cadence

Graphical Output for the Verilog Product Family

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Introduction

This chapter contains the following sections:

Who Should Read This Manual?

The Graphical Output tool for the Verilog® product family requires that you are an advanced Verilog user. This manual does not cover any of the Verilog features, nor does it instruct you in using Verilog. If you are not an advanced and experienced Verilog user, we suggest that you familiarize yourself with the Verilog products before attempting to use the Graphical Output tool.

What This Manual Contains

This manual describes the graphical display features of the Verilog product family. These features are implemented by a set of system tasks which can be called from within a Verilog description. These system tasks create Graphical Output windows where, as simulation time progresses, the values of the arguments passed to these tasks are monitored. The three forms of graphical displays presently available are:

- Waveform
- Bar Graph
- Register (a page-oriented string display)

The waveform output mechanism is implemented by the `$gr_waves` system task. The display it produces is useful for viewing data values with respect to time. The formats in which data is displayed include binary, octal, hexadecimal, decimal, real, and string. Additionally, X

and Z values are represented graphically. The waveform display feature is described in Chapter 2, “Waveform Output.”

The register output mechanism is implemented by the `$gr_regs` system task. The display it produces is useful for viewing the contents of registers in a page-oriented form. String and data arguments are specified in a manner similar to that used with `$display` and `$monitor`, but the output stays in a stationary position in the Graphical Output window instead of scrolling. The register display feature is described in Chapter 3, “REGS Window Output.”

The Bar Graph output mechanism is implemented by the `$gr_bars` system task. The display it produces is useful for viewing data when relative magnitude is important. A set of charts is defined, each consisting of one or more bars. Several charts can be displayed at once. The bar graph feature is described in Chapter 4, “Bar Graph Output.”

Each of these output mechanisms creates its own Graphical Output window. These windows can be manipulated (moved, resized, etc.) using the window commands of the host machine. The idiosyncrasies of each machine are described in Chapter 8, “Limitations.”

All of the product-specific operations performed in the Graphical Output windows are recorded in the standard Verilog key file, and are performed if the simulation is replayed using the key file as a command input file. The system window operations (moving, resizing, etc.) are independent of the application and are not saved in the key file. Thus, they will not be performed automatically during a replay.

The `gr_vlog` object module contains the graphical output mechanism that Verilog uses. It is linked with the Verilog executable file and shipped with platforms that support Verilog graphics capability.

New Features and Enhancements

This document describes several new features and enhancements to be found in the Graphical Output for the Verilog product family. Some of these new features are described below.

Real Numbers and Timescales

Support for real numbers and timescales has been added to this release. This manual has been updated to reflect these changes.

It is recommended that you become familiar with the real number and timescale features in Verilog-XL before reading this document—in particular, the `$timeformat` system task and the `‘timescale` compiler directive.

All three forms of graphical output (WAVES, REGS and BARS) support real numbers. However, only the Waveform and Reg window displays support timescales. The Bar Graph output does not support timescales since it is event-driven, not time-driven. Additionally, the `$ps_waves` system task supports both real numbers and timescales.

64-bit Times

This release provides graphical support for 64-bit times. Additionally, the waveform graphical representations of partial unknown and high-impedance buses have been enhanced.

Support for New Windows Behavior

This release provides enhanced support for Graphical Output window resizing and placement, as well as improved font support, new mouse behavior, and a new system task for customizing the colors of graphic objects.

X-Windows Performance Enhancements

The X-Windows version of Verilog Graphical Output could use an excessive amount of network capacity when running on a high performance platform. This has been improved. In addition, the code no longer issues drawing commands to a window that is an icon or is totally covered.

Overlap in Multi-Page Plots

Multi-page plots now have a small overlap from one page to the next. Scaling of plots is still based on the current scale of the display window.

Faster Refresh of the WAVES Window

To increase window refresh speed, Graphical Output now completely draws each wave before proceeding to the next. Previously, the window was refreshed from right to left.

Change in Definition of $gr_waves_memsize

Previously Graphical Output used the default allocation of 500,000 bytes of memory, or any amount specified using `$gr_waves_memsize`, as a maximum amount of memory to be allocated. Now the default amount or the amount you specify with `$gr_waves_memsize` is used as a guideline for Graphical Output memory management.

The Graphical Output memory manager attempts to stay within this guideline by deleting earlier Graphical Output history up to the last 50 transition times. Occasionally, it will not find an appropriately sized memory cell in earlier history for new data. When this occurs, the Graphical Output memory manager allocates memory, in 1 kbyte units, beyond the specified guideline. Graphical Output issues a message after every 10 allocations (10 kbytes). This message indicates the current amount of allocated Graphical Output memory. The following is an example of the allocation message:

```
> Graphics: No proper size element found at time 100.
> Increasing waves memory allocation to 320480.
```

If the allocation message appears repeatedly, increase the amount of allocated Graphical Output memory using `$gr_waves_memsize`. If, after allocating a large amount of memory, this message still appears repeatedly, check the circuit activity for oscillating signals.

Change in Initial WAVES Window Scale Factor

When a WAVES window is invoked, Graphical Output sets the initial scale factor at 1000 simulator time units per window. After 50 time units where transitions have occurred on monitored signals, Graphical Output recalculates the scale factor to fit these 50 transitions on the window. However, any scale factor you set manually (using *ZOOM*) overrides this recalculation.

Improved Scroll Buttons in WAVES and REGS Windows

A pair of scroll buttons appears at each end of the Time bar on both the WAVES and REGS displays. You can move the time you want to view forward or backward by clicking on the appropriate button at either end of the time bar.

A pair of scroll buttons appears at each end of the *Group* buttons. One pair sits above the *Group* buttons, the other below them. You can scroll the WAVES display vertically by clicking on the appropriate button.

Groups can support more signals

The maximum number of signals that you assign to a group has been increased to 50 (up from 20). However, the number of useful signals in a group is limited to the size of the Current List—that is, the number of signals visible in the WAVES window. The size of the Current List depends on many factors, including the window size and font.

When you define a group using the SELECT window, the number of signals that you assign to a group is limited to those visible in the Current List—up to 50. When you define a group using the `$define_group_waves` system task, the maximum number of signals is limited to 50.

To view a signal in a selected group that is off the bottom of the WAVES window, resize the WAVES window so that it is taller. Scrolling the view of the WAVES window down might not cause the desired signal to move into the window, however.

Default-size WAVES window displays 21 signals

The default-size WAVES window now displays 21 signals (up from 20). The data structure allows up to 50 signals to display when the window is resized.

Limited support for $save and $restart

On execution of a `$save`, Graphical Output saves the state of the Graphical Output windows for restoration on a subsequent `$restart`. However, the Graphical Output history is not saved.

For example, any signals being monitored in the WAVES window on execution of a `$save` is restored to a WAVES window on execution of a `$restart` from the saved file. Any modes, such as `$freeze_waves` and `$gr_waves_memsize`, are also restored.

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Waveform Output

Verilog provides an interactive graphics interface to display data as waveforms. Using this interface, you can continuously monitor the waveforms as the simulation progresses. When in the interactive state of Verilog, you can perform graphics operations using the mouse device. This chapter decribes the waveform displays and the system tasks that are provided to create and facilitate those displays. This chapter contains the following sections:

■ Waveform Output Quick Reference

Setting Up the Display

The `$gr_waves` system task defines the signals to be monitored graphically. When `$gr_waves` is called, a graphics window is created in the upper right-hand corner of the screen, if it does not already exist.

Syntax:

```
$gr_waves ("<signal_label>", <signal>,"<signal_label>", <signal>, ...);
```

Arguments:

<signal_label> — An ASCII string, enclosed in double quotes, which consists of a label followed by an optional format specifier. If a format specifier is used, there must be a space between the label and the format specifier. The associated *<signal>* must be the next argument. Note that only the first seven characters of the *<signal_label>* are used in the display.

<signal> — Specifies the signal to be monitored (usually a scalar variable, vector variable or a general Verilog expression). The format specifiers for this signal are of the form %*<format>*, where *<format>* can be one of the following characters:

- b — binary numeric
- o — octal numeric
- d — decimal numeric
- h — hexadecimal numeric
- s — string
- e or E — real numeric in exponential format
- f or F — real numeric in decimal format
- g or G — real numeric in exponential or decimal format, whichever format results in the shorter printed output
- t — time format

These format specifiers follow the same rules for unknowns and high-impedance values as the specifiers in the `$display` system task (refer to the *Verilog-XL Reference Manual*).

To pass format information to `$gr_waves`, put one specifier after the signal name in each signal label string argument in the system call. This syntax is described in the example below. Note that each signal label must be paired with one (and only one) signal. If the signal label contains no format specifier, the default — %h (hexadecimal) — is assumed.

Example:

If the following signals are declared

```
reg [15:0] a, b;
    wire [31:0] ml_v, dv_v, add_v;
    real i, j, ml_r, dv_r, add_r;
    reg [23:0] fn_string;
    integer loopcnt, func_sel;
    time lpstart;
```

the waveforms of the those signals can be monitored by issuing:

```
$gr_waves("func %s", fn_string,"areg %h", a, "breg %b", b, "addv %h", add_v, "mulv
%d", ml_v, "divv", dv_v, "i_rl %f", i, "j_rl %e", j, "a_rl %f", add_r, "m_rl %g",
ml_r, "d_rl %g", dv_r, "lpST %t", lpstart, "breg[0]", b[0]);
```

As simulation continues, these waveforms are updated whenever a signal value changes. Figure 2-1 on page 18 contains a sample output of this $gr_waves example. Please note that the figure incorporates subsequent examples from this chapter as well.

Subsequent calls to `$gr_waves` during a given simulation use the WAVES window currently in existence. Therefore, the signals listed in the most recent call to `$gr_waves` replace the current list of displayed signals.

Resizing the WAVES Window

Horizontal resizing of the WAVES window causes the waves to expand or contract to fill the width of the window. The width of the Time Bar and the Cursor/Marker and Δ Time areas adjust as well.

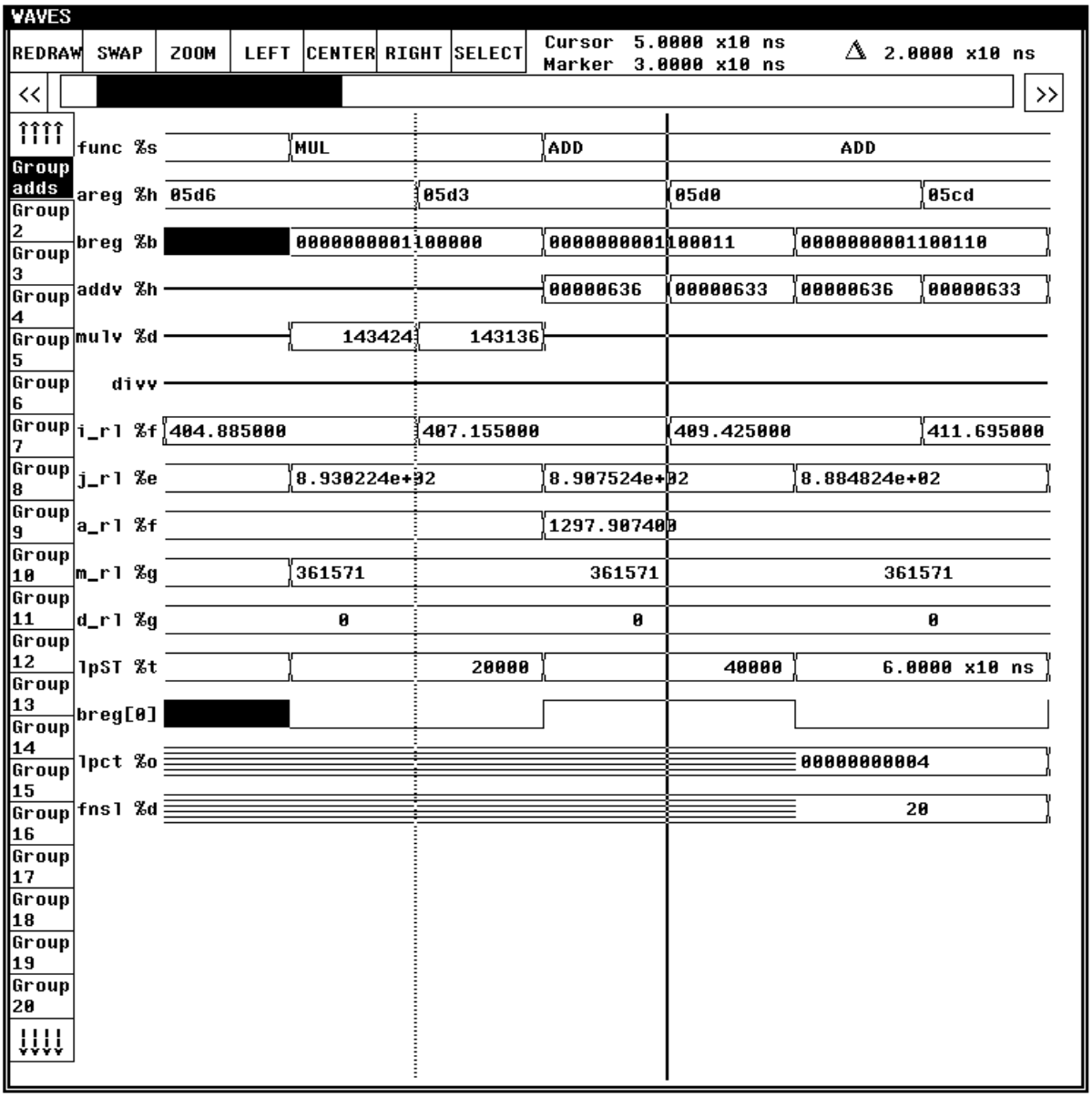
Vertical resizing of the WAVES window allows either more or fewer waves to fit on the screen. The number of visible *Group* buttons increases (to a maximum of 20) or decreases as a result of resizing. The *Scroll Up* and *Scroll Down* buttons remain positioned above and below the visible *Group* buttons as the window height changes.

The maximum window dimensions that you can obtain depends on the windowing system you use. Table 2-1 on page 18 lists these sizes.

Table 2-1 Maximum Dimensions

Windowing System	Dimensions (in pixels)
X-Windows	2048 x 2048
Sunview	1120 x 900
Apollo GPR	1200 x 800

Figure 2-1 Sample WAVES Output



If a window shrinks horizontally past the Cursor Time area, clipping occurs—that is, the window layout takes its minimum width and the right edge of the window cuts off some of the display. If the height of the WAVES window is shorter than ten *Group* buttons, clipping occurs at the bottom edge.

Interrupting WAVES Window Drawing

You can interrupt a redraw of the WAVES window by typing `Control-C` in the Verilog-XL interactive window. Verilog-XL must be in interactive mode to recognize this as a redraw interrupt.

This feature is not currently supported on Apollo™ platforms under GPR. It is supported on Apollo platforms under X Windows.

Positioning and Sizing Windows with a System Task

The `$gr_position` system task gives you the ability to specify placement and size of a Graphics window.

Syntax:

```
<gr_position_task> ::=
     $gr_position("<window_type>", <x_origin>,<y_origin>,<x_width>?,<y_height>?);
```

Arguments:

<*window_type*>	One of the following strings enclosed in double quotes: `regs`, `waves`, `bars`. These strings are case insensitive.
<*x_origin*>	The x-dimension origin location, in pixels, of the window specified by <*window_type*>. This must be a non-negative integer.
<*y_origin*>	The y-dimension origin location, in pixels, of the window specified by <*window_type*>. This must be a non-negative integer.
<*x_width*>	An optional argument used to define the width, in pixels, of the window specified by <*window_type*>. The minimum width is 50. The maximum width depends on your windowing system, as specified in Table 2-1 on page 18.

<*y_height*> An optional argument used to define the height, in pixels, of the window specified by <*window_type*>. The minimum height is 50. The maximum height depends on your windowing system, as specified in Table 2-1 on page 18.

Both <*x_origin*> and <*y_origin*> are required. The optional arguments <*x_width*> and <*y_height*> must be specified as a pair; a placeholder can not be used. If the `$gr_position` parameters do not provide <*x_width*> and <*y_height*>, `$gr_position` uses the current or default dimensions.

Under X Windows, a Graphics window can be positioned totally on, partially on, or totally off the screen. However, under Sunview™ and Apollo® GPR, windows must be fully on the screen. Therefore, under Sunview and GPR, the sum of <*x_origin*> and <*x_width*> cannot be greater than the x dimension specified in Table 2-1 on page 18. Similarly, the sum of <*y_origin*> and <*y_height*> cannot be greater than the y dimension. If either of these sums exceeds the specified value, `$gr_position` adjusts the window origin so that the whole window fits within these dimensions.

Examples:

```
$gr_position("regs",10,10,500,500);
$gr_position("waves",0,0);
```

The first example places a 500 x 500 pixel REGS window on the screen with its upper lefthand corner at pixel location (10,10). The second example places the WAVES window in the upper lefthand corner of the screen. You can schedule the `$gr_position` system task to be executed before or after calling a Graphics window.

Customizing Colors with a System Task

The `$gr_color` system task assigns new colors to specified graphics objects. The parameters consist of a list of one or more object/color pairs.

Syntax:

```
<gr_color_task> ::= $gr_color (<pair> <,<pair>>*);
<pair> ::= "<object_string>","<color_string>"
```

Arguments:

<*object_string*> One of the strings listed in Table 2-1 on page 21, enclosed in double quotes. This table also lists the default colors supplied for

each of these objects. The strings are case-insensitive, and they accept hyphens and underscores interchangeably. For example, “TIME_BUBBLE” and “Time-bubble” both specify the same object.

<color_string> One of the following strings, enclosed in double quotes. These strings are case insensitive.

beige	black	`blue`
brown	cyan	`gray`
green	magenta	`red`
white	yellow	

Table 2-2 Custom-Coloring Objects with $gr_color

Object String	Default Color
`BG` (background)	Black
`bars`	Green
`bars-divide`	Cyan
`bars-max+`	Red
`bars-names`	White
`bars-titles`	Yellow
`bars-values`	White
`bus-values`	Green
`buses`	Cyan
`cursor`	White
`FG` (foreground)	White
`marker`	Yellow
`regs` (the box in which values are displayed)	Yellow
`regs-text`	Green
`regs-time`	White
`regs-values`	Cyan

Table 2-2 Custom-Coloring Objects with $gr_color, *continued*

Object String	Default Color
`time-bubble`	Yellow
`time-labels`	Green
`time-scale`	Gray
`time-values`	Cyan
`wires`	Green
`Xs` (unknown values)	Red
`Zs` (high-impedance)	Brown

Example:

```
$gr_color ("BG", "gray",          // gray background
           "time-scale", "blue", // blue timescale
           "Buses", "yellow");   // yellow buses
```

Understanding the Default Colors

In this release, some of the brighter colors have been toned down, as follows:

- The Time scrollbar is gray, with the currently-visible time in yellow.
- Menu buttons are gray.
- Highlighted menu items, such as defined groups, are white.
- The current group is yellow.
- Fixed signals (on the SELECT window) are gray.
- Selected signals (on the SELECT window) are blue.

These colors were selected to improve readability, as well as color consistency, across all supported platforms.

X-Window Colormap Allocation Problems

The Graphical Output software currently tries to allocate 16 colormap entries. If these can not be uniquely allocated under X11, the X server returns a pointer to the closest available color. A replacement color that is not very close in value to the original color can cause display

anomalies. This colormap allocation problem can occur if other applications are running that require too many colormap entries, or if the hardware supports less than 16 colors.

Selecting Fonts

You can specify the font that the graphics display uses by setting the environment variable *VGR_FONT* to the desired font. Suggested fonts to use are as follows:

- `screen.r.14` (default)
- `screen.b.12`
- `cour.b.12`
- `serif.r.11`

If the *VGR_FONT* environment variable is not set, the default font, `screen.r.14`, is used.

For example, in a UNIX C shell, to set the graphics font to `cour.b.12`, the following should be entered in the login script or at the prompt:

```
setenv VGR_FONT cour.b.12
```

Other fonts listed in the directory `/usr/lib/fonts/fixedwidthfonts` can be used; however, larger fonts than those suggested above are not recommended, since distortions can occur.

The environment variable *VGR_FONT* is recognized under both
X Windows and Apollo GPR. Since the size of a displayed wave is proportional to the size of the font, you can fit more signals on the screen by selecting a smaller font. This is true for all systems.

Under X Windows, if this environment variable is not set, Graphical Output first searches for the font `8x13`; if this is not found, it uses the font named `fixed`, usually a 6x10 font. Fonts larger than 8x13 can cause distortions. The fonts available under X-Windows can be found in `/usr/lib/X11/fonts`.

Under Apollo GPR, if this environment variable is not set, Graphics searches for the font `f5x9`. The fonts available under GPR can be found in `/sys/dm/fonts`.

Scaling Due to Fonts

Changing the selected font can alter scaling within the Graphical Output windows. For example, if the font is made smaller, more waves fit in the WAVES window.

All the buttons in the windows rescale when fonts change. To accommodate this feature, the *Group* buttons have been modified. The default *Group* button labels now appear on one line as `GP <number>` (for example, `GP 5`). When a `group_name` is assigned to the button using `$define_group_waves`, the Graphical Output software replaces the entire *Group* button label. See "Defining Groups" on page 24 for more information on groups.

Learning a New Mouse Behavior

The right mouse button now has new behavior for the WAVES window. If you move the mouse pointer to any position in the window or on the Time bar and then click with the right mouse button, the cursor moves to that position in the WAVES display, and then the window repaints with the cursor centered in the window. This is the functional equivalent of clicking in the window or Time bar with the left mouse button and then clicking the *center* button (*CNTR*).

Using 64-Bit Times

In this release, the WAVES display provides graphical support for 64-bit simulation time values. In prior releases of Graphical Output, simulation time values could not exceed 32-bits in length even though Verilog-XL versions 1.3 and beyond support values to 64-bits. The BAR graph output does not need to support 64-bit times since it is event-driven, not time-driven.

NOTE: To use the `$gr_jumptotime` system task to jump to a time greater than 32 bits, the <*time*> argument must be expressed in the following number format (refer to the *Lexical Conventions* chapter of the *Verilog-XL Reference Manual* for an explanation of this format):

```
ss..s 'f nn..n
```

For example, to jump to time 34,000,000,000, type:

```
$gr_jumptotime(64'd34000000000);
```

Defining Groups

The `$define_group_waves` task provides the ability to group a set of signals together that have already been defined in the `$gr_waves` task and associate a group name to them. During a graphics interaction, you can select any group for display by clicking the mouse button on the menu item associated with the group.

Syntax:

```
$define_group_waves(<group_no>, "<group_name>", "<signal_label>",
     "<signal_label>", ...);
```

Arguments:

<*group_no*>	An integer value between 1 and 20.
<*group_name*>	A string, surrounded by double quotes, with a maximum of 5 characters.
<*signal_label*>	A signal label string, including the format specifier, surrounded by double quotes. This string has already been defined under the $gr_waves task. If a signal label does not match any of the labels defined in $gr_waves, then a blank space is inserted in place of that undefined signal.

Note: A maximum of 30 signals can be included in a group.

Example:

The following string groups the signals defined in the $gr_waves example.

```
$define_group_waves(1, "adds", "areg %h", "breg %b", "addv %h","i_rl %f", "j_rl
%e", "a_rl %f");
```

Here, group 1 consists of the signals a, b, add_v, i, j, and add_r, and the label *adds* appears on the menu button associated with group 1. (See Figure 2-1 on page 18.)

Freezing the Display

The $freeze_waves system task disables continuous update of the Graphical Output window. You can use this task to speed up simulation by avoiding graphics operations associated with every update of the signal values. Interrupting Verilog refreshes the window to the current status of the monitored signals and you can analyze previous simulation history using the interactive operations.

The $unfreeze_waves task reenables the continuous update of the Graphical Output window.

Syntax:

```
$freeze_waves;
```

```
$unfreeze_waves;
```

There are also system-dependent methods for improving simulation speed that can be used in place of the $freeze_waves task. On Sun workstations, closing the Graphical Output

windows inhibits drawing for improved performance. On Apollo workstations, the same effect can be achieved by overlapping other windows on top of the Graphical Output windows.

Setting the Storage Space

The `$gr_waves_memsize` system task informs Verilog of the maximum amount of memory space to be allocated for the waveform display.

Syntax:

```
$gr_waves_memsize(<size>);
```

The size argument is in bytes. Memory is requested by the waveform display as simulation progresses and value changes occur on the signals being displayed. When the maximum specified memory space has been allocated and used, the oldest data is discarded and its space is reused.

The minimum amount of space that can be allocated is 300,000 bytes. The maximum amount is limited only by the amount of virtual memory space available on the host machine. The default amount of space allocated in the absence of a call to `$gr_waves_memsize` is 500,000 bytes. This limit is set when `$gr_waves` is called. A call to `$gr_waves_memsize` after a call to `$gr_waves` can increase the amount of memory available for the waveform display, but it cannot reduce it.

Improving Simulator and Graphical Output Performance

You can reduce network traffic by up to a factor of 8 by observing the following rules:

- Use `$freeze_waves`.
- Reduce the amount of drawing by taking one of the following steps:
  - Totally obscure a REGS or BARS window by placing it under another window
  - Iconize a REGS or BARS window

Adding Signals

The `$gr_addwaves` task adds signals to the waves display.

Syntax:

```
$gr_addwaves("<signal_label>",<signal>,...);
```

This task accepts a list of signals in the same format as `$gr_waves`. The task `$gr_waves` must be executed before `$gr_addwaves`.

Example:

```
$gr_addwaves("lpct %o", loopcnt,"fnsl %d", func_sel);
```

As a result of the above `$gr_addwaves` task, the signals `loopcnt` and `func_sel` have been added to the bottom of the list of signals displayed in the waves window (see Figure 2-1 on page 18). The values of the signals added are not available in the WAVES display prior to the time they were added. If the display is scrolled, zoomed or jumped back to a time prior to the addition of these signals, they are displayed as several horizontal lines, one above the other.

Jumping to a Specified Time

The `$gr_jumptotime` task allows you to jump to a particular time in both the WAVES and REGS displays.The cursor is centered in the WAVES window at the specified time. The REGS window also jumps to the specified time and displays the appropriate values.

Syntax:

```
$gr_jumptotime(<time>);
```

Argument:

<time>	An integer or real expression assumed to be in the units of the currently active timescale, as defined by the most recently executed `$timeformat` system task.

Note: To use the `$gr_jumptotime` system task to jump to a time greater than 32 bits, the *<time>* argument must be expressed in the following number format (refer to the *Lexical Conventions* chapter of the *Verilog-XL Reference Manual* for an explanation of this format):

```
ss..s 'f nn..n
```

For example, to jump to time 34,000,000,000, type:

```
$gr_jumptotime(64'd34000000000);
```

Using the $timeformat System Task

The `$timeformat` system task is a Verilog system task which establishes the time unit for delays entered interactively, as well as the time unit, precision, suffix string, and minimum field width for time information displayed using the `%t` format specifier. The time unit, precision, suffix string, and minimum field width for the cursor, marker, and Δ times—which appear in the upper right-hand corner of the WAVES window—are also derived from the `$timeformat` system task. The same is true for the time in the upper right-hand corner of the REGS window. (Please refer to the *Verilog-XL Reference Manual* for the exact syntax and definition for the `$timeformat` system task.)

The `$timeformat` system task can appear in the Verilog code or it can be entered interactively. The most recently executed `$timeformat` system task formats the times displayed in the upper right-hand corner of the WAVES and REGS windows. If no `$timeformat` system task has been executed, the default time unit is set to the smallest precision argument of the `‘timescale` compiler directives in the source description. When the default time unit is used, no suffix string appears with the cursor, marker, and Δ times or with any variables using the`%t` format specfier. (Please refer to the *Verilog-XL Reference Manual* for more information.)

When a `$timeformat` system task is entered interactively, the times in the Graphical Output windows do not automatically reflect the change. To cause an update to occur, the RDRW button must be selected or a command must be executed which causes a redraw of the screen to occur.

The Graphical Output windows have limited space available for the display of times. If a time exceeds the available space, it is truncated on the left and preceded by a "~" to indicate that an overflow has occurred. Simulation can continue with the overflow, or a `$timeformat` system task can be executed interactively to adjust the time unit to a format which requires a smaller field width.

Example:

```
$timeformat(-8, 4, " x10 ns", 20);
```

In the example shown in Figure 2-1 on page 18, this `$timeformat` system task was executed at 60 nanoseconds. Therefore, both the times in the upper right-hand corner and the final value of the signal `lpstart` (which is formatted by `%t`) have been formatted by this `$timeformat` example.

However, prior to the time 60 nanoseconds, no `$timeformat` system task was executed. Therefore, the first two values of `lpstart` (shown in Figure 2-1 on page 18) are displayed in the time of the simulator. In this particular case, the time unit is picoseconds, since the time of the simulator was determined by the compiler directive:

```
‘timescale 1 ns / 1 ps
```

Interacting with the Waveform Display

The `$gr_waves` system task initializes the Graphical Output window. Mouse interaction for the Graphical Output window is enabled when Verilog is in the interactive mode. The left mouse button is used for input. A set of menu buttons, along the top of the WAVES window, is provided for interaction. Positioning the pointer inside a menu button and clicking the left mouse button selects the graphics operation associated with that menu item.

Two different screens, WAVES_SCREEN and SELECT_SCREEN are provided by the waveform display. Both of these screens accept mouse input.

WAVES_SCREEN

The signal waveforms are displayed on this screen and are displayed as timing diagrams. The unknown state (X-state) of a scalar or vector is displayed as a filled solid box.
High-impedance is displayed as a horizontal line which is vertically centered between the 0 and 1 levels (refer to signals b and `add_v`, respectively, in Figure 2-1 on page 18). The values for vectors appear in their specified format if enough space is available at the given scale. Appropriately adjusting the scale of the display allows these lengthier numbers to appear.

In addition to the waveforms, the WAVES_SCREEN displays the following features (refer to Figure 2-1 on page 18).

Time Bar

A *Time bar* is displayed to represent the total time period over which the preserved data is available. The Current Time window is projected onto this Time bar as a filled rectangle.

Cursor and Marker Lines

A cursor line and a marker line are provided to measure time intervals and to define regions for zooming. The cursor line can be placed by moving the mouse to a waveform edge or to a location on the time bar and clicking the left mouse button. The cursor line moves to the nearest edge for any of the signals defined on the waves screen. The corresponding time is displayed as the cursor time. The time associated with the marker line is displayed as the marker time, and the difference between the cursor time and the marker time is displayed as the Δ time. The marker line and the cursor line appears either on the waveforms or on the time bar depending upon their time values. Only the cursor line can be placed directly using the

left mouse button; the marker line cannot be placed this way. Instead, the marker line can be swapped with the cursor line either by clicking on the *SWAP* button or by pressing the middle mouse button.

The cursor and marker lines can be used to measure point-to-point time differences. In Figure 2-1 on page 18, to measure the length of time that the signal labeled `areg` has the value `05d3`, click the mouse at the point where `areg` transitions to `05d3`; the cursor line moves to that point. Then *SWAP* the cursor and marker lines. This moves the marker line to the transition point of `areg`. Finally, move the cursor to the following transition of `areg`. The difference, in this case 20 nanoseconds, is the time between the cursor and marker lines.

Cursor Time, Marker Time and Δ Time

The cursor, marker and Δ times are displayed in the upper right-hand corner and are all in the format specified by the most recently executed `$timeformat` task. These times change with movement of the cursor and marker lines.

Current List

The signal labels for the waveforms currently displayed on the screen are shown to the left of the waveforms.

Interactive Display Buttons

The following interactive display buttons are provided with the WAVES screen:

SWAP Button

Swaps the cursor and marker lines.

ZOOM Button

Zooms the waveform display so that the data between the marker and the cursor positions fills the entire display. *ZOOM* can be used to both zoom in or zoom out. To zoom in, place the cursor and marker lines on the waveform display and click on *ZOOM*. To zoom out, place one or both of the cursor and marker lines in the time bar (outside the range already displayed) and click on *ZOOM*.

LEFT/CNTR/RGHT Buttons

These buttons are used for traversing along the time bar and for pivoting the display around the cursor position. Each time you click a button, the display moves so that the cursor position is at the left/center/right of the display.

RDRW Button

Redraws the current screen. If a `$timeformat` system task is entered interactively, *RDRW* can be selected to cause the cursor, marker and Δ time formats to update.

Scrolling Buttons

Clicking on the appropriate arrow at the ends of the Time bar causes the waves screen to move forward (">") or backward ("<") in time to the next value change. Clicking on the appropriate arrow above and below the *Group* buttons moves your view of the display by one signal position. The following table illustrates the use of these buttons:

>>	move forward in time to the next value change.
<<	move backward in time to the next value change.
↑↑↑↑	move your view of the display up by one signal position (signals move down).
↓↓↓↓	move your view of the display down by one signal position (signals move up).

SELECT Button

Changes the display to the SELECT_SCREEN, where you are allowed to revise the current list of signals on the WAVES screen, as well as define or redefine signal groups. The SELECT_SCREEN is described in more detail below.

Group Buttons

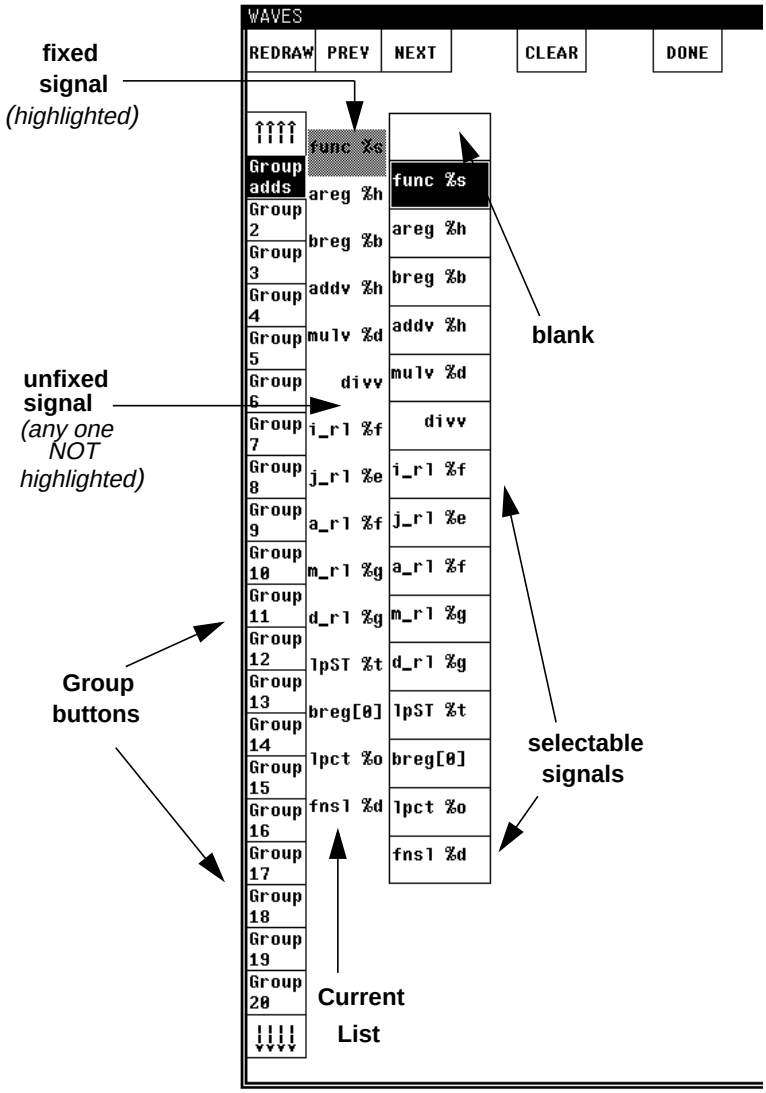
If a group is defined, it can be exposed by moving the pointer onto the appropriate *Group* button and clicking the left mouse button.

SELECT_SCREEN

The SELECT_SCREEN displays the list of signals defined in the `$gr_waves` task along with the current list of signals in the WAVES_SCREEN. You can redefine the existing groups,

define new groups, or just change the current mix of signals on the WAVES_SCREEN. A portion of the SELECT_SCREEN is shown in Figure 2-2 on page 32.

Figure 2-2 Portion of SELECT_SCREEN



The operations available from the SELECT_SCREEN are as follows:

Fix/Unfix Signal

Signals on the Current List can be fixed/unfixed by clicking the left mouse button while the pointer is on one of them. A fixed signal is not overwritten by a selected signal; an unfixed

signal is overwritten. The fixed signals are highlighted. The default state of the signals in the Current List is unfixed.

Select Signal

Signals in the list of all signals can be selected by moving the mouse so that the pointer is on the signal name and clicking the left mouse button. The selected signal replaces the first unfixed signal in the Current List. A particular signal can be selected many times, resulting in multiple copies of its waveform on the WAVES_SCREEN.

Select Blank

Selecting the blank box in the list of all signals replaces the first unfixed signal in the Current List with a blank space, resulting in a blank line on the WAVES_SCREEN. This can be used to separate groups or to separate signals within groups.

Interactive Display Buttons

The following interactive display features are provided with the WAVES screen:

CLEAR Button

Clears the current list of selected signals.

Scroll Buttons

↑↑↑↑	move your view of the unfixed signals up by one position (names move down).
↓↓↓↓	move your view of the unfixed signals down by one position (names move up).

PREV Button

Brings in the previous page of signals in the Signals List. This is useful if all the signals in the Signals List cannot be displayed on the screen at one time.

NEXT Button

Brings in the next page of signals in the Signals List. This is useful if all the signals in the Signals List cannot be displayed on the screen at one time.

REDRAW Button

Redraws the current screen.

Group Buttons

The items in the Current List can be grouped together by clicking the left mouse button on one of the *Group* buttons and then clicking on *CLEAR* or *DONE*. The defined group associates the signals in the Current List; the group can then be exposed in the WAVES window as explained earlier in "Group Buttons" on page 31 in the WAVES_SCREEN section. At the same time, in the SELECT_SCREEN, clicking on a button associated with a group defined by `$define_group_waves` redefines that group to the Current List.

DONE Button

Exits from the SELECT_SCREEN and returns back to the WAVES_SCREEN.

Using Real Numbers

In addition to the data types previously accepted, many of the Graphical Output tasks now accept real number expressions. In the WAVES screens, to display a signal value as a real number, a format specifier should be included in the **<*signal_label*>** argument to the `$gr_waves` system task. Additionally, expressions can be displayed in a time format defined by the `$timeformat` Verilog system task. The format specifiers are of the form `%<format>`, where `<format>` can be one of the following characters:

- `e` or `E` — real numeric in exponential format
- `f` or `F` —real numeric in decimal format
- `g` or `G` —real numeric in exponential or decimal format, whichever format results in the shorter printed output
- `t` —time format

WAVES Output Formats

The following system tasks, provided to facilitate the waveform display, now support the real number format specifiers:

- `$gr_waves`

- `$define_group_waves`
- `$gr_addwaves`

Additionally, the <*time*> argument to the `$gr_jumptotime` system task can now be a real number. The <*time*> value is assumed to be in the unit of the most recently executed `$timeformat` system task.

Displaying Partial Unknown and High-impedance Vectors

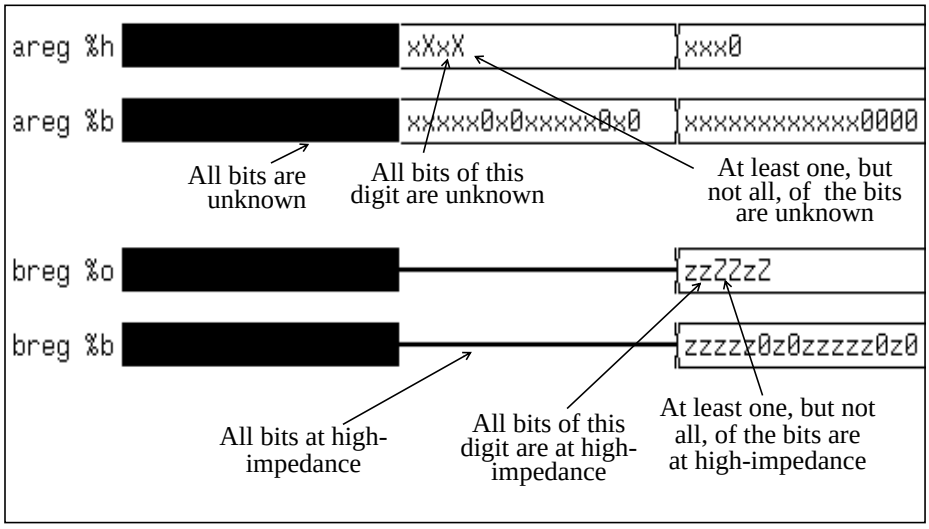
The WAVES output displays partial unknown and partial high-impedance vectors (see Figure 2-3 on page 36). In previous versions of WAVES, any vector that contained at least one bit that evaluated to unknown (X-state), would appear as a filled solid box; any vector that contained at least one bit that evaluated to high-impedance (Z-state), would be displayed as a line in the middle of the 0 and 1 levels. These displays made it difficult to determine whether a vector was partially or fully at one of these states.

In version 2.0, a filled solid box represents a vector where all specified bits are in the X-state; a vector where all specified bits are in the Z-state appears as a line in the middle of the 0 and 1 levels. However, vectors that are partially in the unknown or high-impedance state appear in their specified formats using the following rules:

- `x` — All bits of the digit are unknown.
- `X` — At least one, but not all, of the bits are unknown.
- `z` — All bits of the digit are at high-impedance.
- `Z` — At least one, but not all, of the bits are at high-impedance.

Vectors in decimal format (`%d`) that are partially in the unknown or high-impedance state display a single `X` or `Z`, respectively. Vectors in the binary format (`%b`) display each bit separately using the characters `0`, `1`, `x` and `z`.

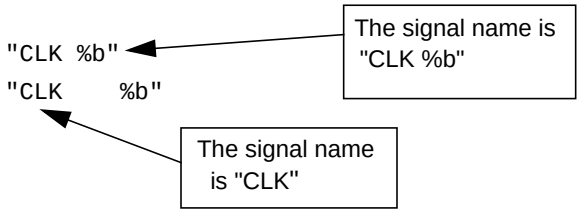
Figure 2-3 Partial Unknown and High-impedance Values



Displaying Signal Names

The name of a signal used in a `$gr_waves` command must be unique within the first seven characters. If the format string following the signal name starts within seven characters of the start of the signal name, a portion of that string, such as %b or %h, appears as part of the signal name. The extra characters display on the screen as part of the name and are also required by `$define_groups` to identify that signal. To avoid this problem for short signal names, use additional spaces in front of the formatting characters so that they do not fall within seven characters from the start of the signal name.

The following two examples illustrate the problem and the solution:



WAVES Window Beeps When Using Cursor

The WAVES window beeps when you place the cursor at a time in the WAVES window where there are no REGS value changes at that time. This is an intentional notification that the WAVES and REGS cursors are now positioned at different times.

Graphical Output Windows with Verilog-XL in the Background

If a Verilog-XL process that has Graphical Output windows open is put in the background with `Control-z`, then the Graphical Output windows cannot be closed, moved, or otherwise manipulated. `Control-z` freezes the Graphical Output windows because they are child processes of Verilog-XL. You cannot perform window operations on them after `Control-z`. If you want to make Graphical Output window icons, do so *before* pressing `Control-z`.

Waveform Output Quick Reference

- The syntax for the `$gr_waves` system task is as follows:

  ```
  $gr_waves("<sig1_label>", <sig1>, "<sig2_label>", <sig2>, ..."<sig<n>_label>",
  <sig<n>>);
  ```

- The X-state is displayed as a filled solid box, while the Z-state is displayed as a line in the middle of 0 and 1 levels.
- Interrupting the simulation after the `$gr_waves` system task enables mouse input.
- Add signals to waves window after calling `$gr_waves` using:

  ```
  $gr_addwaves("<signal1_label>", <signal1>, "<signal2_label>", <signal2>,
  ..."<signal<n>_label>", <signal<n>>)
  ```

- Use the left mouse button for all Graphical Output input.
- The cursor line is a solid line, and the marker line is a dashed line.
- The cursor line can be moved to waveform edges.
- Δ time is the time interval between the marker and cursor lines.
- The middle mouse button can be used to swap cursor and marker lines.
- The format for the cursor, marker, and Δ times can be changed by executing a new `$timeformat` system task.
- Click on *REDRAW* to cause the cursor, marker and Δ time formats to update.
- The *ZOOM* button zooms the waveforms between the cursor and marker lines.
- The *LEFT*, *CENTER*, and *RIGHT* buttons can be used to traverse the Time bar after first positioning the cursor line at the location to which the Current Time window is to be moved.

- The *SELECT* button can be used to invoke the SELECT_SCREEN to select signals and/or to define groups.
- Scrolling backward/forward is in terms of the next value change.
- Scrolling up/down is with respect to your view of the data— think of a window on the data, similar to a text editor.
- Issue keyboard commands to Verilog-XL in the window in which Verilog-XL is running.

3

REGS Window Output

Verilog provides an interactive graphics interface to display data as a window of text along with formatted values of nets and registers. These values are continuously updated as the simulation progresses. When in the interactive state of Verilog, you can perform graphics operations using the mouse device. This chapter describes the REGS window display and the system tasks that are provided to create and facilitate thatdisplay. This chapter contains the following sections:

Setting Up the REGS Window

The `$gr_regs` task defines the layout of the window and specifies the variables to be displayed with their formats. If it does not already exist, a special graphics window is created in the upper left-hand corner of the window. After the `$gr_regs` task is called, the mouse becomes active whenever Verilog is waiting for an interactive command.

Syntax:

```
$gr_regs("<string1>", <optional list of expressions>, "<string2>",
     <optional list of expressions>, ..."<string<n>>", <optional...>);
```

Arguments:

<string> An ASCII string enclosed in double quotes that contains one format specifier for each *<expression>* that follows it.

<optional list of expressions>
A list of general Verilog expressions.

Example:

```
$gr_regs(

        "     MULTIPROGRAMMING VIRTUAL STORAGE SYSTEM           ",
        "                                                       ",
        "  disks %d                terminal %d                  ",
        "                                                       ",
        "  cpu use %f                                           ",
        "  job count %d                                         ",
        "                                                       ",
        "   disk    track seek times     record search time     ",
        "      1           %d                %d                ",
        "      2           %d                %d                ",
        "      3           %d                %d                ",
        "      4           %d                %d                ",
        "                                                       ",
        "    terminal mean user delay    %d                     ",
        "    terminal mean cpu job time  %d                     ",
        "                                                       ",
        "                                                       ",
        "    maximum wait times in queues                       ",
        "                                                       ",
        "        Schq=%d                  Dpchq=%d                ",
        "                                                       ",
        "        Dkq1=%d                  Dkq2=%d                ",
        "        Dkq3=%d                  Dkq4=%d                ",
        "                                                       ",

        s1.numdisks, num_terms,
        (s1.c1.totalbusy*100.0)/$time, jobcount,
        s1.d1.maxseek, s1.d1.maxsearch,
        s1.d2.maxseek, s1.d2.maxsearch,
        s1.d3.maxseek, s1.d3.maxsearch,
        s1.d4.maxseek, s1.d4.maxsearch,
        t1.mean_cpu_time, t1.user_delay,
        sched_q_maxlwt, dispatch_q_maxlwt,
        disk_q_maxlwt[1], disk_q_maxlwt[2],
        disk_q_maxlwt[3], disk_q_maxlwt[4]);
```

The previous example shows how to specify formats to `$gr_regs`. The resulting output can be found in Figure 3-1 on page 42. Note that zero, one, or more expressions can follow a string, as long as the number of expressions equals the number of format specifiers in that string. In other words, a string should not contain format specifiers if no expressions come after it in the argument list. Conversely, every string must contain one format specifier for each

expression that does follow it. The format specifiers are of the form %<*format*>, where <*format*> can be one of the following characters:

- b — binary numeric
- o — octal numeric
- d — decimal numeric
- h — hexadecimal numeric
- s — string
- e or E — real numeric in exponential format
- f or F — real numeric in decimal format
- g or G — real numeric in exponential or decimal format, whichever format results in the shorter printed output
- t — time format

The format specifiers follow the same rules for unknowns and high impedance values as the specifiers in the $display system task.

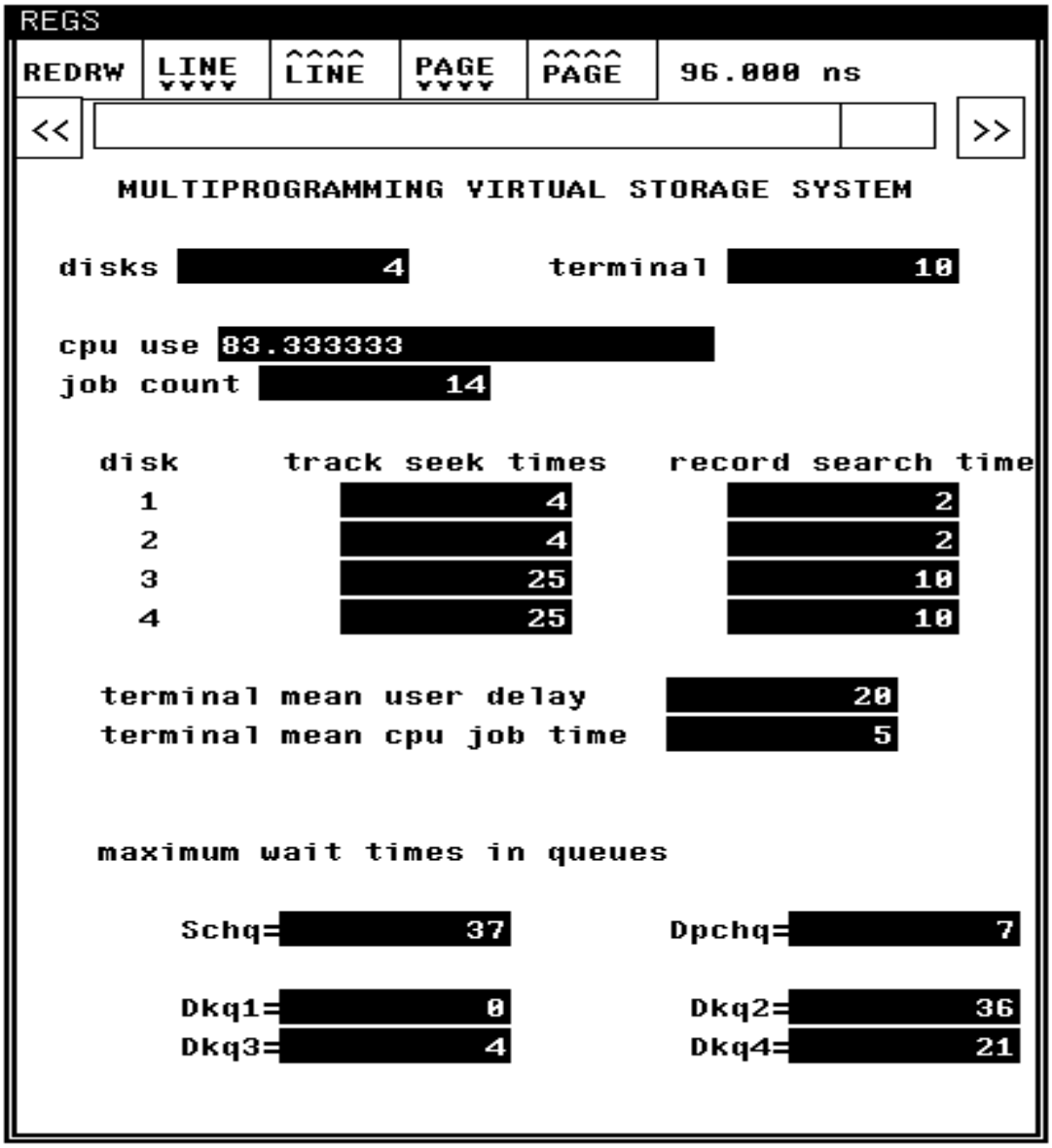
Specifiers match expressions in left-to-right order. Each specifier should be placed at the location in the string where you want the expression it formats to be displayed.

Enough space must be left between format specifiers to allow display of the full width of the registers. Note that the width of real numbers is automatically 25 spaces. If not enough space is provided, the values of the arguments overlap on the window. A warning is issued during compilation if this situation is detected.

The graphics window is updated whenever a value changes for any of the variables defined in $gr_regs during simulation.

A new call to $gr_regs clears the current window and sets up the new window as specified by the new parameter list.

Figure 3-1 REGS Window Output



Resizing the REGS Window

The REGS window previously supported vertical resizing. However, horizontal resizing of the REGS window now causes the Time bar to expand or contract to fill the width of the window as well.

The maximum window dimensions that you can obtain depends on the windowing system you use. Table 3-1 on page 43 lists these sizes.

Table 3-1 : Maximum Dimensions

Windowing System	Dimensions (in pixels)
X-Windows	2048 x 2048
Sunview	1120 x 900
Apollo GPR	1200 x 800

If a window shrinks horizontally past the Cursor Time area, clipping occurs—that is, the window layout takes its minimum width and the right edge of the window cuts off some of the display.

Setting the Storage Space

The `$gr_regs_memsize` system task informs Verilog of the maximum amount of memory space to be allocated for the register window.

Syntax:

```
$gr_regs_memsize(<size>);
```

The size argument is in bytes. Memory is requested by the register window as simulation progresses and value changes occur on the variables being displayed. When the maximum specified memory space has been allocated and used, the oldest data is discarded and its space is reused.

The minimum amount of space that can be allocated is 300,000 bytes. The maximum amount is limited only by the amount of virtual memory space available on the host machine. The default amount of space allocated in the absence of a call to `$gr_regs_memsize` is 500,000 bytes. This limit is set when `$gr_regs` is called. A call to `$gr_regs_memsize` after a call to `$gr_regs` can increase the amount of memory available for the register window, but it cannot reduce it.

Jumping to a Specified Time

The `$gr_jumptotime` task allows jumping to a particular time in both the WAVES and REGS windows. Refer to "Jumping to a Specified Time" on page 27 for syntax and an explanation of this task.

Using the $timeformat System Task

The `$timeformat` system task is a Verilog system task which formats the time displayed in the WAVES and REGS windows, and the `%t` format specifier. Refer to "Using the $timeformat System Task" on page 28 and to the *Verilog-XL Reference Manual* for a more detailed explanation.

Interacting with the REGS Window

The system task `$gr_regs` initializes the Graphics window. Mouse interaction for the graphics window is enabled when Verilog is in the interactive mode. The Left mouse button is used for input. A menu is provided for interaction in the graphics window. Positioning the pointer inside the menu item and clicking the left mouse button selects that menu option for the next graphics operation.

In addition to the data as defined by the parameters of `$gr_regs`, the following features are displayed.

Time Bar

A *Time bar* is displayed at the top of the REGS window to represent the total time period over which the preserved data is available. The current time for which data is displayed is projected on this bar by a vertical line. During the interactive mode one can traverse along the time bar by positioning the pointer at a location and clicking the left mouse button. The data values for the corresponding time are then displayed.

Interactive Display Buttons

The following interactive display features are provided with the REGS window:

REDRAW Button

Redraws the current window. If a `$timeformat` system task is entered, click on the *REDRAW* button to update the time format.

Scrolling Buttons

>> — move forward in time to the next value change

<< — move backward in time to the next value change

LINE (with arrows above) — move your view of the window up one line

PAGE (with arrows above) — move your view of the window up 1/2 page

LINE (with arrows below) — move your view of the window down one line

PAGE (with arrows below) — move your view of the window down 1/2 page

Using 64-Bit Time Values

The REGS window provides graphical support for 64-bit simulation time values. In prior releases of Graphical Output, simulation time values could not exceed 32-bits in length even though Verilog versions 1.3 and beyond support values to 64-bits.

NOTE: To use the `$gr_jumptotime` system task to jump to a time greater than 32 bits, the <*time*> argument must be expressed in the following number format (refer to the *Verilog-XL Reference Manual* for an explanation of this format):

```
ss..s 'f nn..n
```

For example, to jump to time 34,000,000,000, type:

```
$gr_jumptotime(64'd34000000000);
```

Accepting Real Numbers

In addition to the data types previously accepted, many of the graphics tasks now accept real number expressions. In the REGS window, to display a signal value as a real number, a format specifier should be included in the <*string*> argument to the `$gr_regs` system task. Additionally, expressions can be displayed in a time format which is defined by the `$timeformat` Verilog system task. The format specifiers are of the form %<*format*>, where <*format*> can be one of the following characters:

- `e` or `E` — real numeric in exponential format
- `f` or `F`— real numeric in decimal format
- g or `G`— real numeric in exponential or decimal format, whichever format results in the shorter printed output
- `t`—time format

REGS Output Format

The `$gr_regs` system task supports the real number format specifiers. The width of real numbers in the REGS window is automatically 25 spaces.

As in the WAVES window, the `$gr_jumptotime` system task now accept a real number for the <*`time`*> argument.

REG Window Output Quick Reference

- Interrupting the simulation after the `$gr_regs` system task enables mouse input.
- Use the left mouse button for all graphics input.
- Scrolling backward/forward is in terms of next value change.
- Scrolling up/down is with respect to your view of the data — think of a window on the data, similar to a text editor.
- The keyboard commands to Verilog-XL are to be given in the window in which Verilog-XL is running
- The REGS window is slaved to the time operations performed in the WAVES window, but the reverse is not true.
- The time format can be changed by executing a new `$timeformat` system task.
- Click on *REDRAW* to cause the time format to update.

4

Bar Graph Output

Verilog provides the capability to view data as dynamically changing bar graphs. This chapter describes BARS windows and the system task that allows you to set up charts with multiple bars and to update those bars as simulation progresses. This chapter contains the following sections:

Setting up a BARS Window

The system task `$gr_bars` creates a window and legends for the bar graphs to be displayed and then asynchronously updates the windows whenever one of the data arguments changes value.

Syntax:

```
$gr_bars("<chart_name>",<max_height>,"<bar_label>",
     <expr>,"<bar_label>",<expr>, ...);
```

Arguments:

<chart_name>	A string that identifies a group of bars which is displayed side by side. The *<chart_name>* string is displayed beneath the set of bars. The maximum length of the *<chart_name>* string can be 45 characters.

<*max_height*>	An integer or real expression which determines the scale of all the bars of a particular chart. This argument can be real whether or not any real expressions are monitored.
<*bar_label*>	An ASCII string enclosed in double quotes (maximum six characters) which appear beneath the bar in the windows. The associated expression, <*expr*>, must by the next argument.
<*expr*>	Any valid integer or real expression that returns a value. The most common case is a variable name.

When `$gr_bars` is called, it opens a graphics window in the upper right-hand corner of the screen.

This system task should be called once for each group of bars you want to display. Multiple groups can be displayed by calling `$gr_bars` with different chart names. These groups are displayed one above the other in the same window.

Currently, the maximum number of charts that can be displayed is 5. The maximum number of bars in a chart is currently 10.

BARS Output Formats

The `$gr_bars` system task accepts a real expression for the <*max_height*> argument. Additionally, any bar which monitors a real expression has a real value shown at the top of the bar. No format specifier is necessary.

Plotting

The <*begin_time*> and <*end_time*> arguments of the `$ps_waves` system task can now be expressed as real numbers. These values are assumed to be in the units of the most recently executed `$timeformat` system task.

Understanding Bar Values

The current value associated with a bar appears above the bar. Any bar that monitors a real expression has a real value shown at the top of the bar. If the number contains too many digits to fit in the available space, it is truncated on the right, and a "~" appears to indicate truncation has occurred.

When the current value associated with a bar exceeds <*max_height*>, the value shown at the top of the bar is correct, but the bar is only shown at <*max_height*>. On color windows, the bar changes color to indicate this off-the-scale condition.

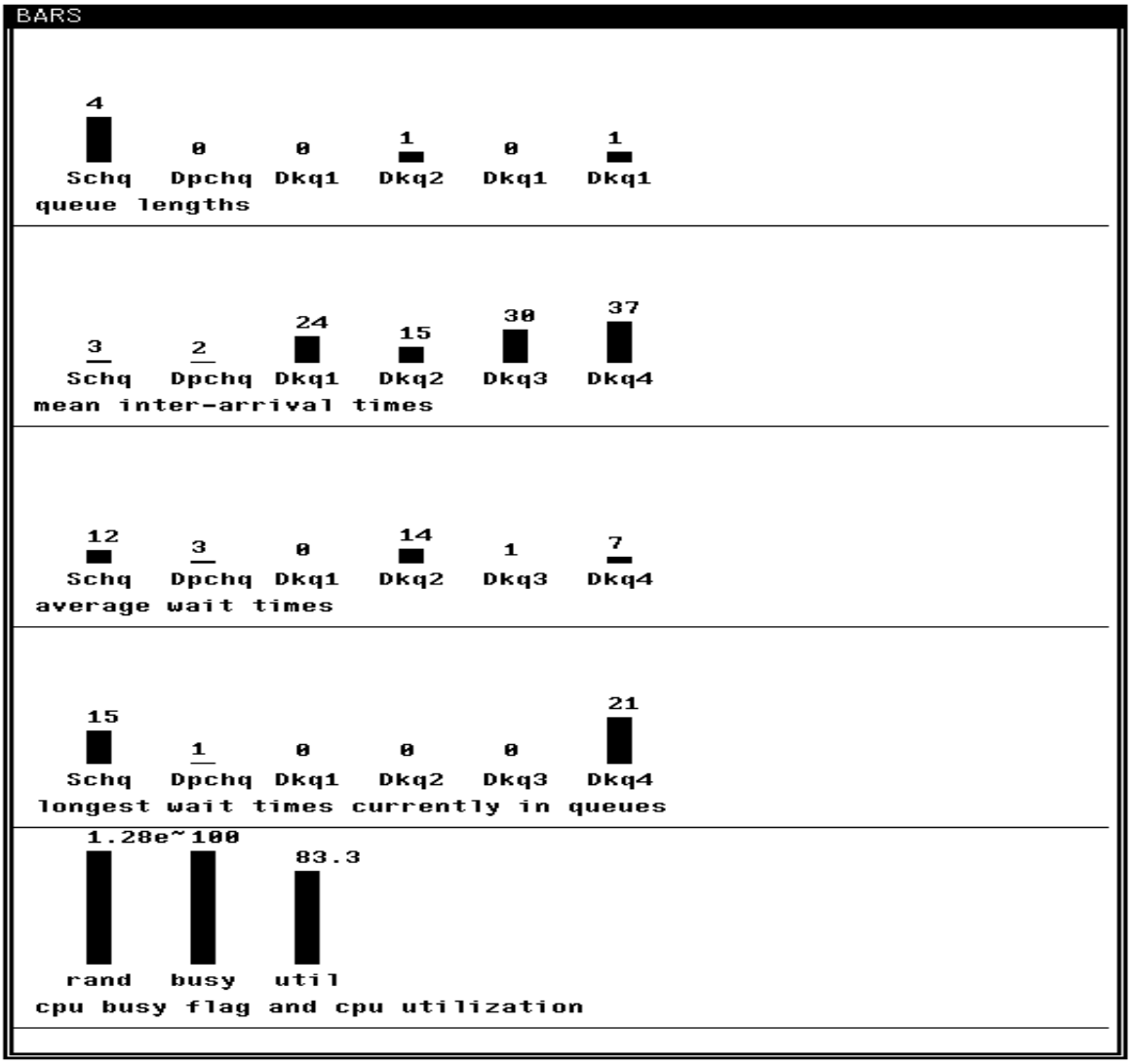
Example Calls to $gr_bars

The following is an example of a multiple calls to `$gr_bars`.

```
$gr_bars("queue lengths", 10, "Schq",sched_q_count, "Dpchq", s1.dispatch_q_count,
"Dkq1",s1.diskq_count[1],"Dkq2",s1.diskq_count[2],"Dkq1",s1.diskq_count[3],"Dkq1
", s1.diskq_count[4]);

$gr_bars("mean inter-arrival times", 100, "Schq", "Dpchq", "Dkq1",
         "Dkq2", "Dkq3", "Dkq4", sched_q_mat, dispatch_q_mat,
         disk_q_mat[1], disk_q_mat[2], disk_q_mat[3], disk_q_mat[4]);

$gr_bars("average wait times", 100, "Schq", "Dpchq", "Dkq1", "Dkq2",
         "Dkq3", "Dkq4", sched_q_awt, dispatch_q_awt, disk_q_awt[1],
         disk_q_awt[2], disk_q_awt[3], disk_q_awt[4]);

$gr_bars(“longest wait times currently in queues", 50.0, "Schq","Dpchq", "Dkq1",
"Dkq2", "Dkq3", "Dkq4", sched_q_lwt,dispatch_q_lwt, disk_q_lwt[1],
disk_q_lwt[2],disk_q_lwt[3], disk_q_lwt[4]);

$gr_bars("cpu busy flag and cpu utilization", 100,
"rand",bignum,"busy",100*s1.c1.cpubusy, "util",(s1.c1.totalbusy*100.0)/$time);
```

The <*chart_names*> are queue lengths, mean-arrival times, average wait times, etc. The <*max_height*> for the first chart is 10 and the strings `Schq`, `Dpchq`, `Dkq1`, `Dkq2`, `Dkq3`, `Dkq4` are the bar legends for the bars representing variable `sched_q_count` (in the current scope) and variables (in scope `s1`) `dispatch_q_count`, `diskq_count[1]`, `diskq_count[2]`, `diskq_count[3]`, and `diskq_count[4]`, respectively. Figure 4-1 on page 50 is a sample output of this example.

Figure 4-1 Example BARS Window Output



5

Timescales

The `$timeformat` system task is a Verilog system task that establishes the time unit for delays entered interactively, as well as the time unit, precision, suffix string and minimum field width for time information displayed using the `%t` format specifier. The time unit, precision, suffix string and minimum field width for the cursor, marker and Δ times—which appear in the upper right-hand corner of the WAVES window—are also derived from the `$timeformat` system task. The same is true for the time in the upper right-hand corner of the REGS window. (Please refer to the *Verilog-XL Reference Manual* for the exact syntax and definition of the `$timeformat` system task).

The `$timeformat` system task can appear in your Verilog source description or it can be entered interactively. The most recently executed `$timeformat` system task formats the times displayed in the upper right-hand corner of the WAVES and REGS windows. If no `$timeformat` system task has been executed, the default time unit is set to the smallest precision argument of the `‘timescale` compiler directives in the source description.

6

Plotting Waveforms

The Verilog graphics interface allows you to create a PostScript™ format file from the WAVES window. This file can then be sent to a laser printer or any other device that can accept a PostScript™ description of the image to be plotted. The plot can be one or many pages long, and the scale of the waveforms on the plot is easily selected using the mouse. This chapter explains how to use the Graphics output to plot and print your waveform data. This chapter contains the following sections:

Using the $ps_waves System Task

The system task `$ps_waves` creates the PostScript™ file. It takes several arguments, all of which are optional.

Syntax:

```
$ps_waves("<filename>", "<header>", <begin_time>, <end_time>);
```

Arguments:

<filename>	A string, enclosed in double quotes, that is a valid operating system filename.
<header>	A string, enclosed in double quotes, that is printed as a header on each page of the plot.

<*begin_time*>	An integer or real number, assumed to be in the units of the most recently executed `$timeformat` system task, that specifies the first time to display on the plot.
<*end_time*>	An integer or real number, assumed to be in the units of the most recently executed `$timeformat` system task, that specifies the last time to display on the plot

Note that the filename passed to `$ps_waves` is limited to a literal string. This is the only system task with this limitation — all others that need a filename can accept a string variable.

If no <*filename*> argument is specified, then the PostScript description of the plot is placed in the file `gr_waves.ps`. If the file specified already exists, it is overwritten.

The header string can be up to 60 characters long. If a longer string is specified, it is truncated and a warning message is issued. To specify a header argument, a <*filename*> argument must also be specified.

The endpoints of the plot can either be specified using the <*begin_time*> and <*end_time*> arguments, or they can be selected using the cursor and marker lines on the WAVES window. If no <*begin_time*> and <*end_time*> argument pair is given, then the lower of the cursor and marker positions is taken as the begin time, and the greater of the two is taken as the end time. If a <*begin_time*> argument is specified, then an <*end_time*> argument must also be specified. To specify a <*begin_time*> and <*end_time*> argument pair, the <*filename*> and <*header*> arguments must also be specified.

Examples:

```
$ps_waves;
$ps_waves("mycircuit.ps");
$ps_waves("mycircuit.ps","read cycle");
$ps_waves("mycircuit.ps","read cycle", 3510, 8900);
```

The <*begin_time*> and <*end_time*> arguments of the `$ps_waves` system task can now be expressed as real numbers. These values are assumed to be in the units of the most recently executed `$timeformat` system task.

Selecting Signals for the Plot

Each plot can display up to 20 signals. The signals to be plotted are selected by displaying them on the window using the standard waves commands such as the SELECT window and the *Group* buttons.

Scaling the Plot

The scale of the plot—that is, how close together the edges appear on the paper—is selected by scaling the window display using the *ZOOM* button. The closer the edges are on the window, the closer they appear on the paper plot.

Making Multi-Page Plots

The number of pages in the plot is determined by the begin time, end time, and scale of the plot. There is no limit to the number of pages that can be plotted.

Performing System Administration for a LaserWriter

The printing of waveform plots has been tested from both the Sun™ and Apollo workstation platforms using an Apple LaserWriter™. While other devices have not been tried, there is every reason to believe that any device capable of printing from a PostScript™ description can print the output from `$ps_waves`.

We are including instructions for setting up the printer on both workstations for your convenience.

Sun Workstations

To set up the printer on a Sun, edit the file `/etc/printcap` to have the following entry:

```
#LaserWriter on RS232 PortA lw|ps|postscript|PostScript:lp=/dev/ttya:sd=/usr/
spool/lw: :lf=/dev/console: :br#9600:rw:fc#0000374:fs#0000003:xc#0:
:xs#0040040:mx#0:sf:sh
```

Create a spooling directory for the LaserWriter such as `/usr/spool/lw`. All users are able to plot PostScript files by typing:

```
lpr -Pps 'postscript_filename'
```

For more information, see the *Sun System & Network Administration* manual.

Apollo Workstations

To set up the printer on an Apollo, edit or create a configuration file for a default LaserWriter on serial port one. Place this file in `/sys/print/printer_config.data`. It must contain the following entries:

```
bottom_margin 0
collate_copies on
cpi 12
device laserwriter
file_banners off
form_feeds 0
interface serial
lpi 6
pageno_column 72
page_headers off
page_width 78
page_reversal on
paper_size A
plot_mode on
print_length 8
print_width 5.5
printer_name p
resolution 300
sio_line 1
speed 9600
top_margin 0
```

Start a print server process by typing the following command:

```
cps /com/sh -c '/com/prsvr'
```

All users are able to plot PostScript files by typing this command:

```
prf 'postscript_filename' -transparent
```

7

Remote Graphics Support

Remote Graphics allows you to run the Verilog simulator on a remote host and, at the same time, view and interact with graphics on a local workstation.

The Remote Graphics system tasks available are:

- `$gr_remote`–Connects a simulation process on one machine with a graphics process on another machine.
- `$gr_synchon`—Synchronizes the simulation and graphics processes with respect to simulation time.
- `$gr_synchoff`—Decouples the simulation and graphics processes with respect to simulation time.

This chapter provides a brief overview of the use of Remote Graphics with Verilog-XL and the Graphical Output. Please refer to the *Remote Graphics Reference Manual* for complete details on the Remote Graphics product and the use of the above system tasks.

This chapter contains the following sections:

Remote Graphics on the Apollo/Aegis System

You can run Remote Graphics only on systems that support the UNIX Transmission Control Protocol / Internet Protocol (TCP/IP). Consequently, a `gr_vlog` graphics object module that supports Remote Graphics uses UNIX TCP/IP for communications.

In light of this requirement, Cadence provides two `gr_vlog` object modules with each Verilog release on Apollo/Aegis™ 9.7 systems: one module that supports Remote Graphics and one that does not.

The Verilog executable file shipped on the Apollo/Aegis 9.7 system is linked with the `gr_vlog` object module that does **NOT** support Remote Graphics. Therefore, Apollo/Aegis 9.7 users whose systems support UNIX TCP/IP and who wish to run Remote Graphics must relink Verilog with the `gr_vlog` object module that does support Remote Graphics. The Verilog configuration program, *Vconfig*, can be used to reconfigure the Verilog executable module appropriately. Please consult the *Vconfig User's Manual* for details about how to use this program.

Graphics Window Scrolling Problem on Apollos

If you run a Verilog-XL simulation on any Apollo, have any Graphics window open (that is, WAVES, REGS, or BARS), and Verilog is stopped at the interactive prompt; you cannot scroll the Verilog window backwards without first pressing the HOLD key. After reviewing the transcript in the Verilog window, press the HOLD key again to release it before continuing.

Graphical Output Features Not Present in Remote Graphics

Remote Graphics does not support the system tasks `$gr_color` and `$gr_position`. Note that the Graphics software executes any `$gr_position` command on all systems in local mode (and only in local mode). You can change the window size and position in remote mode only by manual means.

You cannot interrupt a redraw in a remote WAVES window by typing `Control-C` in the Verilog-XL interactive window.

Clarifications for Use of $save and $restart with Remote Graphics

The next two sections explain some of the ramifications of using `$save` and `$restart` with Remote Graphics.

Setting the Graphics Host

The RHOST environment variable simplifies the naming of the remote system that is to receive the output of a Verilog-XL simulation. You can name the remote host either with the RHOST variable or as an argument to the `$gr_remote` system call as explained below:

- `$gr_remote()` — This defaults the Graphics host to the system specified by the environment variable RHOST. If Remote Graphics is not running on that system, or RHOST is not defined, then the Graphics host defaults to the local system.
- `$gr_remote("xyzzy")` — This defaults the Graphics host to the system named `xyzzy`. If Remote Graphics is not running on that system, then the host is selected as described in the previous bullet item. The `$save` system task saves the host name specified by `$gr_remote` and reassigns this host when `$restart` is executed.

The preferred method for naming the remote host when using `$restart` is to use the RHOST variable. This allows you to change to a different host when restarting after `$save`.

Saving Window Size and Position

The `$save` system task saves the current window size and position only when Graphics is running locally in Sunview. When Remote Graphics runs in Sunview, or when Graphical Output or Remote Graphics runs under Apollo GPR or X-Windows, the window size and position revert to the Graphics defaults on execution of `$restart`.

Bug Fixes

The following bug fixes apply specifically to Remote Graphics.

Remote Graphics crashes after several Verilog-XL runs

In releases prior to version 1.2a, you could run multiple consecutive simulations in communication with Remote Graphics under Sunview. In version 1.2a, this caused a crash, with Sunview running out of windows. This has been fixed.

Second Verilog-XL simulation opens closed window

Under Sunview, a Graphics window that was an icon during one simulation used to open as a window when the next Verilog-XL simulation started (thereby reducing simulator performance). This problem has been fixed.

Remote Graphics does not work with Open Windows

Remote Graphics now works with Open Windows.

Crash occurs on mouse click on group defined after $gr_waves

Remote Graphics used to crash if a group was defined that included signals from a call to `$gr_addwaves`—if there had been a call to `$gr_bars` or `$gr_regs` between the calls to `$gr_waves` and `$gr_addwaves`. This problem has been fixed

Crash caused by space in group_name

Remote Graphics used to crash when there was a space in the group_name specified for `$define_group_waves`. This has been fixed.

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Limitations

This chapter describes the general and platform-specific functional limitations of the Graphical Output software. This chapter contains the following sections:

General Limitations

The current release of the Graphical Output has the following limitations:

- The Verilog save and restart features are not supported after any of the graphics output mechanisms have been used.
- The maximum length of a line in the REG window is 80 characters.
- The maximum number of bars in a bar chart is 10. The maximum number of charts displayed at one time is 5.
- When using the `$define_group_waves` task, the <*`signal_label`*> character string must match **exactly** with the <*`signal_label`*> character string previously defined including spaces and format specifiers. For example, if in the `$gr_waves` task a signal label is specified as `bus %d`, then in the `$define_group_waves` task, the signal label must also be given as `bus %d`(not just `bus`).
- Simulation time values cannot exceed 64 bits in length. All simulation time values are stored in most precise `‘timescale` compiler directive given in the Verilog code. To work around this, use `‘timescale` compiler directives only to the precision absolutely necessary.
- Some of the waveform edges and text might appear brighter than the rest. There is no significance to this.

- The `$gr_regs` and `$gr_waves` windows cannot display formatted values that are more than 256 characters long. The number of characters required for display can be calculated based on the number of bits in a value and the format specifier used. There are two ways to circumvent this limit:

  a. Display the value in a format that requires 256 characters or less.

  b. Split the value into multiple pieces—by using part-selects of a vector, for example—so that each piece requires no more than 256 characters to display.

- String arguments that embed double quote characters (`\"`) cannot be passed to Remote Graphics for display in graphics windows. This is due to the protocol Remote Graphics uses to exchange data between separate simulation and graphics processes. The graphics interface skirts this limitation by automatically converting embedded double quotes to single quotes before passing them to the Remote Graphics process for display.

  For example, if you input the following string:

  ```
  $gr_regs(“problem string: %s”, “This is a quote -> \” “);
  ```

  The resultant output in the REGS window is the following:

  ```
  problem string: This is a quote -> ‘
  ```

  Double quote characters do not pose a problem for the normal graphics operation, which is part of the same process as the simulation.

- When the cursor or marker occurs at that edge due to an XOR operation, The operations for window manipulations are not stored in the keys file; therefore, these operations cannot be replayed from the keys file.

Sun-Specific Information

The graphics interface on Sun workstations has been integrated with the Suntools package. Verilog-XL should be invoked from one of the windows inside the Suntools. The graphics windows can be moved, closed, resized, exposed, hidden, or redisplayed using Sunview’s window, *Frame Menu*. A *quit* on the window is ignored. To get maximum speed and better graphics, we recommend that you do not resize the window.

Sun-Specific Limitations

- The very first mouse input click is always interpreted as a left mouse button click.
- When system loading is heavy, mouse events sometimes get buffered, requiring extra clicks to perform desired operations. This can be identified by characteristic symptoms:

Several clicks produce no response, followed by additional clicks, whose actions lag noticeably behind their trigger clicks.

Methods suggested to recover normal mouse function are as follows:

- ❑ Continue simulation for a few simulation units and try the mouse again.
- ❑ Click on a button that might not greatly affect the target operation —for example, click the middle button to swap cursor and marker. Then, continue simulation for a few seconds and try the display again.
- ❑ If the symptoms persist, try to avoid clicking ahead of the display. Wait for each mouse action to take effect before clicking again.

- ■ Certain graphics programs —such as *FrameMaker*™ from Adobe—aggravate mouse-event buffering. In such cases, it is often necessary to exit Suntools and then reenter to clear up buffering.

Graphics Under the Bourne Shell on Sun Workstations

You can run Verilog Graphics under the Bourne shell (`/bin/sh`) on Sun workstations. Due to a SunOS bug, this used to cause all keyboard interrupts to be ignored and interactive input to hang the process. Because command scripts are fed to `/bin/sh` for processing unless otherwise specified, Verilog Graphics could not be started from inside a shell script. The SunOS bug still exists, but it no longer affects Verilog Graphics.

Running Graphics from a UNIX Command File

You can run Verilog with graphics from a UNIX command file since the interrupt key is now recognized.

Apollo-Specific Information

The graphics interface on Apollo workstations has been integrated with the standard window system. Verilog can be invoked from any AEGIS window. The graphics windows can be moved, resized, or popped using the standard Apollo commands.

Apollo-Specific Limitations

- ■ Only windows that do not have other windows overlapping on top of them have data redisplayed or accept input.

- The windows can turn black due to moving/resizing. The data reappears the next time data is written to that particular window, but only if the window has no overlapping windows on top of it.
- Mouse input can be ignored after a window goes blank. This problem can be alleviated by popping the graphics windows.
- Closing the graphics windows into icons on Apollo workstations has the effect of blocking the Verilog process, thus stopping the simulation.

9

Bugs

This chapter contains the following sections:

Bug Fixes

The following bug fixes have been made for this final release of the Graphical Output for the Verilog product family.

Segmentation fault occurs when $gr_addwaves follows a $gr_waves with no signals

Invoking `$gr_waves` with no signals at time 0, followed by a `$gr_addwaves` very early in the simulation, no longer causes a segmentation fault.

Fatal error occurs when simulation time exceeds 31 bits

In version 1.2a, both the WAVES and REGS windows supported 64-bit simulation time values. However, under certain circumstances, a fatal error used to occur when the span of time units stored in the simulation history exceeded 31 bits. This bug is now fixed so that the Graphics software no longer crashes. However, the Graphics software data structure design still only allows simulation history to span 31 bits worth of simulation time. When the number of time units experienced by simulation history approaches 31 bits, Graphics starts deleting simulation history from memory. At this point, it prints the following message:

```
> Graphics: WARNING - Discarding value changes at time 3100000000:
> Waves history would span too large a time value.
```

Occasionally, the software cannot delete history without fatally impacting the simulation. If deleting simulation history so that the elapsed time fits within 32 bits causes less than fifty history units to remain, the Graphics software exits with the following messages:

```
> WARNING at time 3200000000: Too much waves history would be depleted:
> Must keep at least 50 time cells in memory.
> Check memory allocation and circuit activity
>
> fatal error in routine gr_minimize_ds_times:
> Can't normalize data structure
```

This situation occurs if you are monitoring signals that change infrequently relative to the passing of simulation time. This could require deletion of history resulting in less than 50 time units remaining in memory. In this situation, the software experiences a fatal error. One way to solve this problem is to add monitoring to a signal that changes more frequently.

Control-c and other windows-related Verilog crashes

Verilog-XL no longer crashes when a user types `Control-c` with the Graphics window displayed. A bug that allowed window requests to be serviced when the Graphics data structures were incomplete has been fixed.

Initial delta value is incorrect in successive $ gr_waves calls

The WAVES window no longer displays an erroneous initial delta value for successive `$gr_waves` calls during the same simulation.

Overlapping display of bus values in WAVES window

There is no longer an overlapping display of bus values in the WAVES window.

Core dump occurs when Graphics memory is increased more than once

A core dump used to occur when REGS or WAVES memory was increased more than once before the window was opened. This was fixed so that a second memory allocation now executes correctly. When a memory allocation executes, the Graphics software displays a confirmation message. The following example shows an interactive invocation of `$gr_waves_memsize` and the resulting message. The allocated size total shows how much of the memory available for allocation is currently allocated.

```
> $gr_waves_memsize (600000);
  Waves memory size = 600000 Allocated size = 494208
```

This same form of message would be displayed by `$gr_regs_memsize`.

Incorrect display when $gr_addwaves follows a $gr_waves not at time 0

Waves now displays correctly when `$gr_addwaves` is executed following a `$gr_waves` not at time 0. This bug only occurred in version 1.2a only.

Incorrect data display after Graphics history deleted

A window error sometimes caused signals that changed infrequently to show incorrect values after Graphics history was deleted. This has been corrected.

Fatal error in routine gr_deleted_regs_cell

An error was issued whenever the Graphics memory manager could not find an appropriately sized memory cell in old Graphics history to overwrite with more recent data. This has been corrected by allocating more memory. Refer to "Change in Definition of $gr_waves_memsize" on page 12 for more information.

Overlap of WAVES and REGS windows

Under some windowing environments, the default positions of the WAVES and REGS windows overlapped. This has been corrected.

BARS graphics drawn in WAVES or REGS window

Calls to `$gr_bars` no longer cause pieces of the BARS text and Graphics to be written into the WAVES or REGS window.

Support for Sunview version in OPENLOOK®

The Sunview version of Graphical Output is now supported in the OPENLOOK environment.

Segmentation fault occurs if $ps_waves is issued without a prior $gr_waves

When a `$ps_waves` call was issued with begin and end arguments, but without a prior `$gr_waves` call, the software used to crash with a segmentation fault. This has been fixed. When `$ps_waves` is issued without a prior `$gr_waves`, the following error message displays:

```
no graphics history available
```

Compilation terminates when <max_height> is 0

Verilog-XL compilation no longer terminates when the <*max_height*> argument to the `$gr_bars` system task evaluates to zero.

Fatal error occurs when defining group name

Leaving out the second parameter <*group_name*> for the system task `$define_group_waves` no longer causes Verilog-XL to crash. The compiler now gives a compiler error to identify the omission.

Outstanding Bugs

The following is a list of all known bugs in this final version of the Graphics software, along with their known workarounds.

Monitoring a signal with a zero-delay loop

Monitoring signals of a Verilog description that does not advance in time may cause excessive warnings and increases in memory allocation to occur after simulating for several minutes. If this condition occurs, check for a zero-delay loop in the Verilog code.

Allowing this situation to continue might cause all virtual memory to be exhausted, causing the computer to hang or crash.

Clicking in the Graphics window during simulation (Sunview only)

In Sunview, clicking the mouse in a Graphics window while Verilog-XL simulation is running (not in interactive mode) may cause the cursor to become invisible. However, if the mouse is moved to another window, the cursor reappears.

Limit on simulation time-range available for window

The Graphics software can maintain simulation history to represent approximately 2^{31} bits of simulation time. When this limit is reached, the software starts deleting early simulation history.

Blank transition fields on bus values

In the WAVES window, the value in the first transition field displayed for a bus is sometimes blank until the window is refreshed. As a workaround for this anomaly, click on the *redraw* button (*RDRW*).

Thick lines appear in the window

When scrolling the window, during simulation or interactively, some lines might appear as double the width of others. This is caused by round off differences within the different drawing algorithms. To correct the window, click on the *redraw* button (*RDRW*).

Key file values are incorrect

Under certain conditions, key file values are not correct for time related commands done interactively using the mouse, such as setting the cursor position in either the REGS or the WAVES window. This problem shows when the `$gr_waves` command is issued at a time other than 0, *or* when simulation time exceeds 31 bits. There is no workaround for this problem.

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