

E1 2 3 14 1 2.0

Spice Data Example

%D %1 %2 %3 %4 %V

N+ is the positive node and N- is the negative node. Current flow is from the positive node, through the source, to the negative node. VALUE is the voltage gain.

Note: For SPICE simulation, voltage sources cannot be placed directly in parallel.

See Also

V->V Source

Linear Current-Controlled Current Sources

General Form

FXXXXXXXX N+ N- VNAM VALUE

Netlist Example

```
F1 5 17 VS2 0.5K
```

Spice Data Example

```
V%D %3 %4 DC 0V (measures controlling current)
```

```
%D %1 %2 V%D %V (current source)
```

N+ and N- are the positive and negative nodes, respectively. Current flow is from the positive node, through the source, to the negative node. VNAM is the name of a voltage source through which the controlling current flows. The direction of positive controlling current flow is from the positive node, through the source, to the negative node of VNAM. VALUE is the current gain. **Note:** You cannot place current sources directly in series for SPICE simulation.

See Also

I->I Source

Linear Current-Controlled Voltage Sources

General Form

HXXXXXXXX N+ N- VNAM VALUE

Netlist Example

```
H1 5 17 VS2 0.5K
```

Spice Data Example

```
V%D %3 %4 DC 0V (measures controlling current)
```

```
%D %1 %2 V%D %V (voltage source)
```

N+ and N- are the positive and negative nodes, respectively. VNAM is the name of a voltage source through which the controlling current flows. The direction of positive controlling current flow is from the positive node, through the source, to the negative node of VNAM. VALUE is the transresistance (in ohms). **Note:** You cannot place voltage sources directly in parallel for SPICE simulation.

See Also

I->V Source. Example circuit: 741.CKT.

Nonlinear Dependent Sources

General Form

BXXXXXXX N+ N- <I=EXPR> <V=EXPR>

Netlist Examples

```
BS01 0 1 I=COS(V(1))+SIN(V(2))
```

```
BVS1 0 1 V=LN(COS(LOG(V(1,2)^2))) (3)^4+V(2)^V(1)
```

Spice Data Example

```
%D %1 %2 V=%L
```

N+ is the positive node, N- is the negative node. The values of the V and I parameters determine the voltages and currents across and through the device, respectively. If I is given then the device is a current source. If V is given the device is a voltage source. One and only one of these parameters must be specified for each source.

The expressions given for V and I may be any function of voltages and currents through voltages sources in the system (e.g., V(2) indicates the DC voltage at node 2 referenced to ground, V(3,4) indicates the voltage difference between nodes 3 and 4, and I(VS2) indicates the DC current through the voltage supply (VS2). The following functions of real variables are defined:

abs	acos	acosh	asin	asinh	atan
atanh	cos	cosh	exp	ln	log
sin	sinh	sqrt	tan	u	uramp

“u” is the unit step function, with a value of one for arguments greater than zero and a value of zero for arguments less than zero. “uramp” is the integral of the unit step: for an input x , the value is zero if x is less than zero, or if x is greater than zero the value is x . These two functions are useful in synthesizing piecewise nonlinear functions, though convergence may be adversely affected.

The following standard operators are defined:

+ * / ^ unary -

In addition, the following boolean operators are defined. Input threshold values (BOOLT) and output values (BOOLL and BOOLH) are universally defined in the Analog Options dialog box.

& (AND)

| (OR)

! (XOR)

~ (NOT)

Older versions of SPICE used a POLY function to describe nonlinear sources. For example, the following statements are all equivalent:

```
E1 19 0 POLY(2)7 4 2 0 3 .1 .5 (Spice2)
```

```
E1 19 0 POLY(2)(7,4)(2,0)3.1.5 (Spice2)
```

```
B1 19 0 V = 3 + .1*V(7,4) + .5*V(2,0) (Spice3)
```

```
B1 19 0 V = 3 + .1*V(7,4) + .5*V(2) (Spice3)
```

Each statement indicates that the voltage at node 19 will equal 3 volts plus .1 times the voltage across nodes 7 and 4 plus .5 times the voltage at node 2, using ground (node 0) as a reference. Many existing SPICE subcircuits contain this type of nonlinear source. CircuitMaker automatically converts them to the SPICE3 format each time you run a simulation.

Note: For SPICE simulation, voltage sources cannot be placed directly in parallel and current sources cannot be placed directly in series.

See Also

NLV Source, NLI Source, I-Math, V-Math. Example circuit: 741.CKT

Lossless Transmission Lines

General Form

```
TXXXXXXX N1 N2 N3 N4 Z0=VALUE  
+ <TD=VALUE> <F=FREQ <NL=NRMLN>>  
+ <IC=V1,I1,V2,I2>
```

Netlist Example

```
T1 3 0 2 0 Z0=50 TD=20NS
```

Spice Data Example

```
%D %1 %2 %3 %4 Z0=%V TD=10NS
```

N1 and N2 are the nodes at port1; N3 and N4 are the nodes at port 2. Z0 is the characteristic impedance. The length of the line may be expressed in either of two forms (one form must be specified). The transmission delay (TD) may be specified directly (as TD=10NS, for example). Alternately, a frequency F may be given, together with NL (the normalized electrical length of the transmission line with respect to the wavelength in the line at the frequency F). If a frequency is specified but NL is omitted, 0.25 is assumed (that is, the frequency is assumed to be the quarter-wave frequency).

The initial condition specification consists of the voltage and current at each of the transmission line ports. Initial conditions only apply if the UIC option is enabled for the Transient Analysis.

The lossy transmission line described below with zero loss may be more accurate than the lossless transmission line due to implementation details.

See Also

LossLessLine (example circuit: LLTRAN.CKT)

Lossy Transmission Lines

General Form

```
OXXXXXXXX N1 N2 N3 N4 MNAME
```

Netlist Example

```
O2 3 0 2 0 OXLINE
```

Spice Data Example

```
%D %1 %2 %3 %4 %M
```

This is a two-port convolution model for single-conductor lossy transmission lines. N1 and N2 are the nodes at port1; N3 and N4 are the nodes at port 2. Note that a lossy transmission line with zero loss may be more accurate than the lossless transmission line due to implementation details.

See Also

LossyLine

Uniform Distributed RC Lines (Lossy)

General Form

```
UXXXXXXX N1 N2 N3 MNAME L=LEN <N=LUMPS>
```

Netlist Example

```
U1 1 2 0 UXLINE L=50UM N=6
```

Spice Data Example

```
%D %1 %2 %3 %M L=25u
```

N1 and N2 are the two element nodes the RC line connects, while N3 is the node to which the capacitances are connected. MNAME is the model name, LEN is the length of the RC line in meters. LUMPS, if specified, is the number of lumped segments to use in modeling the RC line (if omitted, a default value based on the model parameters will be used).

See Also

URC-Line

Junction Diodes

General Form

```
DXXXXXXX N+ N- MNAME <AREA> <OFF> <IC=VD> <TEMP=T>
```

Netlist Example

```
D3 2 10 D1N914 OFF
```

```
D5 7 12 D1N4001 3.0 IC=0.2
```

Spice Data Example

```
%D %1 %2 %M OFF IC=.6 TEMP=70
```

N+ is the positive node and N- is the negative node. MNAME is the model name, AREA is the area factor, and OFF indicates an optional starting condition on the device for Operating Point Analysis. The initial condition specification using IC=VD only applies if the UIC option is enabled for the Transient Analysis. The TEMP value is the temperature at which this device is to operate, and overrides the temperature specification in the Analog Options dialog.

See Also

Diode, Zener Diode (example circuit: PS1.CKT)

Bipolar Junction Transistors (BJTs)

General Form

```
QXXXXXXX NC NB NE <NS> MNAME <AREA>  
+ <OFF> <IC=VBE, VCE> <TEMP=T>
```

Netlist Example

```
Q5 11 26 4 Q2N3904 IC=0.6, 5.0  
Q3 5 2 6 9 QNPN .67
```

Spice Data Example

```
%D %1 %2 %3 %M .67 OFF
```

NC, NB and NE are the collector, base and emitter nodes, respectively. NS is the optional substrate node; if unspecified, the ground is used. MNAME is the model name, AREA is the area factor, and OFF indicates an optional starting condition on the device for Operating Point Analysis. The initial condition specification using IC=VBE, VCE only applies if you have enabled UIC for the Transient Analysis. TEMP is the temperature at which this device operates, and overrides the specification in the Analog Options dialog.

See Also

NPN Trans, PNP Trans (example circuit: CEAMP.CKT)

Junction Field-Effect Transistors (JFETs)

General Form

```
JXXXXXXX ND NG NS MNAME <AREA> <OFF> <IC=VDS, VGS> <TEMP=T>
```

Netlist Example

```
J2 6 3 21 J2N3819 OFF
```

Spice Data Example

```
%D %1 %2 %3 %M .67
```

ND, NG and NS are the drain, gate and source nodes, respectively. MNAME is the model name, AREA is the area factor, and OFF indicates an optional initial condition on the device for Operating Point Analysis. The initial condition specification using IC=VDS, VGS only applies if you have enabled UIC for the Transient Analysis. TEMP is the temperature at which this device operates, and overrides the temperature specification in the Analog Options dialog.

See Also

N-JFET, P-JFET. Example circuit: CSJFAMP.CKT

MOSFETs

General Form

```
MXXXXX ND NG NS NB MNAME <L=VAL> <W=VAL> <AD=VAL>  
+ <AS=VAL> <PD=VAL> <PS=VAL> <NRD=VAL> <NRS=VAL> <OFF>  
+ <IC=VDS,VGS,VBS> <TEMP=T>
```

Netlist Example

```
M6 23 16 0 17 MRF150
```

Spice Data Example

```
%D %1 %2 %3 %3 %M TEMP=55
```

ND, NG, NS and NB are the drain, gate, source and bulk (substrate) nodes, respectively. MNAME is the model name. L and W are the channel length and width, in meters. AD and AS are the areas of the drain and source diffusions, in meters². Note that the suffix U specifies microns (1e-6 m) and P sq-microns (1e-12 m²). If any of L, W, AD, or AS are not specified, default values are used. The use of defaults simplifies input file preparation, as well as the editing required if device geometries are to be changed. PD and PS are the perimeters of the drain and source junctions, in meters. NRD and NRS designate the equivalent number of squares of the drain and source diffusions; these values multiply the sheet resistance (RSH) specified in the model for an accurate representation of the parasitic series drain and source resistance of each transistor. PD and PS default to 0.0 while NRD and NRS default to 1.0. OFF indicates an optional starting condition on the device for DC analysis. The initial condition specification (optional) using IC=VDS, VGS, VBS only applies if the UIC option is enabled for the Transient Analysis, when a transient analysis is desired starting from other than the quiescent operating point. See the .IC device for a better and more convenient way to specify transient initial conditions.

The TEMP value (optional) is the temperature at which this device is to operate, and overrides the temperature specification in the Analog Options dialog. The temperature specification is ONLY valid for level 1, 2, 3, and 6 MOSFETs, not for level 4 or 5 (BSIM) devices.

See Also

N-MOSFET 3T, N-MOSFET 4T, P-MOSFET 3T,
P-MOSFET 4T

MESFETs (GaAsFETs)

General Form

```
ZXXXXXXXX ND NG NS MNAME <AREA> <OFF> <IC=VDS, VGS>
```

Netlist Example

```
Z1 3 5 6 ZM2 OFF
```

Spice Data Example

```
%D %1 %2 %3 %M OFF
```

ND, NG and NS are the drain, gate and source nodes, respectively. MNAME is the model name, AREA is the area factor, and OFF indicates an optional starting condition on the device for Operating Point Analysis. The initial condition specification using IC=VDS, VGS only applies if the UIC option is enabled for the Transient Analysis.

See Also

N-MESFET, P-MESFET

Subcircuits

General Form

```
XYYYYYYY N1 <N2 N3 ...> SUBNAM
```

Netlist Example

```
XU1 7 5 6 12 3 XLM741
```

Spice Data Example

```
%D %1 %2 %3 %4 %5 %S
```

Subcircuits are used in SPICE by specifying the device designation beginning with the letter X, followed by the circuit nodes to be used in expanding the subcircuit, followed by the subcircuit name.

See Also

Subcircuits (example circuit: ANALOG.CKT)

SimCode™ Devices

General Form

```
AXXXXXXX [NPI NGI NI1I <NI2I ...>][NPO  
+ NI1O <NI2O ...> NO1O <NO2O ...>] MNAME
```

Netlist Example

```
A2 [6 8 4] [7 9 5] 2404B
```

Spice Data Example

```
%D [%4bi %2bi %1i] [%4bo %1o %2o] %M
```

All nodes listed in a digital SimCode device are the digital nodes of the device. NPI and NGI are the digital input nodes to the power and ground pins. NI1I, NI2I, etc. are the digital input nodes to the device's input pins. NPO is the digital output node from the power pin. NI1O, NI2O, etc. are the digital output nodes from the device's input pins. NO1O, NO2O, etc. are the digital output nodes from the device's output pins. Note the square brackets ([]) surrounding the input nodes and the output nodes. In the Spice Data field, the power and ground buses include the letter "b" to indicate that node numbers for these pins come from the Bus Data field.

See Also

Digital SimCode Devices. Example circuit: Logic Probe.ckt.
See *Chapter 17: Digital SimCode*.

.NODESET Statement

General Form

```
.NODESET V(NODNUM)=VAL V(NODNUM)=VAL . . .
```

Netlist Example

```
.NODESET V(7)=3.33 V(11)=1.5
```

The Nodeset line helps the program find the dc or initial transient solution by making a preliminary pass with the specified nodes held to the given voltages. The restriction is then released and the iteration continues to the true solution. The .NODESET line may be necessary for convergence on bistable or astable circuits. In general, this line should not be necessary.

See Also

```
.NODESET
```


.IC

.IC Statement

General Form

```
.IC V(NODNUM)=VAL V(NODNUM)=VAL . . .
```

Netlist Example

```
.IC V(3)=2.5 V(4)=-1 V(9)=1
```

The IC line is for setting transient initial conditions. It has two different interpretations, depending on whether or not you have enabled the UIC parameter in the Transient Analysis. Also, don't confuse this line with the .NODESET line. The .NODESET line is only to help DC convergence, and does not affect final bias solution (except for multi-stable circuits). The two interpretations of this line are as follows:

- When you have enabled the UIC parameter in the Transient Analysis, the node voltages specified on the .IC control line are used to compute the capacitor, diode, BJT, JFET, and MOSFET initial conditions. This is equivalent to specifying the IC=... parameter on each device line, but is much more convenient. You can still specify the IC=... parameter, which takes precedence over the .IC values. Since no DC bias (initial transient) solution is computed before the Transient Analysis, you should take care to specify all DC source voltages on the .IC control line if you are going to use them to compute device initial conditions.
- If you have *not enabled* the UIC parameter in the Transient Analysis, the DC bias (initial transient) solution is computed before the Transient Analysis. In this case, the node voltages you have specified on the .IC control line are forced to the desired values during the bias solution. The Transient Analysis removes the constraint on these node voltages. This is the preferred method since it allows SPICE to compute a consistent DC solution.

See Also

.IC (example circuit: 555.CKT)

Suggested Reading

Tuinenga, P. W., *SPICE, A guide to Circuit Simulation & Analysis Using PSpice*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1988, ISBN: 0-13-834607-0, Library: TK454.T85 1988, 621.319'2-dc 19

Written as a supplement for electronic circuit design courses, this book focuses on the design and analysis of analog circuits using PSpice (a commercial variation of the industry standard Berkeley SPICE). Through examples, this book demonstrates what a simulator can and cannot do. Although this book is written specifically for PSpice, much of the information it contains can be applied directly to CircuitMaker.

Vladimirescu, A., *The SPICE Book*, John Wiley & Sons, Inc., N.Y., 1994, ISBN: 0-471-60926-9, Library: TK454.V58 1994, 621.319'2028553-dc20

Written as a tutorial and reference for electrical engineering students and professionals just starting to use the SPICE program to analyze and design circuits. This book explains how to use the SPICE program and describes the differences and similarities between the most popular commercial versions of it, including SPICE3, the latest version from Berkeley which is used by CircuitMaker.

Kielkowski, R., *Inside SPICE*, McGraw-Hill, Inc., N.Y., 1994, ISBN: 0-070911525, Library: TK 454.K48 1994, 621.319'2011353-dc20

Written as a tutorial and reference for electrical engineering students and professionals who are familiar with the SPICE program. This book goes beyond the basics and covers the internal operation of the SPICE program to give the reader a solid understanding of how SPICE works. It provides step-by-step coverage of how to overcome nonconvergence, numerical integration instabilities and timestep control errors. It also shows how to make simulations run faster and more efficiently by setting the .OPTION parameters.

CHAPTER 16

Creating New Devices

The devices you can create in CircuitMaker fall into two major categories: 1) nonfunctional device symbols that you simply want to represent schematically or export to a PCB netlist and 2) fully functional devices that will simulate. Simulation functionality is achieved by attaching internal circuitry or a SPICE model/subcircuit to a device symbol.

The term *macro device* is used loosely throughout this manual to refer to any device you create or modify.

What's In This Chapter?

The following summarizes the information contained in this chapter.

- **Creating Device Symbols:** Learn how to use the Symbol Editor to create or edit custom device symbols. Learn how to draw symbols freehand with the mouse, create new symbols based on an existing symbol and quickly create a DIP, LCC or QFP symbols. Learn how pins are used as connection points for wires. Also learn how to prepare the symbol for use in CircuitMaker by adding the default Device Data to the symbol. Go through a step-by-step example to create your own device symbol.
- **Creating Macro Devices with Internal Circuitry:** Learn how to attach hidden internal circuitry to a custom device symbol. Learn how this simple process can be used to expand the selection of simulatable devices in CircuitMaker. Learn how macro devices can be nested for hierarchical construction of a circuit for simulation. Go through a step-by-step example to attach circuitry to a symbol, thus making a functional macro device.
- **Working with SPICE Models:** Learn about the three basic types of components in SPICE, selecting a SPICE model for simulation, modifying SPICE models, and

how to attach a new SPICE model to a device symbol. Go through a step-by-step example to add a new SPICE model.

- **Creating New SPICE Models Using Parameter Passing:** Learn how to create a generic SPICE model which can be used to simulate any number of like components by passing parameters specific to each device into the generic model.
- **Editing Digital Model Parameters:** Learn about Digital Simcode devices, their various parameters, and how to modify them.

Creating Device Symbols

You can create or modify device symbols in one or more of the following ways:

- Drawing a symbol with the mouse.
- Entering a description in the Element List.
- Adding existing shapes.
- Importing a Meta file.
- Adding DIP, LCC, and QFP Packages.

To create a symbol for a new macro,

Macro Button



1 Clear the drawing area by clicking the **New** button on the Toolbar.

2 Click the **Macro** button on the Toolbar.

This is the same as choosing **Macros > New Macro**.

3 Enter a unique name for the macro of 13 characters or less.

The Macro Name is used to identify the macro device in the library.

4 Specify how many of these parts would be found in a single IC package.

Note: The same symbol is used for each device in the package.

- 5 Click OK to display the Symbol Editor (Figure 16.1).



Figure 16.1. Use the Symbol Editor to create or modify schematic symbols.

Think of the Symbol Editor as a drawing program. The following sections describe the use of the Symbol Editor options.

Using Symbol Editor Display Controls

Once you have placed a device symbol in the View window, use the Symbol Editor options to control the view of the symbol. You can click and drag device designations at any time to position them where you want.

Control	What it Does
Redraw	Refreshes the picture.
Grid	Displays or hides the currently defined grid in the View window. We recommend a 9 point spacing for pin placement. Note: The Symbol Editor does not use the Snap To Grid feature. See <i>Chapter 12: Options Menu</i> about grid setup and <i>Chapter 13: View and Window Menus</i> for information about changing the grid color.

Symbol Name	Displays or hides the device's symbol name.
Pin Names	Displays or hides the device's pin names.
Pin Designations	Displays or hides the device's pin designations.
View	Zoom in or out (from 25%-800%) to better view the device while you are working on it.
Trace	Step through the Element List, highlighting each element one at a time beginning with the currently selected element. Select the first element in the list, click the Clear button to erase the drawing window, and then click the Trace button repeatedly. This helps you identify elements that are hidden behind other elements, etc.

Drawing a Symbol with the Mouse

You can draw symbols or parts of symbols freehand with the mouse.

To draw a symbol element with the mouse,

- 1 Select the color and fill.

Any enclosed element will be filled with either the element color or the background color.

- 2 Select an element type by clicking its radio button.

You can draw the following element types: **Line, 1/4 Arc, 1/2 Arc, Circle, Ellipse, Polyline, Polygon, Rectangle, Round Rect, and Pins.**

Pins can point up, down, left or right and can have bubbles to indicate negative logic. Pins with bubbles are indicated with a tilde (~).

Note: Any device symbol you want to wire into a circuit must have pins as connection points for wires.

- 3 To place a line, arc, circle, ellipse, rectangle, or pin, hold down the left mouse button, drag, and release. To place a polyline or polygon, click and release the mouse to begin then single-click to turn; double-click to end.

Note: After you place a pin, a dialog box appears that lets you enter a pin name and designation. Pin names and designations are required for circuit simulation and PCB netlist generation.

When you place an element, its description is appended to the Element List. The element's description and shape are also selected and highlighted, which lets you easily move or delete elements that you have placed. After you have placed an element, the selected Element Type does not change until you select a new Element Type or click on a text line in the Element List.

Selecting Shapes

To select single shapes,

- 1 Choose the **Select/Move** option in the Element Type group box.
- 2 Click the shape in the view window.

OR

Click the description in the Element List.

To select multiple shapes,

- 1 Select the **Select/Move** option in the Element Type group box.
- 2 Drag a selection rectangle around the desired element shape in the view window.

OR

Click and drag the cursor in the Element List.

OR

Hold down the **Shift** key while clicking individual element shapes in the view window or element descriptions in the Element List.

To delete elements,

- 1 Select the elements you want to delete.
- 2 Click the **Delete** button.

To move elements,

- 1 Select the **Select/Move** option in the Element Type group box.
- 2 Drag the element shape with the mouse while holding down the **Left** mouse button.

OR

If you have selected multiple elements, drag one of the elements with the mouse while holding down the **Left** mouse button.

To resize elements,

- 1 Select the **Resize** option in the Element Type group box.
- 2 Drag the end of a line, the corner of a rectangle, the side of a rounded rectangle, or the side of an ellipse with the mouse while holding down the **Left** mouse button.

Note: You must use the Element List or Element Buffer to change the size and shape of other elements. See *Element List and Edit Buffer* later in this chapter for more information.

Adding an Existing Shape

To make it easier to create a new device symbol, you can use and modify existing device shapes as needed.

To add an existing shape,

- 1 In the Symbol Editor dialog box, click the **Add Existing Shape** drop-down list box.
- 2 Select the name of the existing shape you want to add.
- 3 If you want to include pins for the existing device, check the **Include Pins** check box.
- 4 If you want to change the size of the shape you are adding, enter a value in the **Scale** edit box.

- 5 Click the **Add Shape** button.
- 6 Press the **r** key (or click the **Right** mouse button) to rotate the shape.
- 7 Press the **m** key to mirror the shape.
- 8 Move the shape to the desired location in the Symbol Editor's view window.
- 9 Click the **Left** mouse button to place the shape or press the **Spacebar** to cancel.

Note: Only the location (not the size) of included pins will be scaled.

Importing a Metafile Device

The Symbol Editor can import device symbols (pictures) created in another drawing program only if that drawing program can copy the desired symbol to the Windows clipboard in the Metafile format.

To import a Metafile device,

- 1 Copy the Metafile object onto the Windows clipboard.
- 2 From the Symbol Editor, select **Clipboard-WMF** as the existing shape (see *Adding an Existing Shape* earlier in this section).

Note: Only the vector graphics shapes (lines, rectangles, circles, etc.) in the Metafile object will be converted. Colors, bitmaps, and text will not be included.

Adding DIP, LCC, and QFP Packages

Use the Symbol Editor to quickly create DIP (Dual In-line Package), LCC and QFP symbols. LCC and QFP are square outlines with an equal number of pins on each side. The LCC symbol has pin 1 on the center of the top side. The QFP symbol has pin 1 on the top of the left side. You can control the size of the package you are adding using the **Scale** value and the number of **Pin name chars** you enter. You can specify the width of the DIP, LCC, and QFP symbols; however, DIPs cannot be scaled directly, they can only be rotated and mirrored. See Figure 16.2 for an example of the LCC symbol.

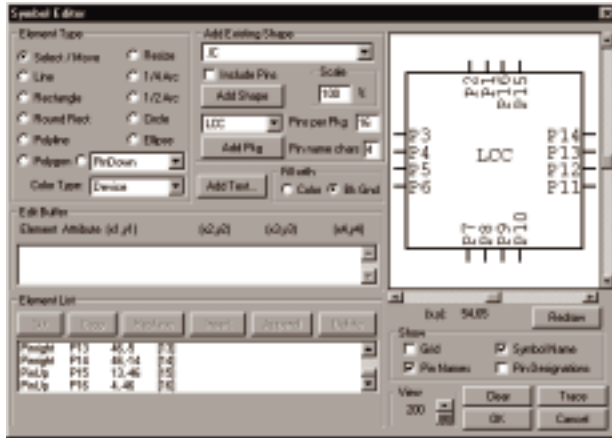


Figure 16.2. Use the Symbol Editor to quickly add DIP, QFP, and LCC symbols.

To add a DIP, LCC, or QFP symbol,

- 1 From the Symbol Editor, specify the number of pins (in 2 pin increments) in the **Pins per Pkg** field.
- 2 Select the Scale (100% by default).
- 3 Click the **Add Pkg** button.
- 4 Move the package to the desired location.

Note: You can press the **Spacebar** to cancel this operation.

- 5 Click the **Left** mouse button to place the package.

Editing Pin Information

Pin names and pin designations are required for circuit simulation and PCB netlist generation. For compatibility with TraxMaker, each pin designation should match the Pad Designation of the corresponding pad in the TraxMaker component.

To edit pin names and pin designations,

- 1 In the Symbol Editor, select the **Select/Move** option in the Element Type group box.

- 2 Right-click a pin to display the dialog box pictured in Figure 16.3.
- 3 Give each pin a name (up to 15 characters) and a designation (up to 5 alphanumeric characters), even if the names are not displayed.

Tip: You can create barred pin names by entering braces { } around all or part of a pin name. Barred pin names work correctly only with monospaced fonts, such as Courier New, CircuitMaker's default font. You can also orient pin names perpendicular or parallel to the pin.

Note: For multipart packages, one pin designation should be listed for each part in the package, separated by commas.

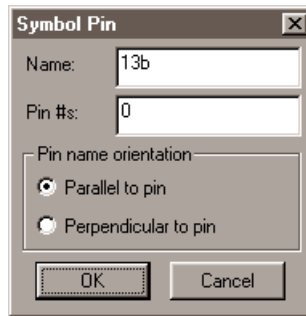


Figure 16.3. Use the Symbol Pin dialog box to edit pin names and designations.

Element List and Edit Buffer

As you add elements to the drawing, they are also added to the Element List. The Element List contains a text description of each element in the device's symbol. The link between the drawing window and the Element List is interactive. When you select an element in the drawing window, it is highlighted in the Element List. Likewise, when you select an element in the Element List, it is highlighted in the drawing window.

Elements at the beginning of the list are drawn first so they are in the back of the drawing (bottom layer); those at the end of the list are drawn last so they are in front (top layer).

Use the Edit Buffer to add or edit the element text descriptions contained in the Element List box. Use the following buttons to edit and change the order of the elements.

Button	What it Does
Cut	Removes the selected elements from the Element List and places them in the Edit Buffer.
Copy	Places a copy of the selected elements in the Edit Buffer.
Replace	Replaces the selected elements with the contents of the Edit Buffer.
Insert	Inserts the contents of the Edit Buffer immediately <i>before</i> the selected element in the Element List.
Append	Attaches the contents of the Edit Buffer to the end of the Element List.
Delete	Removes the selected elements from the Element List.

When editing an element, you must observe strict rules of syntax. The definition for each element must state the element type, attribute (line/fill color or pin name), and a set of xy coordinates. A more complete description of the syntax required for each element is given the *Element Definitions* section which follows.

Element Definitions

When the pen color on an enclosed element is immediately followed by an asterisk (for example, LtBlue*), the fill color will be the same as the pen color, otherwise the fill color will be the background color.

General Format

```
[element type][attribute] x1,y1 x2,y2 x3,y3 x4,y4 [pin
  numbers]
```

Line

Attribute	pen color
x1,y1	start point of the line
x2,y2	end point of the line
x3,y3	n/a
x4,y4	n/a

Example:

Line Device -36,-7 20,-7

Polyline

Attribute	pen color
x1,y1	1st point of the polyline
x2,y2	2nd point of the polyline (optional if +Polyline)
x3,y3	3rd point of the polyline (optional)
x4,y4	4th point of the polyline (optional)
Note	A preceding plus sign (+Polyline) indicates that this is an extension to the preceding polyline element.

Examples:

Polyline Device -24,-46 42,-22 24,35

or

Polyline Device -51,-54 46,-23 34,42 -53,32

+Polyline Device -53,-19

Polygon

Attribute	pen color*
x1,y1	1st point of the polygon
x2,y2	2nd point of the polygon (optional if +Polygon)
x3,y3	3rd point of the polygon (optional if +Polygon)
x4,y4	4th point of the polygon (optional)

Note: A preceding plus sign (+Polygon) indicates that this is an extension to the preceding polygon element.

Example:

Polygon Device -39,12 0,55 -61,75

or

Polygon Device -30,-44 12,-44 29, -21 15,6
+Polygon Device -25,6 -42,16

Rect

Attribute	pen color*
x1,y1	left top corner of the rectangle
x2,y2	right bottom corner of the rectangle
x3,y3	n/a
x4,y4	n/a

Example:

Rect Device -25,-30 15,28

RRect

Attribute	pen color*
x1,y1	left top corner of the rounded rectangle
x2,y2	right bottom corner of the rounded rectangle
x3,y3	width and height of ellipse defining the corners
x4,y4	n/a

Example:

RRect Device -56,-22 11,8 10,10

Ellipse/Circle

Attribute	pen color*
x1,y1	left top corner of the defining rectangle
x2,y2	right bottom corner of the defining rectangle
x3,y3	n/a
x4,y4	n/a

Example:

Ellipse Device -49,-44 9,33

Arc 1/4, 1/2

Attribute	pen color
x1,y1	left top corner of the rectangle defining the complete ellipse
x2,y2	right bottom corner of the rectangle defining the complete ellipse
x3,y3	end point of line 1 whose start point is at the center of the ellipse
x4,y4	end point of line 2 whose start point is at the center of the ellipse

Note: The arc follows the outline of the ellipse and is drawn counterclockwise from line 1 to line 2.

Example:

```
Arc Device -51,-13 -13,33 -32,-13 -51,10 1/4
```

```
Arc Device -28,-11 5,45 5,17 -28,17 1/2
```

Text

Attribute	text color
x1,y1	bottom center location of text
x2,y2	n/a
x3,y3	n/a
x4,y4	n/a
text	string enclosed in single quote marks (15 characters max.)

Example:

```
Text Device 0,25 'symbol text'
```

PinUp, PinDown, PinLeft, PinRight PinUp~, PinDown~, PinLeft~, PinRight~

Attribute	pin name (16 characters max.)
x1,y1	point where pin attaches to package
x2,y2	n/a
x3,y3	n/a
x4,y4	n/a

Examples of single part per package:

```
Pinleft P1 -26,-27 [1]
```

```
Pinright P9 26,36 [9]
```

Examples of two parts per package:

```
Pinleft P1 -26,-27 [1,2]
```

```
Pinright P9 26,36 [9,10]
```

Example of inverted pin:

```
Pinleft~ P7 -26,27 [7]
```

Note: A pin is a connection point for wires. Pins can have bubbles to indicate negative logic. Pins with bubbles are indicated with the tilde (~).

Tutorial: Creating a Device Symbol

The following step-by-step example shows how to use the Symbol Editor to create macro circuits.

- 1 Make a backup copy of the USER.LIB file prior to creating or deleting a macro.

In case the library is damaged or altered in any undesirable way, you will always have a copy of the library as a backup.

- 2 Choose **Macros > New Macro** (or click the **Macro** button on the Toolbar) to display the Define New Macro dialog box shown in Figure 16.4.

It's possible that a message will appear asking if you want to include the present circuit inside the new symbol. For this example you can click **No**.



Figure 16.4. The name you enter here is used later to select the device from the library.

- 3 Enter a unique name up to 13 characters in length in the **Macro Name** text edit field. For this example, type **AND-NOR**.

- 4 Specify the number of parts per package. For this example, use the default of **1** part per package.

This refers to the number of devices found in the same chip. For example, a 7400 package contains 4 NAND gates and a 556 package contains 2 timers.

- 5 Click OK to display the Symbol Editor.

For this example, begin by placing an 8 Pin DIP package in the drawing window.

- 6 Type **8** in the Pins Per Pkg field then click the **Add Pkg** button.

- 7 Click the left mouse button to place the package in the center of the drawing window.

- 8 Change the View to 200% by clicking the **Up Arrow** in the View group box.

The macro name **AND-NOR** displays in the center of the drawing window.

- 9 Click and drag the name into position near the top of the DIP.

Notice that this device consists of 1 Rect, 4 PinLefts and 4 PinRights. You will remove 3 of the 4 PinRights.

- 10 Click the top right-hand pin in the drawing to select it, and then click **Delete**. Repeat for the 2 bottom right-hand pins.

- 11 Click the remaining right-hand pin to select it, and then click **Copy** to copy the pin from the Element List to the Edit Buffer.

- 12 Change **PinRight** to **PinRight~** and change **P7** to **O1**.

- 13 Click **Replace** to replace the selected pin with the new pin.

Notice that the pin in the drawing now has a bubble.

- 14 Click the top left-hand pin to select it.

- 15 Click **Copy** to copy the pin from the Element List to the Edit Buffer.

- 16 Change **P1** to **I1**, and then click **Replace** to replace the selected pin with the new pin. Repeat for each remaining pin, naming them **I2**, **I3** and **I4**.

Compare your device with the one pictured in Figure 16.5. If there is a difference, click Cancel and start over.

- 17 Click OK in the Symbol Editor dialog box.

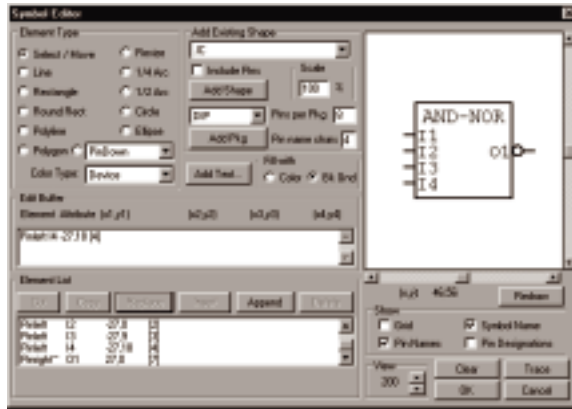


Figure 16.5. This is what the new symbol should look like after completing the steps so far.

After you click OK, the new symbol you created displays and follows the mouse around the work area.

- 18 Click the mouse to place the symbol in the workspace.
- 19 Double-click the macro package.
- 20 Click **Netlist**.

Any data you enter in the Device Data dialog box at this time will be there every time you select this macro from the library menus. Now is a good time to add the default Package, Auto Designation Prefix, Spice Prefix Character(s) and Spice Data if required.

Note: For compatibility with TraxMaker, the Package field must match the name of the corresponding component in TraxMaker.

- 21 If you are satisfied with your macro, choose **Macros > Macro Utilities** to display the Macro Utilities dialog box as pictured in Figure 16.6.

- 22 To place the device in an existing Major or Minor Device Class, click the appropriate items in the lists.
- 23 To create a new Major or Minor Device Class, type the **Major** or **Minor Device Class** name in the appropriate text edit fields.
- 24 Finally, click **Save Macro**.

Clicking Save Macro saves the new macro in the file USER.LIB and clears the workspace. To use the new macro simply select it from the device library and use it just as you would any other device.

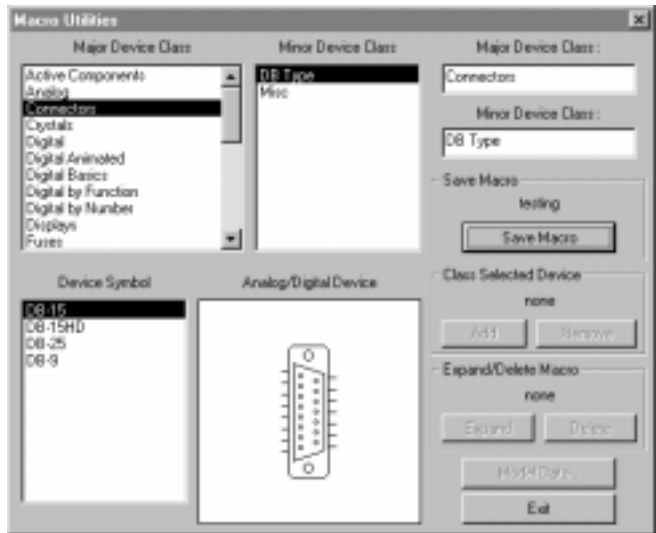


Figure 16.6. You must specify the Major and Minor Device Classes under which your macro will be shown in the Device Selection dialog box.

Expanding an Existing Macro Device

Expanding a macro device lets you modify the device's symbol, the default netlist attributes, and add or edit any internal circuitry.

To expand an existing macro device,

- 1 Place the macro you want to expand in the drawing area.
- 2 Select the macro by clicking it once with the **Arrow Tool**.
- 3 Click the **Macro** button on the Toolbar (or choose **Macros > Expand Macro**).

OR

Double-click the macro device.

Notice that the workspace clears and the dialog box shown in Figure 16.7 appears.

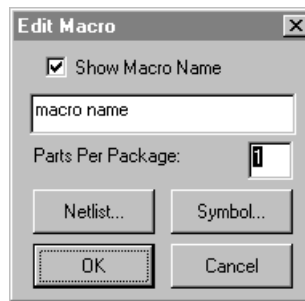


Figure 16.7. Use this dialog box to specify what part of the macro device you want to edit.

- 4 If you want, type a new name for the macro.
Saving a macro under a new name does not delete the old macro device.
- 5 Use the **Parts Per Package** option to change the number of parts that would be found in a single IC package.
Note: Use this option only when creating a new device.
- 6 Click the **Netlist** button to display the Edit Device Data dialog box.

Depending on the macro device you are editing, you might need to specify mandatory parameters for the device, including Label-Value, Package, Auto Designa-

tion Prefix, Spice Prefix, and Spice Data.

- 7 Click the **Symbol** button to display the Symbol Editor, where you can edit the expanded macro's schematic symbol.
- 8 Click OK when you have finished drawing and specifying parameters for the symbol.

Clicking OK returns you to the expanded macro where you can add or edit circuitry before the new device is saved. See *Creating Macro Circuits* later in this chapter for the step-by-step procedure.

Creating Macro Devices with Internal Circuitry

If you cannot find a device in CircuitMaker's library of devices (or elsewhere) that performs a particular function, you can create a functional macro device by attaching hidden circuitry to a custom symbol.

A macro device can contain internal circuitry that you can base on CircuitMaker's library of existing devices. You can also nest macro devices, meaning that a macro can be used within another macro device, letting you create building blocks and piece them together in order to create the final device.

When you save a macro, all of the circuitry you have added to it is hidden within its symbol. The new macro device functions according to the circuitry hidden within. You can then use the new macro in any circuit.

To create a macro device with internal circuitry,

- 1 Make a backup copy of the USER.LIB file.
In case the library is damaged or altered in any undesirable way, you will always have a copy of the library as a backup.
- 2 Create a symbol as described earlier in this chapter (see *Creating Device Symbols* earlier in this chapter).
- 3 Place the symbol that you created in the drawing area and expand it by selecting it and then choosing **Macros**

> **Expand Macro** (see *Expanding an Existing Macro Device* earlier in this chapter for more details).

- 4 Construct the circuitry which performs the function your new macro device is to have.

For example, suppose you want to build a device that performs an AND-NOR function. You would construct something like the circuit shown in Figure 16.8.

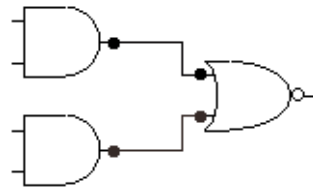
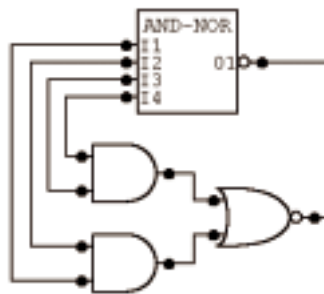


Figure 16.8. You can add functional circuitry such as this AND-NOR function.

- 5 Select the **Wire Tool** from the Toolbar and connect wires from the macro symbol's pins to the other points within the circuit. Figure 16.9 shows an example of a completely wired macro device.



Note: If a macro device contains internal circuitry as well as SPICE data, the SPICE data will be ignored.

Figure 16.9. The functional circuitry is wired to the symbol to create a functional macro device.

- 6 If default data was not added when the symbol was created, then double-click on the macro symbol and click the Netlist button. Add any necessary data such as Package and Auto Designation Prefix. Data entered now in the Device Data dialog box will be there every

time this macro device is selected from the library menus. Note: For compatibility with TraxMaker, the Package field must match the name of the corresponding component in TraxMaker.

- 7 Save the Macro (choose **Macros** > **Save Macro**)

Working with SPICE Models

SPICE is an industry standard program for simulating circuits. In order to make devices work in analog simulation, there must be SPICE data available for each device. Using the Symbol Editor, you can include SPICE model and subcircuit information with a new or existing device. You can also edit SPICE information using an ASCII Text Editor.

Note: If you intend to create new device symbols to export a PCB netlist or simply draw schematics, you do not need to include SPICE information. However, even if you are going to simulate your circuit, adding SPICE models from other sources is easy and beneficial. To learn more about SPICE, see *Chapter 15: SPICE: Beyond the Basics*.

There are 3 basic types of components in SPICE:

- **Elementary** components such as resistors, capacitors, power sources, etc.
- **Models** defining discrete devices such as BJTs, J-FETs, MOSFETs, etc.
- **Subcircuits** which combine multiple items (such as elementary components, models, and other subcircuits) to create a more complex device.

SPICE models and subcircuits are available from many sources, including component manufacturers, engineering magazines and books. You can also download them from the internet. For example, visit MicroCode Engineering's web page at www.microcode.com.

Editing SPICE Models with a Text Editor

Since SPICE models (and subcircuits) are text files (see Figure 16.10), they can be modified with a text editor such as Notepad. If you edit this file with a word processor, be sure to save the file in a TEXT ONLY format.



Figure 16.10. You can open SPICE data into any text editor and edit it directly.

Editing SPICE Models in CircuitMaker

When you double-click a device that has SPICE models associated with it, the dialog box in Figure 16.11 appears.



Figure 16.11. This dialog box lets you select a diode model.

The currently selected model is highlighted in the list. To select a different model, click it with the mouse, then click **Select** (or just double-click on the model). If any subcircuits are found in the .MOD file, they are indicated by an **x** as the first character in the description instead of a **p**.

To edit or view an existing model,

- 1 Click on the name of the model you want to edit or view.
- 2 Click on the **Edit** button to display the dialog box pictured in Figure 16.12.



Figure 16.12. Use the Diode Model Parameters dialog box to change the settings of a particular model.

The model parameters displayed are SPICE model parameters not data book parameters. Unless you are familiar with SPICE modeling, it is recommended that you do not modify the existing SPICE models.

The values listed for each parameter represent values defined for that specific device type. Default SPICE model parameter values are indicated by an asterisk (*) after the value.

To change the value of a SPICE parameter,

- 1 Click the name of the SPICE parameter.

This selects the parameter and copies the parameter's value into the Value edit box.

- 2 Change the data in the **Value** box and click the **Enter** button.

If you want to set a specific parameter to equal that of the DEFAULT model, type an asterisk (*) in the Value edit field and press Enter.

- 3 Click OK to save the model.

OR

To save it under a new name, type the new name into the Name field, and then click OK.

Note: Models created or modified in this manner are stored directly in the .MOD linking file in place of the model reference.

The original .LIB file remains unchanged. When viewed in the Model Selections dialog box, the first character of the device description will be an asterisk (*).

To remove an existing model,

- 1 Select it by clicking it with the mouse.
- 2 Click **Delete**.

This only removes the model reference from the linking file; it does not remove the actual model from the library.

Adding New Models to an Existing Symbol

When you obtain new models from an outside source, they are generally provided in a single ASCII library file.

Note: If you edit this file with a word processor, be sure to save the file in TEXT ONLY format.

Use the **Model Data** button in the **Macro Utilities** dialog box to create a link to each model in the new library file. The following steps illustrate an example of adding a new model.

To add a 2N5209 transistor to CircuitMaker,

- 1 Choose **Macros > Macro Utilities**.
- 2 Select the symbol for an NPN transistor, then click **Model Data**.
- 3 Click **Open** and open the library file (MCEBJT.LIB) in which the 2N5209 model resides.

All of the model and subcircuit names found in this library will be displayed in the list box on the left.

- 4 Click **2N5209**.
- 5 Enter appropriate information about the model in the Description field (for example: **Si 625mW 50V 50mA 30MHz Amp**).
- 6 In the Pkg Name field enter **TO-92B** to match the name of the component pattern in TraxMaker.
- 7 Enter pin numbers to match the pad designations of the component in TraxMaker. On the TO-92B in TraxMaker, with the flat side facing you, pin 1 is on the

Note: Normally you must copy the .lib file that contains the .MODEL or .SUBCKT data to the CircuitMaker Models directory. For this 2N5209 example, the MCEBJT.LIB file is already in the Models directory.

right, pin 2 is in the middle and pin 3 is on the left. For the 2N5902, these pins correspond to the collector, base and emitter, respectively (C=1, B=2, E=3).

- 8 Click **Add** to add the new reference.

You can now select the new model alphabetically from the list of npn transistors.

Adding Existing Models to New Macro Symbol

To add an existing model to a new macro symbol,

- 1 Create a new nonfunctional macro device symbol as described earlier in this chapter.

Be sure to place the pins in the same order as they are listed in the syntax for the corresponding model.

For example, if you are creating a new symbol for a diode, you should place the anode pin first, then the cathode pin to correspond with the SPICE definition of a diode. This is not required, but it will be easier to understand when filling in the Spice Data field for the device.

To link the new symbol to an existing model file, you must name the new symbol appropriately.

For example, you may want to name the symbol **Diode:A** to link to the DIODE.MOD file or **Schottky:A** to link to the SCHOTTKY.MOD file.

- 2 With the new macro expanded, double-click the device, and then click **Netlist** to view the Edit Device Data dialog box.
- 3 Enter the following data:
 - Auto Designation Prefix for the device. For example, Q for transistors, D or CR for Diodes, etc.
 - Set the Spice Prefix Character(s) for this device to be representative of the type of device models you are using. For example, an NPN Bipolar Junction Transistor must have the prefix **QN**. Refer to *Chapter 4: Drawing and Editing Schematics* for a listing of valid prefix characters.

- Enter an appropriate SPICE instruction for this device into the Spice Data field. Refer to *Chapter 4: Drawing and Editing Schematics* for more information.
- 6 Click OK.
 - 7 Click **Macros** > **Save Macro** to save the macro.
 - 8 After you have entered the appropriate data, SPICE models can be linked to the new symbol by following the instructions under *Adding New Subcircuits to an Existing Model* later in this chapter.

Example

To create a new device symbol for standard junction diodes,

- 1 Create a new macro symbol for a diode using the Symbol Editor described in *Creating a New Macro Device* earlier this chapter.
- 2 Name the new macro symbol DIODE:A.

When placing pins on the new device, place the *first* pin on the anode (N+), and the *second* pin on the cathode (N-).

They should be placed in this order to match the syntax for the diode model.

- 3 Expand the new macro symbol (if it is not already expanded) by clicking it once with the left mouse button, and then click the **Macro** button in the Toolbar.
- 4 Double-click on the device symbol, and click on the **Netlist** button.
- 5 Enter the following information in the Edit Device Data dialog box of the expanded macro (to set the defaults for this macro device):

Auto Designation Prefix: D

Spice Prefix Character(s): D

Spice Data field: %D %1 %2 %M

- 6 Save the macro (see *Save Macro* in *Chapter 11: Macros Menu* for more information).

To edit or view an existing subcircuit,

- 1 Click it with the mouse.
- 2 Click **Edit** to display the dialog box in Figure 16.14.



Figure 16.14. Use this dialog box to edit or view an existing subcircuit.

This dialog box lists the subcircuit, beginning with the description line and ending with the .ENDS line. Any changes you make to the subcircuit cause the modified subcircuit to replace the reference in the subcircuit linking file. The original subcircuit remains unchanged in the library file, but the reference to it will be lost. Naming conventions for .SUB files are discussed in *Model and Subcircuit Linking Files* later in this chapter.

Adding New Subcircuits to an Existing Symbol

When you obtain new subcircuits from an outside source, they are generally provided in a single ASCII library file.

Note: If you edit this file with a word processor, be sure to save the file in TEXT ONLY format.

Use the **Model Data** button in the **Macro Utilities** dialog box to create a link to each model in the new library file. The following steps illustrate adding a new subcircuit to an existing symbol.

***Note:** Normally you must copy the .lib file that contains the .SUBCKT data to the CircuitMaker Models directory. For this LF412C example, the MCEMODS2.LIB file is already in the Models directory.*

To add an LF412C operational amplifier (5-pin subcircuit) to CircuitMaker,

- 1 Select **Macros > Macro Utilities**.
- 2 Select the symbol for the 5-pin opamp (Op-Amp5), and then click **Model Data**.
- 3 Click **Open** and open the library file (MCEMODS2.LIB) in which the LF412C model resides.

All of the model and subcircuit names found in this library will be displayed in the list box on the left.
- 4 Click on the **LF412C**.
- 5 Enter appropriate information about the model in the Description field (for example: Dual LoOffset LoDrift JFET OpAmp).
- 6 In the Pkg Name field enter **DIP8** to match the name of the component pattern in TraxMaker.
- 7 Enter pin numbers to match the pad designations of the component in TraxMaker.

Since the **LF412C** is a dual op amp, you must enter pin numbers for both PART A and PART B (click the **Up** or **Down Arrow** to switch between the two).

For PART A the pin numbers should be: IN+ = 3, IN- = 2, V+ = 8, V- = 4 and Out = 1. For PART B the pin numbers should be: IN+ = 5, IN- = 6, V+ = 8, V- = 4 and Out = 7. Note that the V+ and V- power supply pins are the same for both op amps.

- 8 Click **Add** to include the new reference.

You can now select the new subcircuit alphabetically from the list of 5-pin op amps.

Adding Existing Subcircuits to New Macro Symbol

To add an existing subcircuit to a new macro symbol,

- 1 Create a new nonfunctional macro device symbol as

described earlier in this chapter.

Be sure to place the pins in the same order as they are listed in the corresponding subcircuit. For example, if you are creating a new symbol for a 5-pin opamp, you should place the +Input pin first, then the -Input pin, the +Vsupply pin, the -Vsupply pin and finally the Output pin to correspond with the SPICE node connections for the 5-pin opamp subcircuit. This is not required, but it will be easier to understand when filling in the Spice Data field for the device. In order to link the new symbol to an existing subcircuit file, you must name the new symbol appropriately. For example, you may want to name the symbol “Op-Amp5:A” to link to the OPAMP5.SUB file.

Note: Since CircuitMaker identifies pins by the order of placement in a device symbol, for clarity make sure that the placement order of the pins matches the order of the nodes listed in the subcircuits. The actual link between device symbol pins and SPICE subcircuits is controlled by the Spice Data field of the device where %*n* refers to the *n*th pin in the element list. For example, in the Spice Data

```
%D %1 %2 %3 %4 %S
```

the node number connected to the first pin placed on the device symbol is represented by %1, the second pin by %2, etc. When used with a subcircuit which begins

```
.SUBCKT XMR9933A 21 23 6 15
```

node 21 in the subcircuit connects to the first pin on the device symbol, etc.

2 With the new macro expanded, double-click on the device, then click on the **Netlist** button to view the Edit Device Data dialog box. Enter the following data:

- Enter an appropriate Auto Designation Prefix for the device. For example, U or IC for integrated circuits, etc.
- Set the Spice Prefix Character(s) to “X” for subcircuit devices.

- Place an appropriate SPICE instruction for this device into the Spice Data field. Refer to *Editing Devices* in *Chapter 4: Drawing and Editing Schematics* for more information or refer to the examples provided with other devices.

3 Click OK.

4 Choose **Macros > Save Macro** to save the macro.

5 After you have entered the appropriate data, SPICE subcircuits can be linked to the new symbol by following the instructions in *Adding New Subcircuits to an Existing Symbol* earlier in this chapter.

Example

To create a new device symbol for optoisolators,

1 Create a new macro symbol for an optoisolator using the symbol editor described earlier in this chapter.

Name the new macro device symbol Opto Isol:A.

When placing pins on the new device, place the *first* pin on the anode (N+), the *second* pin on the cathode (N-), the *third* pin on the collector, and the *fourth* pin on the emitter.

They should be placed in this order to match the syntax for the optoisolator subcircuits.

2 Expand the new macro symbol (if it is not already expanded) by clicking on it once with the left mouse button, then click on the **Macro** button in the Toolbar.

3 Double-click the device symbol, and click **Netlist**.

4 Enter the following information in the Edit Device Data dialog box of the expanded macro (to set the defaults for this macro device):

Auto Designation Prefix: OP

Spice Prefix Character(s): X

Spice Data field: %D %1 %2 %3 %4 %S

5 Click OK then choose **Macros > Save Macro**.

- 6 Follow the instructions in *Adding New Subcircuits to an Existing Symbol* earlier in this chapter.

Model and Subcircuit Linking Files

Model and Subcircuit data is stored in ASCII text files, typically with the .LIB extension. You can edit these files directly with any ASCII text editor.

Each analog device symbol in CircuitMaker has a linking file associated with it. In order to use SPICE models in CircuitMaker, you must link the models to a corresponding device symbol by placing a reference to the model in the linking file.

To create a new link or to modify an existing link,

- 1 Select **Macros > Macro Utilities**.
- 2 Select the symbol that you want to use for the specific model or subcircuit you are adding.
- 3 Click **Model Data** to display the dialog box pictured in Figure 16.15.

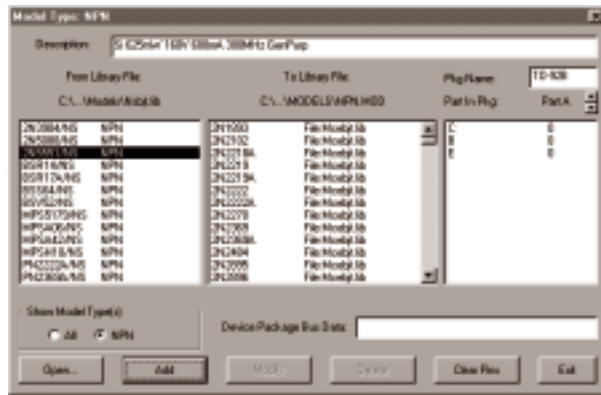


Figure 16.15. Use this dialog box to add, modify, and remove linking information.

Initially, only the center list box will have anything in it. This is a list of the devices in the linking file associated with

the selected symbol. Click one of the models to select it and the the description, package and pinout information appears.

To modify this information,

- 1 Select the name of the model or subcircuit you want to delete.
- 2 Type in the desired changes.
- 3 Click **Modify**.

To remove a reference from the linking file,

- 1 Select the name of the model or subcircuit you want to delete.
- 2 Click **Delete**.

To add new references to the linking file,

- 1 Click **Open** and open the library file in which the actual model or subcircuit resides.

All of the model and subcircuit names found in this library will be displayed in the list box on the left. If desired, the list can be limited to only those devices which are compatible with the selected device symbol.

- 2 Enter appropriate description, package and pin information for the model.

If there are multiple parts per package, be sure to enter pin numbers for each of PART A, PART B, etc. If the model is similar to another part that is already in the linking file, it may be simpler to first select the similar part to fill in the blanks, make any necessary corrections, then select the new model by changing the **Show Model Type**.

- 3 Click **Add** to include the new reference.

The names of the linking files correspond to the device symbol names, with the following exceptions:

- Linking file names are limited to 8 characters, so the device symbol name is truncated to 8 characters when searching for a match.

- All spaces and punctuation characters are removed.
- If the last 1 or 2 characters of a truncated device symbol name are numbers, those numbers replace the last characters in the file name.
- If a device symbol name includes a colon (:), the colon and all characters after the colon are ignored. For example, the devices **NPN Trans**, **NPN Trans:A**, **NPN Trans:B** and **NPN Trans:C** are all associated with the linking file NPNTRANS.MOD.

If CircuitMaker cannot find a linking file using the file name formed from the device symbol name, and if that symbol can be simulated using simple SPICE models, a default file name is used instead. The default file name is based on the SPICE Prefix Character(s). Following is a list of the SPICE prefix character(s) and their corresponding default file names:

SPICE Prefix	Default File Names
C	CAP.MOD
D	DIODE.MOD
DZ	ZENER.MOD
JN	NJFET.MOD
JP	PJFET.MOD
MN	NMOS.MOD
MP	PMOS.MOD
O	LTRA.MOD
QN	NPN.MOD
QP	PNP.MOD
R	RESISTOR.MOD
S	SW.MOD
U	URC.MOD
W	CSW.MOD
ZN	NMESFET.MOD
ZP	PMESFET.MOD

All others, including subcircuit-only device symbols, do not have a default file name. Subcircuit-only device symbols

(symbols that cannot be simulated with a simple model) must use linking files with the .SUB extension.

Transistors are an example of when a default file name is used. Since the file NPNTTRANS.MOD does not exist, CircuitMaker looks in the default file NPN.MOD for the model reference information.

.MOD linking files contain references to a collection of SPICE models and subcircuits specific to a particular discrete device symbol in CircuitMaker. In some cases, it is desirable to replace a model with a subcircuit which will more accurately model a particular device. For example, some RF or Power Transistors are not modeled well by a simple SPICE model. In such cases, it is OK to reference the subcircuit in the .MOD file just like it was a model. For more information on using models, see *Working with SPICE Models* earlier in this chapter.

.SUB linking files contain references to a collection of SPICE subcircuits specific to a particular device symbol in CircuitMaker. For more information on using subcircuits, see *Editing SPICE Subcircuits* earlier in this chapter.

Under normal circumstances, the linking files should not be edited directly. The file format is described below for information only.

The general format for a reference in a linking file is:

```
*Device Description pkg:PACKAGE [DVCC=14;DGND=7;] 1,2,3,...  
.PARAM QXXXXXXXX File:Filenam.lib
```

where PACKAGE [DVCC=14;DGND=7;] 1,2,3,... is the component name and pad designations in TraxMaker (the bus data listed here is for digital component symbols that do not have external power and ground pins), Q is the Spice prefix character for the specific device type, XXXXXXXXX is the model name and Filenam.lib is the name of the library file in which the model or subcircuit actually resides.

There should be an appropriate description of the device on the line *immediately before* each .PARAM line. This line will be displayed as the description in the Model or Subcircuit Selections dialog box. The first character of this description line must be an asterisk (*). When you double-

click a device to select a model, subcircuits that are found in the .MOD file will also be displayed, but the first character in the description will appear as an “x” instead of a “p”. You should also include appropriate package and pin information at the end of the description line. This information is required when creating a PCB netlist for TraxMaker. The package name represents the component name that is to be used in TraxMaker. The pin information indicates the pinout of the device in the package. For example:

```
*500mW 40V 800mA pkg:TO-18 3,2,1  
.PARAM Q2N2222A File:Mcebjts.lib
```

Note that the pin order is specified as 3,2,1. SPICE defines the pin order of a BJT as collector, base, emitter (see *Bipolar Junction Transistors (BJTs) in Chapter 6: Analog/Mixed -Signal Simulation*). In a TO-18 package containing a 2N2222A transistor, the emitter is connected to pin 1 (next to the tab), the base is connected to pin 2 and the collector is connected to pin 3. These pin numbers correspond to the pad designations in TraxMaker. CircuitMaker identifies pins by the order of placement in a device symbol and TraxMaker identifies pads by their designation. This information can be used to create a netlist linking one program to the other.

If the same device is available in different packages, you may specify additional packages using an alias. Notice the SPICE prefix character is replaced with the letter **A** and the file reference is removed:

```
*350mW 40V 800mA alias:Q2N2222A pkg:TO-92B 1,2,3  
.PARAM APN2222A
```

If there are multiple devices in the same package, the pins need to be specified for each device with a letter to indicate the designation extension:

```
*Dual Op Amp pkg:DIP8 (A:3,2,8,4,1)(B:5,6,8,4,7)  
.PARAM XMC1458 File:Mcemods.lib
```

These two methods may be combined if you have multiple devices that are available in different packages.

Linking Inside Subcircuits Using an Alias

Sometimes it is necessary to link two different devices to the same subcircuit. This may be required when two devices contain identical internal circuitry, but different package or pin information. The best way to do this is to add an ALIAS to the subcircuit (*.sub) file using any text editing program (like NotePad^o, WordPad^o, etc.). The file must be saved in standard text format. Below is the general text format:

```
*Description alias:XLINK|SUBNAME pkg:[Package & Pins]
.PARAM XNEWNAME
```

Data	Description
Description	Information about the nature of the device, such as voltage, current, etc.
XLINK	The name of the subcircuit to be referenced. The first letter will always be the appropriate SPICE character, followed by the subcircuit name.
	Vertical bar separator. NOTE: There cannot be a space between the vertical bar separator and the XLINK or SUBNAME.
SUBNAME	The name of the subcircuit file (*.sub) where the subcircuit to be referenced is located. This will include the first 8 characters, not including spaces. Do not include the .sub extension.
pkg	The package name and pin numbers in appropriate format for export to a PCB layout program such as TraxMaker. NOTE: See different .sub files for examples of this format.
XNEWNAME	The new name of the device as seen in the parts list.

The following is an example of a subcircuit internal alias link:

Reference

```
*Instrumentation Amplifier: LOW POWER pkg:DIP8 3,2,7,4,6,5,1,8
.PARAM XAD620A File:AnalogD.lib
```

New Device Data

```
*Instrumentation Amplifier: LOW POWER alias:XAD620A|INSTAMP pkg:SMD8A 3,2,7,4,6,5,1,8
.PARAM XAD620AR
```

Creating New SPICE Models with Parameter Passing

Parameter passing simplifies the task of creating new components. It allows you to pass databook values directly into generic SPICE models or subcircuits, using mathematical equations to create SPICE model parameters. The generic model is placed in the linking file associated with the device symbol, then referenced by an alias.

Devices created in this manner are selected and edited just like any other device model. To edit the parameters being passed, double-click the device, then click **Edit**.

General Form (Generic Model)

```
*MNAME:Device Title
*MNAME:P1:|P1 Description [<<Min>,<Max>>]|Default
*MNAME:P2:|P2 Description [<<Min>,<Max>>]|Default
*MNAME:Pn:|Pn Description [<<Min>,<Max>>]|Default
*{P1=Default P1=Default .. Pn=Default}
*Desc pkg:Package Pins
```

Generic .MODEL or .SUBCKT using {P1, P2, etc. in math expressions}

General Form (Alias)

```
*Desc alias:MNAME {P1=Val P2=Val} pkg:Package Pins
.PARAM ANAME
```

Data

MNAME

Description

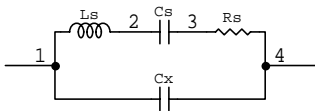
The name of the generic model or subcircuit, including the appropriate SPICE prefix character.

P1, P2, etc.	The names of the parameters being passed.
P1 Description, etc.	The description of the parameters.
Min and Max	Optional items which limit the value that can be entered for each parameter.
Default	The default value for each parameter if no value is specified.
Desc	A description of the device.
Package and Pins	Information used for export to TraxMaker for PCB layout.
ANAME	The alias name (the name of the specific device).

Valid operators in the math expressions include:

+ - * /

Following is an example of a generic subcircuit for a crystal which can be used as a building block for creating other crystals:



Crystal Subcircuit

```
*XCRYSTAL:Crystal Subcircuit Parameters
*XCRYSTAL:FREQ:|Fundamental frequency [1,]|1MEG
*XCRYSTAL:RS:|Series resistance [1,]|750
*XCRYSTAL:CX:|Parallel capacitance [0,]|13pf
*XCRYSTAL:Q:|Quality Factor [10,1000]|1000
*{FREQ=1Meg RS=750 C=13pf Q=1000}
*Generic 1MHz Crystal:crystal pkg:XTAL1 1,2
.SUBCKT XCRYSTAL 1 2
LS 1 2 {((Q*RS)/(6.2831852*FREQ))} IC=0.5M
CS 2 3 {(1/(Q*6.2831852*FREQ*RS))}
RS 3 4 {RS}
CX 1 4 {CX}
.ENDS XCRYSTAL
*alias:XCRYSTAL {FREQ=2E6 RS=250} pkg:XTAL1 1,2
.PARAM A2.000MHZ
```

Since CX and Q are not passed in the alias parameter list, the default values of 13pF and 1000 will be used.

Editing Digital Model Parameters

When you double-click a device that has digital simcode models associated with it, Figure 16.16 appears.



Figure 16.16. Digital simcode devices are mixed-signal digital devices which you can simulate in analog mode using features of XSpice.

Digital simcode devices use event-driven behavioral models created at MicroCode Engineering. You cannot add new simcode models; however, simcode devices can be used in macro circuits to create new mixed-mode digital devices.

While you cannot edit the model itself, you can alter certain parameters of the model. To do so, click it with the mouse, then click **Edit** to display the dialog box in Figure 16.17.



Figure 16.17. Use the Digital Model Parameters dialog box to alter certain parameters of a model.

The radio buttons let you specify whether each of the parameters of the model will be minimum, typical or maximum values for the selected device(s). Refer to *Edit Items* in *Chapter 10: Edit Menu* for information about changing the parameters of multiple devices. The Default setting allows the parameter to remain unchanged. All parameters can vary from pin to pin, part to part and family to family.

Parameter	Description
Propagation Delays	The time it takes for a signal change on an input to affect the data on the output.
Transition Times	The rise and fall times of the outputs.
Input Loading	The amount of load resistance that will be applied to the output of the driving device.
Output Drive	The amount of output current available.
Device Current	The amount of current drawn through the supply pin to ground.
User Defined	This parameter does not affect digital models provided with CircuitMaker.

The edit fields let you enter specific values for certain parameters. The values take precedence over family specific values. Under normal conditions they should be left blank.

Parameter	Description
GND & PWR	These two parameters must be programmed as a pair (if you set one, you must also set the other). Setting these voltages will override any other power and ground voltages specified for the selected devices.
VOL & VOH	These two parameters will override the family defaults.
VIL & VIH	These two parameters will override the family defaults.

WARN Flag:

When set to one (1), warning messages will be generated when there are timing or supply voltage violations on the device.

CHAPTER 17

Digital SimCode™

Digital SimCode™ provides the means for the electronics professional to create and/or modify digital components which operate in Analog/Mixed-Signal Simulation. Digital SimCode *cannot* be used to create components for Digital Logic Simulation. The functionality of devices for Digital Logic Simulation is built-in to CircuitMaker and you cannot add to it except by creating macro circuits.

Due to the complexity of digital devices, it is generally not practical to simulate them using standard, non-event-driven, Spice instructions. For this reason, MicroCode Engineering has created a special descriptive language that allows digital devices to work in Analog/Mixed-Signal Simulation using an extended version of the event-driven XSpice. The digital devices included in the CircuitMaker library are modeled using the Digital SimCode language.

The Digital SimCode language does *not* provide the means to create digital devices with analog characteristics such as analog switches, time-delayed one-shots, etc., nor can it be used to create new components for Digital Logic Simulation. Digital SimCode is a proprietary language created specifically for use with CircuitMaker and devices created with it are not compatible with other simulators, nor are digital components created for other simulators compatible with CircuitMaker.

***Note:** Programming in the Digital SimCode language is not intended for the average CircuitMaker user. It requires a basic understanding of standard programming techniques as well as a complete understanding of the characteristics of the device that you are trying to create. These topics are not covered in this manual.*

Creating New SimCode Devices

Digital SimCode, used in conjunction with XSpice, is what allows digital components to be simulated in Analog/Mixed-Signal Simulation mode.

To create a new digital SimCode device,

- 1 Create a symbol to represent the device in your schematic.

See *Chapter 16: Creating New Devices* for more detailed information about the process.

Note: This step may not be necessary if you are creating a new device that has an equivalent function in another family. For example, if you are creating a 74F190, we recommend that you use the equivalent symbol for the 74190 for a couple of reasons. First, the function of the device is identical and the symbol has already been drawn. Second, if you want to use the component in Digital Logic Simulation mode, the existing symbol will work. New symbols that you create will not work in Digital mode unless they contain internal macro circuitry. This internal macro circuitry would disable the Digital SimCode model in Analog mode.

- 2 Create a .MOD file to be used with the symbol.

The .MOD file name must match the name of the symbol (see *Model and Subcircuit Linking Files* in *Chapter 16: Creating New Devices*). If you are using an existing symbol, you must use the existing .MOD file as well. Just add the new model information (see below) into the existing .MOD file.

Each Digital SimCode model declaration in a .MOD file has two lines. Line 1 is a comment line which contains information used by CircuitMaker. Line 2 contains the model information that is used by WXSpice during simulation. This example is followed by a brief description of each item.

```
*Counter - type:digital pkg:DIP14 [DVCC=5;DGND=10;](6,7,2,3,14,1,11,8,9,12)
.MODEL A74LS90 xsimcode(file="{MODEL_PATH}LS.SCB" func=ls90 {mmtymx})
```

Line 1	What it Does
Counter	Describes the device.
type:digital	Sets the device's Parameters field.
pkg:DIP14	Sets the device's Package field.
[DVCC=5;DGND=10;]	Sets device's Bus Data field (required if supply pins not on symbol).
(6,7,2,3,14,...)	Sets the device's Pin Data list.

Line 2	What it Does
.MODEL	Declares the model statement.
A74LS90	Names the model (digital SimCode models begin with the letter "A").
xsimcode	Model type for a digital SimCode model.
file=	Points to file containing the device's digital SimCode. {MODEL_PATH} is a shortcut to the Models directory as specified in the CircuitMaker preferences.
func=	Names the device's digital SimCode function.
data=	Contains ASCII data for the <i>READ_DATA</i> function (optional).
{mntymx}	Passes the device's Digital Model Parameters into SimCode (this must appear exactly as shown).

3 Create a digital SimCode model for the device.

You can do this in any ASCII text editor such as Notepad. If using a word processor, be sure to save the file in text only format. The file can be given any name and extension as long as it matches the file name listed in the "file=" parameter in the .MOD file. Multiple digital SimCode device models can be placed in the same file.

The simplest process is to start by making a copy of an existing device, preferably one which is similar in either function or characteristics, and make modifications to the SimCode as needed. Some examples of SimCode devices are included in a file called SIMCODE.TXT, for your reference.

- 4 Test the new device in CircuitMaker by creating a simple circuit to test its functionality.

Test only one new device at a time. When you run the simulation, the source code model is automatically compiled and the compiled code is placed in an ASCII text file called SIMLIST.TXT in the same directory as WXSPICE.EXE. This file also contains a listing of the execution order of the source code model. Refine the SimCode source model as needed and continue testing until you've completely debugged the model.

- 5 Copy the compiled model file to your SimCode library.

Create a separate library file in which to place your compiled SimCode models. It does not matter what you name this file, but in order to be used, you must set the "file=" parameter in the .MOD file to be the same as the file name of the compiled SimCode model library.

SimCode models are stored in two types of files. The source models are stored in files with the .TXT extension (for example, LS.txt and S.txt) and the compiled models are stored in files with the .SCB extension (for example, Std.scb and Cmos.scb).

The 74LS74 Example

The following sections contain information about the 74LS74 Digital SimCode model example.

SimCode Function Identification

See ① in the example on page 17-6. **#1s74 source** identifies the beginning of the SimCode source function for the 74LS74.

Data declarations

See ② the example. This section consists of pin and variable declarations.

The *INPUTS* statement declares the names of the input pins. VCC and GND pins are included in this statement. The order of these pins must match the order of their corresponding pin declarations in the device's Spice Data field.

The *OUTPUTS* statement declares the names of the output pins. Notice that the input pins are listed here as well, but with the suffix “_LD”. The input pins must also be declared as outputs so that the device can provide a load on the driving circuitry. VCC pins are included in this statement, but not GND pins. The order of these pins must match the order of their corresponding pin declarations in the device's Spice Data field.

The *PWR_GND_PINS* statement declares which pins will be used for device power and ground and samples their voltage levels for use later in the SimCode.

SimCode Function Initialization

See ③ in the example. The “*IF (init_sim) THEN*” section is executed only once, at the beginning of the simulation. In this section we set the device characteristics that are not subject to change due to outside influences such as databook specifications. The outputs states should also be initialized here to their “most likely” state. The *EXIT* command should be placed at the end of this section.

LOAD and DRIVE Statements

See ④ in the example. These statements are used to declare the load and drive capabilities of the device pins.

Device Functionality

See ⑤ in the example. This section can vary dramatically from part to part. In this example an *EXT_TABLE* command has been used. Other device models use a variety of *IF...THEN*, *STATE_BIT*, *NUMBER*, and other statements to define the logical function of the device.

Tests for Device Setup Violations

See ⑥ in the example. These tests warn of device setup violations which, in the real world, may cause a device not to function properly. In the simulation, the device will generally still function, but warnings, if enabled, will be displayed.

Output Delays/Post Events

See ⑦ in the example. The *DELAY* statements occur at the end of the SimCode function. These statements actually post the events to XSpice to let it know that something has changed and when these events are scheduled to occur relative to the rest of the simulation. Timing (propagation delay) is assigned to each output based on the databook specifications, input stimulus and the functionality of the device.

```
//=====
①# ls74 source
//1/2- 74LS74 D flip-flop Digital Simcode Model
//typical prop delay values from TI 1981 2nd edition data book
//=====
②INPUTS VCC, GND, PRE, DATA, CLK, CLR;
OUTPUTS VCC_LD, PRE_LD, DATA_LD, CLK_LD, CLR_LD, QN, Q;
INTEGERS tblIndex;
REALS tplh_val, tphl_val, ts_val, th_val, trec_val, tt_val, temp_tp,
      clk_twl, clk_twh, pre_clr_twl, ril_val, rih_val, ricc_val;

PWR_GND_PINS(VCC,GND);          //set pwr_param and gnd_param values
SUPPLY_MIN_MAX(4.75,5.25);      //test for min supply=4.75 and max supply=5.25
VOL_VOH_MIN(0.2,-0.4,0.1);      //vol_param=gnd_param+0.2,voh_param=pwr_param-0.4
VIL_VIH_VALUE(1.25,1.35);      //set input threshold values: vil and vih
IO_PAIRS(PRE:PRE_LD, DATA:DATA_LD, CLK:CLK_LD, CLR:CLR_LD);

③ IF (init_sim) THEN
  BEGIN                          //select prop delay, setup, hold, and width times
    //MESSAGE("time\t\tPRE\tCLR\tCLK\tDATA\tQ\tQN"); //debug

    //NOTE: both ttlh and tthl are the same value
    tt_val= (MIN_TYP_MAX(tt_param: NULL, 5n, NULL));

    temp_tp= (PWL_TABLE(sim_temp: -75, -5n, 125, 5n)); //tp temperature affect
    tplh_val= (MIN_TYP_MAX(tp_param: NULL, 14n, 25n)) + temp_tp;
    tphl_val= (MIN_TYP_MAX(tp_param: NULL, 20n, 40n)) + temp_tp;

    ts_val= (20n);
    th_val= (5n);
    trec_val= (5n);
    clk_twl= (25n);                //not specified - derived from fmax
    clk_twh= (25n);
    pre_clr_twl= (20n);

    //LS stdout drive IOL max=8mA @ VOL typ=0.35V:rol_param=0.35V/8mA=43.75
    //LS stdout drive IOL max=8mA @ VOL max=0.5V: rol_param=0.5V/8mA=62.5
    rol_param= (MIN_TYP_MAX(drv_param: 62.5, 43.75, NULL));

    //LS stdout drive IOS min=20mA @ VCC max=5.25V: roh_param=5.25V/20mA=262.5
    //LS stdout drive IOS max=100mA @ VCC max=5.25V:roh_param=5.25V/100mA=52.5
    roh_param= (MIN_TYP_MAX(drv_param: 262.5, NULL, 52.5));

    //LS input load IIH max=20uA @ Vin=2.7V: ril= (2.7-vol_param)/20uA=125k
    ril_val= (MIN_TYP_MAX(ld_param: NULL, NULL, 125k));
```

```

//LS input load IIL max=-0.4mA @ Vin=0.4V:rih= (voh_param-0.4)/0.4mA=10.5k
rih_val= (MIN_TYP_MAX(ld_param: NULL, NULL, 10.5k));

//Icc @ 5V: 2500= 4mA/2 typical, 1250= 8mA/2 max
ricc_val= (MIN_TYP_MAX(i_param: NULL, 2500, 1250));

STATE Q = ONE;           // initialize output states
STATE QN = ZERO;
EXIT;
END;

④DRIVE Q QN = (v0=vol_param,v1=voh_param,ttlh=tt_val,tthl=tt_val);
LOAD PRE_LD DATA_LD CLK_LD CLR_LD =
(v0=vol_param,r0=ril_val,v1=voh_param,r1=rih_val,io=1e9,t=1p);

⑤EXT_TABLE tblIndex
PRE CLR CLK DATA  Q   QN
0  1  X  X        H   L
1  0  X  X        L   H
0  0  X  X        H   H
1  1  ^  X        DATA ~DATA
1  1  X  X        Q    ~Q;

//MESSAGE("%fs\t%d\t%d\t%d\t%d\t%d\t%d",present_time,PRE,CLR,CLK,DATA,Q,QN);
LOAD VCC_LD = (v0=gnd_param,r0=ricc_val,t=1p);

⑥IF (warn_param) THEN
BEGIN
  IF (PRE && CLR) THEN
  BEGIN
    SETUP_HOLD(CLK=LH DATA Ts=ts_val Th=th_val "CLK->DATA");
    RECOVER(CLK=LH PRE CLR Trec=trec_val "CLK->PRE or CLR");
    WIDTH(CLK Twl=clk_twl Twh=clk_twh "CLK");
    WIDTH(PRE CLR Twl= pre_clr_twl "PRE or CLR");
  END;
END;

⑦DELAY Q QN =
CASE (TRAN_LH) : tplh_val
CASE (TRAN_HL) : tphl_val
END;
EXIT;

```

Editing Device Data for SimCode Devices

Each device symbol includes netlist information specific to the device found in the Edit Device Data dialog box. For Digital SimCode devices, the information required is slightly different from other analog devices. For example, the Spice Data field must contain data not found in other devices.

The node list in the Spice Data field is divided into two sections, one for input nodes and one for output nodes. Each of these sections is delimited by square brackets ([]), input nodes first, followed by output nodes. The nodes must be listed in the *same order* as the pins in the *INPUTS* and *OUTPUTS* statements in the SimCode. The pin number used in the Spice Data field (for example, %1i, %2i, etc.) indicates the position of each pin in the devices Pin Data list. If that pin number is followed by the letter “b” (for example, %14bi), that indicates that the pin is found in the Bus Data field rather than on the symbol itself and represents the actual pin number on the package. The “i” and the “o” specify the pin type as input or output. For the 7474 (1/2 device symbol), the Spice Data field is set to:

```
%D [%14bi %7bi %1i %2i %3i %4i][%14o %1o %2o %3o %4o %5o %6o] %M
```

When using these SimCode pin declarations:

```
INPUTS VCC, GND, PRE, DATA, CLK, CLR;
OUTPUTS VCC_LD, PRE_LD, DATA_LD, CLK_LD, CLR_LD, QN, Q;
```

the items in the Spice Data field have the following meanings:

Item	Meaning
%D	Device Designation
%14bi	VCC (pin 14 on the actual package, declared in Bus Data field)
%7bi	GND (pin 7 on the actual package, declared in Bus Data field)
%1i	PRE input (1st pin in Pin Data list)
%2i	DATA input (2nd pin in Pin Data list)

%3i	CLK input (3rd pin in Pin Data list)
%4i	CLR input (4th pin in Pin Data list)
%14o	VCC_LD (still pin 14, but acts as load on VCC supply)
%1o	PRE_LD (load applied by PRE input)
%2o	DATA_LD (load applied by DATA input)
%3o	CLK_LD (load applied by CLK input)
%4o	CLR_LD (load applied by CLR input)
%5o	QN output (5th pin in Pin Data list)
%6o	Q output (6th pin in Pin Data list)
%M	A74LS74 (the name of the selected SimCode model)

Other information for the Edit Device Data dialog box includes:

Option	Information
Analog checkbox	Enabled
Label-Value	74LS74
Auto Designation Prefix	U
Spice Prefix Character	A
Bus Data	DVCC=14;DGND=7;
Parameters	type:digital

SimCode Language Definition

The following items make up the Digital SimCode language. The following pages described each of these items in detail.

INPUTS	Input pins (pins that monitor the circuit).
OUTPUTS	Output pins (pins that drive or load the circuit).
INTEGERS	Integer variables and arrays.
REALS	Real variables and arrays.
PWR_GND_PINS	Power and ground pins and record supply voltage.
IO_PAIRS	Input/output pin associations for input loading.

Device Setup Functions

Use these functions to set certain characteristics of the device pins.

VIL_VIH_VALUE	Sets absolute VIL and VIH values.
VIL_VIH_PERCENT	Sets VIL and VIH values to a percentage of supply voltage.
VOL_VOH_MIN	Sets VOH and VOL relative to power and ground.

Device Test Functions

Use these functions to test for any device setup violations which may occur in the circuit. These violations may not affect the simulation of the device's functionality (i.e., the device may continue to function in simulation even with setup violations). In order to know if any of these setup violations have occurred, you must enable warnings.

SUPPLY_MIN_MAX	Tests supply pins for min/max supply voltage violations.
RECOVER	Tests inputs for recovery time violations.
SETUP_HOLD	Tests inputs for setup and hold time violations.

WIDTH Tests inputs for minimum pulse width violations.

FREQUENCY(FMAX) Tests inputs for minimum & maximum frequency violation.

Output Pin Functions

Use these functions to program the output pins of a device.

STATE Sets outputs to the declared logic state.

STATE_BIT Sets outputs to binary weighted logic states.

LEVEL Sets the level of the output state.

STRENGTH Sets the strength of the output state.

TABLE Sets output logic states based on truth table.

EXT_TABLE Sets output logic states based on extended truth table.

LOAD Declares loading characteristics of input pins.

DRIVE Declares drive characteristics of output pins.

DELAY Sets propagation delay to specified outputs.

NO_CHANGE Leaves output state of I/O pins unchanged.

EVENT Causes a digital event to be posted.

Expression Operations

Use these operators and functions in expressions to manipulate data and to make comparisons which control program flow. Expressions are always contained within parentheses (). Operator precedence is from left to right, starting with the inner most parentheses.

Operators +, -, *, /, ~, !, &&, ||, ^, &, |, >>, <<, >, <, =, !=, >=, <=

Math Functions POW, ABS, SQRT, EXP, LOG, LOG10,
SIN, COS, TAN, ASIN, ACOS, ATAN,
HSIN, H COS, HTAN

Expression Functions

Use these functions various expressions.

PARAM_SET	Determines if a predefined SimCode param has been set.
PWL_TABLE	Returns value from interpolative lookup table.
SELECT_VALUE	Returns value from simple lookup table.
MIN_TYP_MAX	Returns value from MIN_TYP_MAX lookup table.
NUMBER	Returns number based on binary weighted pin states.
VALUE	Returns state of the specified pin.
CHANGE_TIME	Returns time when the specified pin last changed state.
WIDTH_TIME	Returns last pulse width encountered on specified pin.
INSTANCE	Checks to see if this is the specified device instance.
CHANGED_xx	Checks to see if the specified pin has changed state.
READ_DATA	Reads data from an ASCII file into arrays.

Program Control

Use these statements to control the flow of the program.

#xxxx source	Identifies the beginning of the SimCode source function.
IF ... THEN	Conditionally controls flow through the SimCode.
WHILE ... DO	Conditionally controls looping in the SimCode.
GOTO	Jumps to a new location in the SimCode.
GOSUB	Jumps to a subroutine in the SimCode.
RETURN	Returns from a subroutine in the SimCode.
EXIT	Terminates SimCode execution.

Output Text

Use these commands to display messages during simulation and debugging.

PROMPT	Pause simulation and display a message.
MESSAGE	Display a message without pausing.

Debug

Use these commands to trace through the execution of the SimCode for debugging purposes.

STEP_ON	Turn on the SimCode trace mode
STEP_OFF	Turn off the SimCode trace mode

SimCode Language Syntax

This section describes each of the language items in detail. The following punctuations are used in describing the syntax:

<i>italics</i>	reserved words or emphasis
<>	value/variable/pin/expression
[]	optional parameter
{ }{ }	selections (you must choose ONE of these parameters)

xxxx source

Identifies the beginning of the SimCode source function.

General Form

```
# <func name> source
```

Parameters

<func name> Name of the SimCode function.

Use

This statement identifies the SimCode function so that it can be called when it is time to simulate this device. It must be the first statement of each Digital SimCode device function.

Notes

WXSpice has the ability to read either source code models or compiled code models. The keyword “source” identifies this as a source code model to be compiled by WXSpice. When the simulation is run, the source code model is compiled and the compiled code is placed in an ASCII text file called SIMLIST.TXT in the same directory as WXSPICE.EXE.

Example

```
//=====
# MyDevice source
//=====
INPUTS VCC, GND, IN1, IN2;
OUTPUTS VCC_LD, IN1_LD, IN2_LD, OUT;
.
.
.
EXIT;
```

CHANGE_TIME

Returns time when the specified pin last changed state.

General Form

```
CHANGE_TIME (<pin>)
```

Parameters

<pin> Input or output pin name.

Use

This function returns a real value that indicates the last time the specified input or output pin changed states.

Example

```
T1 = (CHANGE_TIME (INA));
```

CHANGED_xx

Checks if the specified pin has changed state.

General Form

```
CHANGED_xx(<pin> [{<>|{<=}|{>}|{>=}] <var/time/value>])
```

Parameters

<pin> Input or output pin name.

<var/time/value> Item to which <pin> is compared.

Use

The *CHANGED_xx* function is used to determine if the specified <pin> has changed state. The *_xx* that follows the keyword *CHANGED* can be eliminated (to indicate *any* type of change) or the *xx* can be set to:

LH, LX, HL, HX, XL, XH, LZ, ZL, ZH, ZX, HZ or XZ

to indicate a specific type of change. The optional compare operator (<, <=, >, >=) and <var/time/value> would be included to check for a more specific change. If they are not included, the function will return 1 if the pin has changed at the current simulation step.

Examples

```
IF (CHANGED_LH(CLK)) THEN ...
IF (CHANGED(DATA < 10n)) THEN ...
```

DELAY

Sets propagation delay to specified outputs.

General Form 1

```
DELAY <output> [<output> ...] = <delay>;
```

General Form 2

```
DELAY <output> [<output> ...] =
  CASE (<conditional exp>) : <delay>
  CASE (<conditional exp>) : <delay>
  [CASE (<conditional exp>) : <delay> ...]
END;
```

Parameters

<output>	Name of/variable index to the output pin.
<conditional exp>	Conditional expression that determines which delay is used.
<delay>	Propagation delay time to the output pin.

Use

The *DELAY* command is executed once for each pin listed and posts a propagation delay for each pin that has changed its level. The *CASE* option allows more than one <delay> to be specified. The <conditional exp> then determines which <delay> will be used. If a delay is set for a pin that has not changed then the pin will be flagged as *NO-CHANGE* and the delay will *not* be posted. The <delay> can be a real constant, a real variable or a real expression.

Notes

The *DELAY* command must be executed exactly once for each output pin, that is, for each pin declared in the *OUT-PUTS* statement which is *not* listed in the *LOAD* or *NO_CHANGE* statements. The order in which the delays are set is based on the order in which these pins are listed in the *DELAY* command (i.e. first pin listed is set first). Each <conditional expression> is evaluated in the order it is listed until one expression evaluates *TRUE*. When this occurs, the <delay> value associated with the *TRUE* expression is posted for the output being set. When using the *CASE* option, at least one <conditional exp> should evaluate as *TRUE* for each output pin listed. If no <conditional exp> evaluates to *TRUE*, the <delay> associated with the last *CASE* statement is posted.

In addition to the standard expression functions, the following terms apply *only* to the output pin being set and can be used in the <conditional exp> :

TRAN_LH	low-to-high
TRAN_LX	low-to-other
TRAN_HL	high-to-low
TRAN_HX	high-to-other
TRAN_HZ	high-to-tristate
TRAN_XL	other-to-low
TRAN_XH	other-to-high
TRAN_LZ	low-to-tristate
TRAN_ZL	tristate-to-low
TRAN_ZH	tristate-to-high
TRAN_ZX	tristate-to-other
TRAN_XZ	other-to-tristate
TRAN_XX	other-to-different

If the <delay> value is less than or equal to 0.0 a run-time error message will be displayed. Output pins can be specified by using the output pin name or by an integer variable the contains the *index* of an output pin. Pin names and variables *cannot* be mixed in the same *DELAY* statement. References to outputs must be either all pin names or all variable names.

Examples

```

DELAY Q1 Q2 Q3 Q4 = 10n;
DELAY Q QN =
    CASE (TRAN_LH) : tplh_val
    CASE (TRAN_HL) : tphl_val
END;

data = (E0_1 && (CHANGED(D0) || CHANGED(D1)));
DELAY Q1 Q0 =
    CASE (data && TRAN_LH) : tplh_D_Q
    CASE (data && TRAN_HL) : tphl_D_Q
    CASE (TRAN_LH) : tplh_E_Q
    CASE (TRAN_HL) : tphl_E_Q
END;

```

In this example, if data is nonzero and Q1 is changing from High to Low, the *tphl_D_Q* delay will be posted for Q1. Then, if Q0 is changing from Low to High, the *tplh_D_Q* delay will be posted for Q0.

DRIVE

Declares drive characteristics of output pins.

General Form

```
DRIVE <output> [<output> ...] =
    (v0=<value> v1=<value> ttlh=<value> tthl=<value>);
```

Parameters

<output>	Name of or variable index to the output pin.
<value>	Real value or variable.
<i>v0</i>	VOL for the output pin.
<i>v1</i>	VOH for the output pin.
<i>ttlh</i>	Low-to-high transition time for the output pin.
<i>tthl</i>	High-to-low transition time for the output pin.

Use

The *DRIVE* command is used to declare the output pin's *DRIVE* characteristics. When the output is set to a LOW state, the output pin is connected to voltage value *v0* through resistance *rol_param*. When the output is set to a HIGH state, the output pin is connected to voltage value *v1* through resistance *roh_param*. The low-to-high transition time is set by *ttlh* and the high-to-low transition time is set by *tthl*.

Notes

Pin names and variables *cannot* be mixed in the same *DRIVE* statement. References to outputs must be either all pin names or all variable names.

The values used for *rol_param* should be derived using the databook specs for VOL. This value represents the total saturation resistance of the pull-down structure of the device's output. A standard LS output in the LOW state, for example, sinking 8mA will not exceed 0.5V, typically closer to 0.35V. Therefore:

for typ LOW state drive: $rol_param = VOL_{typ} / IOL_{max}$
 $rol_param = 0.35V / 8mA$
 $rol_param = 43.75 \text{ ohms}$

for min LOW state drive: $rol_param = VOL_{max} / IOL_{max}$
 $rol_param = 0.5V / 8mA$
 $rol_param = 62.5 \text{ ohms}$

The values used for roh_param should be derived using the databook specs for IOS, if available. This value represents the total saturation resistance of the pull-up structure of the device's output. A standard LS output in the HIGH state with the output shorted to ground and $V_{cc}=5.25V$ will source at least 20mA but not more than 100mA. Therefore:

for min HIGH state drive: $roh_param = VCC_{max} / IOS_{min}$
 $roh_param = 5.25V / 20mA$
 $roh_param = 262.5 \text{ ohms}$

for max HIGH state drive: $roh_param = VCC_{max} / IOS_{max}$
 $roh_param = 5.25V / 100mA$
 $roh_param = 52.5 \text{ ohms}$

Example

```
rol_param = (MIN_TYP_MAX(drv_param: 62.5, 43.75, NULL));
roh_param = (MIN_TYP_MAX(drv_param: 262.5, NULL, 52.5));
DRIVE Q QN = (v0=vol_param, v1=voh_param, ttlh=ttlh_val,
             tthl=tthl_val);
```

See Also

LOAD

EVENT

Causes a digital event to be posted.

General Form

```
EVENT = ({<time>}|{<expression>})
```

Parameters

<time>	Time at which event should occur.
<expression>	Expression indicating time at which event should occur.

Use

In most cases a digital event is posted when one or more INPUT pins for a simcode model changes state. When the event is processed, the simcode for the specified event is called and run. This instruction allows a simcode model to post a digital event at a specified <time>. If the specified EVENT time is greater than the simulation time (indicated by present_time), then a digital event will be posted. If more than one EVENT is posted in a single call to a simcode model, only the longest EVENT <time> will be used. This function allows the creation of one-shots and other similar device models.

Notes

If a digital event for a specific simcode model occurs before an EVENT <time> posted by that simcode, the EVENT <time> must be posted again. For example, if 1) the present simulation time is 1us, 2) a simcode model sets EVENT = 2us and 3) an INPUT pin in the simcode model changes state at 1.5us, then the 2us event must be posted again.

Example

```
EVENT = (present_time + 1e-6); //return in  
1us
```

EXIT

Terminates SimCode execution.

General Form

```
EXIT;
```


Use

The *EXIT* statement is used to terminate SimCode execution.

Notes

This is the last line of a SimCode model, but it may also be placed at other locations to abort execution of remaining SimCode.

EXT_TABLE

Sets output logic states based on extended truth table.

General Form

```
EXT_TABLE <line>
<input pin> [<input pin> ...] <output pin> [<output pin> ...]
<input state> [<input state> ...]
    <output state> [<output state> ...];
```

Parameters

<line>	Variable into which the line number used in the table is placed
<input pin>	Name of the input pin
<output pin>	Name of the output pin
<input state>	State of the individual inputs
<output state>	State of the individual outputs based on input conditions

Use

The *EXT_TABLE* statement is an extended truth table function used to set the level and strength of the specified outputs. Valid input states are:

0	low (input voltage is \leq <i>vil_param</i>)
1	high (input voltage is \geq <i>vih_param</i>)
^	low-to-high-transition
v	high-to-low-transition
X	don't care what input voltage is

Valid output states are:

L	ZERO (set output level to <i>vol_param</i>).
H	ONE (set output level to <i>voh_param</i>).
Z	UNKNOWN (set output level to <i>v3s_param</i>).

It also allows INPUT and/or OUTPUT pin names with optional prefixes to specify the output states. Prefixes are:

- State is the previous state.
- ~ State is the inverse of the state.
- State is the inverse of the previous state.

Output state letters can be followed by a colon and a letter to indicate strength:

- s STRONG (set output to *rol_param* for L and *roh_param* for H).
- z HI_IMPEDANCE (set output to *r3s_param*).

If a strength character is *not* specified after an output state then STRONG will be used for L and H states and HI_IMPEDANCE will be used for Z states.

Notes

Each row is tested sequentially from top to bottom until the input conditions are met. The outputs are set for the *first* row to meet the input conditions. <line> is set to the line number in the table that was used. If no match was made then <line> is set to 0. Pin names used to specify output states do not need to be in the table heading. Unlike the TABLE statement, input variables are not allowed.

Example

```
EXT_TABLE tblIndex
PRE CLR CLK DATA Q QN
0 1 X X H L
1 0 X X L H
0 0 X X H H
1 1 ^ X DATA ~DATA
1 1 X X Q ~Qi
```

This example is representative of 1/2 of a 7474 D type flip-flop. If input pins PRE, CLR, and DATA are all high ($\geq v_{ih_param}$) and CLK has a low-to-high transition, Q is set to high (v_{oh_param}) and STRONG (roh_param), QN is set to low (v_{ol_param}) and STRONG (rol_param) and tblIndex is set to 4.

See Also

REALS, STATE, STATE_BIT, TABLE

FREQUENCY (FMAX)

Tests inputs for minimum and maximum frequency violation.

General Form

```
FREQUENCY(<input> [<input>...] MIN=<frequency>  
          MAX=<frequency> [ "<message>" ])
```

Parameters

<input>	Name of or variable index to the input pin under test.
MIN	Minimum frequency allowed on the pin under test.
MAX	Maximum frequency allowed on the pin under test.
<message>	Text string that will be displayed if a warning occurs.

Use

The *FREQUENCY* function compares the <input> period (the time from one low-to-high edge to the next low-to-high edge) with the reciprocal of the specified <frequency> (1/freq). If the time period for the <input> is smaller than the reciprocal of the specified MAX<frequency> or the time period for the <input> is greater than the reciprocal of the specified MIN<frequency>, then a WARNING will be displayed. An optional <message> string can be included in the *FREQUENCY* statement which will be output if a WARNING is displayed.

Notes

Databook specifications should be used with this function. Pin and variable names *can* be mixed in the same *FREQUENCY* statement. Only the first *FREQUENCY* failure for each pin listed will be reported.

Example

```
FREQUENCY(CLK MAX=10MEG "CLK"); //check fmax  
only
```

GOSUB

Jumps to a subroutine in the SimCode.

General Form

```
GOSUB <label>;
```

Parameters

<label> Location in SimCode where program flow resumes.

Use

The *GOSUB* instruction is used to perform non-sequential execution of the SimCode. However, unlike the *GOTO* statement, SimCode execution will continue on the instruction following the *GOSUB* instruction when a *RETURN* instruction is encountered in the SimCode being run.

Example

```
GOSUB Shift_Left;
.
.
.
Exit;

Shift_Left:
.
.
.
RETURN;
```

See Also

RETURN

GOTO

Jumps to a new location in the SimCode.

General Form

```
GOTO <label>;
```

Parameters

<label> Location in SimCode where program flow resumes.

Use

The *GOTO* instruction is used to perform non-sequential execution of the SimCode.

Notes

Program flow resumes from the location where <label>: appears in the SimCode. <label> must begin with an alpha character, followed by any number of alpha-numeric characters or the underscore (_) character. Where <label> appears in the code, it must be followed *immediately* by a colon (:).

Example

```
GOTO Shutdown;
.
.
.
Shutdown:
.
.
.
Exit;
```

See Also

GOSUB, IF ... THEN

IF ... THEN

Conditionally controls flow through the SimCode.

General Form 1

```
IF (<expression>) THEN BEGIN ... [ELSE ...] END;
```

General Form 2

```
IF (<expression>) THEN GOTO <label>;
```

Parameters

<expression> Any expression that can be evaluated as true or false.

<label> Location in SimCode where program flow resumes.

Use

The *IF ... THEN* statement is used to control the flow of the program, based on whether <expression> evaluates to true or false. Multiple *IF ... THEN* statements may be nested.

Notes

When the BEGIN...ELSE...END form of this statement is used and <expression> evaluates to true, program flow resumes from the BEGIN statement and skips any optional SimCode between the ELSE and END statements. If <expression>

evaluates to false, program flow resumes from the optional ELSE statement if it exists or after the END statement if it does not exist.

When the GOTO form of this statement is used and <expression> evaluates to true, program flow resumes from the location where <label>: appears in the SimCode. <label> must begin with an alpha character, followed by any number of alpha-numeric characters or the underscore (_) character. Where <label> appears in the code, it must be followed *immediately* by a colon (:).

Examples

```
IF (EN) THEN
  BEGIN
    STATE Q0 = UNKNOWN;
  ELSE
    IF (IN2) THEN
      BEGIN
        STATE Y2 = ONE;
      ELSE
        STATE Y2 = ZERO;
      END;
    END;

IF (x = -2) THEN GOTO Do_Neg2;
.
.
.
Do_Neg2:
.
.
.
```

See Also

GOTO, WHILE ... DO

INPUTS

Declares input pins (pins that monitor the circuit).

General Form

```
INPUTS <input pin>[, <input pin>, ...];
```

Parameters

<input pin> Name of the input pin.

Use

The *INPUTS* data type is used to define the pins which monitor stimulus external to the device. These generally include input, i/o, power and ground pins.

Notes

Input pin names *must* begin with a letter and be defined before they are used.

Example

```
INPUTS VCC, GND, PRE, DATA, CLK, CLR;
```

See Also

OUTPUTS, IO_PAIRS, PWR_GND_PINS

INSTANCE

Checks if this is the specified device instance.

General Form

```
INSTANCE("<instance name>")
```

Parameters

<instance name> Text string indicating instance name.

Use

The *INSTANCE* function returns 1 if the present instance of the SimCode device matches the <instance name> specified. Otherwise it returns 0;

Notes

A circuit may contain more than one of any given device. During simulation it may be important to know if the device being simulated at this moment is the one you are interested in. This would allow you, for example, to print messages for one specific NAND gate without having to wade through messages for all the other NAND gates as well. The instance name is the device Designation preceded by its Spice Prefix Character (the letter A).

Example

```
IF (INSTANCE("AU23")) THEN
  BEGIN
    MESSAGE("U23-Q0 = %d", Q0);
  END;
```

INTEGERS

Declares integer variables and arrays.

General Form

```
INTEGERS <var>[ , <var> , ... ];
```

Parameters

<var> Name of the variable.

Use

The *INTEGERS* data type is used to define integer variables and arrays.

Notes

Integer variables and arrays *must* begin with a letter and be defined before they are used. Integer arrays are defined by following the array name with a left bracket ([), an integer number which defines the size of the array, and a right bracket (]). Integer arrays can be set and/or used in expressions.

The following are reserved SimCode integer variables which do not need to be declared:

Variable	Use	Digital Model Parameter	Spice Option
<i>tp_param</i>	tplh/hl index	Propagation Delays	TPMNTYMX
<i>tt_param</i>	ttlh/hl index	Transition Times	TTMNTYMX
<i>ld_param</i>	LOAD index	Input Loading	LDMNTYMX
<i>drv_param</i>	DRIVE index	Output Drive	DRVMNTYMX
<i>i_param</i>	ICC index	Device Current	IMNTYMX
<i>user_param</i>	USER index	User Defined	USERMNTYMX
<i>warn_param</i>	Warning messages	WARN flag	SIMWARN
<i>init_sim</i>	1 during simcode init	N/A	N/A
<i>tran_pin</i>	TRAN_xx pin index	N/A	N/A

The first six variables in this list are expected to have a value of 1, 2 or 3. These values represent an index into the min/typ/max arrays:

Value	Represent
1	Index to minimum value.
2	Index to typical value.
3	Index to maximum value.

The Digital Model Parameter can be set independently for each digital device in the Digital Model Parameters dialog box. If a Spice Option parameter is set in the Analog Options dialog box, that setting will globally override the Digital Model Parameter settings for all digital devices. If the variable is set explicitly in the SimCode, that setting will override all other settings.

warn_param can be set to any positive value to conditionally display warning messages for the device. Different levels of warning could be created by the device programmer, accessed by entering different positive values. The value of *init_sim* is set 1 during SimCode initialization, otherwise it is set to 0. The value of *tran_pin* is set to the index of the pin being set during a *DELAY CASE* statement. This index is used to determine which pin the *TRAN_xx* instruction is applied to.

Example

```
INTEGERS tblIndex, count, data[64];
```

See Also

DELAY, MIN_TYP_MAX

IO_PAIRS

Declares input/output pin associations for input loading.

General Form

```
IO_PAIRS (<ipin:opin>[, <ipin:opin>, ...]);
```

Parameters

<ipin:opin> Pin names of associated input and output pins.

Use

The *IO_PAIRS* statement defines which of the *INPUTS* pins are associated with which of the *OUTPUTS* pins. This association is used by the *LOAD* statement.

Notes

Each physical input pin on a device consists of both an ipin and an opin in SimCode. The opin is required to provide input loading characteristics. This statement can only be used once in the SimCode. Power pins are not listed in the *IO_PAIRS* statement.

Example

```
IO_PAIRS ( IN1 : IN1_LD, IN2 : IN2_LD );
```

In this example, IN1 and IN2 are *INPUTS* and IN1_LD and IN2_LD are *OUTPUTS*. IN1 and IN1_LD both refer to the same physical pin on the device.

See Also

INPUTS, OUTPUTS, LOAD

LEVEL

Sets the level of the output state.

General Form 1

```
LEVEL <output> [<output> ...] = (<expression>);
```

General Form 2

```
LEVEL <output> [<output> ...] =
  {ZERO} | {ONE} | {UNKNOWN};
```

Parameters

<output> Name of or variable index to the output.

<expression> Any expression compared to VOL or VOH.

Use

The state of an output pin is determined by its level and its strength. Use the *LEVEL* command to set the level of one or more output pins.

<expression>	State	Level
<= <i>vil_param</i>	ZERO	<i>vil_param</i>
>= <i>voh_param</i>	ONE	<i>voh_param</i>
other	UNKNOWN	<i>v3s_param</i>

Notes

Output pins can be specified by using the output pin name or by an integer variable the contains the INDEX of an output pin. Pin and variable names *cannot* be mixed in the same *LEVEL* statement. References to outputs must be either all pin names or all variable names.

Examples

```
LEVEL Q = ONE;
LEVEL Q1 Q2 Q3 Q4 = ZERO;
LEVEL OUT = ((1+2)/3);
```

In the last example, OUT will be:

ZERO if *vil_param* > 1

UNKNOWN if *vil_param* < 1 and *vih_param* > 1

ONE if *vih_param* < 1

See Also

REALS, *STATE*, *STATE_BIT*, *STRENGTH*

LOAD

Declares loading characteristics of input pins.

General Form

```
LOAD <output> [<output> ...] =
    (v0=<value> r0=<value> [v1=<value>
    r1=<value>] [io=<value>] t=<value>);
```

Parameters

<output>	Name of or variable index to the output pin.
<value>	Real value or variable.
<i>v0</i>	Load voltage for HIGH state input.
<i>r0</i>	Load resistance for HIGH state input.
<i>v1</i>	Load voltage for LOW state input.
<i>r1</i>	Load resistance for LOW state input.
<i>io</i>	Off-state load resistance for unused load.
<i>t</i>	Time delay before the load will be applied.

Use

The *LOAD* command is typically used with input or power pins to provide loading for the driving circuit. Since only output pins can provide a load, each input must have a corresponding output. These are assigned using the *IO_PAIRS* statement.

If different loads are required for different inputs, multiple *LOAD* statements may be used. Power pins should be placed in a separate *LOAD* statement which does not include the *v1/r1* load or *io*. Power pins are not included in the *IO_PAIRS* statement. The *IO_PAIRS* statement must be entered before any *LOAD* statements that contain *io*.

Notes

An input load consists of a voltage and a resistance (*v0/r0* or *v1/r1*). The voltage level of the incoming signal determines which load will be used. If the voltage level goes

below V_{IL} and remains below V_{IH} , then the input is considered to be in the LOW state and the v_l/r_l is applied. If the voltage level goes above V_{IH} and remains above V_{IL} , then the input is considered to be in the HIGH state and the v_o/r_o is applied. i_o is the input state off resistance. The unused load is essentially removed from the circuit by changing its r value to the value specified for i_o .

The values for v_o , r_o , v_l and r_l can be either real constants or real variables. The values for i_o and t must be real constants. Pin names and pin variables *cannot* be mixed in the same *LOAD* statement. References to outputs must be either all pin names or all variable names.

For input pins, the values used for r_o should be derived using the databook specs for I_{IH} . A standard LS input, for example, will sink a maximum of 20uA at $V_{in}=2.7V$. Therefore, if $vol_param = 0.2V$, then:

$$\begin{aligned} \text{for max HIGH state load: } r_o &= (V_{in} - vol_param) / I_{IHmax} \\ r_o &= (2.7V - 0.2V) / 20\mu A \\ r_o &= 125k \text{ ohms} \end{aligned}$$

The values used for r_l should be derived using the databook specs for I_{IL} . A standard LS input, for example, will source a maximum of 400uA at $V_{in}=0.4V$. Therefore, if $voh_param = 4.6V$ then:

$$\begin{aligned} \text{for max LOW state load: } r_l &= (voh_param - V_{in}) / I_{ILmax} \\ r_l &= (4.6V - 0.4V) / 400\mu A \\ r_l &= 10.5k \text{ ohms} \end{aligned}$$

For power pins, the value used for r_o should be derived using the databook specs for I_{CC} . For a 74LS151, $I_{cc \text{ typ}}$ is 6mA at $V_{cc}=5V$ and $I_{cc \text{ max}}$ is 10mA at $V_{cc}=5.25V$. Therefore:

$$\begin{aligned} \text{for } I_{cc \text{ typ:}} \quad r_o &= 5V / 6mA = 833 \text{ ohms} \\ \text{for } I_{cc \text{ max:}} \quad r_o &= 5.25V / 10mA = 525 \text{ ohms} \end{aligned}$$

If creating a multiple-parts-per-package device, such as a 74LS00 quad NAND gate, you should adjust the I_{cc} load for the individual parts accordingly.

Examples

```

r0_val = (MIN_TYP_MAX(ld_param: NULL, NULL, 125k);
r1_val = (MIN_TYP_MAX(ld_param: NULL, NULL, 10.5k);
ricc_val = (MIN_TYP_MAX(ld_param: NULL, 833, 525);
LOAD PRE_LD DATA_LD CLK_LD CLR_LD = (v0=vol_param, r0=r0_val,
    v1=voh_param, r1=r1_val, io=1e9, t=1p);
LOAD VCC_LD = (v0=gnd_param, r0=ricc_val, t=1p);

```

See Also

IO_PAIRS, DRIVE

MATH FUNCTIONS

Function	Description	Example
POW	power	X= (12 POW(3));
ABS	absolute value	X= (ABS(-12));
SQRT	square-root	X= (SQRT(2));
EXP	exponent	X= (EXP(10));
LOG	natural log	X= (LOG(0.1));
LOG10	log base 10	X= (LOG10(0.1));
SIN	sine	X= (SIN(0.1));
COS	cosine	X= (COS(0.1));
TAN	tangent	X= (TAN(0.1));
ASIN	arc sine	X= (ASIN(0.1));
ACOS	arc cosine	X= (ACOS(0.1));
ATAN	arc tangent	X= (ATAN(0.1));
HSIN	hyperbolic sine	X= (HSIN(0.1));
HCOS	hyperbolic cosine	X= (HCOS(0.1));
HTAN	hyperbolic tangent	X= (HTAN(0.1));

See Also

OPERATORS

MESSAGE

Displays a message without pausing.

General Form

```
MESSAGE(" <message> "[ , <value/pin>... ] );
```

Parameters

<message>	Message string including formatting characters as needed.
<value>	Variable or constant value.
<pin>	Pin name or index to pin variable.

Use

The *MESSAGE* statement is used to output the information specified by the <message> string. It does *not* interrupt the simulation. The message is displayed in the XSpice window during simulation.

Notes

A format string in *MESSAGE* is similar to a format that may be used in a printf statement in C. Valid formatting characters include (but are not limited to):

\t	tab
\n	new line
\r	carriage return
%d	Decimal display for short variable or current input/output state
%D	Decimal display for short variable or old input/output state
%x	Hex display for short variable or current input/output state
%X	Hex display for short variable or old input/output state
%c	Character display for short variable or current input/output state
%C	Character display for short variable or old input/output state

%e	Exponential display for real variable
%f	Floating point engineering display for real variable
%g	Short display (%e or %f) for real variable
%s	String constant display. The <i>only</i> valid string constants are:
INSTANCE	The present SimCode device instance name.
FUNC	The present SimCode device function name.
FILE	The present SimCode device file name.

Examples

```
MESSAGE("time\t\tCLK\tDATA\tQ\tQN");
MESSAGE("device instance= %s",INSTANCE);
MESSAGE("%.3e\t%d\t%d\t%d",present_time,CLK,DATA,Q,QN);
```

See Also

PROMPT

MIN_TYP_MAX

Returns value from MIN_TYP_MAX look-up table.

General Form

```
MIN_TYP_MAX(<index>: <min>, <typ>, <max>);
```

Parameters

<index>	Input variable (index to select min, typ or max values).
<min>	Minimum databook value.
<typ>	Typical databook value.
<max>	Maximum databook value.

Use

The *MIN_TYP_MAX* function is similar to the *SELECT_VALUE* function except that three (3) values/variables *must* be entered. The keyword “NULL” can be

substituted for one or two unknown values. If a predefined integer variable (see *INTEGERS*) is used as the <index>, unknown (NULL) values are calculated from the known values as follows:

Known Values Formula

<min>, <max>	$\text{typical} = (\text{<max>} + \text{<min>}) / 2;$
<min> only	$\text{typical} = (\text{<min>} / \text{<min scale factor>})$ $\text{maximum} = (\text{<min>} / \text{<min scale factor>}) * \text{<max scale factor>}$
<typ> only	$\text{minimum} = (\text{<typ>} * \text{<min scale factor>})$ $\text{maximum} = (\text{<typ>} * \text{<max scale factor>})$
<max> only	$\text{minimum} = (\text{<max>} / \text{<max scale factor>}) * \text{<min scale factor>}$ $\text{typical} = (\text{<max>} / \text{<max scale factor>})$

Notes

If <index> is not one of the predefined variables listed below, then <min scale factor> = 0.5 and <max scale factor> = 1.5. The <min scale factor> and <max scale factor> for each of these predefined variables can be changed in CircuitMaker’s Analog Options dialog box. The <min scale factor> and <max scale factors> are reversed for *ld_param*, *drv_param* and *i_param* because these parameters control a resistance value rather than a current value (i.e., maximum load equates to minimum resistance.)

Variable	Spice Option	Parameter	Default
<i>tp_param</i>	PROPMNS	<min scale factor>	0.5
<i>tp_param</i>	PROPMXS	<max scale factor>	1.5
<i>tt_param</i>	TRANMNS	<min scale factor>	0.5
<i>tt_param</i>	TRANMXS	<max scale factor>	1.5
<i>ld_param</i>	LOADMNS	<min scale factor>	1.5
<i>ld_param</i>	LOADMXS	<max scale factor>	0.5
<i>drv_param</i>	DRIVEMNS	<min scale factor>	1.5
<i>drv_param</i>	DRIVEMXS	<max scale factor>	0.5
<i>i_param</i>	CURRENTMNS	<min scale factor>	1.5

<i>i_param</i>	CURRENTMXS	<max scale factor>	0.5
<i>vth_param</i>	VTHMNS	<min scale factor>	0.5
<i>vth_param</i>	VTHMXS	<max scale factor>	1.5
<i>user_param</i>	USERMNS	<min scale factor>	0.5
<i>user_param</i>	USERMXS	<max scale factor>	1.5

Examples

```
tplh_val = (MIN_TYP_MAX(tp_param: NULL, 5n, NULL));
```

In this example, if we assume that PROPMNS and PROPMXS are set to their default values, then:

if *tp_param* = 1, then *tplh_val* = 2.5n

if *tp_param* = 2, then *tplh_val* = 5n

if *tp_param* = 3, then *tplh_val* = 10n

```
ricch_val = (MIN_TYP_MAX(i_param: NULL, 2500, 1250));
```

In this example, if we assume that CURRENTMNS and CURRENTMXS are set to their default values, then:

if *i_param* = 1, then *ricch_val* = 5000

if *i_param* = 2, then *ricch_val* = 2500

if *i_param* = 3, then *ricch_val* = 1250

See Also

INTEGERS, *SELECT_VALUE*

NO_CHANGE

Leaves output state of I/O pins unchanged.

General Form

```
NO_CHANGE <output> [<output> ...];
```

Parameters

<output> Name of or variable index to the output pin.

Use

Use the *NO_CHANGE* function to indicate no-change for specified output pins. Use this statement on bi-directional pins when the bi-directional pin is being treated as an input.

Notes

Pin names and variables *cannot* be mixed in the same *NO_CHANGE* statement. References to outputs must be either all pin names or all variable names.

Example

```
NO_CHANGE Q1 Q2 Q3 Q4;
```

NUMBER

Returns number based on binary weighted pin states.

General Form

```
NUMBER(<MSB pin>, [<pin>, ...] <LSB pin> );
```

Parameters

<pin> Name of or index to a pin.

Use

The *NUMBER* function returns a short integer that represents the decimal value of the binary number represented by the list of <pin>. Each bit (represented by a <pin>) is set to 1 if the <pin> is non-zero, otherwise it is set to 0.

Notes

The first <pin> in the list represents the most-significant-bit (MSB) and the last <pin> in the list represents the least-significant-bit (LSB).

Example

```
A = (NUMBER(D3,D2,D1,D0));
```

In this example, if D3 is HIGH, and D2, D1 and D0 are LOW (1000_2), then $A = 8$.

OPERATORS

Assignment Operator

= Equals (sets a variable or output pin to a value or state).

Math Operators

+ Add
- Subtract
* Multiply
/ Divide

Unary Operators

~ Logical not
! Bitwise complement

Logical Operators

&& AND
|| OR
^^ XOR

Bitwise Operators

& AND
| OR
^ XOR
<< Shift left
>> Shift right

Relative Comparators

= Equal
!= Not equal
< Less than
<= Less than or equal to
> greater than
>= greater than or equal to

Use

Operators are used to set and manipulate variables and expressions.

Notes

Expressions must enclosed within parentheses (). Expressions are *always* evaluated from left to right within parentheses. You should use parentheses to set precedence within an expression. When using the Unary Operators on values, variables, expressions, etc. the values, variables, expressions, etc. must be in parentheses ().

Examples

```

clk_twl = (25n);
reg = (reg + 1);
vx = (vol_param - 10m);
C = (A * B);
val = (xval / 2);
X = (A && ~(B));
Y = (!X); //if X=1 then Y=FFFFFFFE
A = (X & 1); //if X=1 then A=1, if X=2 then A=0
B = (X | 8); //if X=1 then B=9, if X=2 then B=10
C = (X >> 2); //if X=1 then C=0, if X=2 then C=0
D = (2 >> X); //if X=1 then D=1, if X=2 then D=0
E = (X << 2); //if X=1 then E=4, if X=2 then E=8
F = (2 << X); //if X=1 then F=4, if X=2 then F=8
IF (A >= B) THEN ...
IF ((A < 2) && (B > 3)) THEN ...
IF ((C < 2) || (X > 4)) THEN ...

```

See Also

MATH FUNCTIONS

OUTPUTS

Declares output pins (pins that drive or load the circuit).

General Form

```
OUTPUTS <output pin>[, <output pin>, ...];
```

Parameters

<output pin> Name of the output pin.

Use

The *OUTPUTS* data type is used to define the pins which affect the operation of circuitry external to the device. These generally include input, output, I/O and power pins. Input and power pins are included in this list because their presence constitutes a load on the driving circuitry.

Notes

Output pin names *must* begin with a letter and be defined before they are used.

Example

```
OUTPUTS VCC_LD, PRE_LD, DATA_LD, CLK_LD,  
        CLR_LD, QN, Q;
```

See Also

INPUTS, IO_PAIRS, PWR_GND_PINS

PARAM_SET

Determines if a predefined SimCode param has been set.

General Form

```
PARAM_SET(<param var>)
```

Parameters

<param var> SimCode model definition parameter.

Use

The *PARAM_SET* function is used to determine if a parameter in the SimCode model definition has been set. It returns 1 if the specified parameter was set (e.g., vil_param=0.8) otherwise it returns 0.

Notes

See *INTEGER* and *REAL* declarations for a list of SimCode model definition parameters and their associated variable names.

Example

```
A = PARAM_SET(ld_param);  
IF (PARAM_SET(voh_param)) THEN ...
```

See Also

INTEGERS, REALS

PROMPT

Pauses simulation and displays a message.

General Form

```
PROMPT(" <message>" [ , <value/pin>... ] );
```

Parameters

<message>	Message string including formatting characters as needed.
<value>	Variable or constant value.
<pin>	Pin name or index to pin variable.

Use

The *PROMPT* statement is used to stop simulation and display the information specified by the <message> string. The message is displayed in the XSpice window during simulation. The user must click on a button to continue execution of the SimCode.

Notes

A format string in *PROMPT* is similar to a format that may be used in a printf statement in C. Valid formatting characters include (but are not limited to):

\t	tab
\n	new line
\r	carriage return
%d	Decimal display for short variable or current input/output state.
%D	Decimal display for short variable or old input/output state.
%x	Hex display for short variable or current input/output state.
%X	Hex display for short variable or old input/output state.
%c	Character display for short variable or current input/output state.

%C	Character display for short variable or old input/output state.						
%e	Exponential display for real variable.						
%f	Floating point engineering display for real variable.						
%g	Short display (%e or %f) for real variable.						
%s	String constant display. The <i>only</i> valid string constants are: <table><tr><td>INSTANCE</td><td>The present SimCode device instance name.</td></tr><tr><td>FUNC</td><td>The present SimCode device function name.</td></tr><tr><td>FILE</td><td>The present SimCode device file name.</td></tr></table>	INSTANCE	The present SimCode device instance name.	FUNC	The present SimCode device function name.	FILE	The present SimCode device file name.
INSTANCE	The present SimCode device instance name.						
FUNC	The present SimCode device function name.						
FILE	The present SimCode device file name.						

Example

```
PROMPT("input=%d time=%f device=%s", D1, t1, INSTANCE);
```

See Also

MESSAGE

PWL_TABLE

Returns value from interpolative look-up table.

General Form

```
PWL_TABLE (<IN var>:
  <IN1>, <OUT1>, <IN2>, <OUT2>[ , . . . <OUTn>, <OUTn> ] )
```

Parameters

<IN var>	input variable (integer or real)
<INx>	input compare value
<OUTx>	output value at <INx>

Use

This piece-wise-linear function is essentially a look-up table. The value of <IN var> is used to look up an entry in the table which consists of pairs of values. The first value in each pair is an input compare value and the second value is the corresponding output value. If the <IN var> value is less than the first <IN> value the first <OUT> value is returned. If the <IN var> value is greater than the last <INn> value then the last <OUTn> value is returned. Linear interpolation is done between entries according to the formula:

$$\text{value} = (((\text{OUTA} - \text{OUTB}) / (\text{INA} - \text{INB})) * (\text{IN var} - \text{INA}) + \text{OUTA})$$

where <IN var> falls between the input compare values INA and INB. The actual output value will fall between output values OUTA and OUTB.

Notes

Two or more IN/OUT data value pairs must be entered and the IN values must be entered in ascending order. There is no limit to the maximum number of IN/OUT data pairs that can be entered.

Example

```
twh = (PWL_TABLE(var: 5, 180n, 10, 120n, 15, 80n));
```

In this example, if var = 10 then twh = 120n and if var = 12 then twh = 104.

See Also

SELECT_VALUE

PWR_GND_PINS

Declares power and ground pins; records supply voltage.

General Form

```
PWR_GND_PINS (<pwrpin>, <gndpin>);
```

Parameters

<pwrpin> name of the power pin

<gndpin> name of the ground pin

Use

The *PWR_GND_PINS* statement defines which of the *INPUTS* pins are power and ground and sets the Power and Ground parameters of the device to absolute voltages as follows:

pwr_param = voltage on <pwrpin>

gnd_param = voltage on <gndpin>

Notes

This statement can only be used once in the SimCode. Only one pin can be defined for power and one for ground.

Example

```
PWR_GND_PINS (VCC, GND);
```

See Also

INPUTS, *OUTPUTS*, *REALS*, *VIL_VIH_PERCENT*,
SUPPLY_MIN_MAX

READ_DATA

Reads data from an ASCII file into arrays.

General Form

```
READ_DATA(<array>[, <array>, ...])
```

Parameters

<array> Name of the array into which the value is placed.

Use

The *READ_DATA* function opens the file specified by the “data=” parameter in the device’s .MODEL statement and reads ASCII text data. The number and type (integer/real) of the values per line that will be read is based on the number and type of array variables that are specified in the function call. The number of data lines read is determined by the number of data lines in the specified file and/or the size of the smallest array in the function call. The *READ_DATA* function returns the number of lines read. A negative number is returned if an error is encountered:

-1	Invalid file name
-2	Can’t find file
-3	Invalid array
-4	Illegal array access
-5	Data type
-6	Expected data value

Notes

Multiple values per line in the data file must be separated by commas. The real values in the data file *must* be in scientific notation. The device’s .MODEL statement which contains the “data=” parameter must be placed in the device symbol’s .MOD file.

Example

MYDEVICE.MOD file:

```
.MODEL AMYDEVICE XSIMCODE(file="{MODEL_PATH}MYDEVICES.SCB"  
+ func=MyDevice data="{MODEL_PATH}MYDEVICE.DAT" {mntytux})
```

MYDEVICE.DAT file:

```
8, 8E-6  
9, 9E-6  
10, 1E-5  
11, 1.1E-5
```

MyDevice SimCode:

```
nlines = READ_DATA(int_array, real_array);
```

This example opens a file called MYDEVICE.DAT in the Models directory. It reads 2 columns of data from the file where the first column contains integer values and the second column contains real values. If the arrays are declared as `int_array[3]` and `real_array[5]` then only the first 3 data lines will be read and `nlines` will be set to 3.

REALS

Declares real variables and arrays.

General Form

```
REALS <var>[ , <var>, ... ];
```

Parameters

<var> name of the variable

Use

The *REALS* data type is used to define real variables and arrays.

Notes

Real variables and arrays *must* begin with a letter and be defined before they are used. Real arrays are defined by following the array name with a left bracket ([), an integer number which defines the size of the array, and a right bracket (]). Real arrays can be set and/or used in expressions.

The following are reserved SimCode real variables which do not need to be declared:

Variable	Use	Digital Model Parameter
<i>vil_param</i>	low input state value	VIL value
<i>vih_param</i>	high input state value	VIH value
<i>vol_param</i>	low output state value	VOL value
<i>voH_param</i>	high output state value	VOH value
<i>v3s_param</i>	tri-state output state value	N/A
<i>rol_param</i>	low output strength value	N/A
<i>roh_param</i>	high output strength value	N/A
<i>r3s_param</i>	tri-state output strength value	N/A
<i>pwr_param</i>	voltage on power pin	PWR value
<i>gnd_param</i>	voltage on ground pin	GND value
<i>present_time</i>	present simulation time	N/A
<i>previous_time</i>	previous simulation time	N/A
<i>sim_temp</i>	circuit operating temperature	N/A (Spice Option: TEMP)

The Digital Model Parameter can be set independently for each digital device in the Digital Model Parameters dialog box. If the variable is set explicitly in the SimCode, that setting will override all other settings.

The values of *pwr_param* and *gnd_param* are set each time the *PWR_GND_PINS* statement is executed. The value of *present_time* and *previous_time* are set each time the time step changes. The value of *sim_temp* is the current operating temperature of the circuit which can be set from the Spice Option “TEMP”.

Example

```
REALS tplh_val, tphl_val, ricc_val, vbias, values[64];
```

See Also

PWR_GND_PIN, *VIL_VIH_VALUE*, *VIL_VIH_PERCENT*,
VOL_VOH_MIN

RECOVER

Tests inputs for recovery time violations.

General Form

```
RECOVER(<clk input> = {LH}|{HL} <mr input> [<mr input> ...]
      {TREC=<time>}|{TRECL=<time> TRECH=<time>} [ "<message>" ]);
```

Parameters

<clk input>	Name of or index to the input clock/reference pin under test
<mr input>	Name of or index to the input set/reset pin under test.
<i>TREC</i>	Recovery time for both low and high going <mr pin>.
<i>TRECL</i>	Recovery time for low going <mr pin>.
<i>TRECH</i>	Recovery time for high going <mr pin>.
<message>	Text string that will be displayed if a warning occurs.

Use

The *RECOVER* function compares the time difference between a level change (LH or HL) on the <clk input> and a level change on the <mr input> to a specified test time. *RECOVER* test times are specified jointly using *TREC=<time>* (which sets *TRECL* and *TRECH* to the same value) or individually using *TRECL=<time>* and *TRECH=<time>*. If the compare time is less than the specified <time> a warning will be displayed during simulation. An optional <message> string can be included in the *RECOVER* statement which will be output if a warning is displayed.

Notes

Databook specifications should be used with this function. *TRECL=<time>* and *TRECH=<time>* can be entered in the same *RECOVER* test. The *RECOVER* test will be made only if the state of the <mr input> matches the time parameter (*TRECL=LOW*, *TRECH=HIGH*) when the <clk input> makes the specified transition (LH or HL). For example, if <clk input> = LH and *TRECL* is specified then the <mr input> must be LOW when the <clk input> goes from LOW to HIGH for a *RECOVER* test to be made. Pin names and variables *can* be mixed in the same *RECOVER* statement.

Example

```
RECOVER(CLK=LH PRE CLR TREC=trec_val
        "CLK->PRE or CLR");
```

RETURN

Returns from a subroutine in the SimCode

General Form

```
RETURN;
```

Use

The *RETURN* instruction is used to return program flow to the instruction that followed the last *GOSUB* instruction.

See Also

GOSUB

SELECT_VALUE

Returns value from simple look-up table.

General Form

```
SELECT_VALUE (<index>: <val/pin/var>,
              <val/pin/var>[, <val/pin/var>, ...]);
```

Parameters

<index> input variable (index to <val/pin/var>)

<val/pin/var> output value, pin or variable

Use

The *SELECT_VALUE* function returns the value of the number or variable indicated by the value of the index variable.

Notes

The number of values and/or variables used is not limited.

Example

```
A = (SELECT_VALUE(B: 16, 8, 4, 2, 1));
In this example, if B = 2 then A = 8 (the 2nd value).
```

See Also

PWL_TABLE, *MIN_TYP_MAX*

SETUP_HOLD

Tests inputs for setup and hold time violations

General Form

```
SETUP_HOLD(<clk input> = {LH}|{HL}
  <data input> [<data input> ...]
  {TS=<time>}|{TSL=<time> TSH=<time>}
  {TH=<time>}|{THL=<time> THH=<time>} ["<message>"];
```

Parameters

<clk input>	Name of or index to the input clock/reference pin under test.
<data input>	Name of or index to the input data pin under test.
<i>TS</i>	Setup time for both low and high going <data input>.
<i>TSL</i>	Setup time for low going <data input>.
<i>TSH</i>	Setup time for high going <data input>.
<i>TH</i>	Hold time for both low and high going <data input>.
<i>THL</i>	Hold time for high going <data input>.
<i>THH</i>	Hold time for low going <data input>.
<message>	Text string that will be displayed if a warning occurs.

Use

The *SETUP_HOLD* function compares the time difference between a level change (LH or HL) on the <clk input> and a level change on the <data input> to a specified test time. *SETUP* test times are specified jointly using *TS=<time>* (which sets *TSL* and *TSH* to the same value) or individually using *TSL=<time>* and *TSH=<time>*. *HOLD* test times are specified jointly using *TH=<time>* (which sets *THL* and *THH* to the same value) or individually using *THL=<time>* and *THH=<time>*. If the compare time is less than the specified <time> a **WARNING** will be displayed. An optional <message> string can be included in a *SETUP_HOLD* statement which will be output if a **WARNING** is displayed.

Notes

Databook specifications should be used with this function. TSL=<time>, TSH=<time>, THL=<time> and THH=<time> can be entered in the same *SETUP_HOLD* statement. The SETUP and/or HOLD test will be made only if the state of the <data input> matches the time parameter (TSL or THL=LOW, TSH or THH=HIGH) when the <clk input> makes the specified transition (LH or HL). For example, if <clk input>=LH and TSL is specified, then the <data input> must be LOW when the <clk input> goes from LOW to HIGH for a SETUP test to be made. Pin names and variables *can* be mixed in the same *SETUP_HOLD* statement.

Example

```
SETUP_HOLD(CLK=LH DATA Ts=ts_val Th=th_val
           "CLK->DATA");
```

STATE

Sets outputs to the declared logic state.

General Form 1

```
STATE <output> [<output>...] = (<expression>);
```

General Form 2

```
STATE <output> [<output>...] =
    {ZERO} | {ONE} | {UNKNOWN};
```

Parameters

<output>	Name of or variable index to the output pin.
<expression>	Any expression to be compared to VIL or VIH.

Use

The state of an output pin is determined by its level and its strength. The *STATE* command sets the level and strength for one or more output pins or variables. If <expression> is less than or equal to *vil_param*, the output will be set to ZERO. If <expression> is greater than or equal to *vih_param*, the output will be set to ONE. Otherwise, the output will be set to UNKNOWN. The level and strength values are set according to the state:

<expression>	State	Level	Strength
$\leq vol_param$	ZERO	vol_param	rol_param
$\geq voh_param$	ONE	voh_param	roh_param
other	UNKNOWN	$v3s_param$	$r3s_param$

Notes

Output pins can be specified by using the output pin name or by an integer variable that contains the *index* of an output pin. Pin and variable names *cannot* be mixed in the same *STATE* command. References to outputs must be either all pin names or all variable names.

Examples

```
STATE Q = ONE;
STATE Q1 Q2 Q3 Q4 = ZERO;
STATE OUT = ((1+2)/3);
```

In the last example, OUT will be:

ZERO if $vil_param > 1$

UNKNOWN if $vil_param < 1$ and $vih_param > 1$

ONE if $vih_param < 1$

See Also

REALS, STATE_BIT, LEVEL, STRENGTH, TABLE, EXT_TABLE

STATE_BIT

Sets outputs to binary weighted logic states.

General Form

```
STATE_BIT <output> [<output> ...] = (<expression>) ;
```

Parameters

<output> name of or variable index to the output pin

<expression> any expression which can be bitwise
matched with the listed outputs

Use

The state of an output pin is determined by its level and its strength. The *STATE_BIT* command is used to set the level and strength for one or more output pins based on the value of the <expression>. The state of the first pin listed is set according to the first (least-significant-bit) of the expression's value, the state of the second pin listed is set according to second bit of the expression's value, and so on. The level and strength values are set by the bit's value:

Bit Value	State	Level	Strength
0	ZERO	<i>vol_param</i>	<i>rol_param</i>
1	ONE	<i>voh_param</i>	<i>roh_param</i>

Notes

Output pins can be specified by using the output pin name or by an integer variable that contains the *index* of an output pin. Pin and variable names *cannot* be mixed in the same *STATE_BIT* statement. References to outputs must be either all pin names or all variable names. The maximum number of output pins/vars is limited to 16.

Example

```
STATE_BIT Q1 Q2 Q3 Q4 = (internal_reg);
```

In this example, if *internal_reg* = 11 (1011 binary) then Q1 (LSB) = ONE, Q2 = ONE, Q3 = ZERO and Q4 (MSB) = ONE.

See Also

REALS, STATE, LEVEL, STRENGTH, TABLE, EXT_TABLE

STEP_OFF

Turns off the SimCode trace mode.

General Form

STEP_OFF

Use

The *STEP_OFF* statement turns off the SimCode TRACE mode.

See Also

STEP_ON

STEP_ON

Turns on the SimCode trace mode.

General Form

STEP_ON

Use

The *STEP_ON* statement turns on the SimCode TRACE mode. This causes the SimCode to display the Program Counter (PC) number and each SimCode instruction before it is executed.

See Also

STEP_OFF

STRENGTH

Sets the strength of the output state.

General Form 1

```
STRENGTH <output> [<output> ...] = (<expression>);
```

General Form 2

```
STRENGTH <output> [<output> ...] = {STRONG} | {HI_IMPEDANCE};
```

Parameters

<output>	Name of or variable index to the output pin.
<expression>	Any expression to be used directly as a strength.

Use

The state of an output pin is determined by its level and its strength. Use the *STRENGTH* command to set the strength of one or more output pins.

Value	State	Strength
STRONG	ZERO	<i>rol_param</i>
STRONG	ONE	<i>roh_param</i>
HI_IMPEDANCE	N/A	<i>r3s_param</i>
<expression>	N/A	<expression>

Notes

Output pins can be specified by using the output pin name or by an integer variable that contains the *index* of an output pin. Pin and variable names *cannot* be mixed in the same *STATE* statement. References to outputs must be either all pin names or all variable names.

See Also

REALS, STATE, STATE_BIT, LEVEL

SUPPLY_MIN_MAX

Tests supply pins for min and max supply voltage violations.

General Form

```
SUPPLY_MIN_MAX(<min value>, <max value>);
```

Parameters

<min value>	Minimum recommended power supply voltage.
<max value>	Maximum recommended power supply voltage.

Use

The *SUPPLY_MIN_MAX* function checks the voltage difference between the power and ground pins defined in *PWR_GND_PINS*. If the “WARN flag” is set in the Digital Model Parameters dialog box and the voltage difference (*pwr_param* - *gnd_param*) is less than <min value> or greater than <max value> a warning will be displayed during simulation.

Notes

Databook specifications should be used with this function. *PWR_GND_PINS* must be defined to use this function.

Example

```
SUPPLY_MIN_MAX(4.75, 5.25);
```

See Also

INTEGERS, *PWR_GND_PINS*

TABLE

Sets output logic states based on truth table.

General Form

```
TABLE <line>
<input> [<input> ...] <output pin> [<output pin> ...]
<input state> [<input state> ...] <output state> [<output state> ...];
```

Parameters

<line>	Variable into which the line number used in the table is placed.
<input>	Name of the input pin or variable index to the input pin.
<output pin>	Name of the output pin.
<input state>	State of the individual inputs.
<output state>	State of the individual outputs based on input conditions.

Use

The *TABLE* statement operates like a truth table to set the level and strength of the specified outputs. Valid input states are:

0	low (input voltage is $\leq v_{il_param}$).
1	high (input voltage is $\geq v_{ih_param}$).
X	don't care what input voltage is.

Valid output states are:

L	ZERO (set output level to v_{ol_param})
H	ONE (set output level to v_{oh_param}).
Z	UNKNOWN (set output level to v_{3s_param}).

Output state letters can be followed by a colon and a letter to indicate strength:

s	STRONG (set output to r_{ol_param} for L and r_{oh_param} for H).
z	HI_IMPEDANCE (set output to r_{3s_param}).

If a strength character is *not* specified after an output state then STRONG will be used for L and H states and HI_IMPEDANCE will be used for Z states.

Notes

Each row is tested sequentially from top to bottom until the input conditions are met. The outputs are set for the *first* row to meet the input conditions. The <line> is set to the line number in the table that was used. If no match was made then <line> is set to 0. Input pin and variable names *cannot* be mixed in the same TABLE statement. References to inputs must be either all pin names or all variable names.

Example

```
TABLE tblIndex
INA   INB   OUT
0     0     H
0     1     H
1     0     H
1     1     L;
```

This example is representative of 1/4 of a 7400 2-input NAND gate. If input pins INA and INB are both high (>= *vih_param*), OUT is set to ZERO (*vol_param*) and STRONG (*rol_param*) and tblIndex is set to 4.

See Also

REALS, STATE, STATE_BIT, EXT_TABLE

VALUE

Returns the value of the specified pin.

General Form

```
VALUE(<pin>)
```

Parameters

<pin> Name of or index to a pin.

Use

The VALUE function returns a real number that indicates the voltage level of the specified pin.

Example

```
v = (VALUE(D3));
```

VIL_VIH_PERCENT

Sets VIL and VIH values to a percentage of supply voltage.

General Form

```
VIL_VIH_PERCENT (<vil %>, <vih %>);
```

Parameters

<vil %> Percentage of the supply voltage which defines vil.

<vih %> Percentage of the supply voltage which defines vih.

Use

VIL and VIH do not use a min/typ/max array to select their values, but must be declared explicitly for each digital device. The *VIL_VIH_PERCENT* statement sets the VIL and VIH parameters of the device to a percentage of the supply voltage as follows:

$$vil_param = (pwr_param - gnd_param) * <vil \%>$$
$$vih_param = (pwr_param - gnd_param) * <vih \%>$$

Notes

PWR_GND_PINS must be defined to use this function. The % values must be greater than 0 and less than 100. The *vil_param* and *vih_param* values set by *VIL_VIH_PERCENT* are overridden by any values set for “VIL value” and “VIH value” in the Digital Model Parameters dialog box.

Example

```
VIL_VIH_PERCENT(33, 67);
```

See Also

REALS, *PWR_GND_PINS*, *VIL_VIH_VALUE*

VIL_VIH_VALUE

Sets absolute VIL and VIH values.

General Form

```
VIL_VIH_VALUE (<vil>, <vih>);
```

Parameters

<vil> Absolute voltage level which defines vil.

<vih> Absolute voltage level which defines vih.

Use

VIL and VIH do not use a min/typ/max array to select their values, but must be declared explicitly for each digital device. The *VIL_VIH_VALUE* statement sets the VIL and VIH parameters of the device to absolute voltages as follows:

```
vil_param = <vil>
```

```
vih_param = <vih>
```

Notes

In order to more accurately model the actual switching characteristics of a digital input, VIL and VIH are *not* generally set to their specified databook values. The exception is the case of devices with a specified hysteresis such as the 74LS14. Typically, the hysteresis of a digital device is small, in the order of 100mV, but never 0V.

The *vil_param* and *vih_param* values set by *VIL_VIH_VALUE* are overridden by any values set for “VIL value” and “VIH value” in the Digital Model Parameters dialog box.

Example

```
VIL_VIH_VALUE(1.25, 1.35);
```

See Also

REALS, *VIL_VIH_PERCENT*

VOL_VOH_MIN

Sets VOH and VOL relative to power and ground.

General Form

```
VOL_VOH_MIN (<vol offset>, <voh offset>, <min voh-vol>);
```

Parameters

<vol offset>	Voltage offset which must be applied to ground pin voltage to get vol.
<voh offset>	Voltage offset which must be applied to power pin voltage to get voh.
<min voh-vol>	Minimum allowed difference between voh and vol.

Use

VOL and VOH do not use a min/typ/max array to select their values, but must be declared explicitly for each digital device. The *VOL_VOH_MIN* statement sets the VOL and VOH parameters of the device as follows:

$$vol_param = gnd_param + \text{<vol offset>}$$

$$voh_param = pwr_param + \text{<voh offset>}$$

Notes

In order to more accurately model the actual characteristics of a digital output, VOH is *not* generally set to its specified databook value. The reason for this deviation is that databook values for VOH are specified for maximum IOH load. In digital SimCode, VOL and VOH represent an *unloaded* output voltage.

PWR_GND_PINS must be defined to use this function. The *vol_param* and *voh_param* values set by *VOL_VOH_MIN* are overridden by any values set for “VOL value” and “VOH value” in the Digital Model Parameters dialog box. These are offset values rather than absolute voltages. The <voh offset> is negative so that when added to *pwr_param*, the resulting VOH will not be greater than *pwr_param*. If the difference between the resulting *vol_param* and *voh_param* is less than <min voh-vol>, then *vol_param* will be set to the value of *gnd_param* and *voh_param* will be set to *gnd_param* + <min voh-vol>.

Example

```
VOL_VOH_MIN(0.2, -0.4, 0.1);
```

In this example:

- 1 If *gnd_param* = 0V and *pwr_param* = 5.0V, then
vol_param = 0.2V and *voh_param* = 4.6V
- 2 If *gnd_param* = 0V and *pwr_param* = 0.5V, then
vol_param = 0.0V and *voh_param* = 0.1V

See Also

REALS, PWR_GND_PINS

WHILE ... DO

Conditionally controls looping in the SimCode.

General Form

```
WHILE (<expression>) DO BEGIN ... END;
```

Parameters

<expression> Any expression that can be evaluated as true or false

Use

The *WHILE ... DO* statement is used to loop through a section of SimCode until <expression> evaluates to false.

Notes

Program flow will remain in a loop between the *BEGIN* and *END* statements until <expression> evaluates to false, then program flow resumes after the *END* statement.

Examples

```
i = 1;  
WHILE (i <= 5) DO  
  BEGIN  
    data[i] = data[i + 1];  
    i = i + 1;  
  END;
```

See Also

IF ... THEN

WIDTH

Tests inputs for minimum pulse width violations.

General Form

```
WIDTH(<input> [<input>...]  
      {TWL=<time>}} {TWH=<time>} [ "<message>" ] ;
```

Parameters

<input>	Name of or variable index to the input pin under test.
<i>TWL</i>	Width of a low going pulse.
<i>TWH</i>	Width of a high going pulse.
<message>	Text string that will be displayed if a warning occurs.

Use

The *WIDTH* function compares the pulse width on each <ipin> to the specified test *WIDTH* times. A low level test time is specified using *TWL*=<time> while a high level test time is specified using *TWH*=<time>. If the compare time is less than the specified <time> a **WARNING** will be displayed. An optional <message> string can be included in the *WIDTH* statement which will be output if a **WARNING** is displayed.

Notes

Databook specifications should be used with this function. The input pins can be input pin names and/or integer variables that contain an index value to an input pin. Pin names and variables *can* be mixed in the same *WIDTH* statement.

Examples

```
WIDTH(CLK TWL=clk_twl TWH=clk_twh "CLK");  
WIDTH(PRE CLR TWL= pre_clr_twl "PRE or CLR");
```

WIDTH_TIME

Returns last pulse width encountered on specified pin.

General Form

```
WIDTH_TIME(<input>)
```

Parameters

<input> Name of or index to an input pin.

Use

This function returns a real value that indicates the last pulse width encountered on the specified <input>.

Example

```
PW = (WIDTH_TIME(CP2));
```

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