NightStar LX Tutorial

Version 4.3

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Preface

General Information

NightStar LX™ allows users running Linux® to schedule, monitor, debug and analyze the run-time behavior of their time-critical applications as well as the Linux operating system kernel.

NightStar LX consists of the NightTrace™ event analyzer; the NightProbe™ data monitoring tool, the NightView™ symbolic debugger, and the NightTune™ system and application tuner.

Scope of Manual

This manual is a tutorial for NightStar LX.

Structure of Manual

This manual consists of six chapters and an appendix which comprise the tutorial for NightStar LX.

Syntax Notation

The following notation is used throughout this guide:

italic

Books, reference cards, and items that the user must specify appear in *italic* type. Special terms and comments in code may also appear in *italic*.

`list bold`

User input appears in **`list bold`** type and must be entered exactly as shown. Names of directories, files, commands, options and man page references also appear in **`list bold`** type.

`list`

Operating system and program output such as prompts and messages and listings of files and programs appears in `list` type. Keywords also appear in `list` type.

emphasis

Words or phrases that require extra emphasis use emphasis type.

window

Keyboard sequences and window features such as push buttons, radio buttons, menu items, labels, and titles appear in window type.

[ ]

Brackets enclose command options and arguments that are optional. You do not type the brackets if you choose to specify such option or arguments.

{ }

Braces enclose mutually exclusive choices separated by the pipe (|) character, where one choice must be selected. You do not type the braces or the pipe character with the choice.

. . .

An ellipsis follows an item that can be repeated.

::=

This symbol means *is defined as* in Backus-Naur Form (BNF).

Referenced Publications

The following publications are referenced in this document:

0897395	*NightView™ User's Guide*
0897398	*NightTrace™ User's Guide*
0897465	*NightProbe™ User's Guide*
0897515	*NightTune™ User's Guide*

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1
Overview

NightStar LX™ is an integrated set of debugging tools for developing time-critical Linux® applications. NightStar LX are designed to be minimally intrusive, preserving the execution behavior and determinism of your applications. Users can quickly and easily debug, monitor, analyze, and tune their applications.

The NightStar LX tools consist of:

- NightView™ source-level debugger
- NightTrace™ event analyzer
- NightProbe™ data monitor
- NightTune™ system and application tuner

In this tutorial, we will integrate these tools into one cohesive example incorporating various scenarios which demonstrate their extensive functionality.

NightStar LX operates with the standard Linux kernel. Certain features that are available in the NightStar RT product are not available in NightStar LX because they require kernel features not available in the standard Linux kernel.

Getting Started

Creating a Tutorial Directory

We will start by creating a directory in which we will do all our work. Create a directory and position yourself in it:

- Use the **mkdir(1)** command to create a working directory.

  We will name our directory **tutorial** using the following command:

  ```
  mkdir tutorial
  ```

- Position yourself in the newly created directory using the **cd(1)** command:

  ```
  cd tutorial
  ```

Source files, as well as configuration files for the various tools, are copied to **/usr/lib/NightStar/tutorial** during the installation of NightStar LX. We will copy these tutorial-related files to our **tutorial** directory.

- Copy all tutorial-related files to our local directory.

  ```
  cp /usr/lib/NightStar/tutorial/* .
  ```

Building the Program

Our example uses a cyclic multi-threaded program which performs various tasks during each cycle. The cycle will be controlled by the main thread which uses a timeout with a configurable rate.

A portion of the main source file, **app.c**, is shown below:

```
int
main (int argc, char * argv[])
{
   pthread_t thread;
   pthread_attr_t attr;
   struct sembuf trigger = {0, 2, 0};
   nosighup();

   trace_begin ("/tmp/data",NULL);

   sema = semget (IPC_PRIVATE, 1, IPC_CREAT+0666);

   pthread_attr_init(&attr);
   pthread_create (&thread, &attr, sine_thread, &data[0]);

   pthread_attr_init(&attr);
   pthread_create (&thread, &attr, cosine_thread, &data[1]);
```

```
   pthread_attr_init(&attr);
   pthread_create (&thread, &attr, heap_thread, NULL);

   for (;;) {
      struct timespec delay = { 0, rate } ;
      nanosleep(&delay,NULL);
      work(random() % 1000);
      if (state != hold) semop(sema,&trigger,1);
   }

   trace_end () ;
}
```

The program creates three threads and then enters a loop which cyclically activates each of two threads based on a common timeout. The third thread, `heap_thread`, runs asynchronously.

To build the executable

From the local **`tutorial`** directory, enter the following command:

```
cc -g -o app app.c -lntrace_thr -lpthread -lm
```

NOTE

The NightStar LX tools require that the user application is built with DWARF debugging information in order to read symbol table information from user application program files. For this reason, the **`-g`** compile option is specified. However, the tools can be used to debug programs without symbols with reduced functionality.

2
Panels

NightStar provides flexibility in configuring the graphical user interface to suit your needs through the use of resizable and movable panels.

This chapter presents the concepts involved in moving and resizing panels. It is designed merely for reference, not as a step-by-step instructional guide.

Please read this chapter before proceeding to the first steps in using the tools, which follows in “Using NightView” on page 3-1.

Moving Panels

Consider the following NightProbe page which contains a List view and a Graph view each in their own panel:

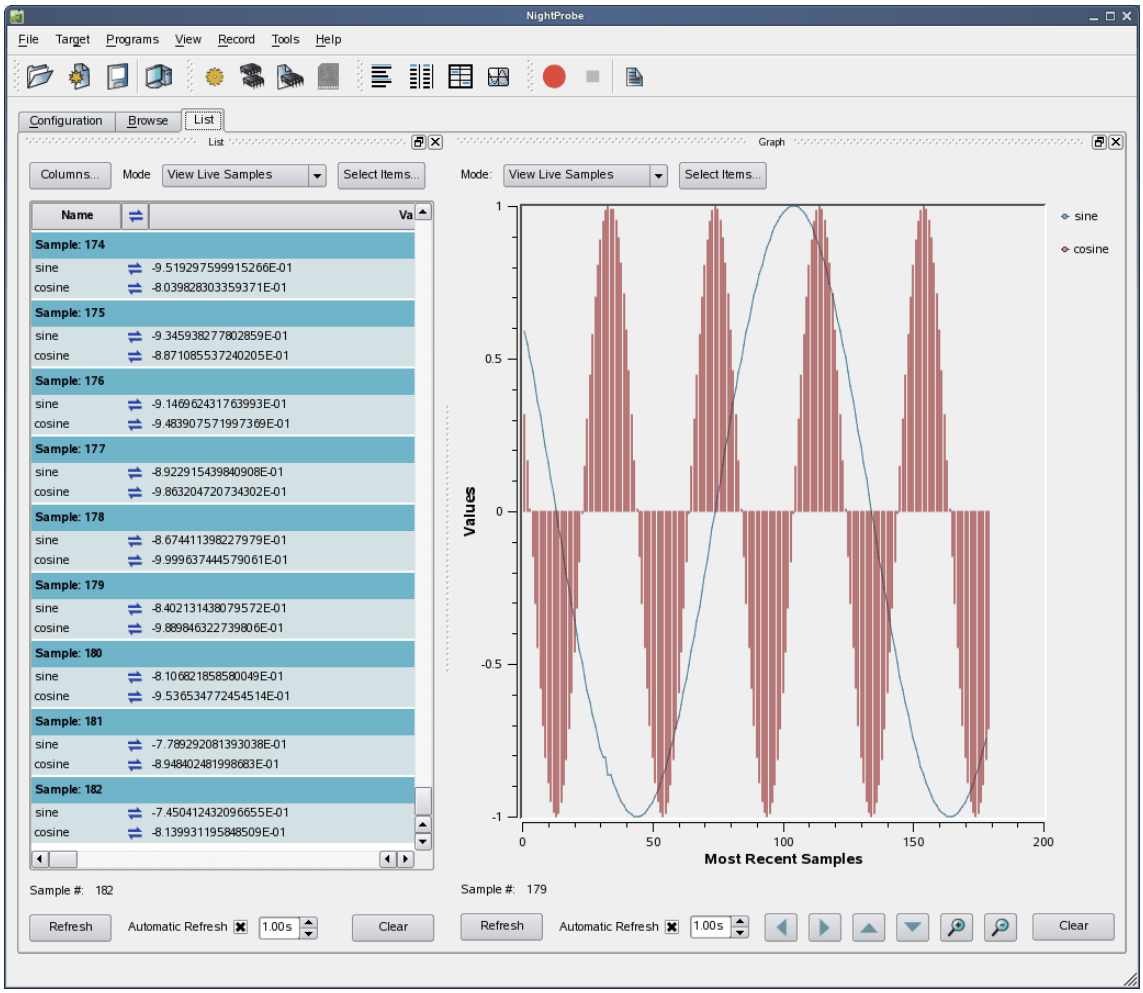


Figure 2-1. Viewing Page with List & Graph Panels

Panels are moved by left-clicking the title bar, dragging them to a new location, and then releasing the mouse button. Depending on the location of the panel when the mouse button is released, the panel will either remain detached or will be inserted into the page again.

To detach the panel from the page without inserting it, click the left-most control box in the upper right-hand corner of the panel.

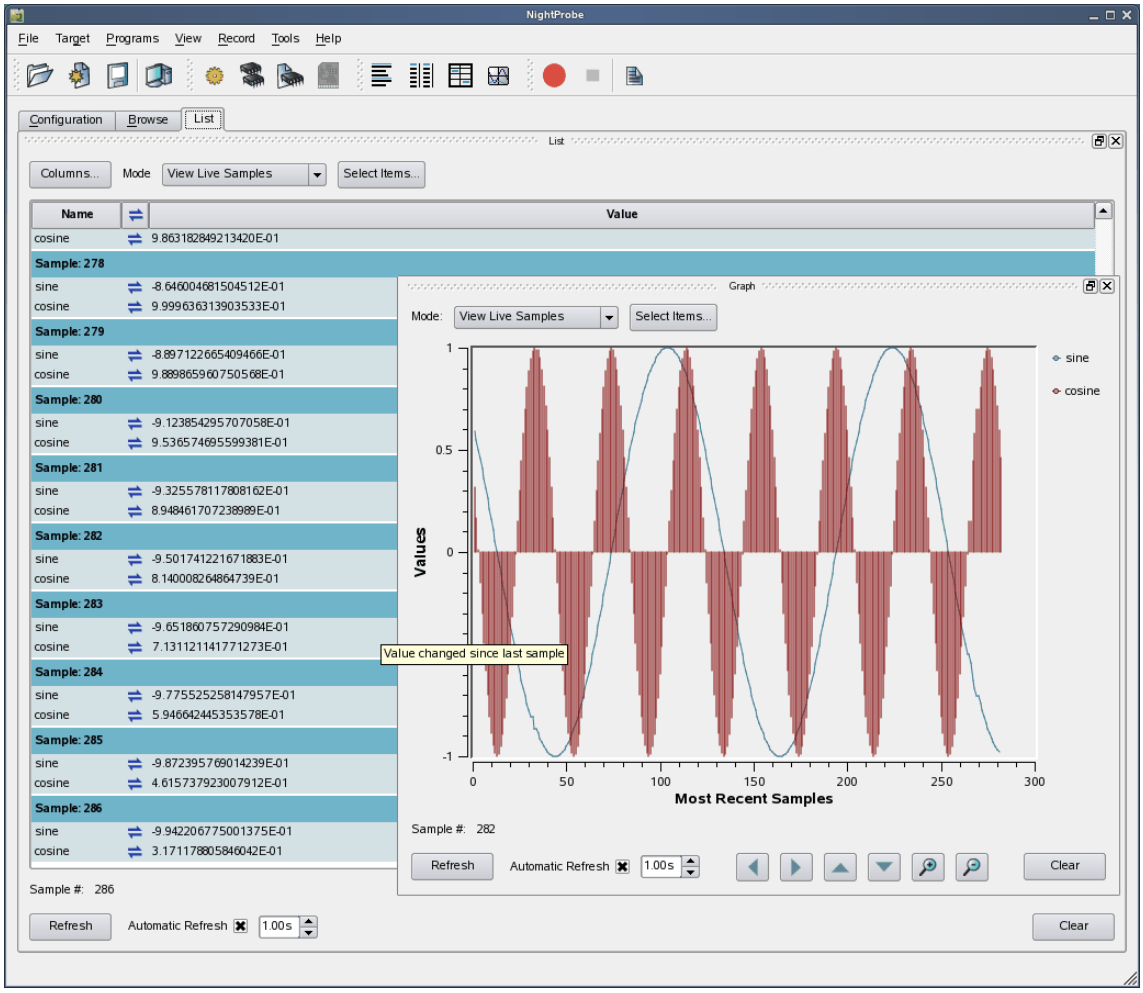


Figure 2-2. Panel Detaches from Page

The Graph panel detaches from the page and becomes free floating.

If moved outside the boundaries of the main window and released, the panel will remain detached from the main window. However, even in detached mode, if the main window is iconified, the detached panel will be iconified with it. For this reason, detached panels are not very useful in and of themselves. Detaching is most often useful as part of moving a panel and re-docking it.

To insert a panel into the page at a new location, drag the panel using the left mouse button on its title bar and move it until it approaches a boundary of the page. The window will respond by creating space indicating where the panel will be inserted.

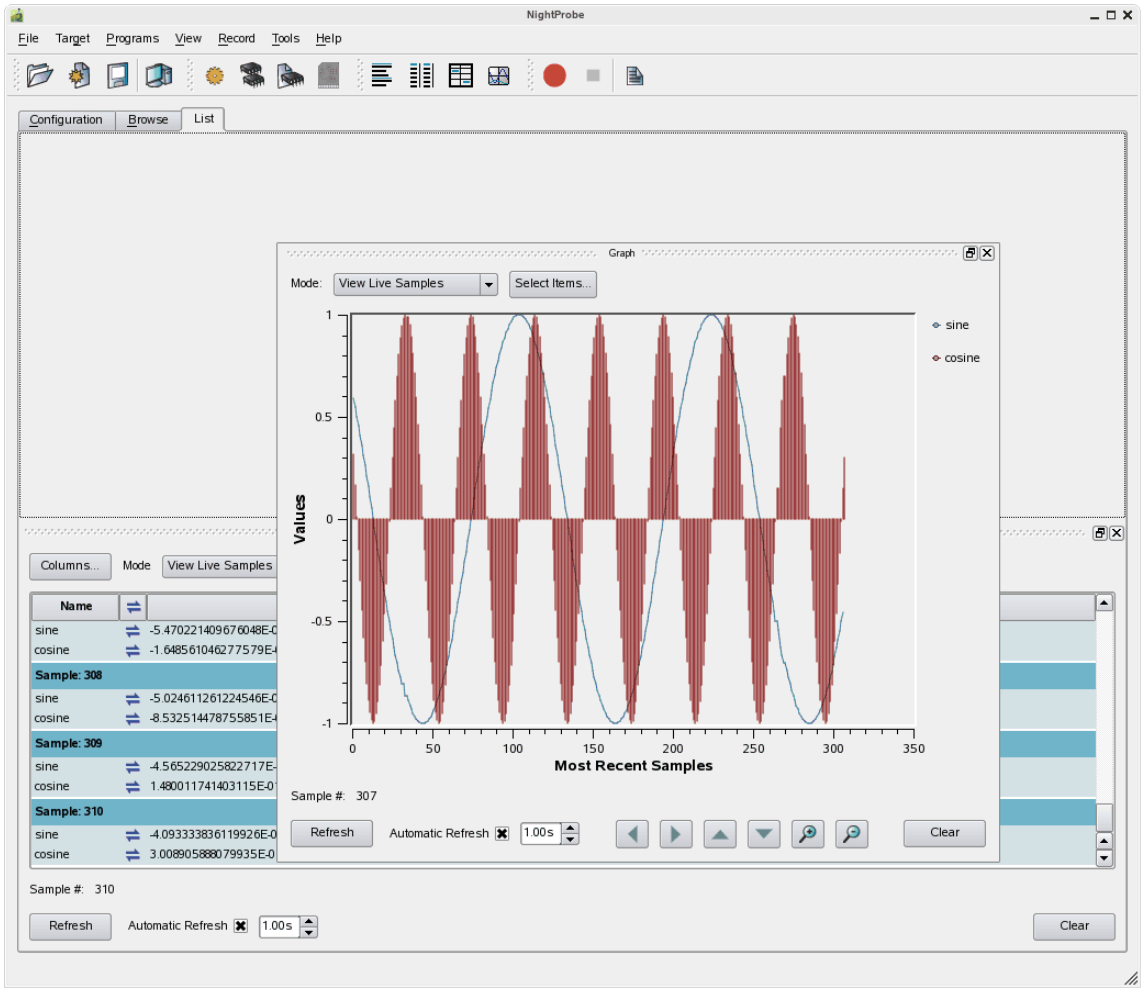


Figure 2-3. Panel Movement in Progress

The figure above shows space being created above the List panel as the Graph panel is dragged towards the upper horizontal boundary of the page.

At this point, releasing the mouse button will cause the Graph panel to be inserted into the page, consuming the recently created space.

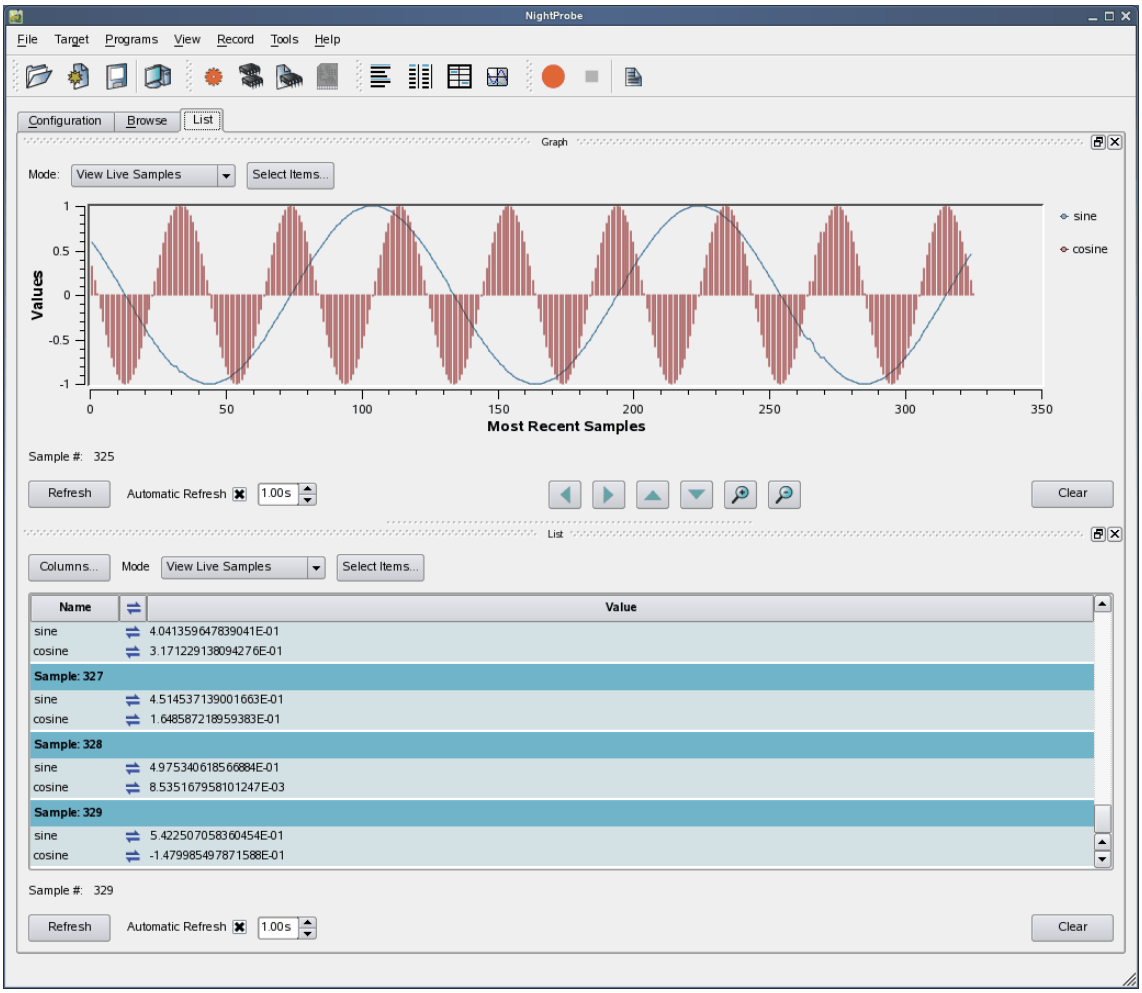


Figure 2-4. Graph Panel on Top of List Panel

IMPORTANT

When attempting to move panels inside of a page, if an empty space does not appear where you desire it, try increasing the size of the main window, decreasing the size of the undocked panel, and moving an alternative edge of the undocked panel near where you want to place it.

By default, the tools usually add panels to the right-hand side of the page when a new panel is created.

In the following figure, a Table panel has been added to the right-hand side of the Graph and List panels.

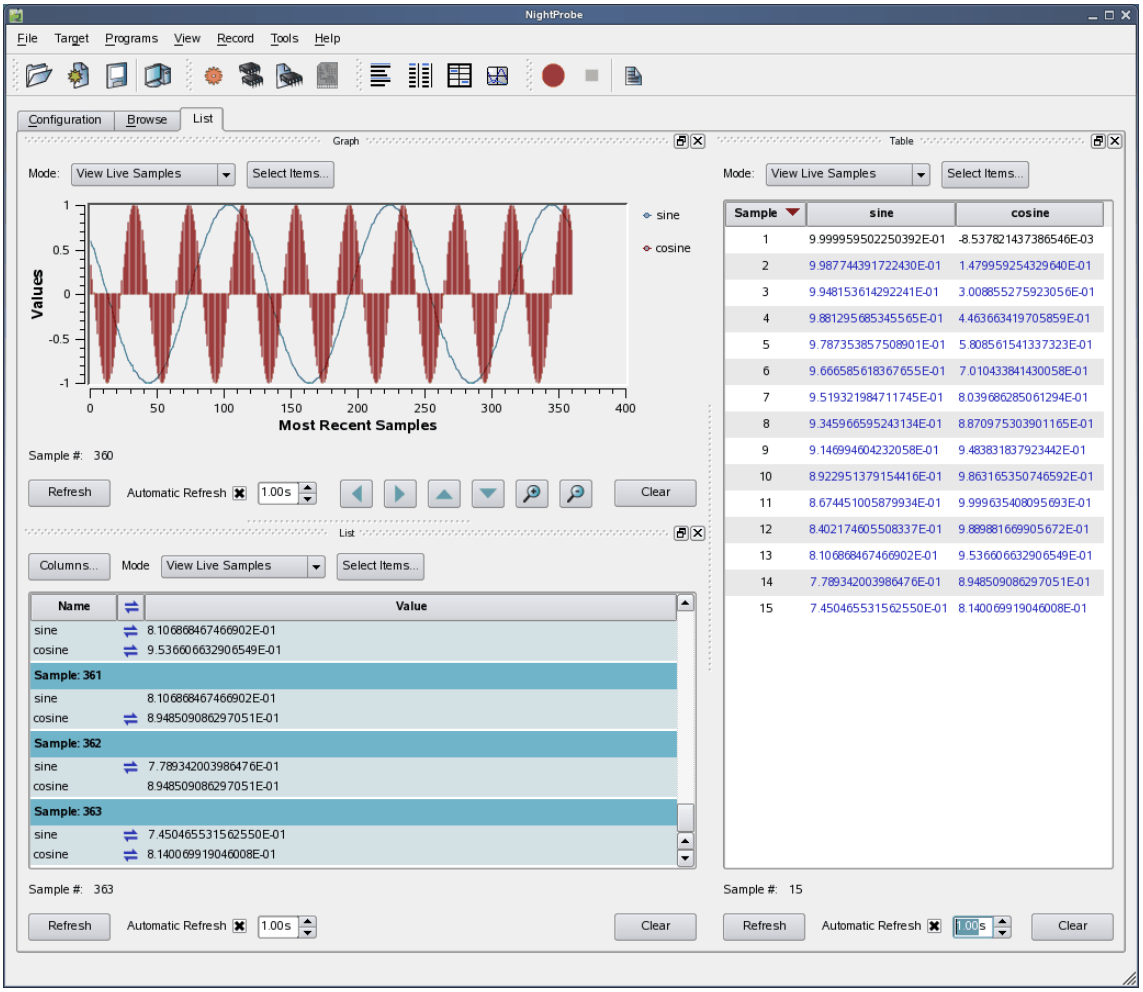


Figure 2-5. Table View added to Page

Panels can be resized by left-clicking on the separator between the panels and dragging it to the desired size.

Tabbed Panels

Another feature of the graphical user interface is the use of tabbed panels. Tabbed panels allow you to maximize your GUI real estate by placing two or more panels in the same location by stacking them on top of each other. You can then raise a panel to the top by clicking on its tab.

To create a tabbed panel, move a panel to the lower horizontal edge of another panel until a tab appears at the bottom of the panel still connected to the page.

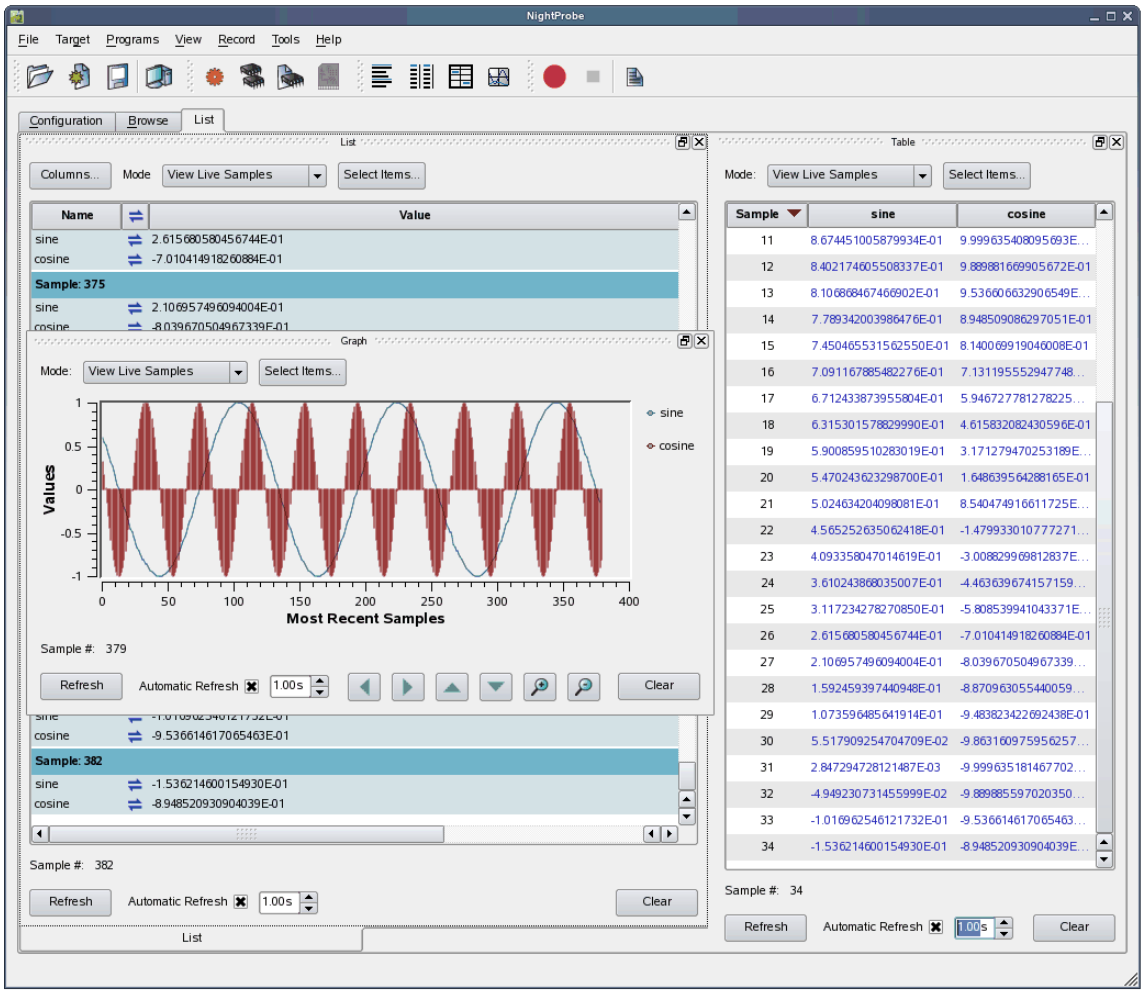
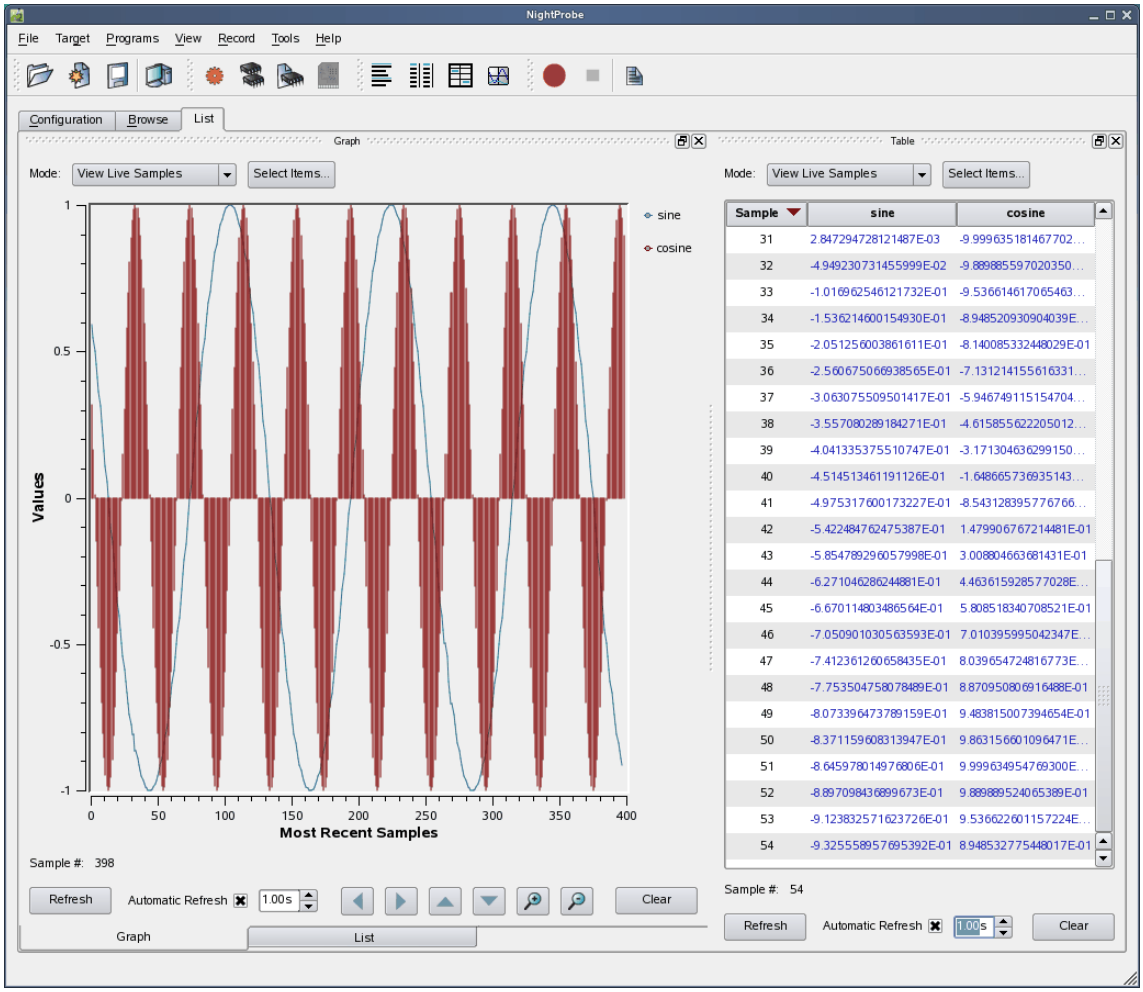


Figure 2-6. Panel in Motion Creating Tab

In the figure above, the Graph panel is being dragged from its original position on top of the List panel towards the bottom of the List panel. A tab appears on the List panel indicating that if the mouse button is released, the Graph and List panels will be tabbed and therefore consume the same area of the page.



IMPORTANT

To move a panel above another panel, move the desired panel to the top boundary of the other panel. If you move a panel to the bottom boundary of another panel, it will become a tabbed panel instead.

Context Menus

The NightStar tools rely heavily on use of context menus.

Context menus are menus that appear when you use the mouse to right-click when the mouse cursor is positioned over an area or item of interest. They are called context menus because their content is often dependent on the context of the area in which you right-click, or the item which you right-click upon.

When in doubt, try a right-click operation and see if a menu becomes available.

Tutorial Screen Shots

In order to show full screen shots in this tutorial, the size of each main window has often been left to its default setting. Displaying larger windows would require compression in order to fit the image within the available space of a printed page; such compression obscures detail.

However, as a user of the tutorial, increasing the size of the main window is highly recommended so you can see more data without having to scroll the contents of individual panels.

In many cases within this tutorial, portions of expanded areas of the screen have been extracted from the main window and are included as stand-alone screen shots. These correspond to panels within the main window of each tool.

3
Using NightView

NightView is a graphical source-level debugging and monitoring tool specifically designed for time-critical applications. NightView can monitor, debug, and patch multiple processes running on multiple processors with minimal intrusion.

NightView supports all the features you find in standard debuggers, including:

- breakpoints
- single stepping through statements
- single stepping over function calls
- full symbolic expression analysis
- conditions and ignore counts for breakpoints
- hardware-assisted address traps (watchpoints)
- assembly and symbolic debugging

In addition to standard debugging capabilities, NightView provides the following features:

- application-speed eventpoint conditions
- the ability to patch code to change program flow or modify memory or registers during program execution
- hot patch and eventpoint control
- synchronous data monitoring
- loadable modules
- support of multi-threaded programs
- debugging of multiple processes
- dynamic memory debugging
- traversing linked lists
- searching segments of memory

Invoking NightView

- Execute NightView by issuing the following command:

  `nview &`

  at the command prompt or by double-clicking on the desktop icon.

NOTE

If you do not have desktop icons for the NightStar tools, run **`/usr/lib/NightStar/bin/install_icons`**.

When we launch NightView, the NightView main window is presented.

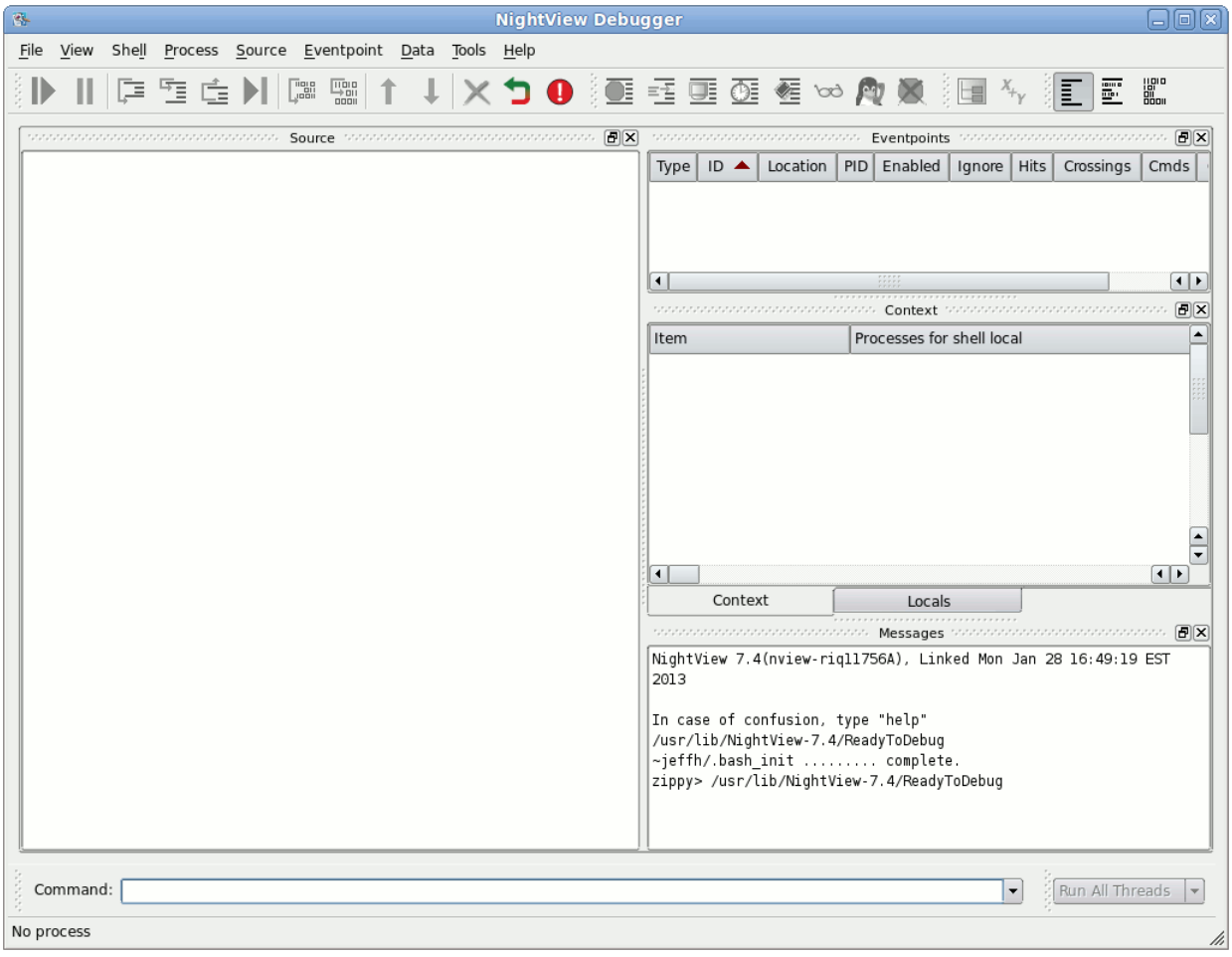


Figure 3-1. NightView Main Window

NOTE

If this is the first time you've invoked NightView since installing NightStar or upgrading to the latest version, you may see a welcome screen. You can disable the welcome screen for subsequent invocations using the checkbox in the lower left corner of that screen. If the screen appears, press the NightView button to proceed.

In our example, we'll be debugging a single application.

NOTE

If you have not yet created the **`app`** program, see "Building the Program" on page 1-2.

- Invoke our tutorial application in the NightView main window by selecting Run… from the Process menu and entering:

  ```
  ./app
  ```

  in the text field of the Run on local dialog.

- Press OK to close the dialog and run the program.

Any output generated by the program will appear in the Messages panel.

When the **app** program begins to execute, NightView displays the source in the source panel and stops the program at the first line of code.

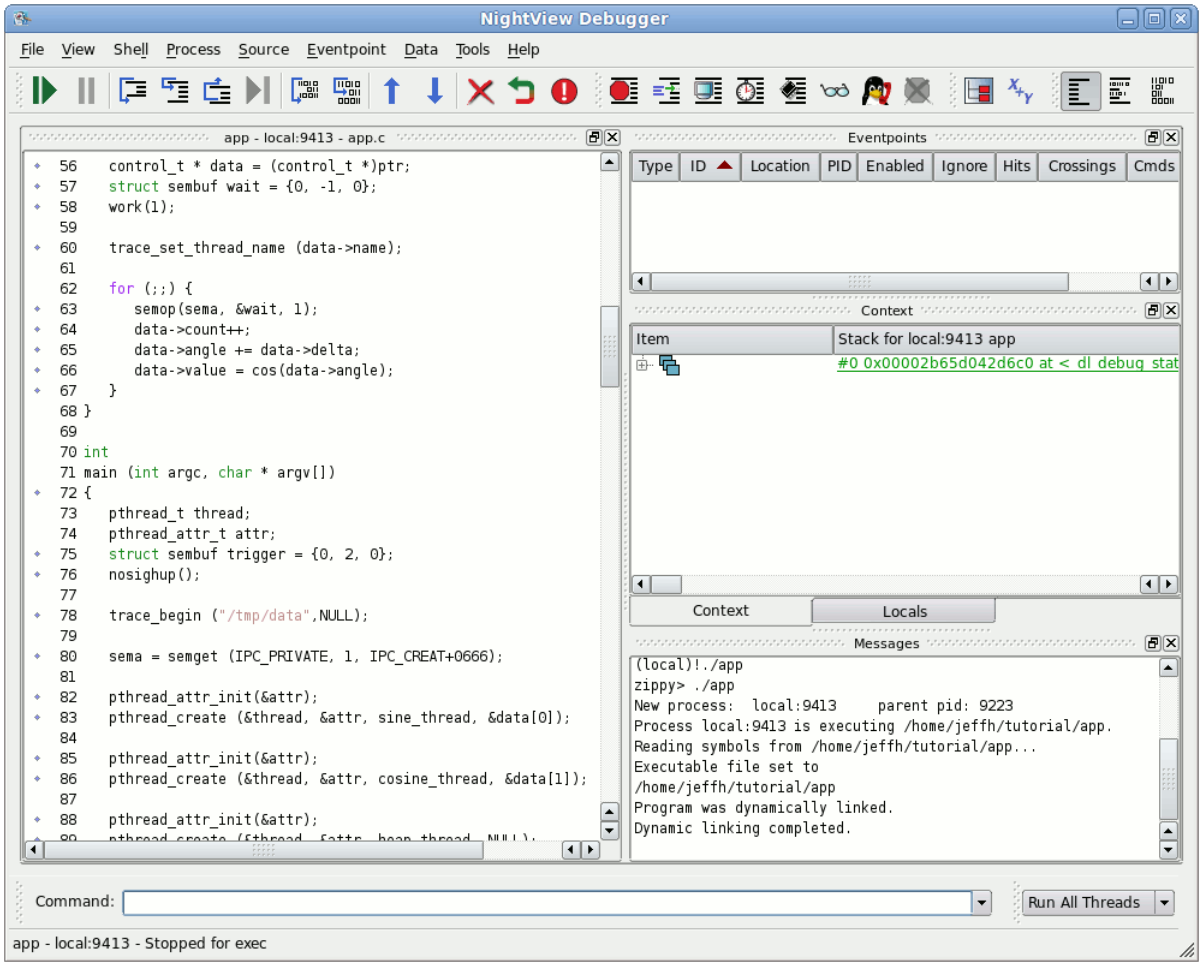


Figure 3-2. app Program Loaded

IMPORTANT

Do not resume execution of the program at this time.

NightView supports debugging multiple processes as well as single and multi-threaded processes. In this tutorial, you will be debugging a single process.

Heap Debugging

Debugging dynamic memory problems can be difficult and extremely time-consuming. The word *heap* refers to a collection of allocated and freed memory typically controlled by the `malloc()` and `free()` utilities in the C language.

NightView provides the unique ability to monitor and detect memory allocations, frees, and sets of user errors without requiring a non-standard allocator to be compiled or linked into your program.

One advantage of this is that often when you switch to a debugging allocator, the way blocks are allocated and freed changes -- often hiding the very bugs you're trying to find.

NightView offers a variety of settings and debugging levels that are useful in catching common heap-related errors. Some settings will change the behavior of the system allocator, affecting the size of allocated blocks and, ultimately, the address values returned.

Dynamic memory errors are detected in one of four ways:

- a check of the entire heap at a specified frequency in terms of the number of heap functions (e.g., `malloc`, `free`, `calloc`, etc.) called
- a check of an individual allocated block when `free` or `realloc` is called
- a check of the entire heap when a **`heappoint`** is crossed
- a check of the entire heap when a **`heapcheck`** command is issued

The frequency setting of the **`heapdebug`** command or `Debug Heap` window controls how often NightView should check for heap errors when a utility routine is called. Setting the frequency to 1 causes NightView to check for heap errors on every heap operation.

A **`heappoint`** causes NightView to check for errors when the process executes instructions where the heappoint is inserted. An unlimited number of heappoints can be inserted into your program.

The check of an individual block when `free` or `realloc` is called is automatic.

All four mechanisms are useful. With the first three mechanisms, the heap error detection is executed at program application speed without context switching to the debugger.

Activating Heap Debugging

One limitation of heap debugging is that it requires that you activate the debugging before any allocations occur in your program. If you attempt to activate the heap debugging features after allocations have already occurred, NightView will inform you of its inability to satisfy your request.

NOTE

If you have mistakenly resumed execution of the program already, kill the program and restart it in the NightView main window. Type the following commands in the Command area:

```
kill
run ./app
```

- Select the Debug Heap… menu option from the Process menu in the NightView main window.

  The Debug Heap window is shown.

- Select the Enable heap debugging checkbox at the top of the dialog.
- Press the Medium button in the Debugging Level area.
- Change the Specify check heap freq text field to 1.

The Debug Heap window should look similar to the following figure:

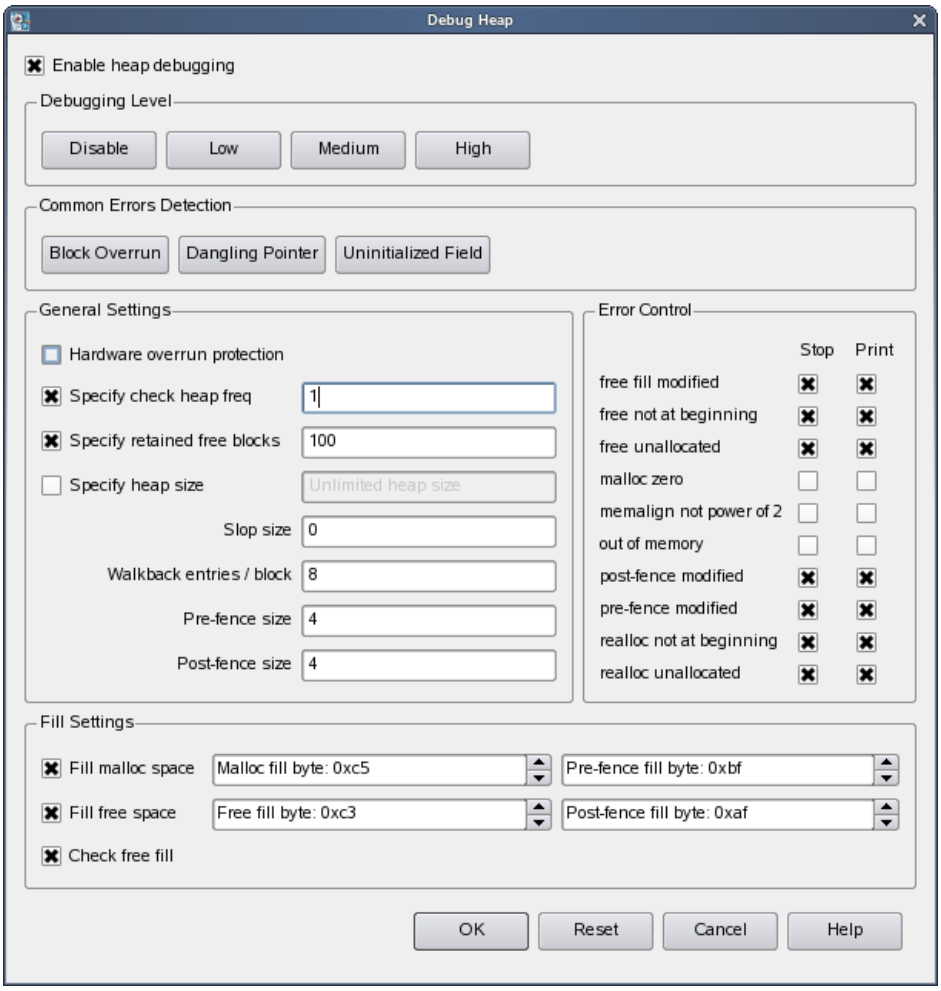


Figure 3-3. NightView Debug Heap Dialog

- Press the OK button to apply the changes and close the dialog.

These options instruct the debugger to activate heap debugging, retain freed blocks to detect certain kinds of errors, allocate some additional memory past the end of the requested size to detect errors, and stop the program when any heap error is detected.

Controlling the app Program

The third thread created by the main program executes a routine called `heap_thread`.

This routine iteratively executes various dynamic memory operations based on the setting of the `scenario` variable. These operations are representative of common user errors relating to dynamic memory.

Let’s set a breakpoint on line 115.

- Scroll to line 115 in the source window:

```
sleep(5);
```

- Right-click anywhere on that line and select Set simple breakpoint from the pop-up menu.

NOTE

Optionally, you could set a breakpoint on line 115 by using either the Set Breakpoint menu item from the Eventpoint menu or enter the following command in the Command panel of the NightView main window:

```
break app.c:115
```

Scenario 1: Use of a Freed Pointer

A common error is to read or write a block of memory that has already been freed.

A way to detect this is to tell NightView to retain freed blocks and fill the freed blocks with a specific pattern. If the blocks are subsequently read, your application may more quickly discover the error since the contents are unexpected. If the blocks are subsequently written, NightView can detect this.

- Resume the process and let it reach the breakpoint on line 115 by pressing the Resume icon on the Process toolbar:

NOTE

Alternatively, you can resume the process by typing **`resume`** into the Command field:

By default, the `heap_thread` will not actually execute any of the five scenarios.

- To cause it to execute scenario 1, set the variable `scenario` to 1 by entering the following commands in the Command field:

```
set scenario=1
resume
```

This causes the following snippet of code to be executed after a delay of 5 seconds:

```
ptr = alloc_ptr(1024,3);
free_ptr (ptr,2);
memset (ptr, 47, 64);
```

The last line represents usage of dynamically allocated space that has already been freed.

NightView will detect this at a heappoint inserted by the user, or at a subsequent heap operation (based on the **`frequency`** setting of the **`heapdebug`** command), in this case on line 155.

NightView will stop the process once the heap error has been detected and issue a diagnostic similar to the following:

```
Heap errors in process local:3771:
   free-fill modified in free block (value=0x804a818)
#0 0x8048b6d in heap_thread(void*unused=0) at app.c line 155
```

The error refers to the fact that locations within the freed block were modified by the process after the block was freed.

The Data panel is useful for displaying heap-related information as well as a variety of other attributes.

- Select Heap Information from the Data menu.

  The Data panel is added to the NightView main window in the same location as the Locals and Context panels. A new tab will be created for the Data panel.

- Click on the newly-created Data tab.

- Resize the first column (if necessary) by clicking on the divider between the column headings and dragging it to the right so that the items of interest below can be seen in their entirety.

- Expand the `Configuration` item under `Heap Information` in the Data panel to show the current **`heapdebug`** settings.

- Expand the `Totals` item under `Heap Information` to show summary statistics related to heap activity.

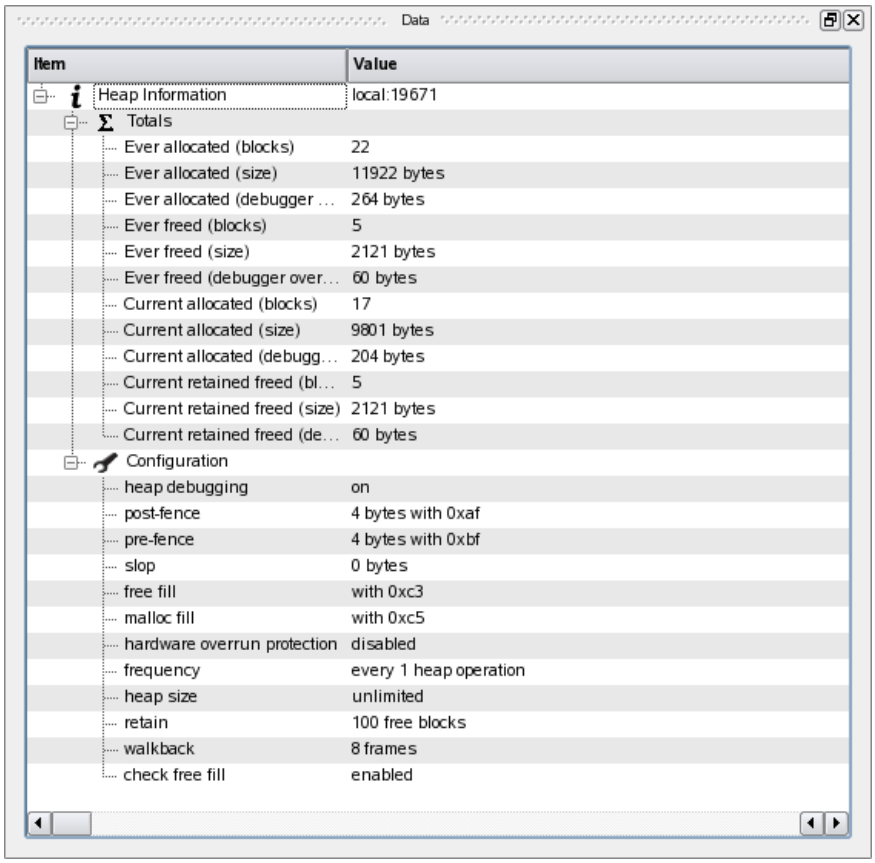


Figure 3-4. Heap Totals and Configuration

NOTE

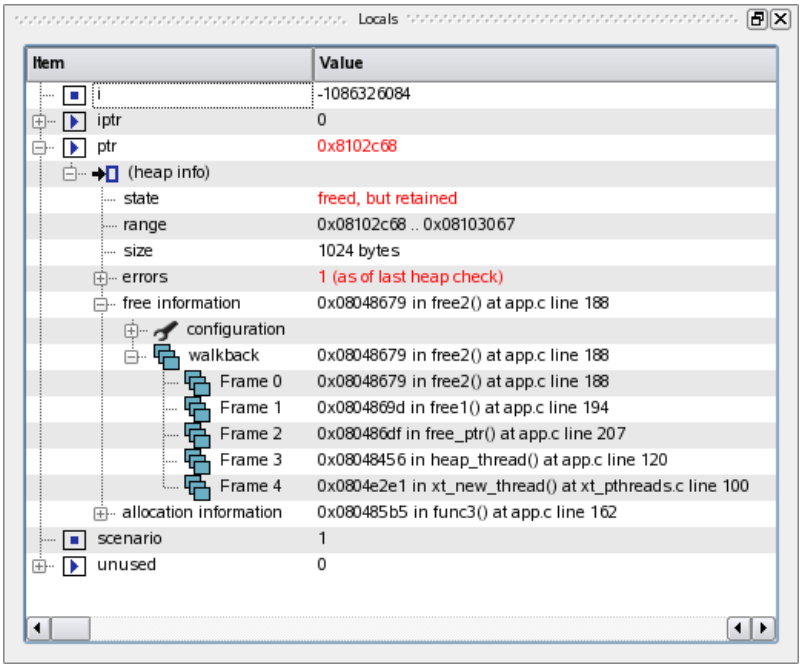
In general, all information in the Data panel is updated whenever the process being debugged stops.

- Collapse the `Totals` and `Configuration` items.
- Click on the tab labeled `Locals`.

The list of items in the `Locals` panel changes each time the process stops to represent the local variables associated with the current frame being displayed. Note that the value of the variable `ptr` is displayed in red because it no longer contains a valid (allocated) heap address.

Expanding the `ptr` item reveals the `(heap info)` item. Expanding that item reveals additional information relating to the block that the pointer once referred to including:

- its state - freed, but retained
- its address range
- its size
- errors
- free and allocation information, which when expanded include walkback information relating to the routines which allocated and freed the block



Scenario 2: Freeing an Invalid Pointer Value

Another common error is to free a pointer multiple times or to free a value which doesn't actually refer to a heap block.

- Resume the process and let it reach the breakpoint on line 115:

```
resume
```

- Set the variable `scenario` to 2:

```
set scenario=2
resume
```

This causes the following snippet of code to be executed after a delay of 5 seconds:

```
ptr = alloc_ptr(1024,3);
free_ptr(ptr,2);
free(ptr);
```

NightView will detect the failure and print a diagnostic similar to the following:

```
Heap error in process local:3771: free called on freed or
unallocated block (value=0x804ac40)
#0 0x8048a78 in heap_thread(void*unused=0) at app.c line 127
```

Another way of obtaining information about the heap block in question is to use the **`info memory`** command. It provides textual output of the information available in the Locals panel under the `ptr` item to the Messages panel of the NightView main window.

- Issue the following command in the Command panel:

```
info memory ptr
```

NightView will provide output similar to the following in the Messages panel:

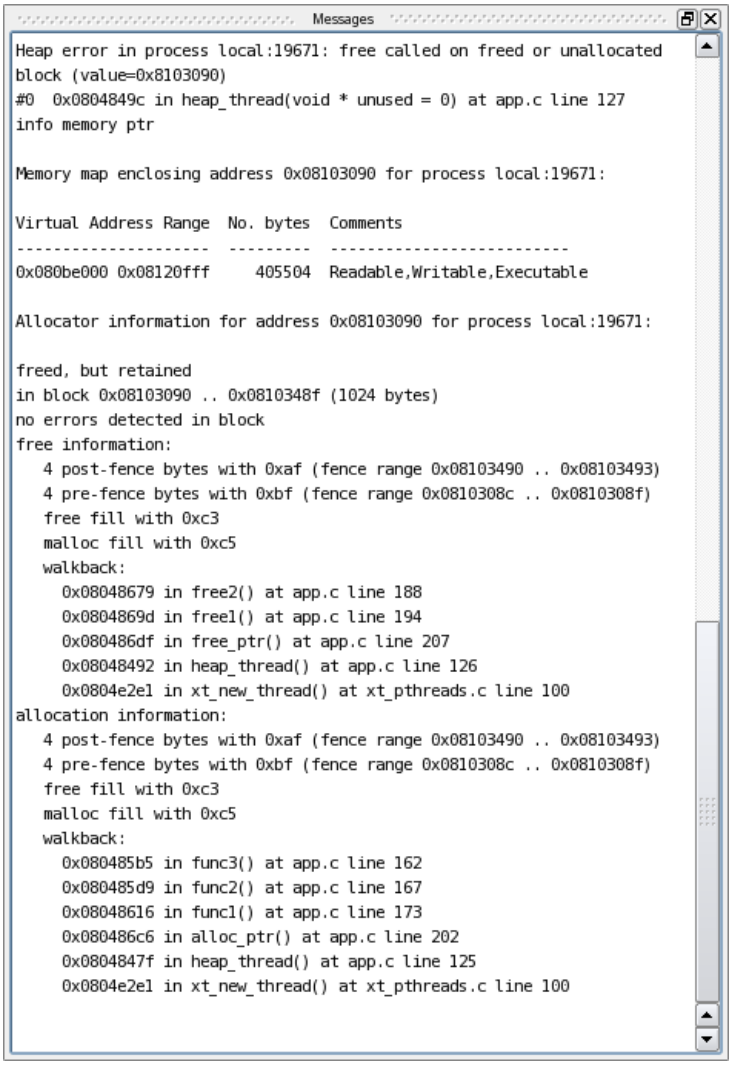


Figure 3-5. info memory Command Output

Note that it reports no error in the block per se. The actual problem here is that a second attempt was made to free the block when it already had been freed previously.

In this case, the walkback information associated with the actual free is useful as you can quickly locate what code segment actually freed the block.

Scenario 3: Writing Past the End of an Allocated Block

Another common error is to allocate insufficient space or to write past the end of an allocated block.

- Resume the process and let it reach the breakpoint on line 115:

```
resume
```

- Set the variable `scenario` to 3:

```
set scenario=3
resume
```

This causes the following snippet of code to be executed after a delay of 5 seconds:

```
ptr = alloc_ptr(strlen(MyString),2);
strcpy (ptr, MyString); // oops -- forgot the zero-byte
```

NightView will detect the failure and print a diagnostic similar to the following:

```
Heap errors in process local:3771:
   post-fence modified in block (value=0x804b068)
#0 0x8048b6d in heap_thread(void*unused=0) at app.c line 155
```

Note that the description of the variable `ptr` in the Locals panel does not indicate an invalid status. That is because `ptr` does point to a valid heap block.

However, expanding the (`heap info`) information for `ptr` and the `errors` list indicates that the block referenced by the `ptr` is invalid because the post-fence was modified.

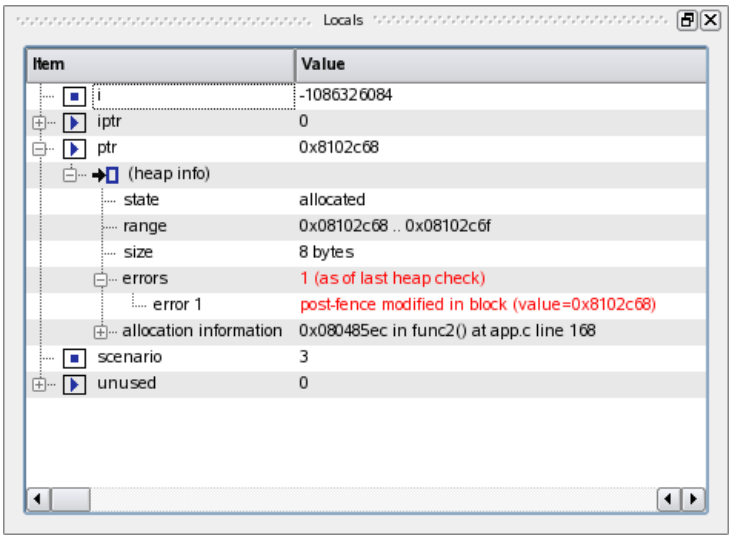


Figure 3-6. Heap Error Description

Scenario 4: Use of Uninitialized Heap Blocks

Another common error is forgetting to initialize dynamically allocated memory before using it. Code segments may assume that dynamically allocated memory is initialized to zero, as is the case with `calloc()` but not `malloc()`.

- Resume the process and let it reach the breakpoint on line 115:

  `resume`

- Tell NightView to stop whenever a SIGSEGV is sent to the process and also set the variable `scenario` to 4:

  ```
  handle sigsegv stop print pass
  set scenario=4
  resume
  ```

This causes the following snippet of code to be executed after a delay of 5 seconds:

```
iptr = (int**)alloc_ptr(sizeof(int*),2);
if (*iptr) **iptr = 2778;
```

NightView will detect the failure and print a diagnostic similar to the following:

```
Process local:3771 received SIGSEGV
#0 0x8048ad2 in heap_thread(void*unused=0) at app.c line 138
```

One heap debugging option instructs NightView to fill newly allocated, uninitialized space with a specific pattern to make it easier to detect use of uninitialized memory. The Fill malloc space field in the Debug Heap dialog that we used when enabling heap debugging specified the byte pattern to be `0xc5`.

- Issue the following command to view the content of the uninitialized memory block:

  `x/x iptr`

A `SIGSEGV` signal is a fatal error so we must restart the process to continue the tutorial.

- Issue the following command:

  `kill`

- Re-initiate the program by pressing the ReRun icon in the Process toolbar:

NOTE

Alternatively, you can issue the following command directly from the Command field to initiate the process:

`rerun`

NOTE

NightView automatically re-applies all eventpoint and heap control settings when it sees the subsequent execution of the program.

Scenario 5: Detection of Leaks

Another situation which may be indicative of error or inappropriate use of memory are leaks. In this instance, we define a leak as a dynamically allocated block of memory that is no longer referred to by any pointer in the program.

Detection of leaks is a ***very expensive*** process with respect to CPU utilization and intrusion on the user application. As such, leak detection is only executed when an explicit request is made from the user.

- Resume the process and let it reach the breakpoint on line 115:

  ```
  resume
  ```

- Set the variable `scenario` to 5:

  ```
  set scenario=5
  resume
  ```

This causes the following snippet of code to be executed after a delay of 5 seconds:

```
ptr = alloc_ptr(37,1);
ptr = 0;
```

NightView does not detect the leak automatically, as mentioned above. The process will stop again when the breakpoint on line 115 is reached.

- At that time, specifically request a leak report by selecting Heap Leaks… from the Data menu, check the New Leaks radio button, and press OK in the Data Heap Leaks dialog to add the item to the Data panel.

  This operation causes NightView to analyze the program for leaks and displays a `Leak Sets` item in the Data panel. On small programs, this operation may appear to be insignificant, but for larger programs it can take some significant time.

- Click on the Data tab.

- Expand the `Leak Sets` item, if necessary.

  An additional item is displayed for every leak set with a matching block size that was allocated with a matching walkback. Expansion of individual sets provides the common walkback shown for each allocation as well as expandable descriptions of each individual leaked block.

- Expand the leak set item with size 37 and then expand the `walkback` item associated with it.

Note the walkback indicating that it was allocated by the `heap_thread()` routine on line 142 of **`app.c`**.

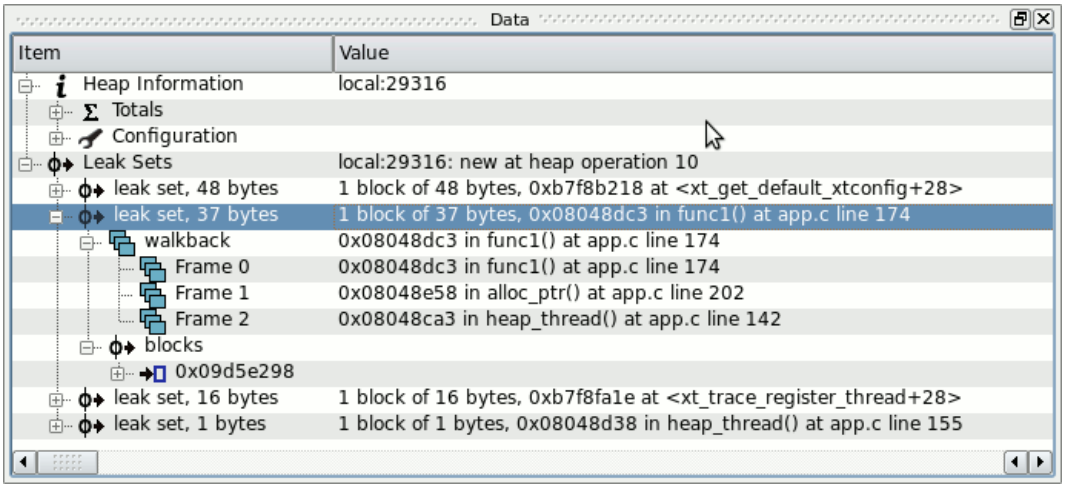


Figure 3-7. Heap Leaks Display

NOTE

The Leak Sets display will vary depending on your system type. Concentrate on the leak set of 37 bytes as shown above.

NOTE

Unlike most items in the Data panel, the `leak sets` item is not automatically updated when the process stops. The description is a snapshot of the leaks at a certain moment in the execution of the program, and therefore it will remain unchanged even if additional leaks occur. To get updated information, request another leak report (select Heap Leaks… from the Data menu).

Scenario 6: Allocation Reports

NightView provides a detailed report of all allocated memory.

Construction of this report is a ***very expensive*** process with respect to CPU utilization and intrusion on the user application execution time. As such, allocation reports are only executed when an explicit request is made from the user.

- Set the variable `scenario` to 6:

```
set scenario=6
resume
```

This causes additional allocations to be made.

The process will stop again when the breakpoint on line 115 is reached.

- At that time, specifically request an allocation report by selecting Still Allocated Blocks... from the Data menu, click the All Blocks radio button, and press OK in the Data Still Allocated Blocks dialog to add the item to the Data panel.

This operation causes NightView to analyze the program and displays a `Still Allocated Sets` item in the Data panel. On small programs, this operation may appear to be insignificant, but for larger programs it can take some significant time.

- Resize the first column (if necessary) by clicking on the divider between the column headings and dragging it to the right so that the items of interest below can be seen in their entirety.
- Expand the `Still Allocated Sets` item, if necessary. An additional item is displayed for every allocation set with a matching block size that was allocated with a matching walkback. Expansion of individual sets provides the common walkback shown for each allocation as well as expandable descriptions of each individual leaked block.
- Expand the `allocated set` item with size 1048576 and then expand the `walkback` item associated with it.

Note the walkback indicating that it was allocated by the `heap_thread()` routine on line 147 of **`app.c`**.

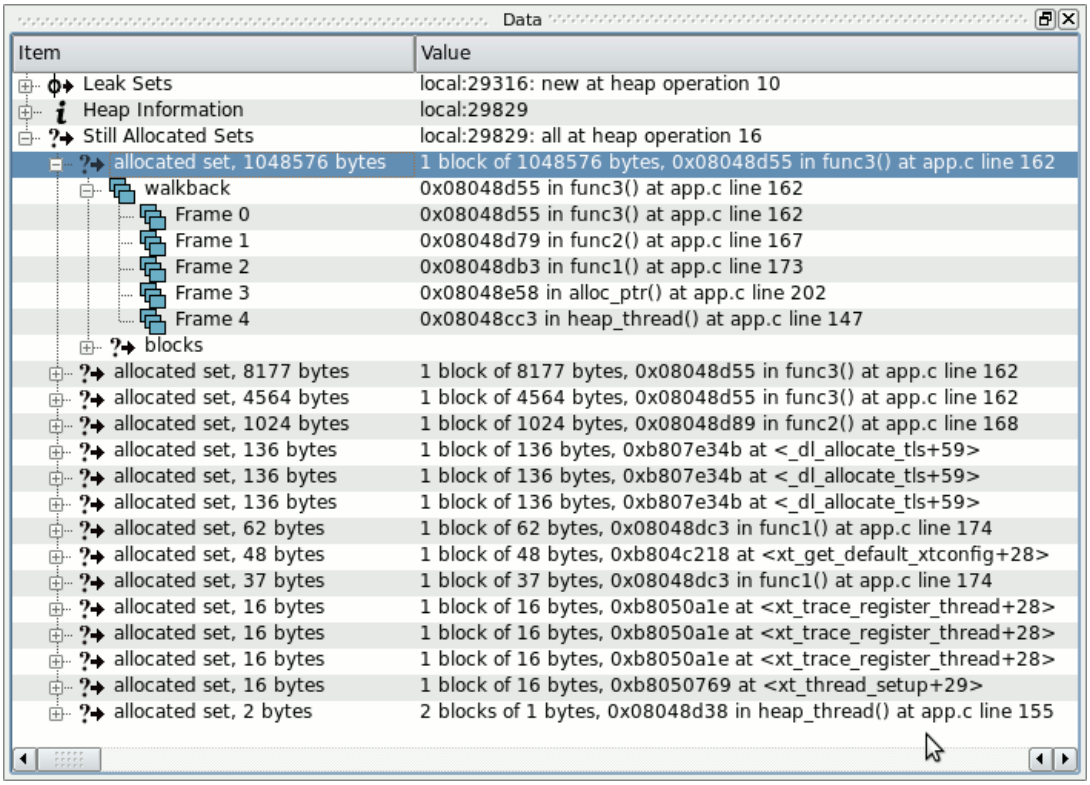


Figure 3-8. Still Allocated Blocks Display

NOTE

The data from the Still Allocated Sets will vary depending on your system. Concentrate on the allocated set of 1048576 bytes as shown above.

NOTE

Unlike most items in the Data panel, the `Still Allocated Sets` item is not automatically updated when the process stops. The description is a snapshot of the leaks at a certain moment in the execution of the program, and therefore it will remain unchanged even if additional items are allocated or freed. To update the information, request another allocation report (select Still Allocated Blocks... from the Data menu).

Disabling Heap Debugging

- Disable all overhead associated with heap debugging, issue the following command:

  `heapdebug off`

- Delete the breakpoint on line 115 by right-clicking on that breakpoint in the Eventpoints panel and selecting Delete or by issuing the following command:

  `clear app.c:115`

This concludes the tutorial's topic on heap debugging. We will now continue on to other capabilities of NightView.

Debugging Multiple Threads

Our application consists of the main thread and three additional ones created by the main thread.

- Set a breakpoint on line 47 by issuing the following command:

```
b 47
```

- Resume the process by clicking on the resume icon or by issuing the following command:

```
resume
```

The process will run until one of the threads reaches the breakpoint on line 47.

- Click on the Context tab to raise the Context panel.
- Expand the thread which is displayed in green.
- Expand the first item in the walkback list that appeared as a result of the last step

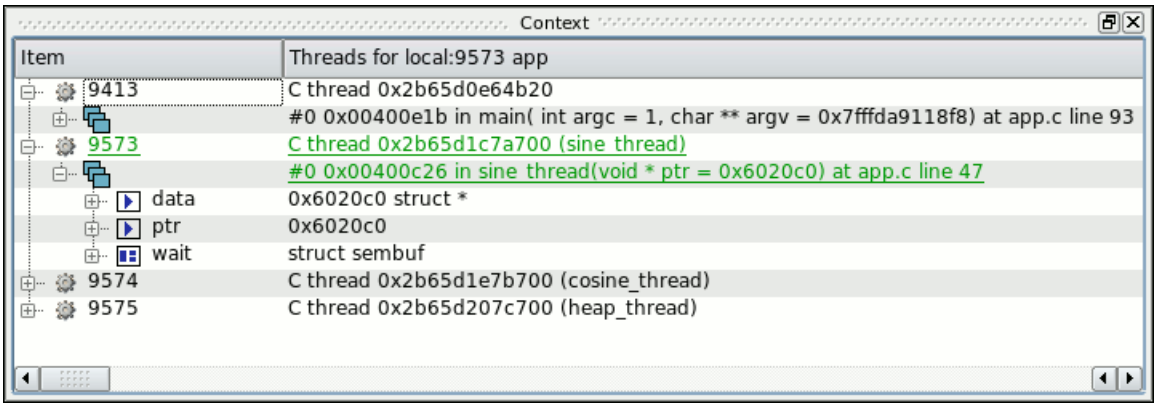


Figure 3-9. Context Panel With Stack Frames Expanded

Expanding an individual Frame in the walkback list shows all local variables for that frame. You can further expand composite and pointer variables in the local variables items.

The source shown in the Source panel is that associated with the program counter of the thread which caused the process to stop. You can tell which thread you are stopped in by looking for the name of the thread's start routine in parenthesis. NightView automatically assigns names to threads based on the start routine which was passed to **`pthread_create(2)`**. Additionally, you can set the name of a thread inside NightView using the **`set-thread-name`** command.

You can switch to the context of other threads by clicking on the thread of interest. When you click on a thread, the source displayed in the NightView main window changes to location where that thread is executing.

Alternatively, you can use the **select-context** command and specify the thread name as shown in the C Threads display or from the output of the **info threads** command:

```
info threads /v
select-context name="cosine_thread"
```

When thread names are not unique across threads, you can use the thread ID which is always unique. A thread ID is a hexadecimal number representing the thread -- it is assigned by the threads library upon thread creation. The thread ID immediately follows the words "C thread" on each thread item in the Context panel.

- Switch to the context of the thread executing `sine_thread()` by clicking on it.

NightView provides a Run Mode which specifies how threads are resumed and stopped. By default, the Run Mode is Run All Threads. Thus when the application hits a breakpoint or is otherwise stopped by NightView, all threads in the application will stop. Similarly, when NightView resumes execution of a thread, all threads will resume execution.

If you change the Run Mode to Run One Thread, then when you resume a thread, it is the only one that runs. All stopped threads remain stopped.

On one of the toolbars, you will see a option list which represents the current run mode. By default, this item is at the bottom of the screen to the right of the Command area.

Figure 3-10. Run Mode Selector

- Change the mode to Run One Thread by clicking on the list and selecting that mode.

- Click the Next icon  several times until the green PC icon  stops on line 46, the call to `semop()`.

- Now click the Next icon one more time.

Notice that the Next operation does not complete. This is because we were only allowing a single thread to execute, and the thread is blocked in the `semop()` call, waiting for another thread to unblock it (the main thread).

- Press the Interrupt icon  to cancel the Next operation.

NOTE

Some versions of glibc on some distributions may be missing proper walkback information for the **`semop(2)`** routine, which is where the thread is stopped. In this case, the **`walkback`** and **`interest`** instructions below will not react as described below for this specific example.

Also, some systems may have debug versions of glibc installed, in which case NightView may show you source code inside `semop()`, or routines it calls. Regardless, you will likely be presented with a gray triangular arrow, as described below, unless you are stopped at the lowest level, a system call.

The gray triangular arrow before the line number in the source panel represents the fact that we are positioned at a stack frame which is not the topmost stack frame and that the current frame is executing a subprogram call.

By default, NightView hides uninteresting frames. If you desire to see all frames for all routines, even those that have no debug information, you can set your *interest threshold* to the keyword `min`:

```
interest threshold min
```

Once that command is issued, the walkback information shows all frames and you can position to any frame and debug at the assembly level if desired.

- Reset the **`interest threshold`** to zero via the following command:

  ```
  interest threshold 0
  ```

- Delete the breakpoint on line 47 by right-clicking on that breakpoint in the Eventpoints panel and selecting Delete or by issuing the following command:

  ```
  clear app.c:47
  ```

- Change the Run Mode to Run All Threads.

- Resume execution of the process.

NOTE

A significant feature of NightView is the ability to execute most debugging operations without having to stop execution of the process.

All subsequent debugging operations in this tutorial can be done without stopping the process!

Traversing Linked Lists

NightView's data display panels allow you to view variables, indirect through pointers, and expand or collapse levels of detail. Variables are presented in a tree to facilitate viewing.

NightView provides two features which make viewing complex data structures easier: linked lists and filtering.

Our application has created a list of structures which are linked via a member of each structure. The variable `head` represents the start of this linked list.

For simplicity, we will remove the existing data panel before proceeding with this section.

- Raise the existing data panel and then close it by clicking the close icon in the upper-right of the panel's control area.
- Add the variable `head` to a new data panel by typing the following command:

```
data head
```

A new data panel now appears and contains the pointer variable `head`.

- Expand the pointer variable and the `link` pointer member of it, and several of its children.

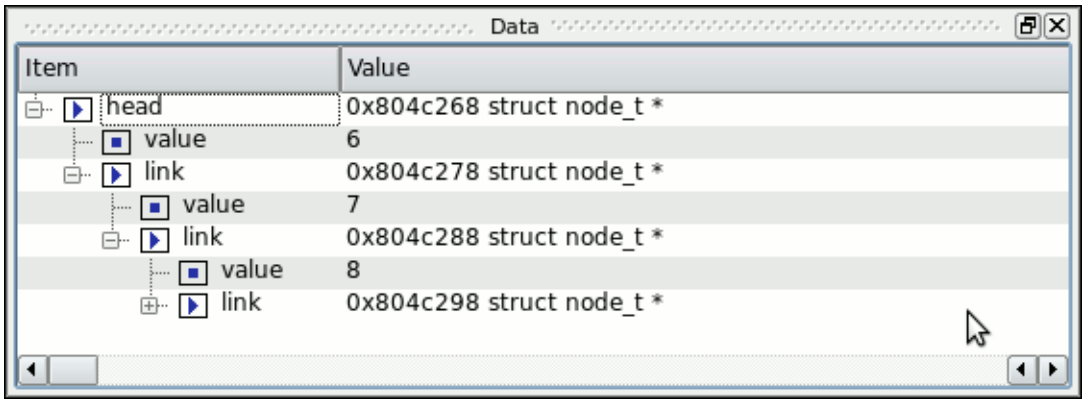


Figure 3-11. Pointer to Linked List Expanded

As shown in the figure above, each node in the linked list is nested under the previous node in the list. While this is a fine representation, it becomes cumbersome once you display more than just a few nodes.

As an alternative, you can tell NightView that the pointer is a member of a linked list.

- Right-click on the `head` variable and select Treat As Pointer To Linked List...

A small dialog is presented which allows you to specify the member of the structure which defines the next element in the list.

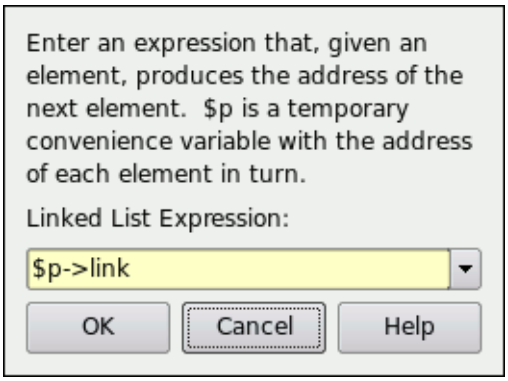


Figure 3-12. Dialog Selecting Linked List Component

NightView automatically populates a drop-down list with all members which have types appropriate for indicating a link in a list. In our case, it has correctly chosen the member which identifies the next node in the list.

- Press OK

  The `head` variable in the data panel is now displayed using an alternative method.

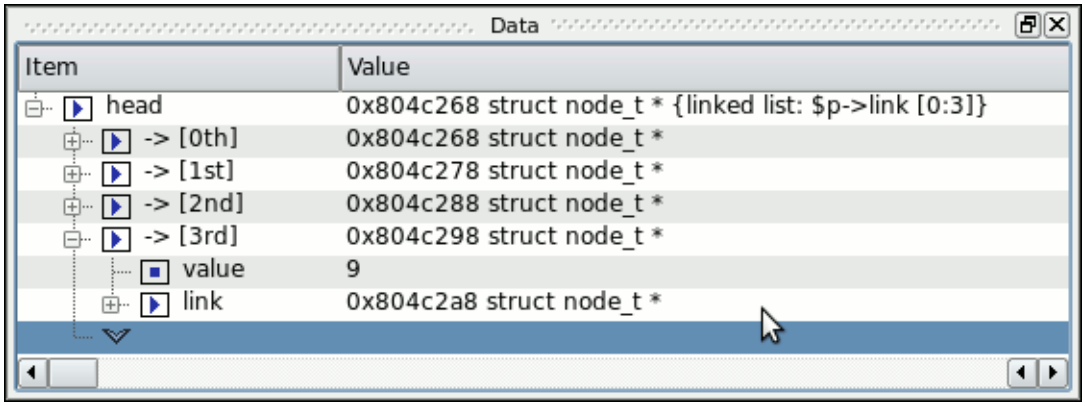


Figure 3-13. Pointer Variable Displayed As Linked List

In the figure above, the various nodes in the linked list are displayed at the same level and are numbered, starting from 0.

- Click on the guard symbol (blue triangle) several times until the “3rd” node is shown and then expand it to match the figure above.

NightView will allow you to expand the list as long as the member that you selected above that defines the next item in the list is not `NULL`. You can also use the context-menu to tell NightView how many nodes in the list to display (as opposed to continuing to click on the guard symbol to extend the list).

Often when viewing a linked list you may want to identify a particular node in the list. We will use NightView's filtering capability to do this.

- Right-click on the `head` variable and select Filter Elements with a Condition...

The following dialog appears which allows you to type in an expression which defines the nodes in the list to be shown.

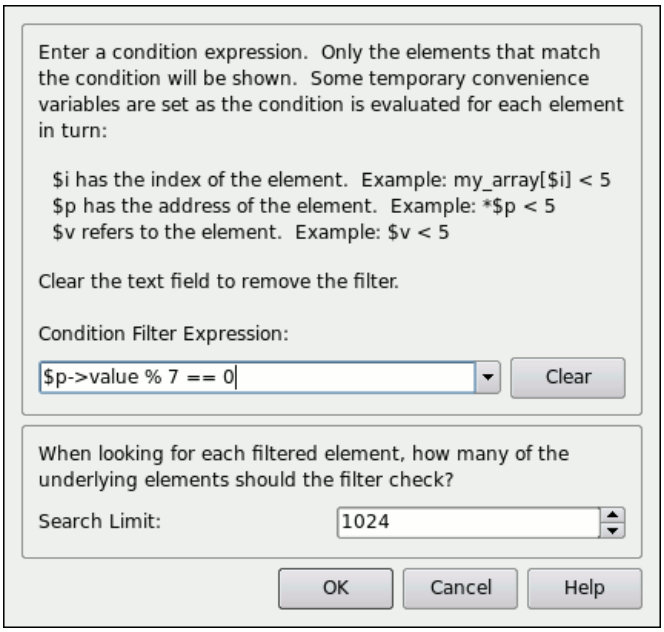


Figure 3-14. Filter Dialog

The expression can include several special built-in variables which aid you in specifying the filter. The text in the dialog explains these variables: $i, $p, and $v.

- Type in the following text in the Condition Filter Expression field, as shown in the figure above, and the press OK.

```
$p->value % 7 == 0
```

We have told NightView to only show us nodes in the list whose member `value` is a multiple of seven.

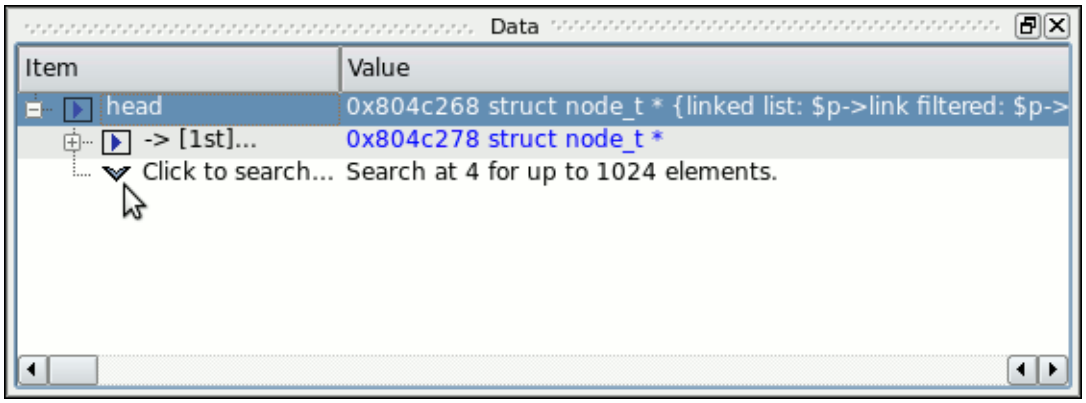


Figure 3-15. Filtered Linked List

Initially, the first node in the list matching the filter condition is shown -- it is node # 1, the second node in the list (node numbering starts at 0).

- Expand the filtered list by clicking the guard symbol two times, and then expand all three filtered elements to match the figure below:

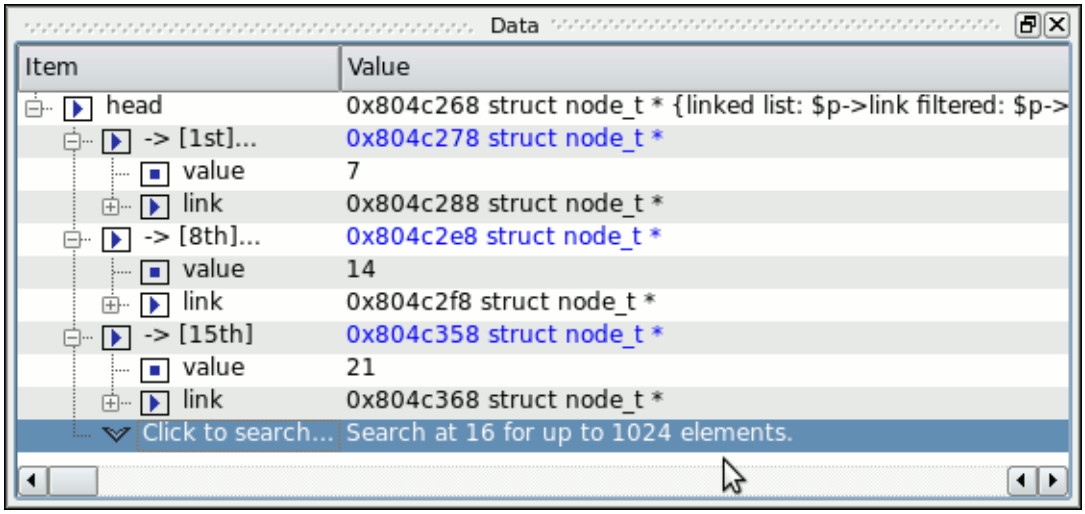


Figure 3-16. Filtered Linked List Expanded

See that all nodes shown in the list have a `value` member which is a multiple of seven, which satisfies the filter expression we specified above.

Notice that an ellipsis follows each node number when the next node in the list is not consecutive, indicating that there are gaps in the displayed list due to filtering. The description field of the head of the linked list also indicates filtering is active.

You can use NightView's filtering capability on arrays as well as linked lists. In fact, you can use it to search through memory for a particular value. Just add a pointer value to the

data panel, tell NightView to treat it as an array using the context menu, and then apply a filter expression.

Using Monitorpoints

Monitorpoints provide a means of monitoring the values of variables in your program without stopping it. A monitorpoint is code inserted by the debugger at a specified location that will save the value of one or more expressions, which you specify. The saved values are then periodically displayed by NightView in a Monitor panel.

Unlike asynchronous sampling, monitorpoints allow you to view data which is synchronized with execution of a particular location in your application.

- Right-click on line 46 and select Set eventpoint from the pop-up menu and select Set Monitorpoint… from the sub-menu.

NOTE

Alternatively, you could select the Set Monitorpoint… option from the Eventpoint menu or click the Set Monitorpoint icon from the toolbar to launch the Set New Monitorpoint dialog.

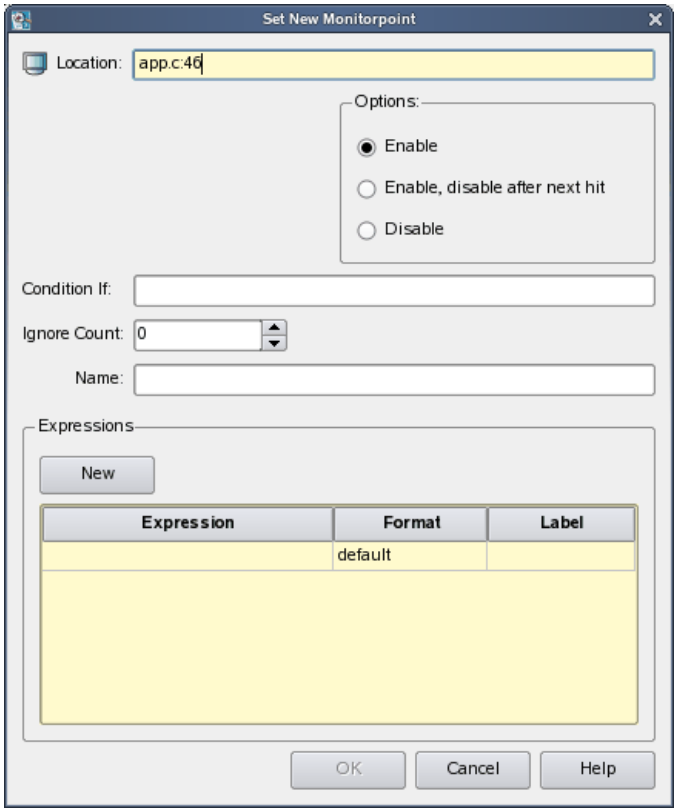


Figure 3-17. Monitorpoint Dialog

- Ensure that the Location text field has `app.c:46`, correcting if it need be.

- Enter the following:

  `data->count`

  in the text field below the Expression column head, but do *not* press the Enter key yet.

- You can control the format in which the value is displayed by clicking the option list under the Format column. Using the mouse, click and select Hexadecimal from the list.

- Enter the following in the Label column:

  `sine count`

- While still positioned in the cell under the Label column, press the Tab key. This positions you to the next row and allows you to continue adding expressions.

NOTE

If you have already left the cell and only one row is shown, press the New button.

- In the second row under the Expression column, type the following:

  `data->value`

- Set its label value in the Label column, by typing the following there:

  `sine value`

- Press the OK button in the Set New Monitorpoint dialog.

A Monitor panel is created containing an entry for the commands entered above.

- Likewise, set a monitorpoint on line 63 with the same commands as in the previous monitorpoint, substituting `cosine` for `sine` in the Label fields.

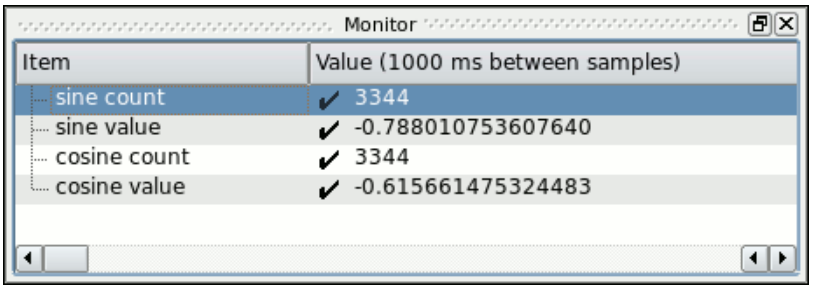


Figure 3-18. NightView Monitor Panel

At this point, the data values in the Monitor panel change.

The values are sampled whenever line 46 or 63 are executed, respectively. NightView displays the latest set of values in the Monitor panel at a user-selectable rate.

Using Eventpoint Conditions and Ignore Counts

All eventpoints in NightView have optional *condition* and *ignore* attributes.

A *condition* is a user-supplied boolean expression of arbitrary complexity which is evaluated before the eventpoint is executed. Conditions can involve function calls in the user application.

Similarly, the *ignore* attribute is a count of the number of times to ignore an eventpoint before actually executing it.

Conditions and ignore counts are evaluated by the application itself via patched-in code and, as such, run at full application speed. Other debuggers evaluate the conditions and ignore counts from within the context of the debugger which takes significant time and can drastically affect the behavior of your program.

- Click the cell in the Ignore column of the first row of the Eventpoint panel.
- Change the value to 500 and press Enter.

The Monitor panel now indicates that the values for that monitorpoint have not been sampled by displaying a question mark before the value. When the ignore count reaches zero, the values will start updating again.

Finally, monitorpoints can include complex expressions that aren't just simple variables.

- Enter the following commands in the Command field of the NightView main window:

```
monitor app.c:93
   p FunctionCall()
end monitor
```

A new item is added to the Monitor panel which represents the result of the function call `FunctionCall()` as executed by the user application each time line 93 is crossed.

Using Patchpoints

Unlike breakpoints and monitorpoints, patchpoints allow you to modify the behavior of your program.

Patchpoints allow you to change program flow or modify variables or machine registers.

First, we will use a patchpoint to branch around some statements in our program.

NOTE

If the source file **app.c** is not displayed, issue the following command:

```
l app.c:48
```

- Scroll the source file displayed in the NightView main window and right-click on line 48:

  ```
  data->angle += data->delta
  ```

  and select Set eventpoint from the context menu and select Set Patchpoint… from the sub-menu.

NOTE

Alternatively, you could select the Set Patchpoint... option from the Eventpoint menu or click on the Set Patchpoint icon in the toolbar to launch the Set New Patchpoint dialog.

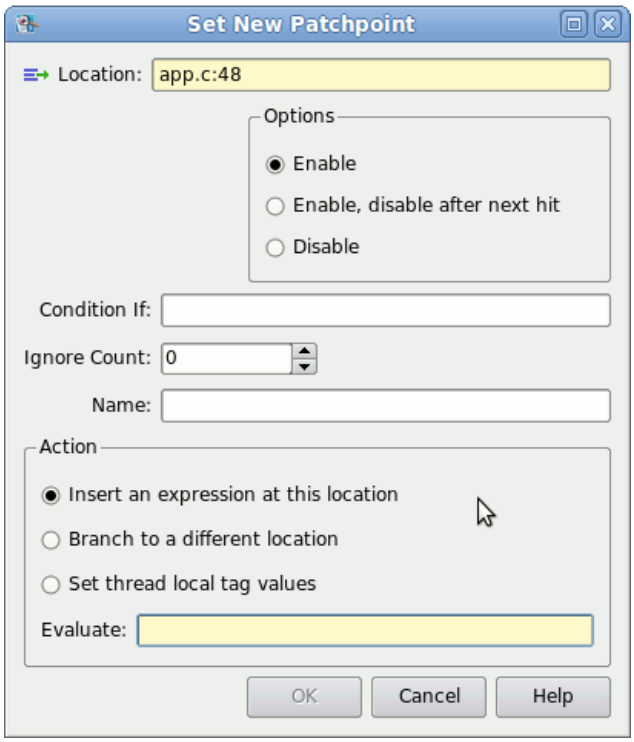


Figure 3-19. Patchpoint Dialog

- In the Location text area, ensure the text indicates `app.c:48`.
- Click on the Branch to a different location radio button in the lower portion of the dialog.
- In the Go To: text area, type:

  `app.c:49`

  then press the OK button.

This will effectively cause the application to skip execution of line 48, where it updates the angle used in the subsequent `sin()` call.

Note that the `sine value` in the Monitor panel stops changing, yet the associated `sine count` value continues to change.

Alternatively, we can use patchpoints to change the value of expressions or variables.

- Type the following command in the Command panel of the NightView main window:

```
patch app.c:49 eval data->count -= 2
```

Note that the value of `sine count` is decrementing, because for each iteration, it continues to be incremented by 1, but now also is decremented by 2.

We can disable the patchpoints without deleting them.

- Select both patchpoints in the Eventpoints panel (as indicated in the Type column by the word `Patch`), right-click and select Disable from the pop-up menu.

The patches are disabled and the values shown in the Monitor panel return to their original behavior.

Adding and Replacing Functions Dynamically

NightView provides the ability to dynamically add new functions to the application being debugged, as well as to replace existing functions.

- In a terminal session outside of NightView, compile the **`report.c`** source file which was copied into your current directory in the initial steps of this tutorial:

  ```
  cc -g -c report.c
  ```

- Load the new module into the program using the following command in the Command panel of the NightView main window:

  ```
  load report.o
  ```

We have added a simple function which prints information to **`stdout`**. The function could have been arbitrarily complex and referenced any variable in the application. The only limitation is that the function cannot reference symbols that are absent from the module being loaded and are not already in the user application.

- Issue the following command to see the source code for the function `report()`:

  ```
  l report.c
  ```

You will see that the `report()` function expects a pair of arguments whose types are `char *` and `double`, respectively.

- Go back to the application source file by issuing the following command:

  ```
  l app.c
  ```

We will install a new patchpoint which will call the newly added function.

- Set a patchpoint on line app.c:63 with the following expression:

  ```
  report("cos",data->value)
  ```

The program is now generating output to **`stdout`** in the Messages panel of the NightView main window as calls to the `report()` function are executed.

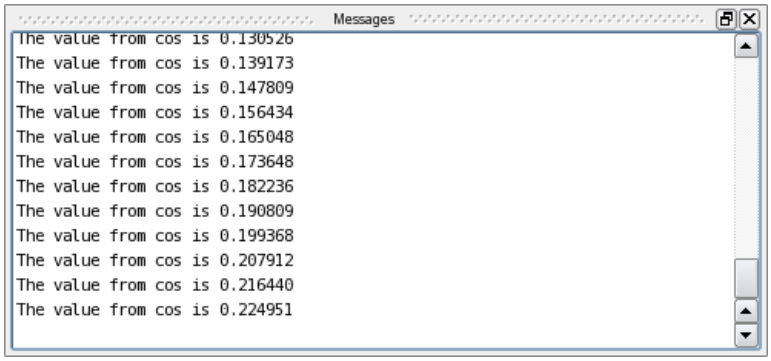


Figure 3-20. Result of Patching in Call to Newly Loaded Function

- Disable the patchpoint that was just added by clearing its Enabled checkbox in the Eventpoint panel.

Finally, we will replace a function that already exists in the application.

- In a terminal session outside of NightView, list the contents of the source file **`function.c`** which was copied into your current directory in the initial steps of this tutorial, and compile it with the following commands:

```
cat function.c
cc -g -c function.c
```

- Now load the replacement code by entering the following command in the Command panel of the NightView main window:

```
load function.o
```

Note how the Monitor panel value for the `FunctionCall()` value no longer pertains to the value computed by the application, but rather is a monotonically increasing number as per the source file **`function.c`**.

- Return the NightView main window source panel to the **`app.c`** source file via the following command:

```
l app.c:40
```

Using Tracepoints

The last portion of NightView we will cover in this tutorial is integration with NightTrace.

A tracepoint is a specialized eventpoint which essentially patches a call to log a trace event with optional arguments.

Even if the application doesn't already use the NightTrace API, NightView can link in the required components and activate the tracing module. Our application already uses the NightTrace API, so this will not be necessary (see the **`set-trace`** command in the *NightView User's Guide* for more information on using tracepoints in applications which don't already use the NightTrace API).

Suppose that we were interested in measuring the performance of our cycles in the `sine_thread()` and `cosine_thread()` routines and that we also were interested in logging data values during the cycle.

- Scroll the source file displayed in the NightView main window and right-click on line 48:

  ```
  data->angle += data->delta
  ```

  and select Set eventpoint from the pop-up menu and select Set Tracepoint… from the sub-menu.

NOTE

Alternatively, you could launch the dialog by selecting Set Tracepoint… from the Eventpoint menu or click on the Set Tracepoint icon on the toolbar to launch the Set New Tracepoint dialog.

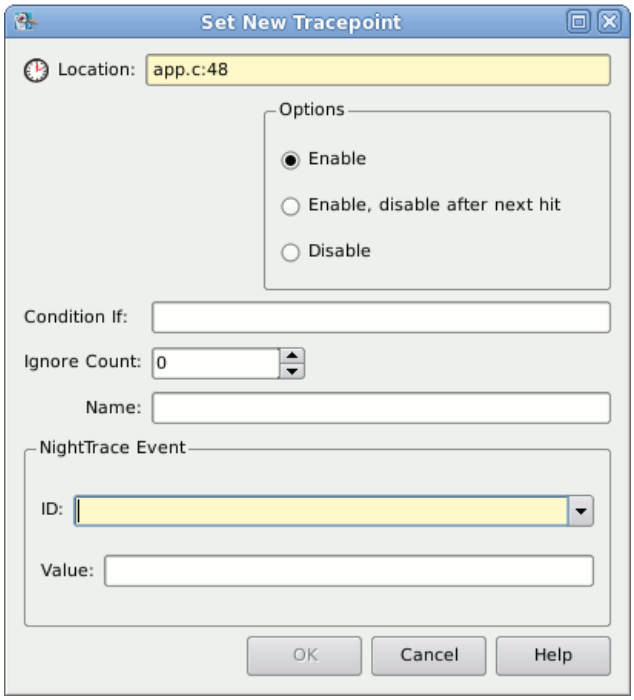


Figure 3-21. Tracepoint Dialog

- In the Location: text field ensure that **`app.c:48`** is displayed.
- In the Event ID field, type the following:

  `1`

- Press the OK button

Similarly, we'll set additional tracepoints but we will also specify a value to be logged with the tracepoint.

- Set a tracepoint on line **`app.c:46`** and specify an Event ID of **`2`** and enter the following in the Value text field:

  `data->value`

- Set a tracepoint on line **`app.c:63`** and specify an Event ID of **`3`** and enter the following in the Value text field:

  `data->value`

Trace events can now be logged with the NightTrace tool which is described in the next section of this tutorial.

- Launch NightTrace by selecting the NightTrace Analyzer menu item from the Tools menu of the NightView main window.

The remaining sections of the tutorial do not use NightView, however, we want to keep the tracepoints patched into the executable. So simply iconfiy the NightView window and do not exit from NightView.

Conclusion - NightView

This concludes the NightView portion of the NightStar LX Tutorial.

4
Using NightTrace

NightTrace is a graphical tool for analyzing the dynamic behavior of single and multiprocessor applications. NightTrace can log user-defined application data events from simultaneous processes executing on multiple CPUs or even multiple systems. NightTrace RT can also log kernel events such as individual system calls, context switches, machine exceptions, page faults and interrupts, but no kernel support exists for this in standard Linux. Furthermore, NightTrace allows users to zoom, search, filter, summarize, and analyze those events in a wide variety of ways.

Using NightTrace, users can manage multiple user and kernel NightTrace daemons simultaneously from a central location. NightTrace provides the user with the ability to start, stop, pause, and resume execution of any of the daemons under its management.

NightTrace users can define and save a “session” consisting of one or more daemon definitions. These definitions include daemon collection modes and settings, daemon priorities and CPU bindings, and data output formats, as well as the trace event types that are logged by that particular daemon.

Invoking NightTrace

NightTrace was invoked during the last step of the Using NightView section.

If you skipped the Using NightView section, execute the steps in “Using Tracepoints” on page 3-39 before beginning this section of the tutorial (and resume execution of the pro-

cess).

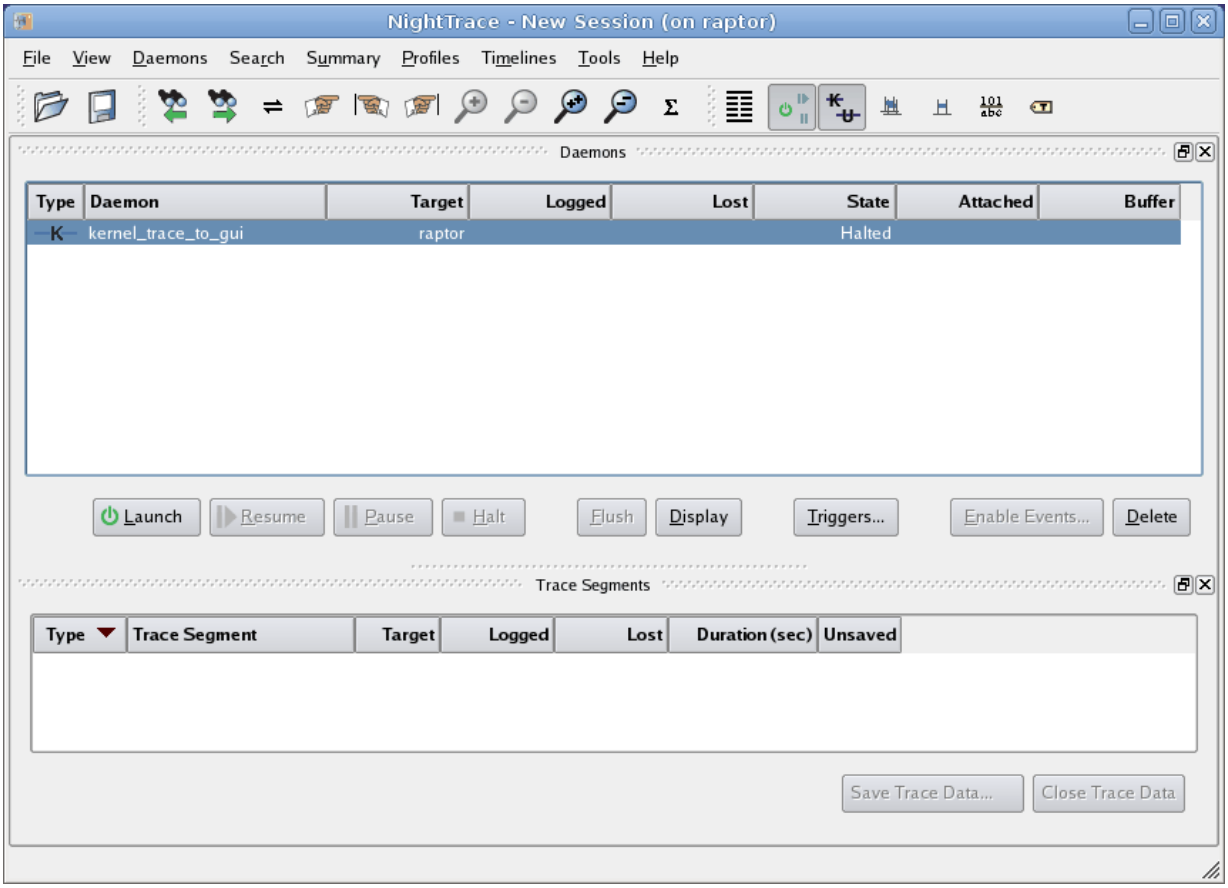


Figure 4-1. NightTrace Main Window

Below the menu bar and toolbar, the first page of the NightTrace main window contains the following two panels:

Table 4-1. NightTrace Panels

Daemons	Shows the daemons configured.
Trace Segments	Shows each trace segment (contiguous collection of trace data).

The statistics on the Daemons panel indicate the number of raw events in the shared memory buffer used between the daemon and the user application and the number of raw events written to NightTrace by the daemon (under the Buffer and Logged columns, respectively).

The Trace Segments panel indicates the number of processed events that are currently available for immediate analysis through the Events panels and timelines.

NOTE

The number of events shown in the Trace Segments panel will normally differ from the number of events shown in the Daemons panel. The former are processed events whereas the latter are raw events -- a processed event is often constructed from multiple raw events.

Configuring a User Daemon

NightTrace allows the user to configure a user daemon to collect user trace events.

User trace events are generated by user applications that use the NightTrace API.

We will configure a user daemon to collect the events that our **app** program logs.

To configure a user daemon based on a running application

- Select the Running Application option from the Import… menu option from the Daemons menu.

  The Import Daemon Definitions dialog is presented:

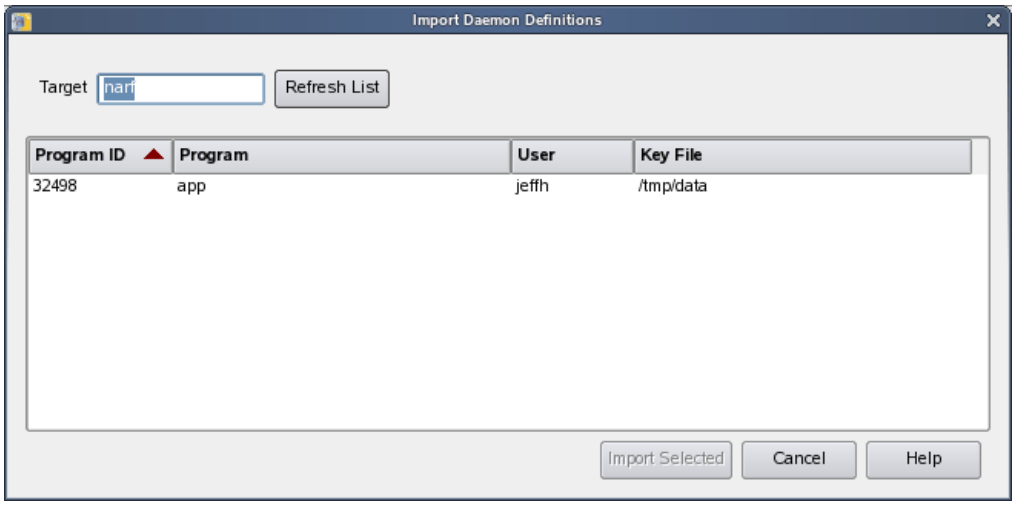


Figure 4-2. Import Daemon Definitions Dialog

The Import Daemon Definitions dialog allows the user to define daemon attributes based on a running user application containing NightTrace API calls.

- Select the entry corresponding to the **app** application.
- Press the Import Selected button.

The Import Daemon Definitions dialog closes and a new user daemon is created and added to the Daemon Control Area in the NightTrace main window.

Streaming Live Data to the NightTrace GUI

NightTrace allows you to use a daemon to capture trace events and store them in a file for subsequent analysis or to stream the events directly into the graphical interface for live analysis.

Our daemon is configured for live streaming.

- Select the daemon labeled `app_data` from the Daemons panel in the NightTrace main window.
- Press the Launch button.
- Press the Resume button.

The daemon is now collecting events which are being generated by the **`app`** program from the tracepoints we inserted in “Using Tracepoints” on page 3-39.

In the Daemons panel, the count of events shown in the Buffer column will begin to change.

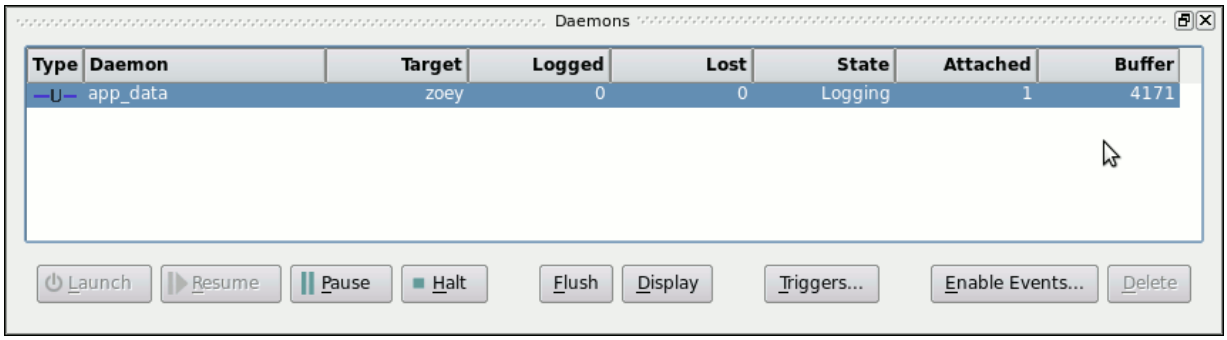


Figure 4-3. Logging Data

NOTE

A tabbed page is created in the NightTrace main window when Launch is pressed. This page is an automatically customized page containing a list of the events logged and a timeline for graphical representation of those events.

- Click on the newly-created tab labeled `app_data` that contains the Events panel and the timeline associated with those events.

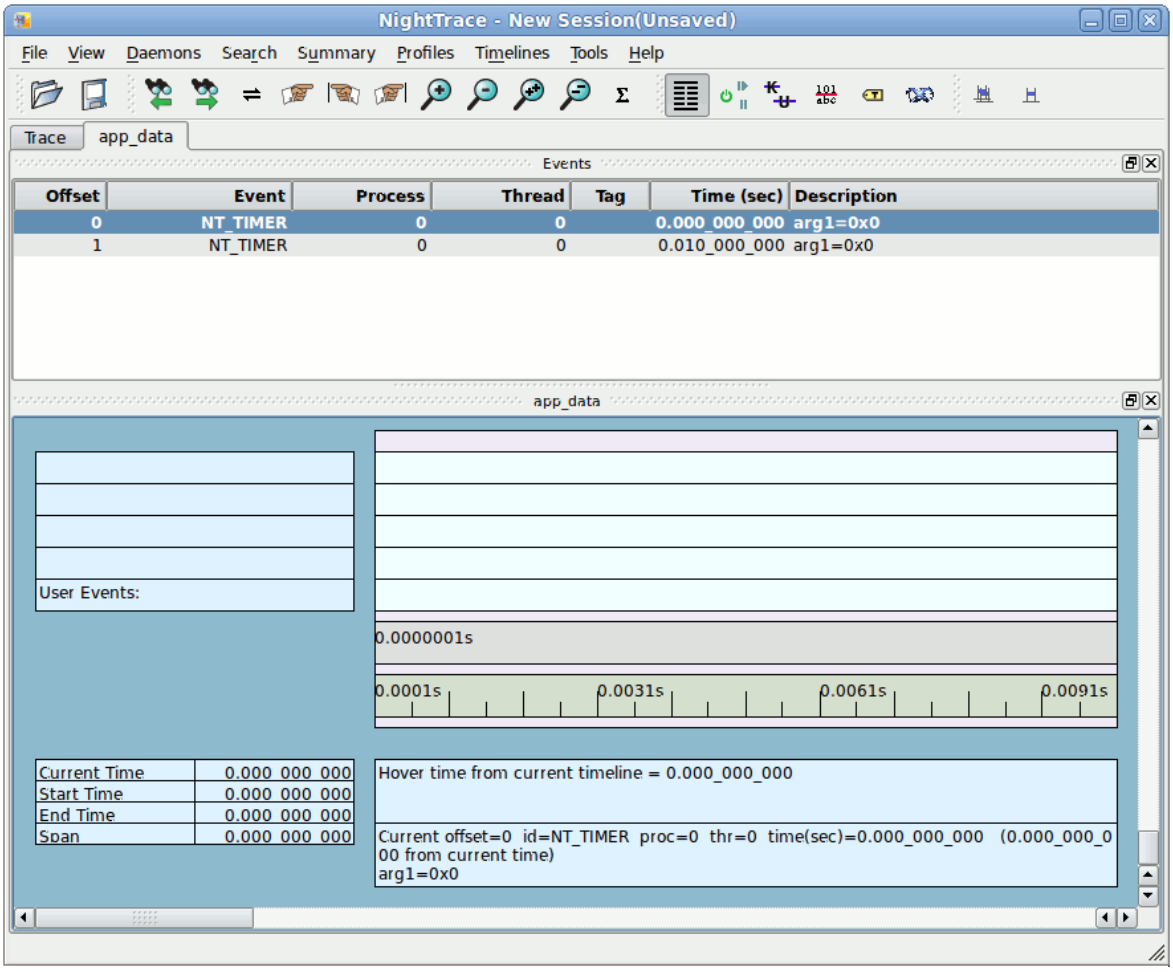


Figure 4-4. app_data Page

Initially, the panels will be mostly blank.

You can force events to be flushed from the daemon buffer and output stream to be brought into the segment area for immediate viewing by zooming out on a timeline.

- Click anywhere in the display area containing the timelines.
- Press Up to zoom out
- Press Alt-Up to zoom out completely.

  The Events list will be populated with the events currently logged and the timeline will graphically display those events.

- Click in the middle of the lower panel.

NOTE

If you plan to leave the tutorial for an extended period of time before returning, press the Pause button on the Trace page to temporarily prevent the collection of trace points. When you return, press the Resume button.

Using NightTrace Timelines

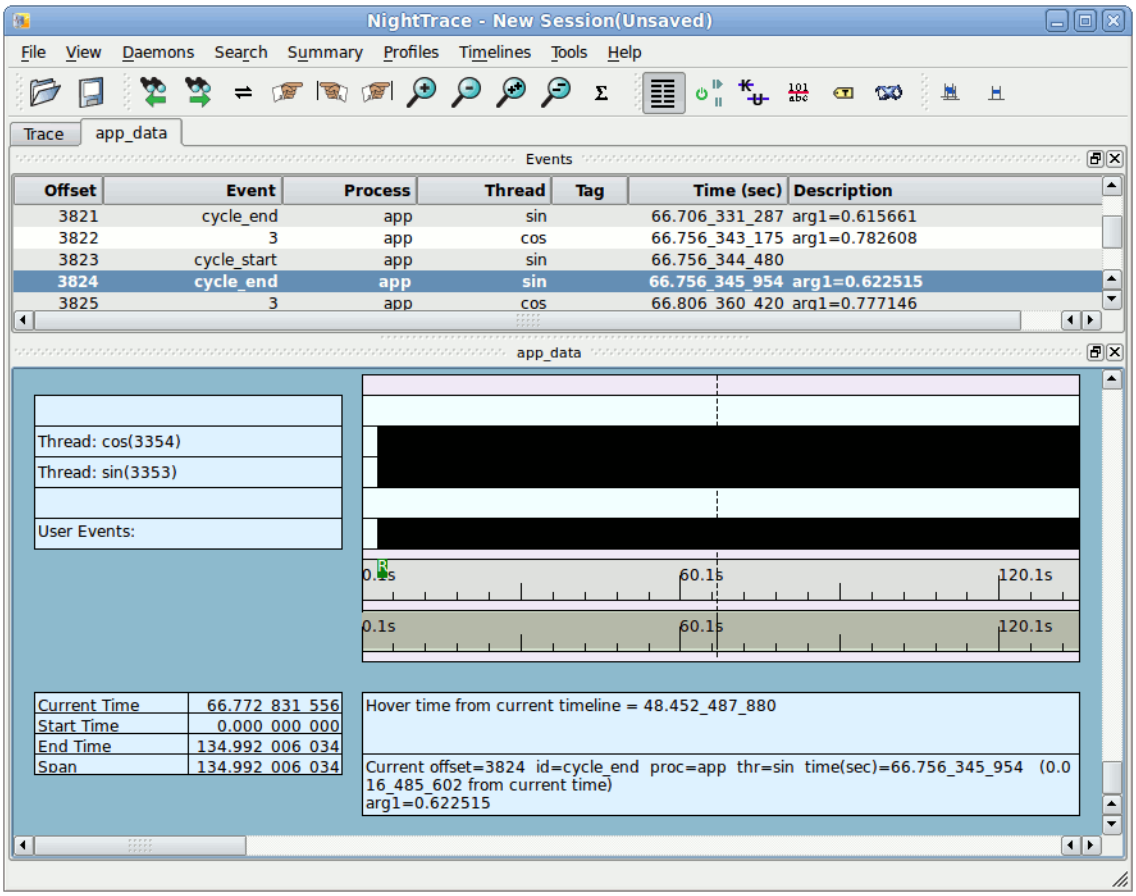


Figure 4-5. NightTrace Timeline

The timeline contains static and dynamic labels and event and state graphs.

By default, NightTrace detects the threads that have registered themselves through Night-Trace API calls and creates individual labels and graphs for each thread.

Our application contains four threads: heap, sin, cos, and main. Rows for individual threads show only events logged by that thread. In addition, there is a user events graph near the bottom that shows events for all threads.

NOTE

You will see blank labels and graphs in your timeline. These are the labels and graphs for the main and heap threads which are not logging any events. The contents of the label are not shown until at least one event is logged by the main thread.

If you see all blank labels, you likely didn't click in the middle of the timeline as instructed in the preceding step.

In "Using Tracepoints" on page 3-39 in the Using NightView section, we inserted tracepoints into the `sine` and `cosine` threads, which registered themselves as "`sin`" and "`cos`", respectively.

Zooming

Each vertical line in the graph represents at least one event. You can zoom in and zoom out to adjust the level of detail.

- Left click anywhere within the timeline
- Press the Down key repeatedly until you can see individual lines in the graph
- Press the Up key to zoom back out
- If you have a mouse wheel, move the wheel back and forth to zoom in and out

The vertical dashed line is the current timeline and is directly connected to the highlighted event in the Events panel.

Left-clicking the mouse in the display area moves the current timeline. The information in the Event Detail area below the timeline changes to reflect the event closest to the left of the current timeline.

Moving The Interval

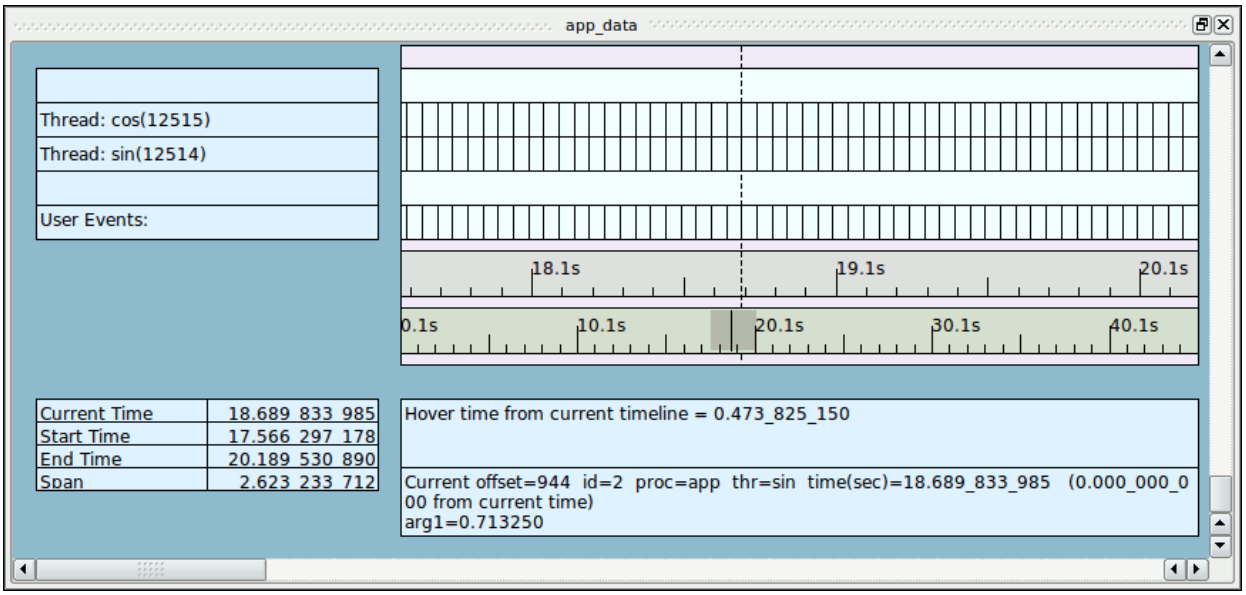


Figure 4-6. Timeline Interval Panel

By default, each timeline panel has two ruler rows positioned below the event graphs and above the descriptive boxes at the bottom of the panel.

The ruler on top indicates the timespan currently shown.

The ruler on the bottom indicates the timespan for all data currently available for viewing. This ruler is called the control ruler and has a gray area within it. The gray area represents the amount of the entire timespan that is currently shown in the panel. Thus zooming in will decrease the width of the gray area and zooming out will have the opposite effect.

NOTE

If you do not see a gray area, zoom out until you do.

There are several methods of moving through the entire timeline.

- Press the Right key

  This causes the current timeline to go to the next event. If you are zoomed out too far, you may not notice the timeline moving. In this case, either zoom out or hold the Right key down until you can see the timeline move.

  Alternatively, pressing the Left key causes the current timeline to go to the previous event.

- Press Ctrl+Right

This causes the displayed interval to move 25% of a section to the right by default. The section is the amount of time currently visible in the interval. Notice how the gray are in the control ruler moves.

Alternatively, pressing Ctrl+Left causes a shift one section to the left.

- Click midway between the gray area and the right hand portion of the control ruler

  Clicking anywhere in the control ruler causes the interval to shift to be centered at the selected time at the current zoom setting.

  Thus to move the very beginning of the data set or the end, you can click the beginning or end of the control ruler.

Using the Events Panel for Textual Analysis

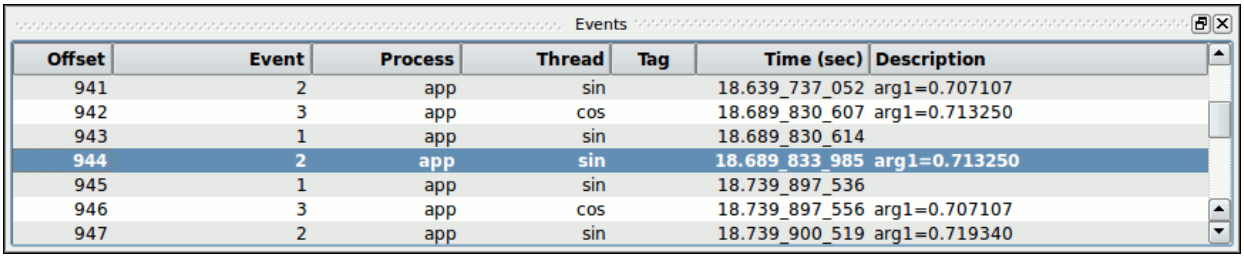


Figure 4-7. Events Panel

The events shown in the Events panel are synchronized with the events shown in the timeline. The highlighted event indicates the current timeline.

- Click on a line in the Events panel
- Press the Down key to advance to the next event.
- Press the Up key to advance to the previous event.

Whenever an event is selected or the current event line moves, the Event Detail area below the timeline on the right shows additional information about the event, if available.

- Press the PageDown to advance to the next set of events.
- Press the PageUp to shift to the previous set

  These actions only move the current timeline by the number of events that can be shown in the Events panel.

Customizing Event Descriptions

The event values we logged with the **`tracepoint`** commands in NightView were event IDs 1-3. We will customize the description of these events.

- Click on a row in the Event panel that shows event ID **`1`**.
- Right-click that row and select Edit Current Event Description… from the context menu.

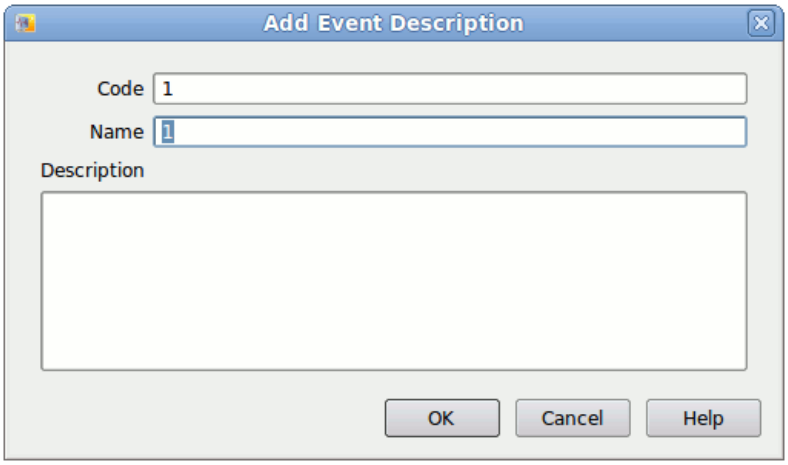


Figure 4-8. Add Event Description dialog

- Enter:

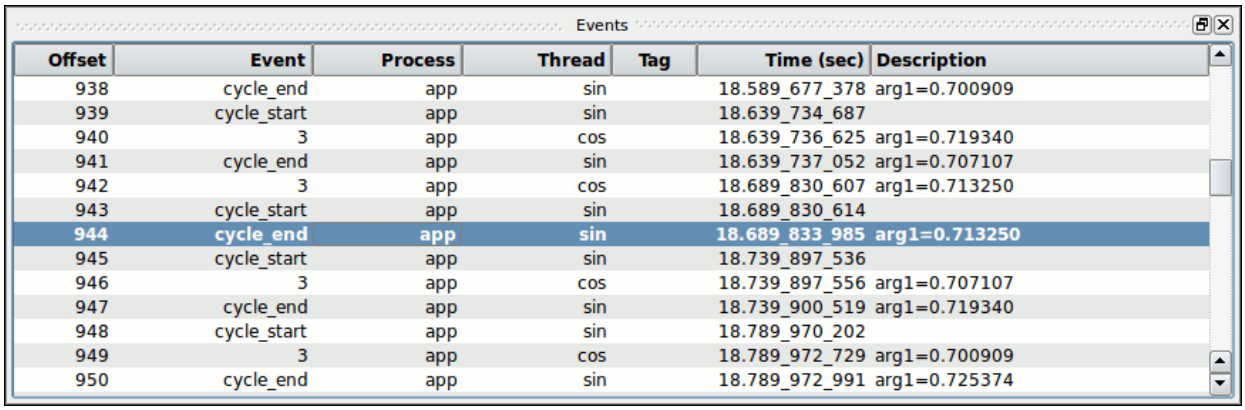
  `cycle_start`

  in the Name field.
- Press OK.
- Right-click on an entry whose value in the Event column has the value **`2`**.
- Select Edit Current Event Description… from the context menu.
- Enter:

  `cycle_end`

  in the Name text field.
- Press the OK button.

The descriptions of the events in the Events panel now correspond to the textual identifiers we assigned to them.



Offset	Event	Process	Thread	Tag	Time (sec)	Description
938	cycle_end	app	sin		18.589_677_378	arg1=0.700909
939	cycle_start	app	sin		18.639_734_687	
940	3	app	cos		18.639_736_625	arg1=0.719340
941	cycle_end	app	sin		18.639_737_052	arg1=0.707107
942	3	app	cos		18.689_830_607	arg1=0.713250
943	cycle_start	app	sin		18.689_830_614	
944	cycle_end	app	sin		18.689_833_985	arg1=0.713250
945	cycle_start	app	sin		18.739_897_536	
946	3	app	cos		18.739_897_556	arg1=0.707107
947	cycle_end	app	sin		18.739_900_519	arg1=0.719340
948	cycle_start	app	sin		18.789_970_202	
949	3	app	cos		18.789_972_729	arg1=0.700909
950	cycle_end	app	sin		18.789_972_991	arg1=0.725374

Searching the Events List

We can use the search capabilities of NightTrace to search for a specific occurrence of an event or condition relating to an event or its arguments.

- Select the Change Search Profile... menu item from the Search menu in the NightTrace main window or press Ctrl+F.

A dialog appears containing the Profile Status List and Profile Definition areas:

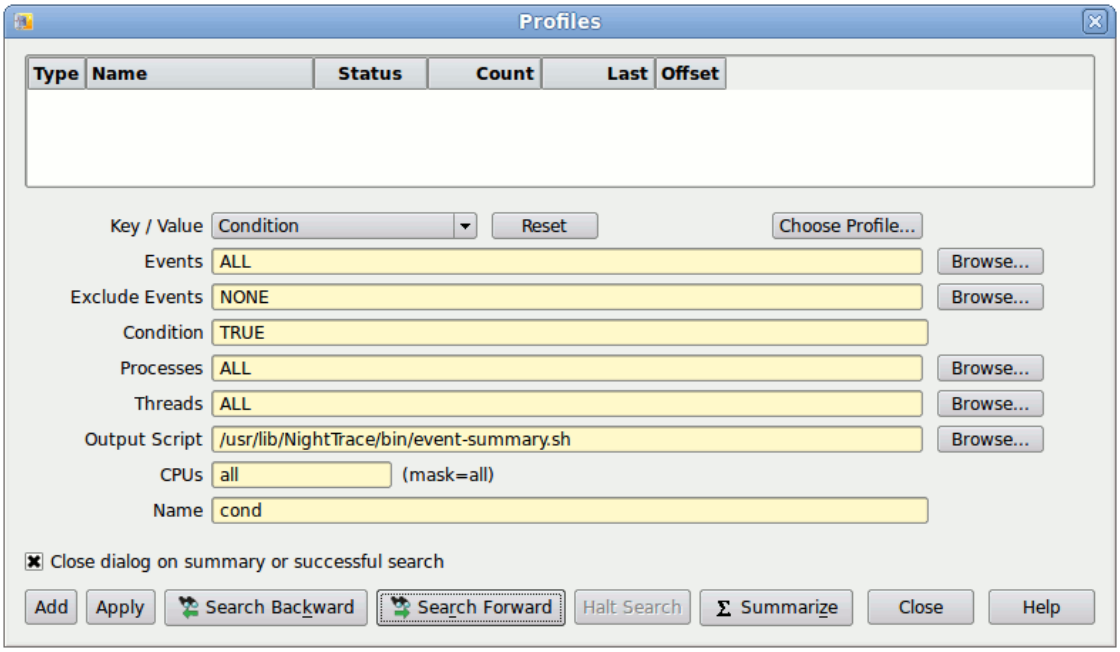


Figure 4-9. Searching using the Profiles Dialog

- Press the Browse… button to the right of the Events field.

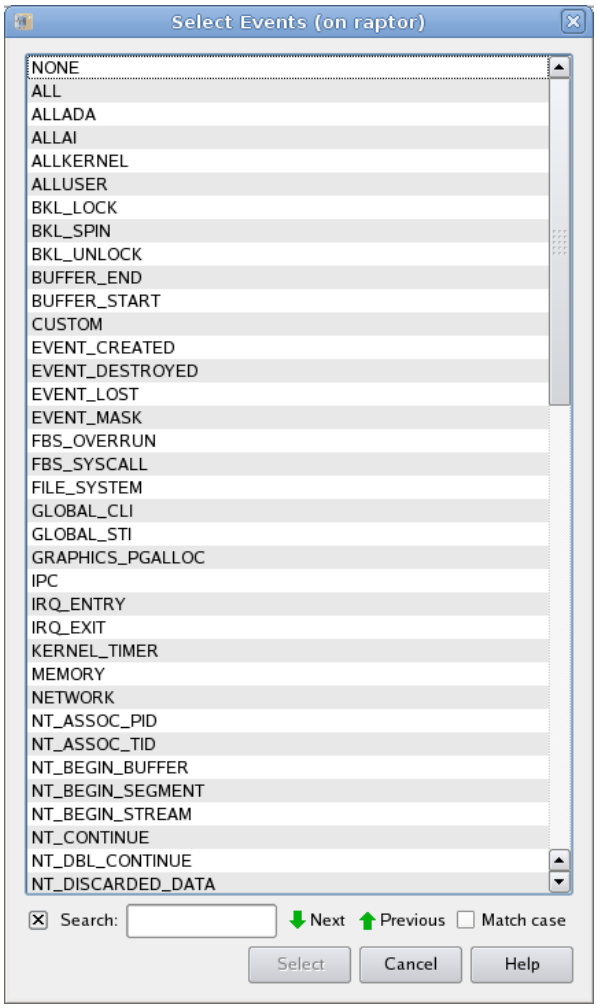


Figure 4-10. Browse Events Dialog

- Click in the Search text field and type **`cycle`**. The first event name that includes that word is shown. Ensure that **`cycle_end`** is selected in the event list, or press the Next icon until it is. Then press the Select button.

- Enter the following text in the Condition text field of the Profile panel:

  ```
  arg_dbl > 0.8
  ```

- Enter the following text into the Name text field:

  ```
  obtuse
  ```

- Press the Add button in the Profiles panel.

  A profile called `obtuse` is now defined and appears in the Profile Status List panel.

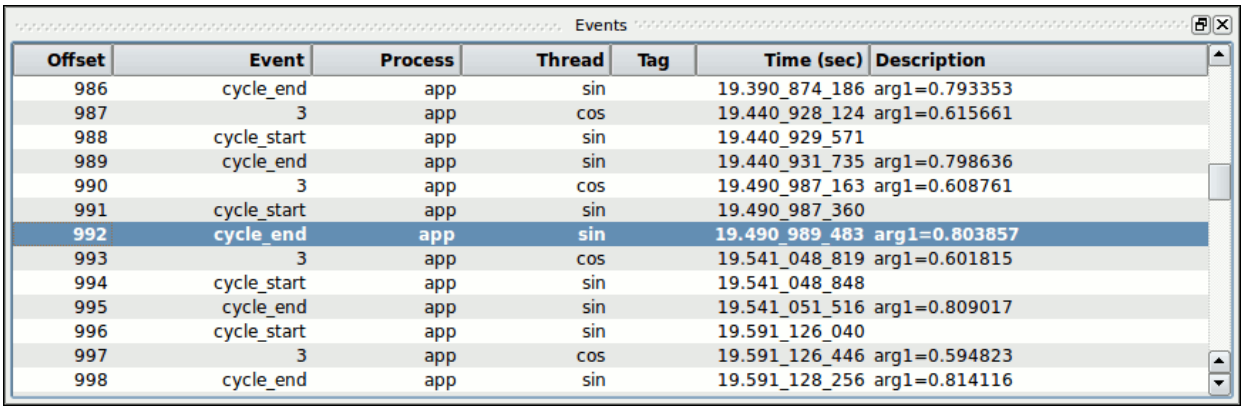
- Press the Search Forward button at the bottom of the Profiles dialog.

  The current timeline is moved to the first event that matched the search criteria, that being the end of a cycle when the sine value exceeded 0.8.

NOTE

If a pop-up dialog telling you that NightTrace has reached the end of the available dataset and asks you whether it should resume the search at the beginning, press OK.

- Click on the tab labeled `app_data` and verify that the current event listed in the Events panel indicates `arg1` with a value exceeding 0.8.



Offset	Event	Process	Thread	Tag	Time (sec)	Description
986	cycle_end	app	sin		19.390_874_186	arg1=0.793353
987	3	app	cos		19.440_928_124	arg1=0.615661
988	cycle_start	app	sin		19.440_929_571	
989	cycle_end	app	sin		19.440_931_735	arg1=0.798636
990	3	app	cos		19.490_987_163	arg1=0.608761
991	cycle_start	app	sin		19.490_987_360	
992	**cycle_end**	**app**	**sin**		**19.490_989_483**	**arg1=0.803857**
993	3	app	cos		19.541_048_819	arg1=0.601815
994	cycle_start	app	sin		19.541_048_848	
995	cycle_end	app	sin		19.541_051_516	arg1=0.809017
996	cycle_start	app	sin		19.591_126_040	
997	3	app	cos		19.591_126_446	arg1=0.594823
998	cycle_end	app	sin		19.591_128_256	arg1=0.814116

Figure 4-11. Events Panel After Search

Similarly, the timeline shows a description of the current event in the Event Detail area in the bottom portion of the panel.

- Move the mouse cursor to the event description box at the bottom of the panel and leave it there without moving it

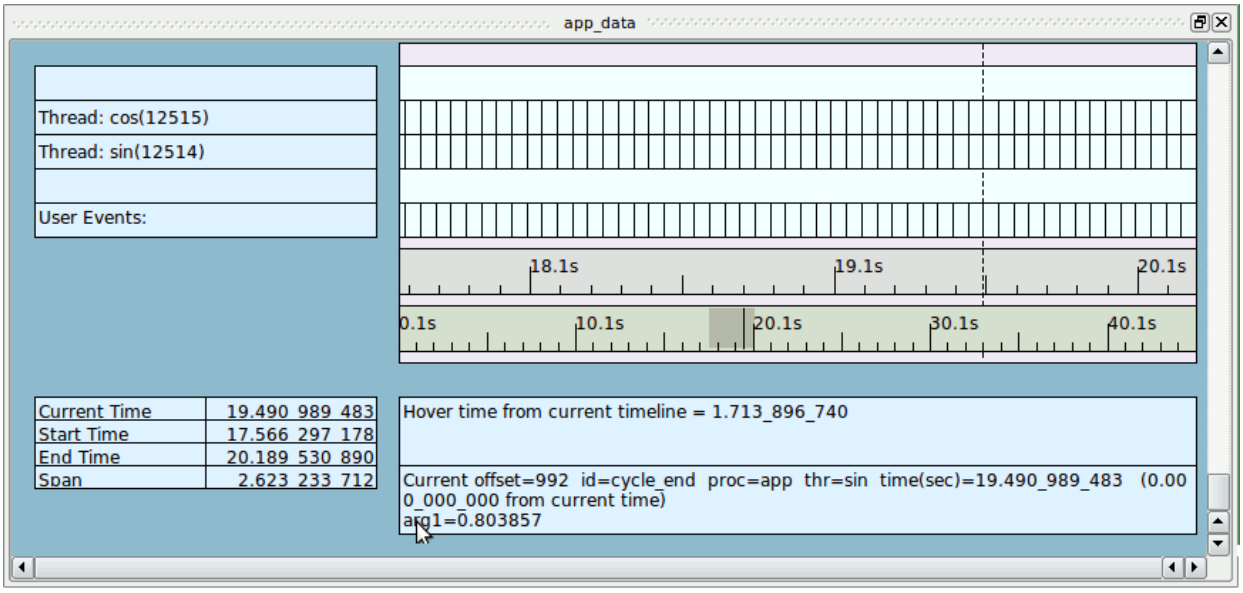


Figure 4-12. Timeline Panel After Search

NOTE

It is possible that the search will fail if an insufficient number of events have been brought into live analysis. If this occurs, bring in more events using the Event list scroll bar and retry the search by pressing the forward search icon on the tool bar.

Halting the Daemon

Since the NightTrace portion of the tutorial is rather lengthy and may likely be a new experience for many users, we will halt the daemon to reduce memory usage.

On the Trace tab, halt the daemon by pressing the Halt button to reduce memory usage as we slowly move through the NightTrace portion of the tutorial.

NOTE

Do not be concerned if the number of events shown in the Trace Segments panel is smaller than the number of events shown in the Daemon Control Area just before you halted the daemon. The latter shows raw event counts whereas the Trace Segments panel shows processed event counts -- a processed event is often constructed from multiple raw events.

Using States

In addition to displaying individual events, NightTrace can display states.

- Click either of the Profiles icons on the toolbar 

  The Profiles dialog is displayed with the previously defined profile selected.

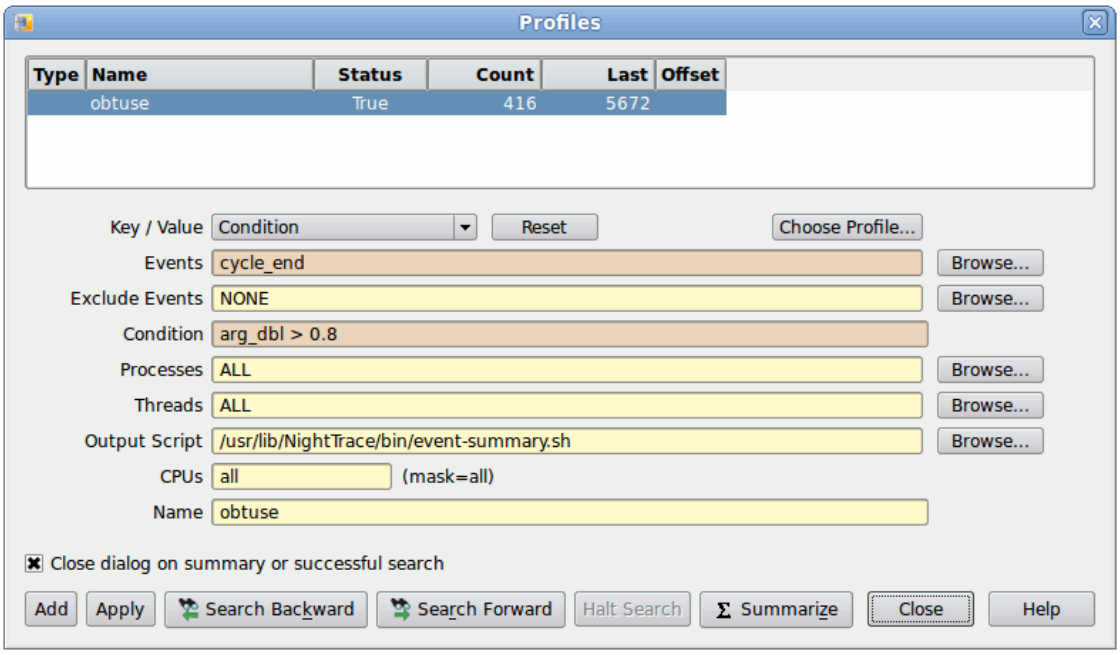


Figure 4-13. Profiles Dialog With Obtuse Profile Selected

- Press the Reset button.
- Select State in the Key / Value option list.
- Enter:

  ```
  cycle_start
  ```

  in the Start Events text area

- Enter:

  ```
  cycle_end
  ```

  in the End Events text field.

- Enter:

  ```
  sin
  ```

in the Threads text field.

- Enter:

  sine

  in the Name text field.

- Press the Add button.
- Close the dialog.

A state named `sine` has now been defined and occurrences can be displayed in the graphs in the display page.

- Click on the tab labeled `app_data` to show the timeline.
- Right-click anywhere in the display area and select Edit Mode from the context menu or press Ctrl-E to enter *edit mode*.

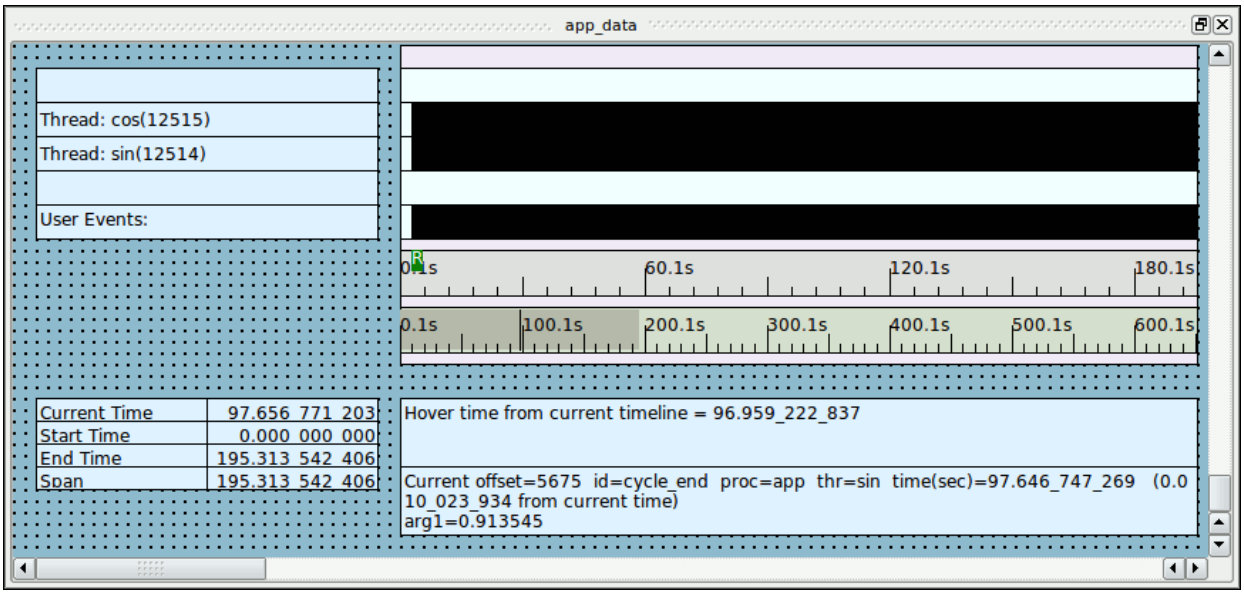


Figure 4-14. Timeline Editing

- Double-click on the graph associated with the row labeled "Thread: sin". That graph is a row with vertical lines representing events inside the larger graph area, aligned with the label "Thread: sin".

The Edit State Graph Profile dialog is displayed as shown below:

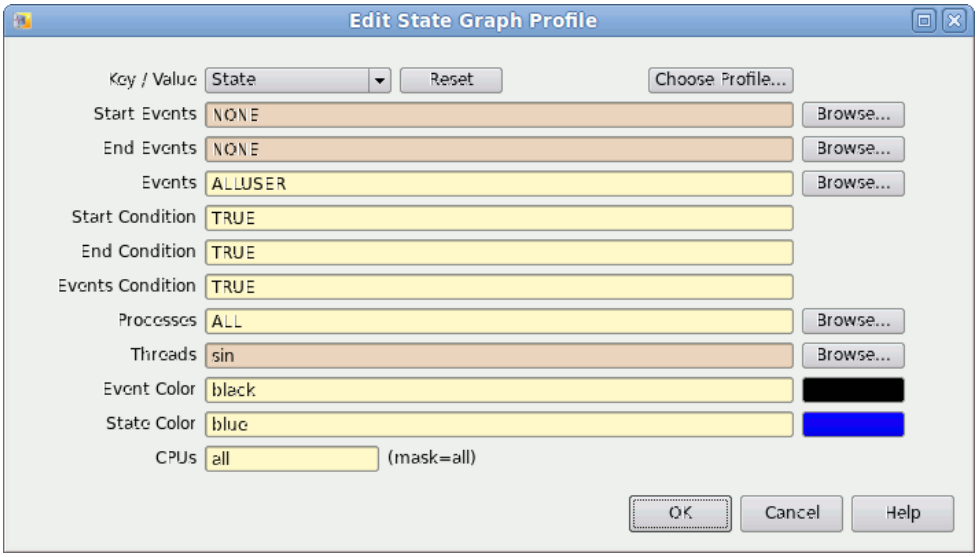
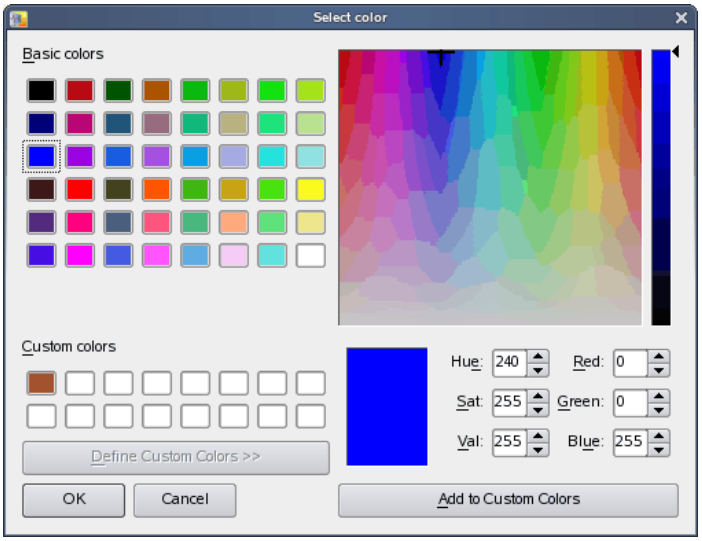


Figure 4-15. Edit State Graph Profile dialog

- Select State from the Key / Value option list.
- Press the Choose Profile… button.

  The Choose Profile dialog is displayed.
- Select the `sine` state from the list.
- Make sure the Import by reference checkbox is checked.
- Press Select.

- Click on the colored button to the right of the row labelled State Color. The Select color dialog is presented.



- Select a pleasing color in the Select color dialog and press OK.
- Press OK in the Edit State Graph Profile dialog.
- Right-click anywhere in the display area and select Edit Mode from the pop-up menu or press Ctrl-E to return to *view mode*.

The graph has now been configured to display the sine state as a solid bar in the lower portion of the state graph. Events will still be displayed as vertical black lines that extend over the entire vertical height of the graph.

It is likely that the display page has not changed in a significant way. This is because the `cycle_start` and `cycle_end` events occur so closely together in time that you cannot distinguish them at the current zoom setting.

- Click in the middle of the state graph.
- Zoom in using the mouse wheel or using the Zoom In icon on the toolbar or the Down key until the two events can be distinguished and a state bar is shown.

  You may need to readjust the current timeline as you zoom in.

NOTE

If the Down key has no effect, press the Num Lock key and try again.

NOTE

The state may vanish at some zoom levels where it is still very small compared to the zoom level's scale. If so, just continue to zoom in and it will reappear.

The figure below displays an instance of the sine state.

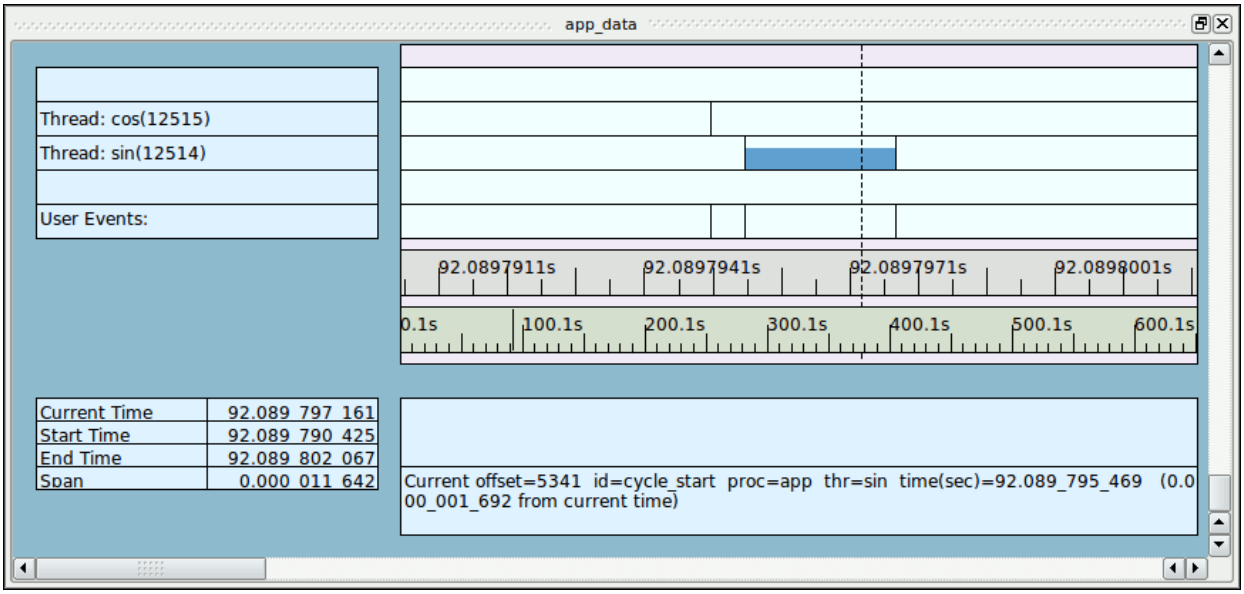


Figure 4-16. Sine State in Timeline

NOTE

If no states are visible, recheck the definition of the sine profile in the Profiles panel as described in "Using States" on page 4-17.

Displaying State Duration

The duration of the most recently completed state can be displayed via a data box.

- Right-click anywhere in the display area on the page labeled `app_data` and select Edit Mode from the pop-up menu or press Ctrl-E to enter *edit mode*.
- Right-click anywhere in the grid and select Add Data Box option from the pop-up menu.

  The cursor will turn into a + character.
- Using the left mouse button, click an empty area in the left-side of the display page on the grid (outside of any currently displayed graph or data box

-- i.e. only on an available area whose background shows the dotted grid) and drag the mouse to create the outline of the new data box -- release the mouse button.

- Double-click the data box. The Edit Data Box Profile dialog is presented.
- Enter the following into the Output field:

```
format ("cycle = %F. ms", state_dur(sine)*1000.0)
```

- Press the OK button.
- Right-click anywhere in the display area and select Edit Mode from the pop-up menu or press Ctrl-E to return to *view mode*.

The data box now displays the length of the most recently completed instance of the sine state in milliseconds.

Generating Summary Information

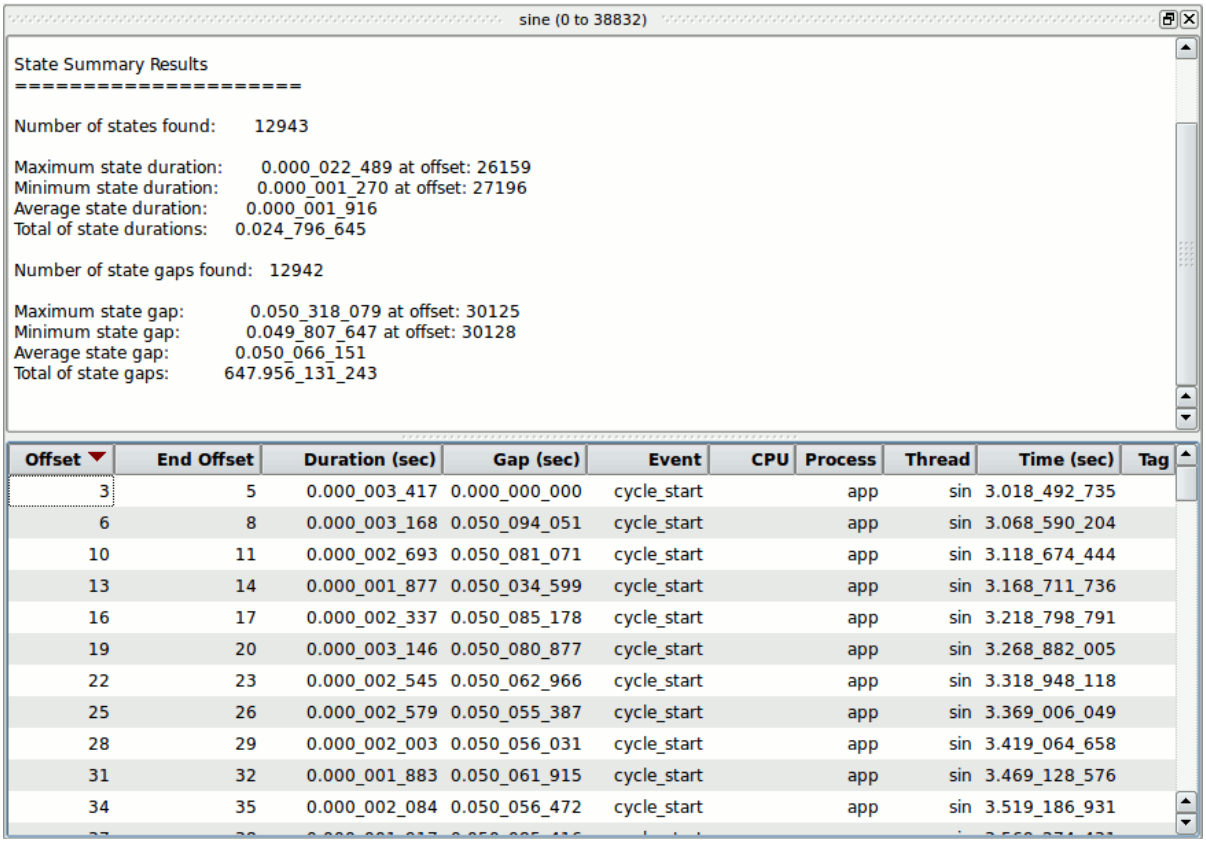
In addition to obtaining detailed information about specific events and states, summary information is easily generated.

- Select the Change Summary Profile... menu item from the Summary menu.
- Select the profile matching the `sine` state from the list of profiles shown in the Profile Status List table.

  It is likely that the `sine` profile is already selected. Check the profile name shown in the Name text area near the bottom of the dialog.

- Press the Summarize button.

A new page is created displaying the results of the summary.



Offset	End Offset	Duration (sec)	Gap (sec)	Event	CPU	Process	Thread	Time (sec)	Tag
3	5	0.000_003_417	0.000_000_000	cycle_start		app	sin	3.018_492_735	
6	8	0.000_003_168	0.050_094_051	cycle_start		app	sin	3.068_590_204	
10	11	0.000_002_693	0.050_081_071	cycle_start		app	sin	3.118_674_444	
13	14	0.000_001_877	0.050_034_599	cycle_start		app	sin	3.168_711_736	
16	17	0.000_002_337	0.050_085_178	cycle_start		app	sin	3.218_798_791	
19	20	0.000_003_146	0.050_080_877	cycle_start		app	sin	3.268_882_005	
22	23	0.000_002_545	0.050_062_966	cycle_start		app	sin	3.318_948_118	
25	26	0.000_002_579	0.050_055_387	cycle_start		app	sin	3.369_006_049	
28	29	0.000_002_003	0.050_056_031	cycle_start		app	sin	3.419_064_658	
31	32	0.000_001_883	0.050_061_915	cycle_start		app	sin	3.469_128_576	
34	35	0.000_002_084	0.050_056_472	cycle_start		app	sin	3.519_186_931	

Figure 4-17. Summary Results Page

The summary results page provides a number of columns of information including the state's starting and ending offsets, the state's duration, and the gap between a state and its most recent previous occurrence. You can click on the column headers to control how the list is sorted.

Double-clicking on a row in the list positions the current timeline to the beginning of that instance of the state and creates a tag at that position.

To go to the instance of the longest state duration, do the following:

- Click on the Duration header to select duration as the sort key

Repeated clicking on the header toggles the direction of the sort.

- Click the Duration header until the sort order is largest to smallest.
- The instance of the state with the longest duration is shown in the top row
- Double click on that row

  The current timeline is moved to that instance of the state, as shown in the Events and Timeline panels.

The minimum and maximum state occurrences are often of interest. However, a graphical display of state durations can be more enlightening.

- Select the Graph State Durations... option from the Summary menu in the Profiles dialog.
- Change the standard deviation value in the dialog to `0`.
- Press the OK button.

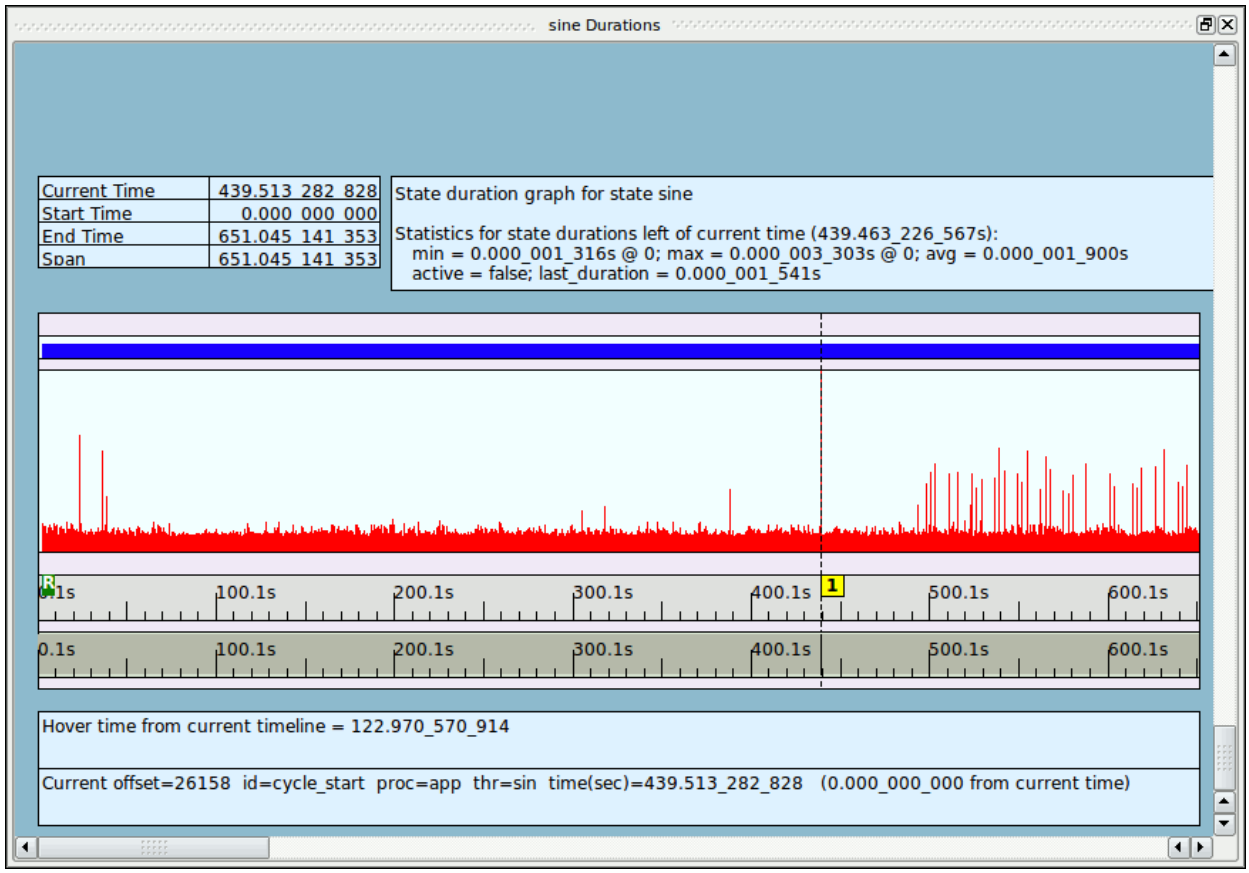


Figure 4-18. Summary Graph

A new page is created with a summary graph and a textual description of the instances of the state.

The row with blue shown indicates individual instances of the state. If the blue bar appears to be a single bar, zoom in until individual instances can be seen.

- Zoom all the way out by pressing Alt+Up.

  A data graph is shown in the wide column beneath the row with blue state indicators.

  Each red line indicates the duration of an instance of the state.

Sometimes a single occurrence of the state may be much longer than most occurrences. In such cases, the detail is obscured.

We can rebuild the page using a different standard deviation index.

- Right-click the tab that contains the summary and click Delete Current Page.
- From the Summary menu, select Graphs State Durations and supply a value of 1 to the standard deviation request dialog.

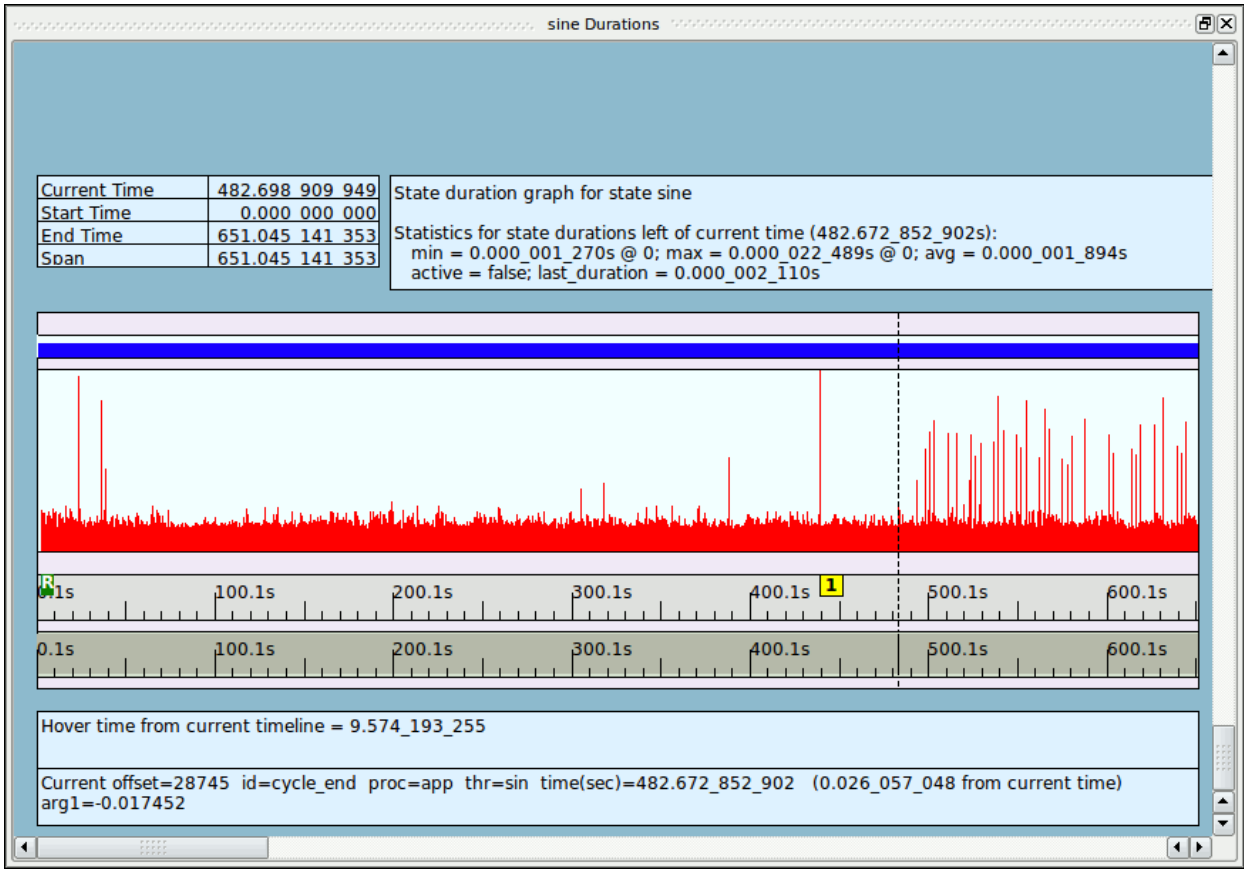


Figure 4-19. State Durations Graph Modified

The graph now shows more detail. The current timeline in the data graph is linked to the current timeline in all timelines and the Events panel. Clicking anywhere in the graph will move the current timeline in all such panels.

Defining a Data Graph

The area containing the timelines has a blank area above the graphs for each of the threads in the program. We will now add a data graph in this area.

- Raise the `app_data` timeline page by clicking on its tab.
- Remove the Events panel by clicking the close box at the upper right-most portion of the panel's title bar.
- Right-click anywhere in the display panel labeled `app_data` and select Edit Mode from the pop-up menu or press Ctrl-E to enter *edit mode*.
- Click on the middle of the upper horizontal line of the column containing the graphs in the panel.
- Move the mouse cursor so that it hovers over the middle of the upper horizontal line of the column.
- When the cursor changes to two arrows pointing up and down, click and drag the upper boundary of the column upward to make space for the data graph.

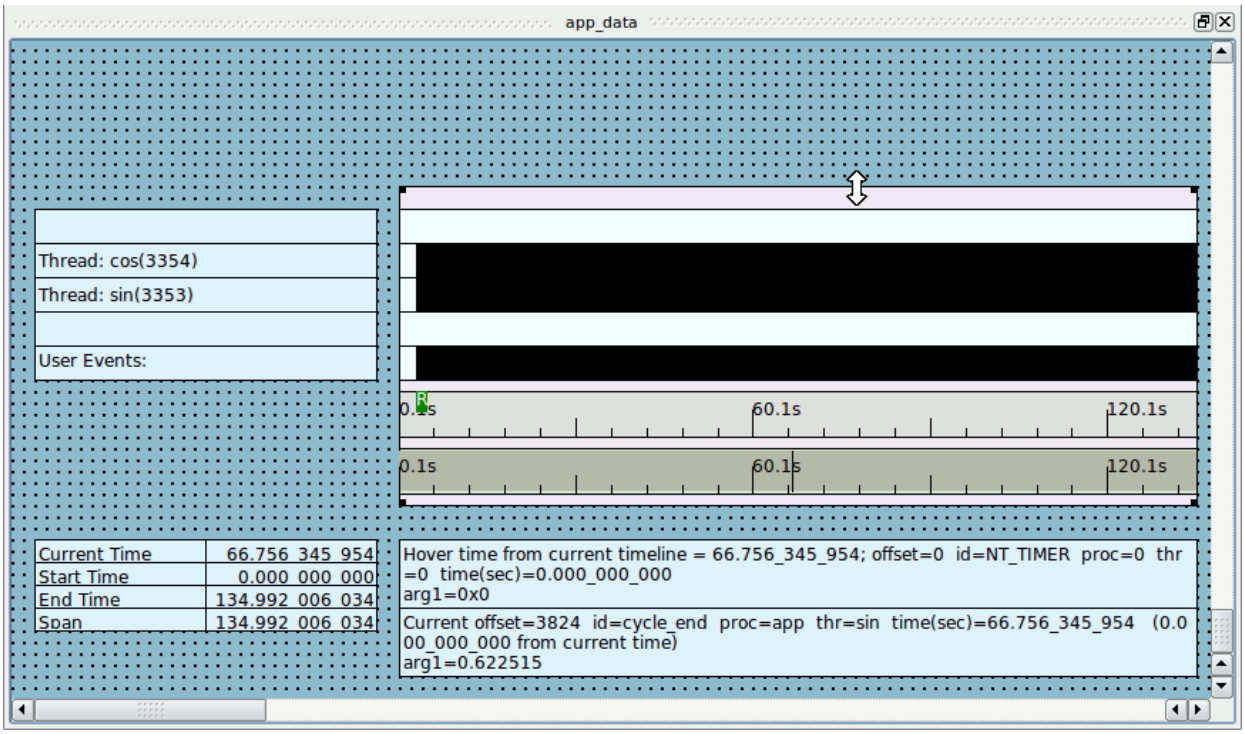


Figure 4-20. Timeline in Edit Mode

- Release the mouse button when sufficient space has been made (approximately an inch or more vertically).
- Click on the upper horizontal line of the column.
- Right-click inside the graph container and select Add to Selected Graph Container from the pop-up menu and select Data Graph from the sub-menu.

  The cursor changes to a block plus sign

- Click in the space created by the previous steps.

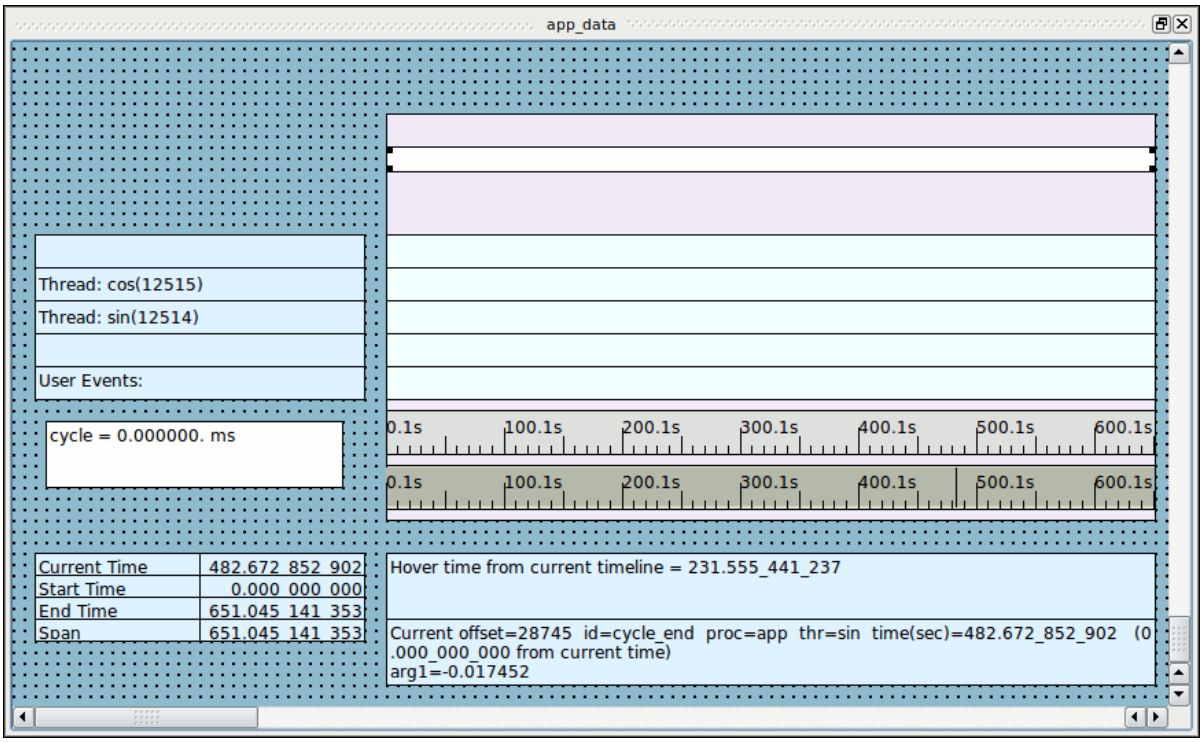


Figure 4-21. Adding a Data Graph

- Click inside data graph you just inserted.
- Drag the top border to the top of the graph container and the bottom border to the bottom of the graph container so that the data graph fills the graph container you created.
- Click and drag the upper and lower lines of the newly inserted data graph to fill the available space.
- Double-click in the middle of the data graph.

The Edit Data Graph Profile dialog is presented.

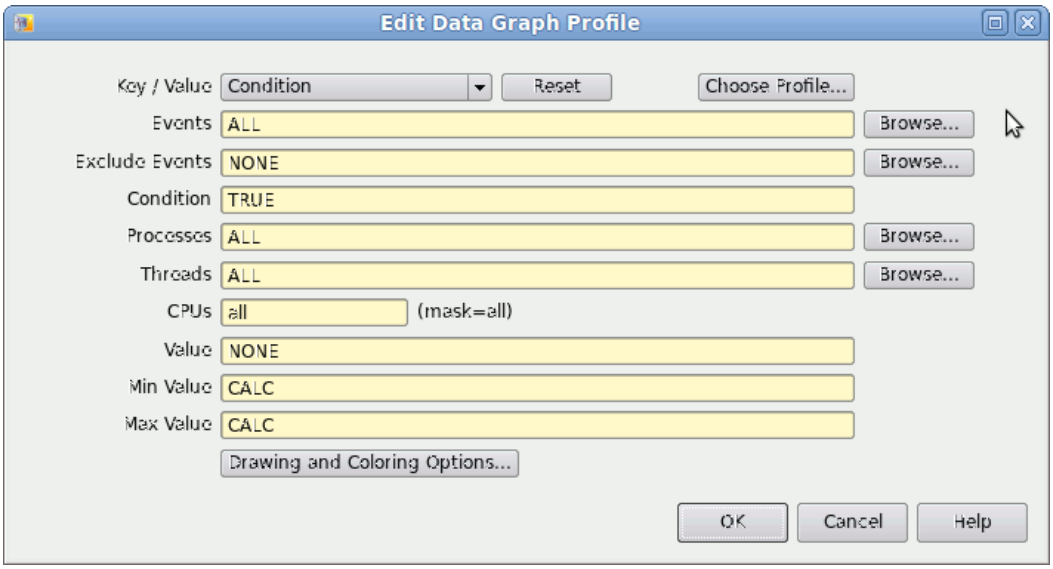


Figure 4-22. Edit Data Graph Profile Dialog

- Enter:

  ```
  cycle_end
  ```

  in the Events text field.

- Enter:

  ```
  arg1_dbl
  ```

  in the Value text field.

- Press OK to close the Edit Data Graph Profile dialog.

- Right-click inside the data graph and select Adjust Colors in Selected from the pop-up menu and select Data Graph Value Color... from the sub-menu.

- Select a pleasing color from the Select color dialog for the data graph. Click OK to close the Select color dialog.

- Right-click anywhere in the display panel labeled `app_data` and select Edit Mode from the pop-up menu or press Ctrl-E to return to *view mode*.

- Zoom the display to see the sine wave generated by the program.

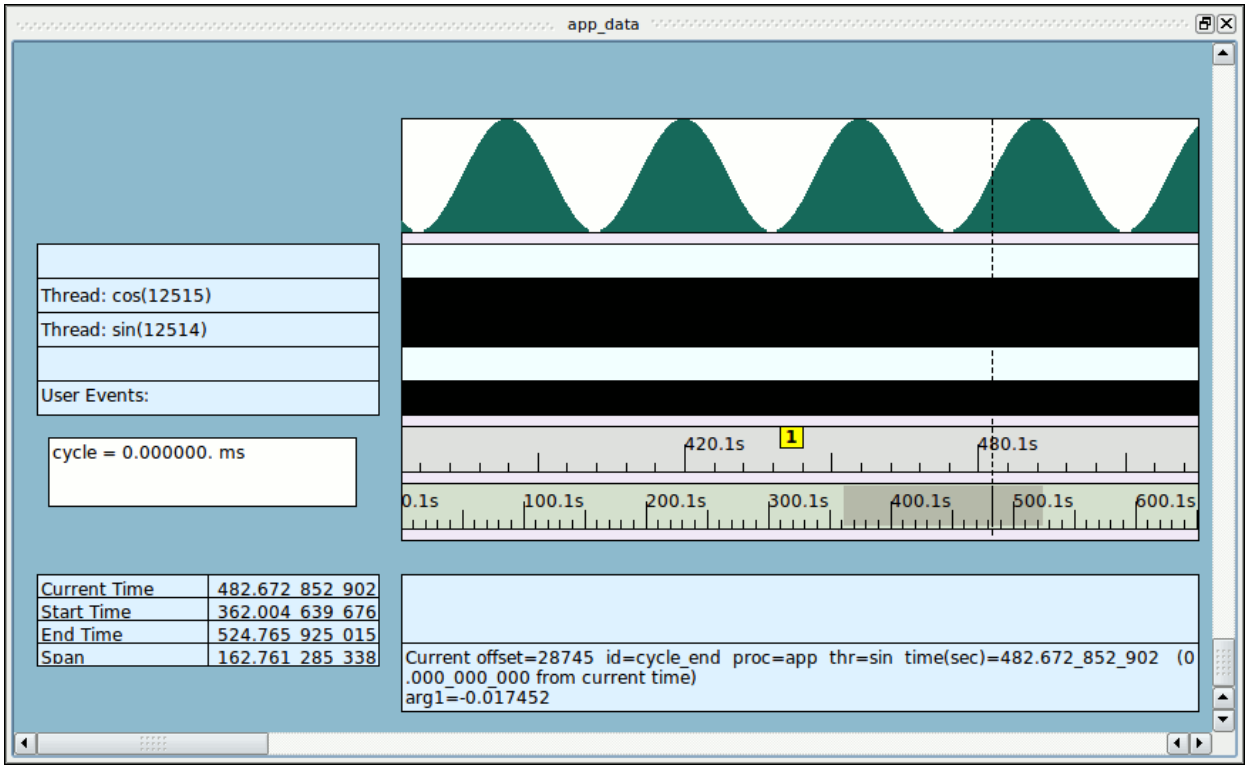


Figure 4-23. Display Page with Data Graph

Using the NightTrace Analysis API

NightTrace provides a powerful API which allows user applications to analyze pre-recorded trace data or to monitor and analyze live trace data.

Users can write programs that define states and conditions and process events as they occur.

In this tutorial, we will instruct NightTrace to build an API program automatically.

- Click on the Profiles tab.
- Select the `sine` profile from the Profile Status List.
- Select the Export to API Source... menu item from the Profiles menu.

The following dialog is displayed:

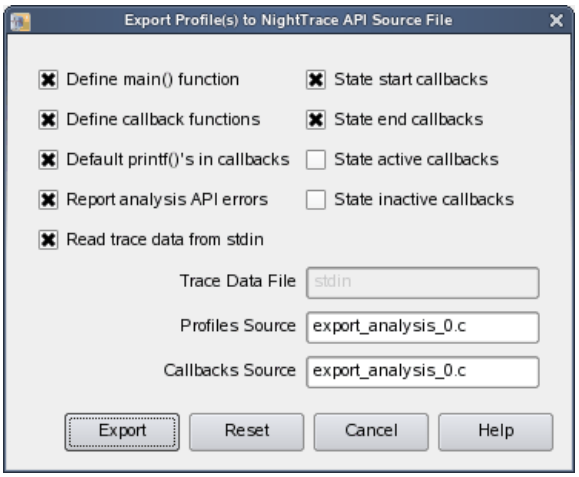


Figure 4-24. Export Profiles to NightTrace API Source File dialog

- Clear the State start callbacks checkbox.
- Press the Export button.
- Select the Exit Immediately menu item from the NightTrace menu to exit NightTrace.

NightTrace has created an API program which listens for occurrences of the state defined by the **`sine`** profile and prints out some information for each instance.

- Build the API program using the following command:

```
cc -g export_analysis_0.c -lntrace_analysis
```

This program expects to consume live trace data.

You can configure a user daemon with the NightTrace GUI and have NightTrace launch the analysis program automatically.

Alternatively, you can use the command line user daemon program **ntraceud** to achieve the same effect.

- Type the following command:

```
ntraceud --stream --join /tmp/data | ./a.out
```

This command instructs **ntraceud** to start capturing trace data from a running application which is using the file **/tmp/data** as a handle. The **--stream** option indicates that instead of logging the data to the named file, it should be sent to **stdout**.

The application program may not immediately begin generating output because the data rate is fairly low and buffering is involved.

- To flush the current buffers for immediate consumption by the application, issue the following command in a different terminal session:

```
ntraceud --flush /tmp/data
```

NOTE

You may need to repeat that command several times over a period of a few seconds to allow the data to pass through system buffers.

Data similar to the following will appear on **stdout** in the terminal session where the analysis program was launched:

```
sine (end)offset 665 occur 333 code 2 pid 3399 time 16.628649 duration 0.000003
sine (end)offset 667 occur 334 code 2 pid 3399 time 16.678631 duration 0.000003
sine (end)offset 669 occur 335 code 2 pid 3399 time 16.728655 duration 0.000003
sine (end)offset 671 occur 336 code 2 pid 3399 time 16.778676 duration 0.000003
sine (end)offset 673 occur 337 code 2 pid 3399 time 16.828693 duration 0.000003
sine (end)offset 675 occur 338 code 2 pid 3399 time 16.878716 duration 0.000004
sine (end)offset 677 occur 339 code 2 pid 3399 time 16.928745 duration 0.000003
sine (end)offset 679 occur 340 code 2 pid 3399 time 16.978760 duration 0.000003
sine (end)offset 681 occur 341 code 2 pid 3399 time 17.028779 duration 0.000003
```

- Issue the following command to terminate the daemon:

```
ntraceud --quit-now /tmp/data
```

Automatically Tracing Your Application

This section will utilize a new invocation of the NightTrace analysis tool.

- If you still have a NightTrace session active, exit NightTrace by selecting Exit NightTrace Immediately from the File menu.

NightTrace provides a component called Application Illumination, which automatically instruments your application with trace points that record the entry and exit of subprograms.

The arguments and return values to those subprogram calls, among other things, can be included as part of the trace data, so that you can see them when you analyze the data.

Not all subprograms can be automatically instrumented. Application Illumination cannot detect functions which do not have globally visible external symbol names (e.g. `static void func();` in the C programming language). Similarly, it cannot detect functions which are completely internal to a linked shared library (i.e. functions that have no external entry point). Similarly, by default, Application Illumination only operates on functions which have compiler-generated debug information -- although you can change this behavior.

The utility **`/usr/bin/nlight`** is the primary interface used to instrument your application.

`nlight` provides for selection and exclusion of subprograms as well as customization of detail levels.

In this tutorial, we'll use **`nlight`**'s wizard to quickly and easily instrument the **`app`** program we've been using thus far.

nlight Wizard - Selecting Programs

- While positioned in the tutorial test directory you created in the initial stages of this tutorial, invoke the **`nlight`** tool:

  ```
  nlight &
  ```

The following window is displayed.

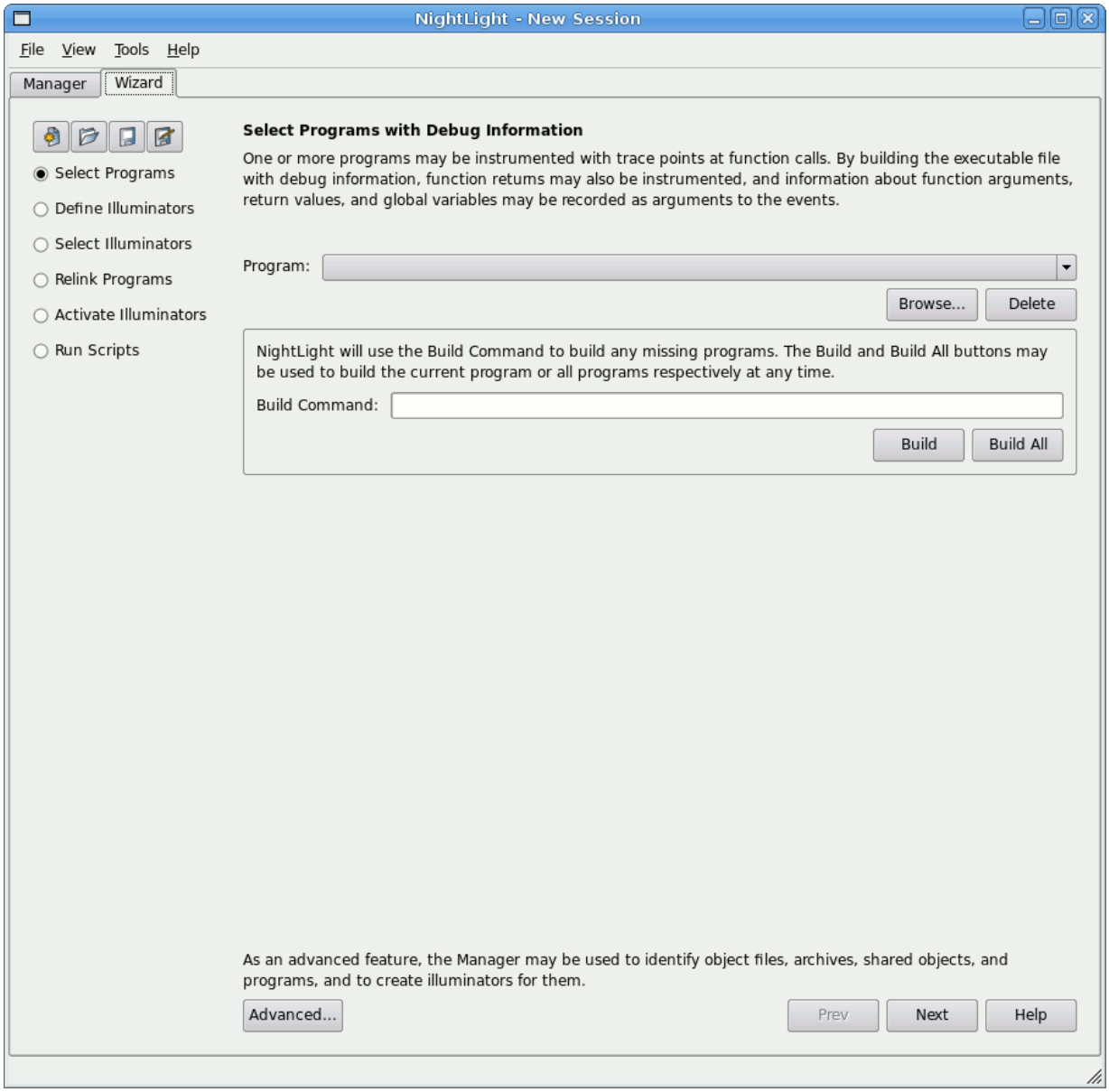


Figure 4-25. nlight Wizard - Select Programs Step

The Wizard tab is raised by default and provides step-wise instructions for instrumenting your application.

The bullet list on the left side of the page indicates what step you're currently working on within the wizard, while the Prev and Next buttons at the bottom navigate through the steps.

The initial step is Select Program, in which we tell **`nlight`** which program to illuminate.

- Press the Browse… button and select the **app** program file from the file selection dialog, then press Save to close the file selection dialog.

Note that the Build Command text area below the program selection now contains a default **make** command. While not specifically required, it is convenient to provide **nlight** a command which can rebuild your original program, in case you should choose to do so from within **nlight**. Further, **nlight** will automatically invoke this command if it finds that the specified program file does not exist.

- Press the Next button to proceed to the next step.

nlight Wizard - Defining Illuminators

The Define Illuminators step is displayed, which allows us to select the portions of code in the application that we want to illuminate.

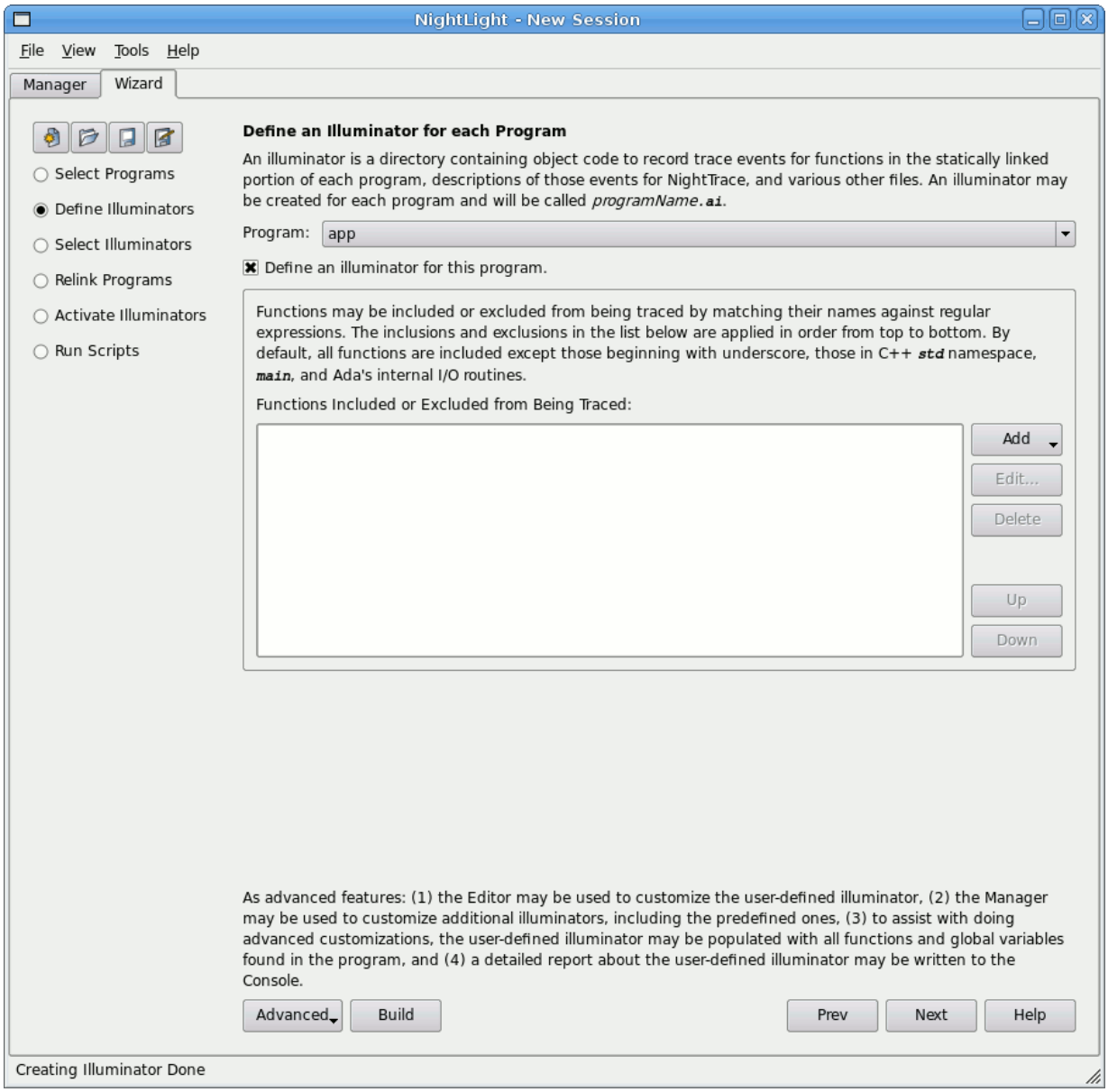


Figure 4-26. nlight Wizard - Define Illuminators Step

The term *illuminator* refers to a directory which contains the **`nlight`**-generated files required for instrumenting code. Normally, you don't interact directly with the contents of that directory; **`nlight`** does all the work. The Define an illuminator for this program checkbox tells **`nlight`** that we want to instrument the statically-linked portions of the **`app`** program.

This page also includes a selection and exclusion area which allows you to specify specific subprograms you want to include or exclude from instrumentation. You can also specify patterns via regular expressions to include or exclude multiple functions easily.

We'll just let **`nlight`** illuminate all the statically-linked portions of our **`app`** program at this step.

- Ensure the checkbox labeled Define an illuminator for this program is checked.
- Press the Next button to proceed to the next step.

nlight Wizard - Selecting Illuminators

The Select Illuminators step is now displayed.

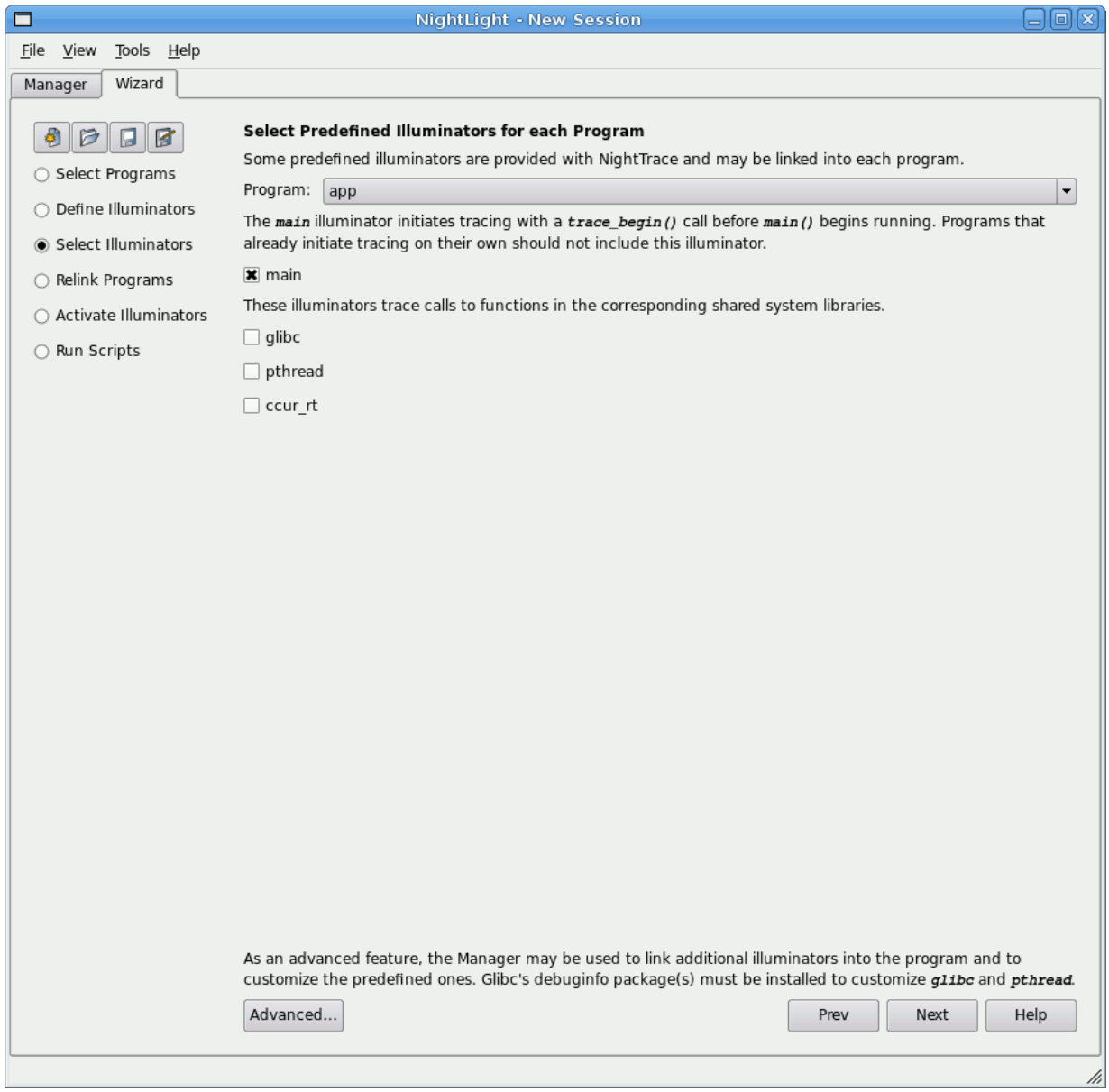


Figure 4-27. nlight Wizard - Select Illuminators Step

This step allows us to select additional, predefined illuminators for our program.

NOTE

The list of predefined illuminators may be different on your system. However, all systems should have `main`, `glibc`, and `pthread`.

The **main** illuminator is special and is only needed if your application doesn't already use the NightTrace API. Our **app** program already does, so we should clear this checkbox.

- Clear the main checkbox.

Additional illuminators are already built and shipped with NightTrace. In the middle section of the page, we can include illuminators for system libraries that our program uses.

- Check the glibc checkbox to include the **glibc** illuminator.
- Check the pthread checkbox to include the **pthread** illuminator.
- Press the Next button to proceed to the next step.

nlight Wizard - Relinking the Program

The Relink Programs step is now displayed.

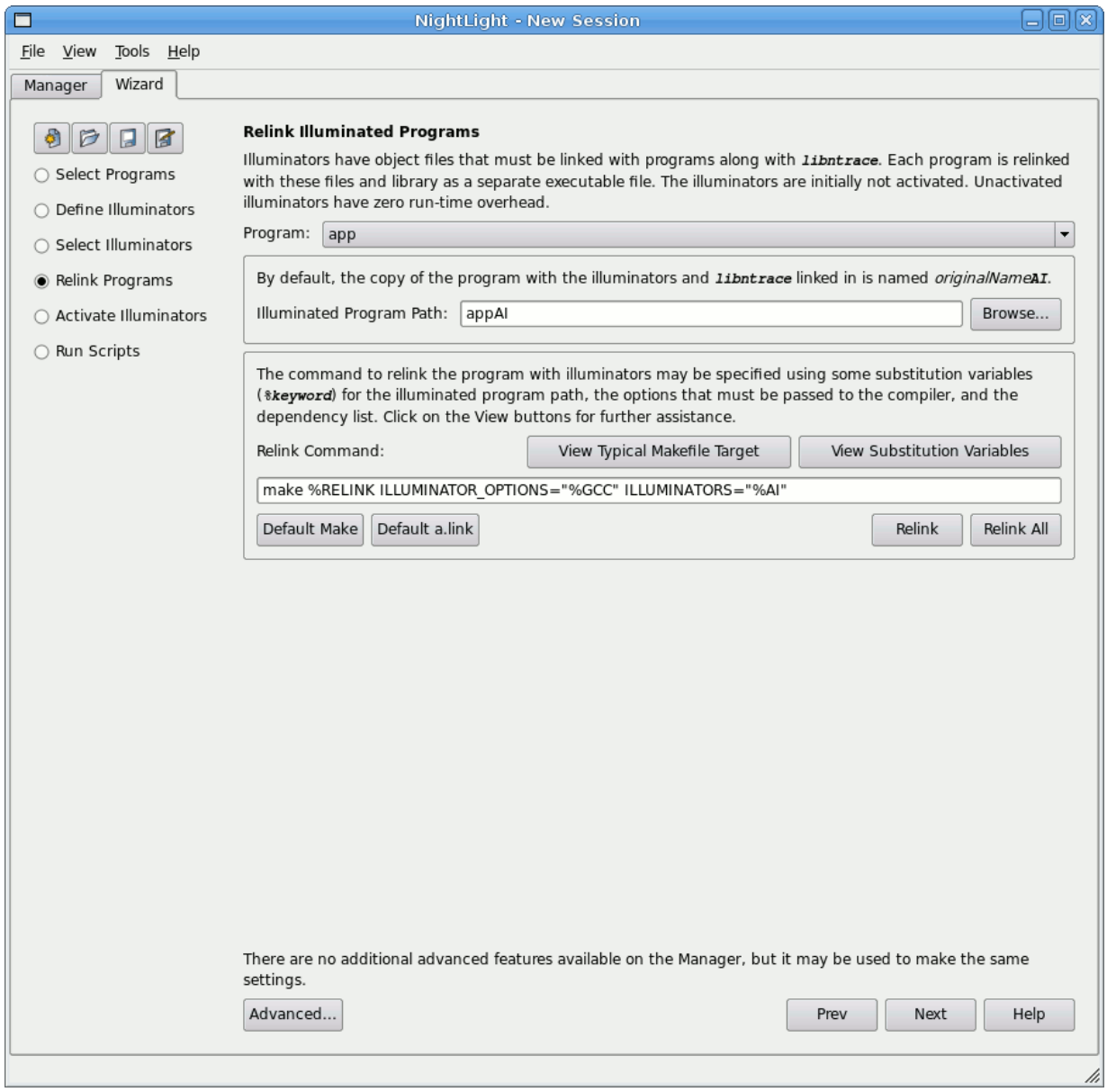


Figure 4-28. nlight Wizard - Relink Programs Step

In order to utilize the illuminators, we need to create a new version of our executable program which links with exactly the same objects and libraries as the original program, but also includes the **`nlight`**-generated illuminator files.

The resultant executable will contain the unmodified object files and libraries from the original program, but it will also include instrumented “wrapper” functions which inject the actual trace event calls at runtime.

Since we need to essentially recreate the original program and add some new link options, the wizard needs you to enter a command that will do this. The default "relink" command is already filled in and assumes you will use the **make** utility to build the program. It passes some **make** parameters which make it very easy for you to form the **Makefile** rule to build the new program.

In most cases, you can simply copy the final rule required to create your original application and rename it and add the options passed by the wizard on the link line.

Our **Makefile** in the tutorial test directory already has a rule defined for the instrumented program name, which, by convention, is the original name of the program with the letters "AI" appended to it. The following is an excerpt from the **Makefile** that shows the rules to build **app** and **appAI**.

```
app: app.c
   cc -g -o app app.c \
      -lntrace_thr -lpthread -lm

appAI: app.c
   cc -g -o appAI app.c \
      $(ILLUMINATOR_OPTIONS) -lntrace_thr -lpthread -lm
```

Notice that the rule to build **appAI** (the instrumented version of the program) is exactly the same as the rule to build the original **app** program, except that we also include the options passed in by the wizard in the "relink" command.

- Press the Next button to proceed to the next step.

nlight Wizard - Activating Illuminators

The Activate Illuminators step is now displayed.

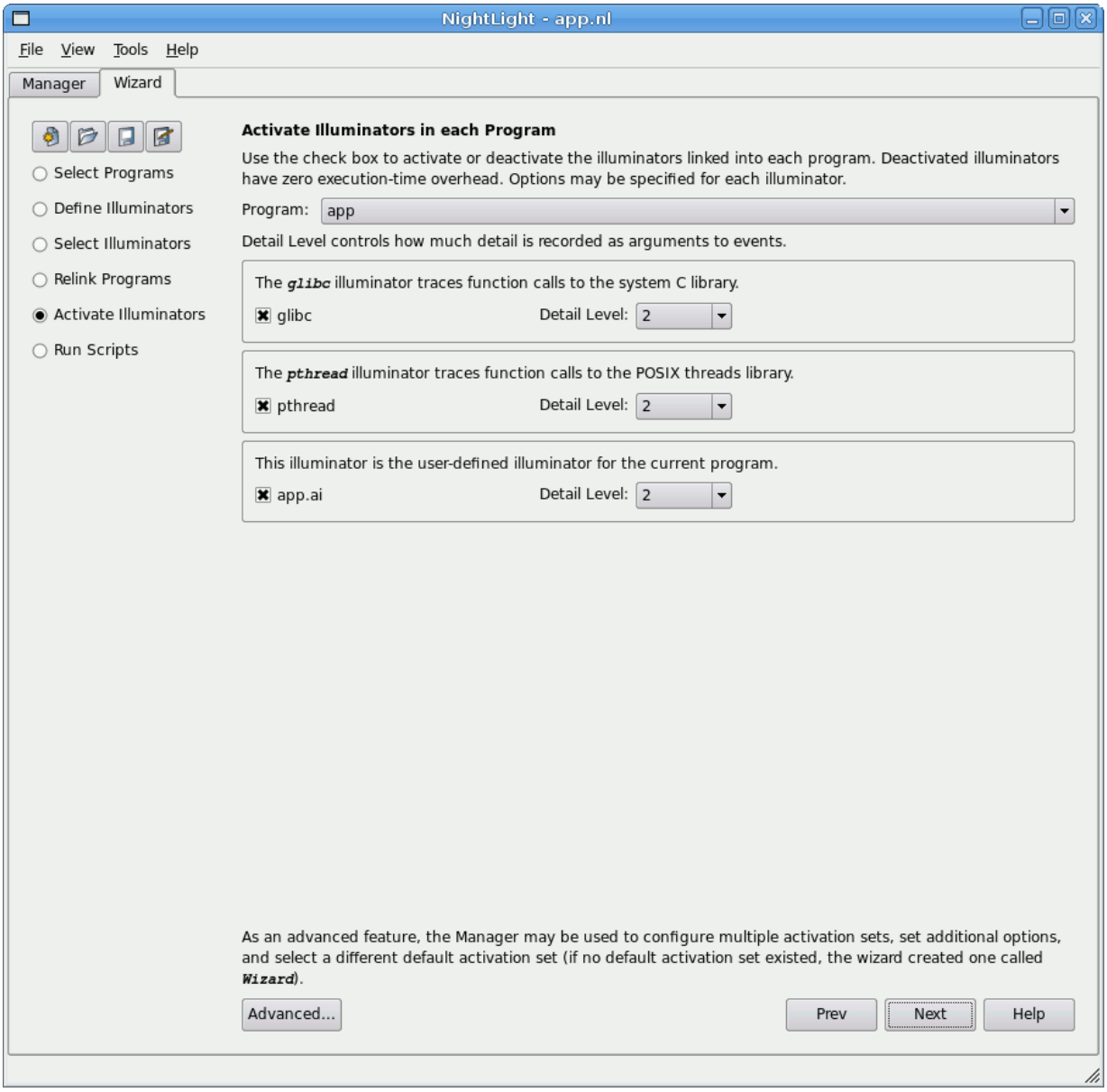


Figure 4-29. nlight Wizard - Activate Illuminators Step

An important feature of Application Illumination is that once you relink your program and include the illuminators, the illuminators are inert. You can run your application with zero overhead while the illuminators are inert.

In this step, we'll activate them so that when we run the program trace data will be logged.

The default activation level is 2, which provides a medium amount of detail with each event. In this tutorial we want to see more detail, so we'll increase the detail level of each illuminator.

- Change the Detail Level for the glibc illuminator to 3.
- Change the Detail Level for the pthread illuminator to 3.
- Change the Detail Level for the app.ai illuminator to 3.
- Press the Next button to proceed to the next step.

Running the Program

The Run Scripts step is now displayed in the wizard.

The wizard provides this step for convenience.

We'll go ahead and close **nlight** now and run the application ourselves outside of **nlight**.

- Select Exit Immediately from the File menu.
- In a shell session, start the illuminated program: **./appAI &**

IMPORTANT

Make sure you invoked **appAI**, the instrumented program, and not **app**.

Analyzing Application Illumination Events

Now we'll invoke NightTrace to analyze the data generated by our instrumented program.

- Enter the following command while positioned in the directory that contains the **appAI** program: **ntrace --import=appAI**

The NightTrace analysis interface appears.

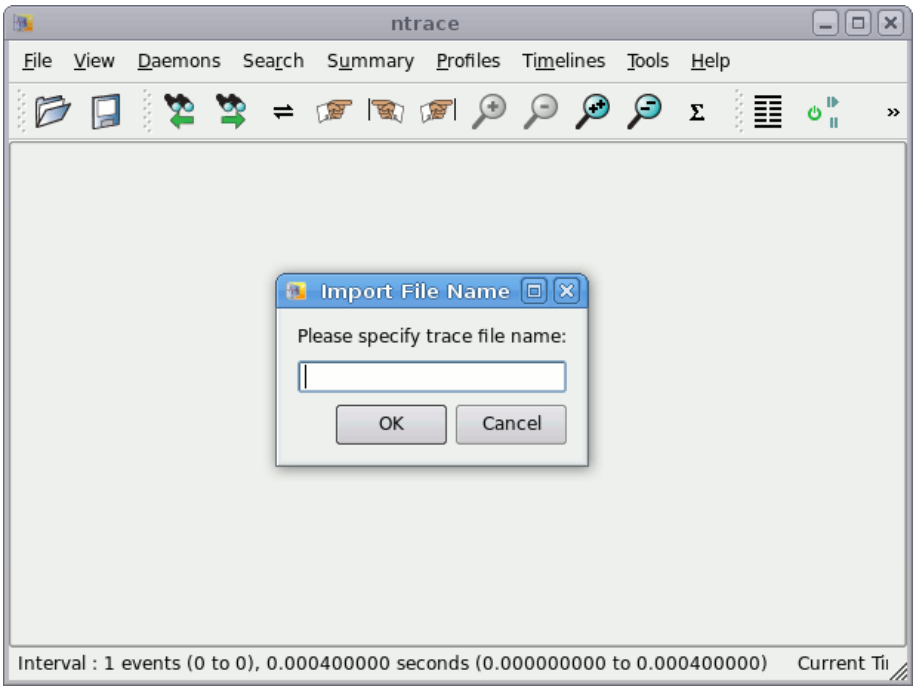


Figure 4-30. NightTrace - Import File Name

Since NightTrace was invoked with the **`--import`** option, it prompts you for the name of the trace data file, which is the first parameter your program passed to the `trace_begin` call.

- Enter **`/tmp/data`** in the prompt dialog and press OK.

Use of the **`--import`** option instructs NightTrace to load auxiliary data created by **`nlight`** so that it can fully describe the trace events it collects. The location of that information is embedded within the instrumented application, in our case, **`appAI`**.

NOTE

If the `main` illuminator had been selected in **`nlight`**, **`ntrace`** would have already known the name of the trace file. In our example, we didn't include the `main` illuminator, because our program already initiated tracing independently of **`nlight`**.

The Daemons panel now includes a user daemon which is ready to collect trace points from our instrumented **appAI** program.

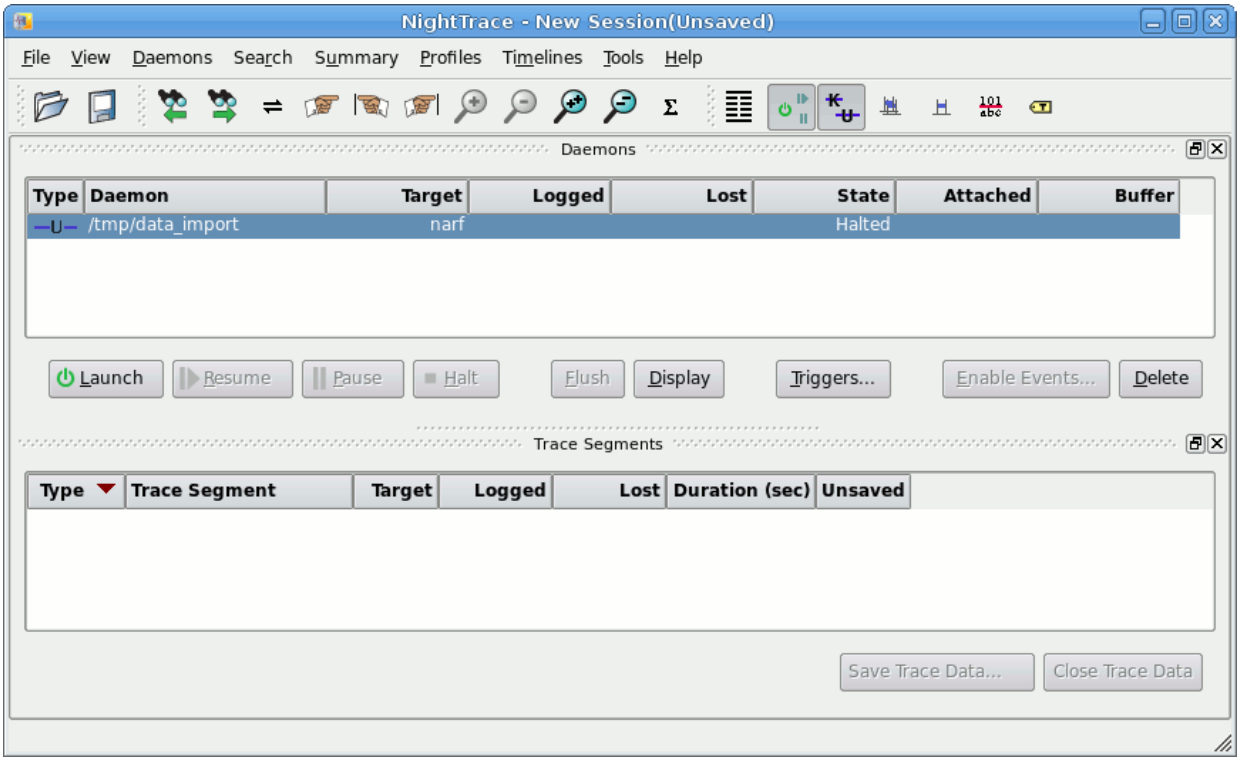


Figure 4-31. NightTrace - Daemon Ready to Launch

- Press the Launch button to launch the daemon.
- Press the Resume button to start collecting trace events.

Returning to the NightTrace window, you can see that the user daemon is collecting events as the number in the Buffer column in the Daemons panel is steadily increasing.

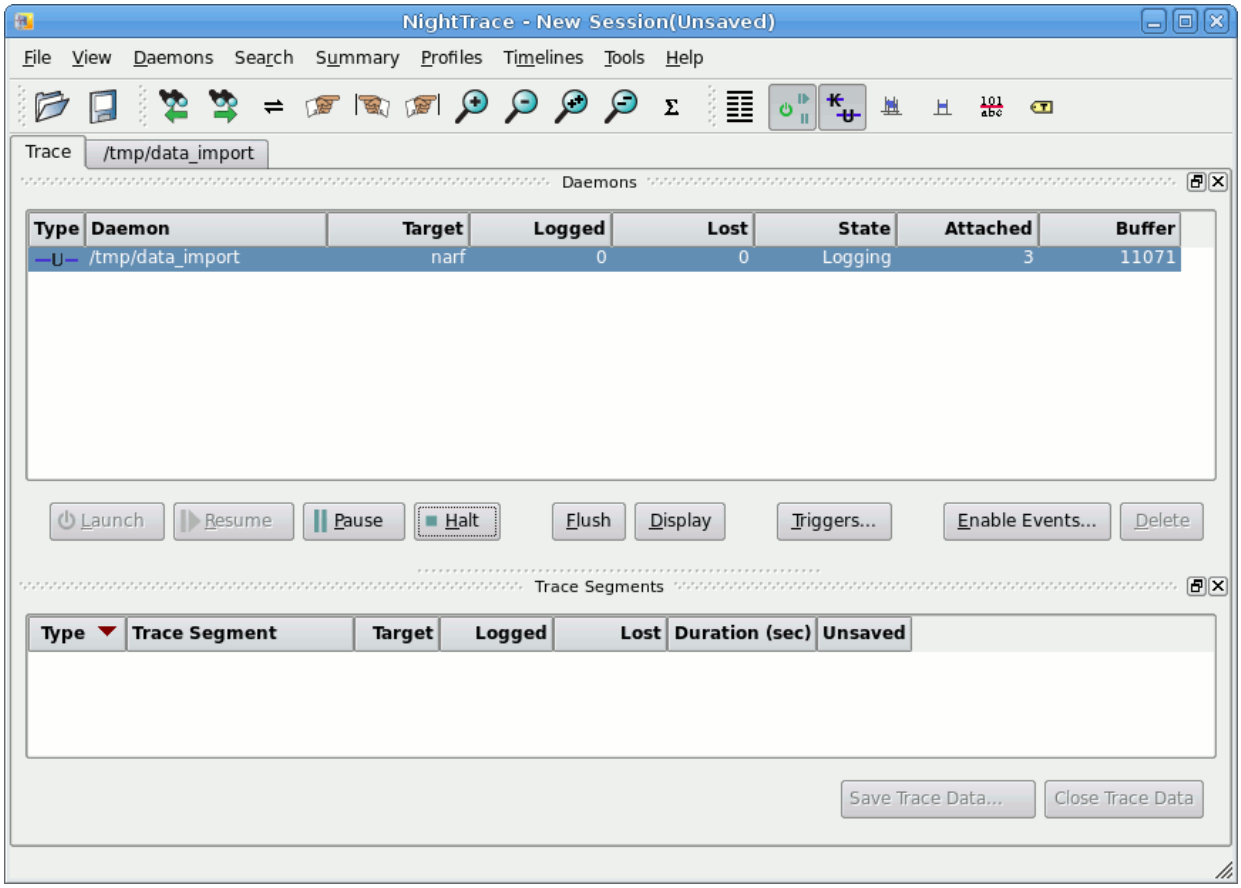


Figure 4-32. NightTrace - Daemon Collection Events

- Wait until the event count in the Buffer column reaches 10,000 or more.
- Press the Halt button in the Daemons panel to stop the daemon.
- Click on the /tmp/data_import tab to bring the Events and Timeline panels to the top of the NightTrace window.

- Click in the middle of the activity in the timeline.

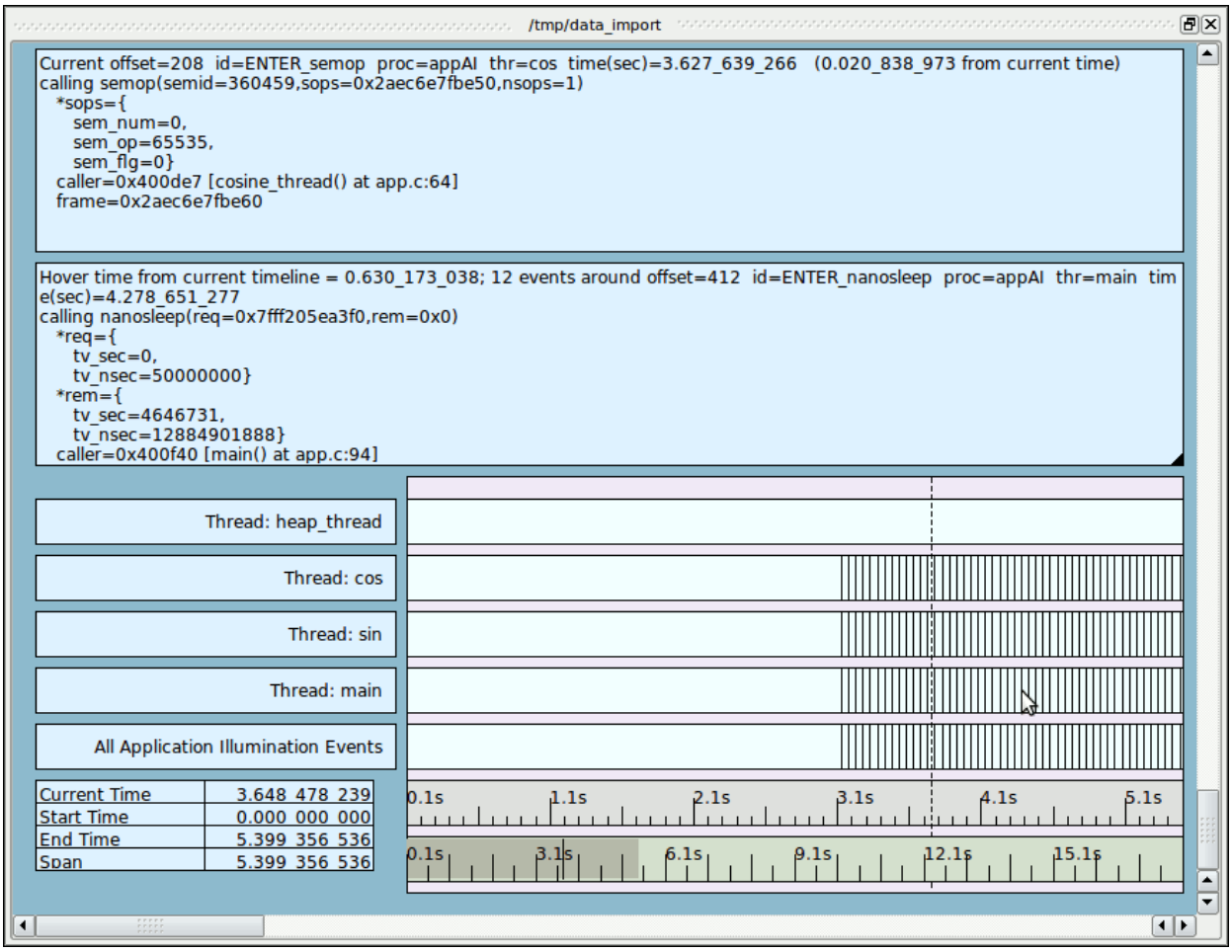


Figure 4-33. NightTrace - /tmp/data_import Timeline

AI timelines are much like standard user trace timeline, except that the event description and hover description areas are much bigger, because such descriptions are more detailed and verbose than most ordinary trace data.

In the figure above, notice the description of the `semop` and `nanosleep` library calls, including details about their arguments.

Let’s turn our attention to the Events panel.

- Hover the mouse over the description area of the selected event.

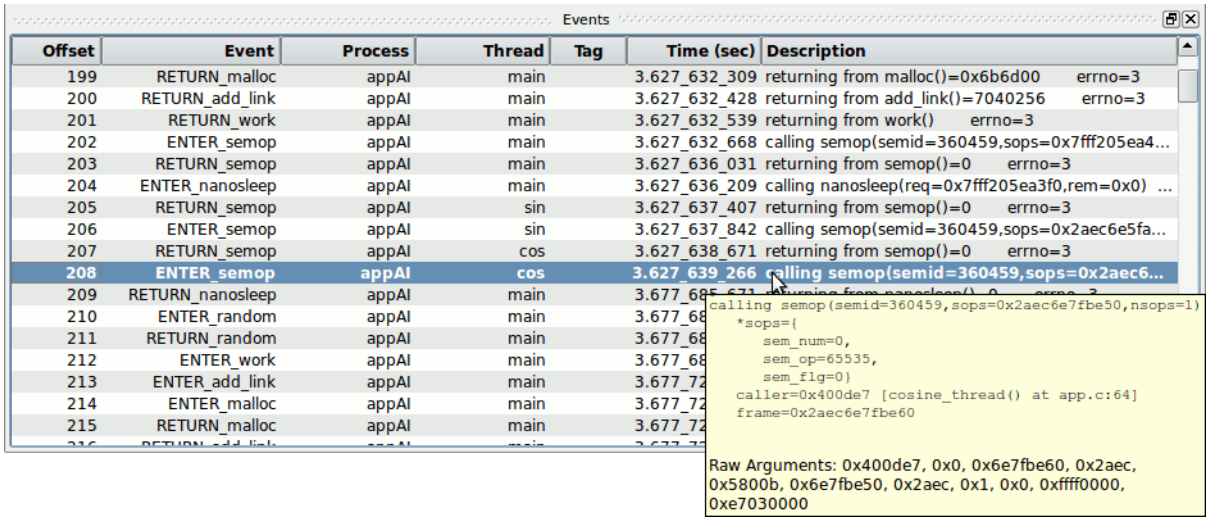


Figure 4-34. NightTrace - Events Panel w/ Tool Tip

As mentioned before, trace event descriptions are quite long, and the description in the last column in the Events panel may be truncated. Hovering over those areas provides the full description.

- Activate the Textual Search dialog by pressing Ctrl+T while the focus is in the Events panel.

A textual search dialog is shown.

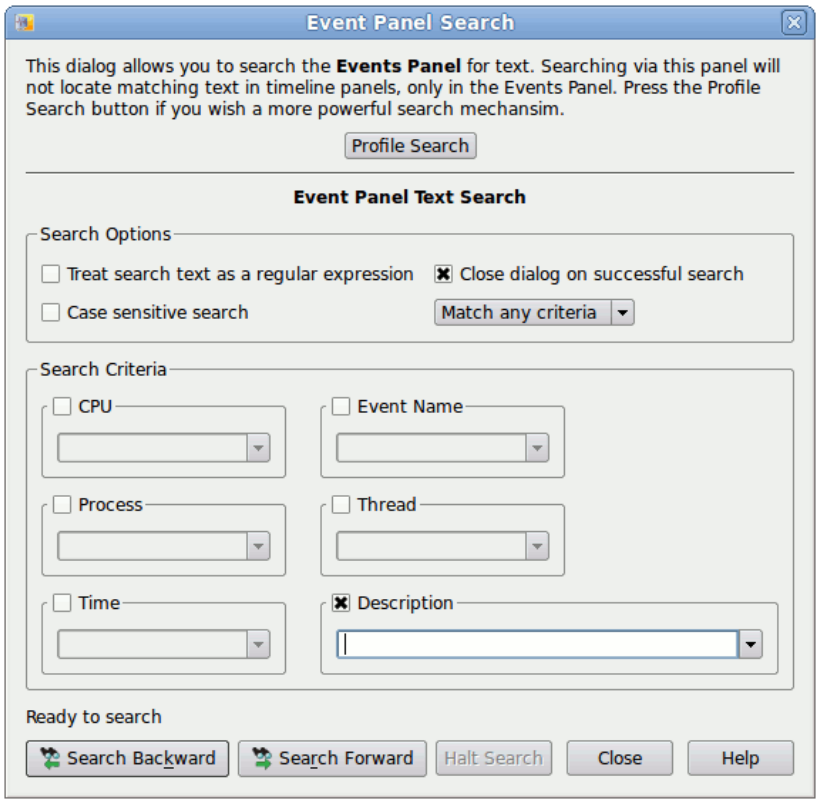
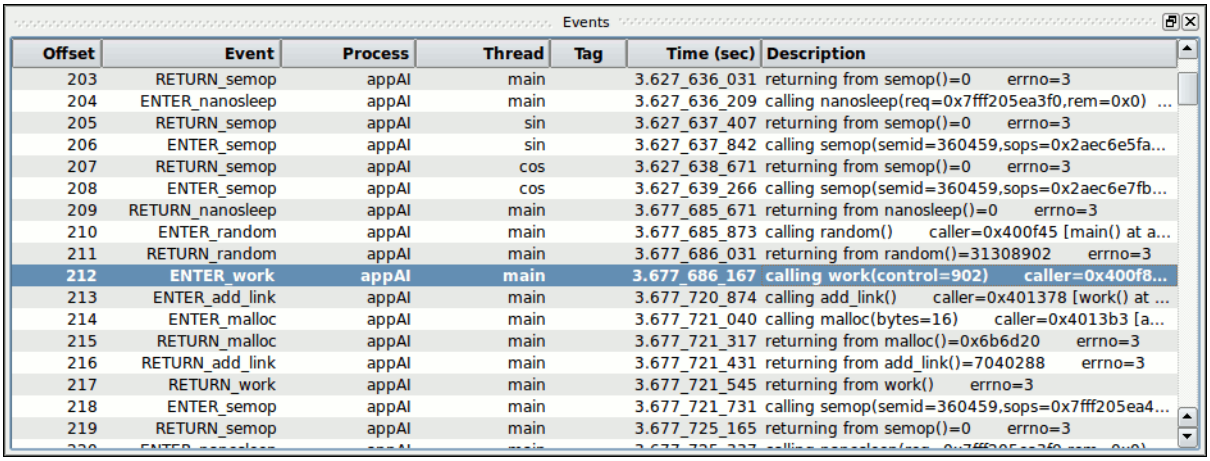


Figure 4-35. NightTrace - Event Panel Search Dialog

- Activate the Event Name field by checking its checkbox.
- Type ENTER_work into the Event Name text field and press the Search Forward button.

The Events panel now has the next occurrence of the `ENTER_work` event selected.



Offset	Event	Process	Thread	Tag	Time (sec)	Description
203	RETURN_semop	appAl	main		3.627_636_031	returning from semop()=0 errno=3
204	ENTER_nanosleep	appAl	main		3.627_636_209	calling nanosleep(req=0x7fff205ea3f0,rem=0x0) ...
205	RETURN_semop	appAl	sin		3.627_637_407	returning from semop()=0 errno=3
206	ENTER_semop	appAl	sin		3.627_637_842	calling semop(semid=360459,sops=0x2aec6e5fa...
207	RETURN_semop	appAl	cos		3.627_638_671	returning from semop()=0 errno=3
208	ENTER_semop	appAl	cos		3.627_639_266	calling semop(semid=360459,sops=0x2aec6e7fb...
209	RETURN_nanosleep	appAl	main		3.677_685_671	returning from nanosleep()=0 errno=3
210	ENTER_random	appAl	main		3.677_685_873	calling random() caller=0x400f45 [main() at a...
211	RETURN_random	appAl	main		3.677_686_031	returning from random()=31308902 errno=3
212	ENTER_work	appAl	main		3.677_686_167	calling work(control=902) caller=0x400f8...
213	ENTER_add_link	appAl	main		3.677_720_874	calling add_link() caller=0x401378 [work() at ...
214	ENTER_malloc	appAl	main		3.677_721_040	calling malloc(bytes=16) caller=0x4013b3 [a...
215	RETURN_malloc	appAl	main		3.677_721_317	returning from malloc()=0x6b6d20 errno=3
216	RETURN_add_link	appAl	main		3.677_721_431	returning from add_link()=7040288 errno=3
217	RETURN_work	appAl	main		3.677_721_545	returning from work() errno=3
218	ENTER_semop	appAl	main		3.677_721_731	calling semop(semid=360459,sops=0x7fff205ea4...
219	RETURN_semop	appAl	main		3.677_725_165	returning from semop()=0 errno=3

Figure 4-36. NightTrace - Events Panel after Search

Notice that the description field includes the location of the caller using both the hexadecimal PC location as well as the name of the subprogram and file and line number information (hover the mouse over the description to see it):

```
caller=0x400f83 [main() at app.c:95]
```

NOTE

Depending on compiler versions and actual source contents, the line number displayed may actually be associated with the next code-generating source line after the call. This is because the return value of the PC that is included with the trace event is the "return address"; the instruction that will execute after the called function.

NightTrace will always attempt to map the PC address in the caller portion of the description to the subprogram and file/line values, but it will not be able to provide this information if the corresponding routine wasn't compiled with debug information.

When a file and line number is available in an event's description, you can ask NightTrace to show you the source line in a text editor using the context menu.

- Right-click the mouse on the description of the ENTER_work event and select the Show Source File From Description... option from the context menu.

Figure 4-37. NightTrace - Events Panel Context Menu

NightTrace will load the source file and position your text editor at the appropriate line number, as shown in the following figure.

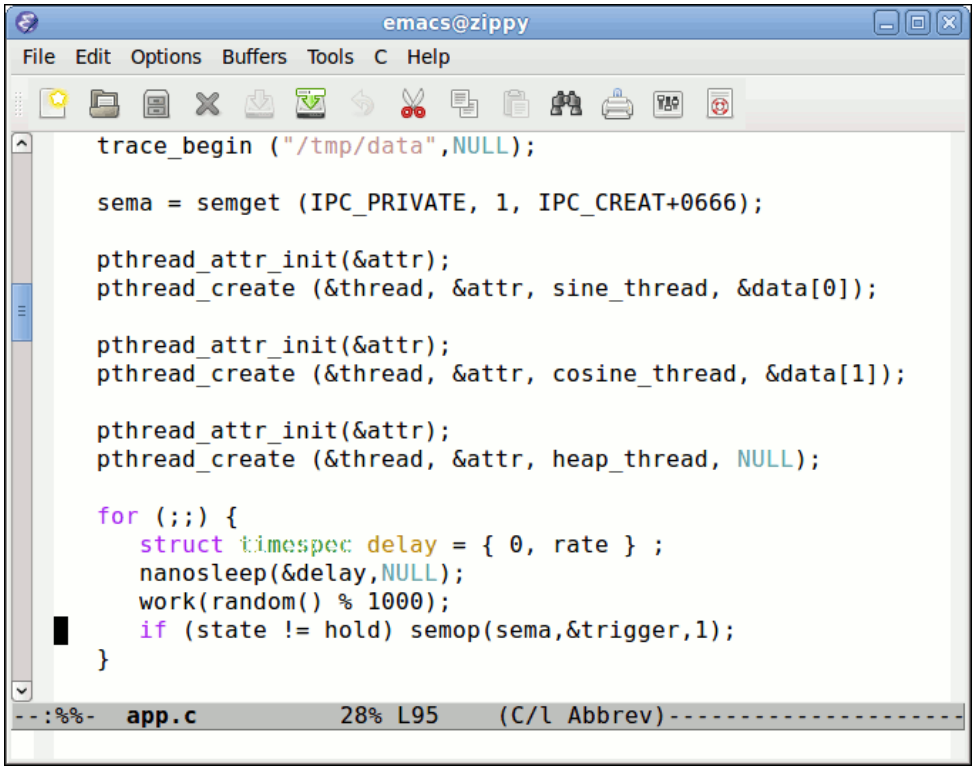


Figure 4-38. NightTrace - Launches Editor with Source File at Line Number

NOTE

As mentioned above, the return PC is always in the next instruction after the call, which may mean it is associated with the next source line, as it is in the example above.

NOTE

NightTrace selects your editor via the `EDITOR` environment variable.

- Close the editor before proceeding.

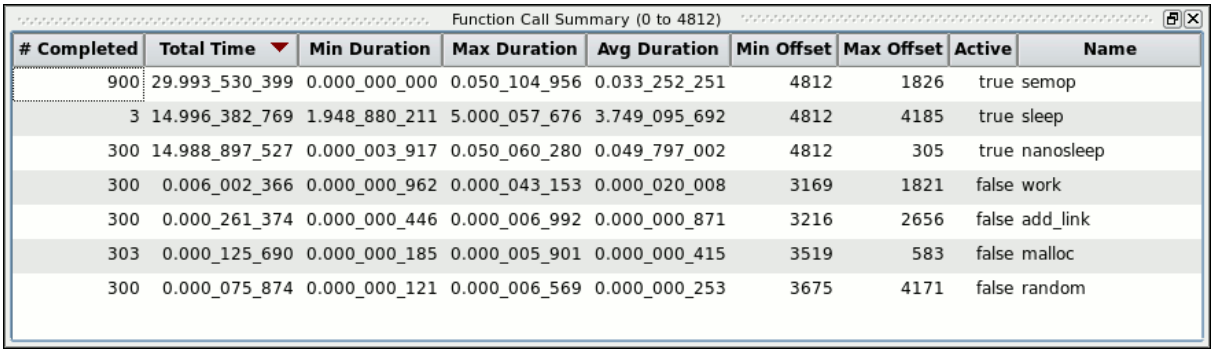
Summarizing Workload Performance

Remember that we summarized the workload performance of our threads in a previous section of this tutorial? We used trace points that we inserted via NightView and defined states for them.

We'll do the same basic thing here, but this time we'll just use the trace events that were automatically created for us by **`nlight`**.

- Select Summarize Functions from the Summary menu.

A panel with a summary of all instrumented functions that were called appears.



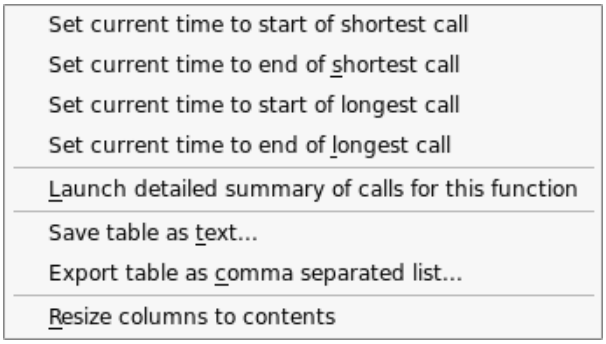
# Completed	Total Time	Min Duration	Max Duration	Avg Duration	Min Offset	Max Offset	Active	Name
900	29.993_530_399	0.000_000_000	0.050_104_956	0.033_252_251	4812	1826	true	semop
3	14.996_382_769	1.948_880_211	5.000_057_676	3.749_095_692	4812	4185	true	sleep
300	14.988_897_527	0.000_003_917	0.050_060_280	0.049_797_002	4812	305	true	nanosleep
300	0.006_002_366	0.000_000_962	0.000_043_153	0.000_020_008	3169	1821	false	work
300	0.000_261_374	0.000_000_446	0.000_006_992	0.000_000_871	3216	2656	false	add_link
303	0.000_125_690	0.000_000_185	0.000_005_901	0.000_000_415	3519	583	false	malloc
300	0.000_075_874	0.000_000_121	0.000_006_569	0.000_000_253	3675	4171	false	random

Figure 4-39. NightTrace - Functions Summary Table

A table is created that presents a single row for each instrumented function. It contains statistics about the number of invocations, their minimum, maximum, and average length, and the name of the function.

The column labelled Active indicates whether a function call was ongoing at the end of the data set (or the end of the summarized interval).

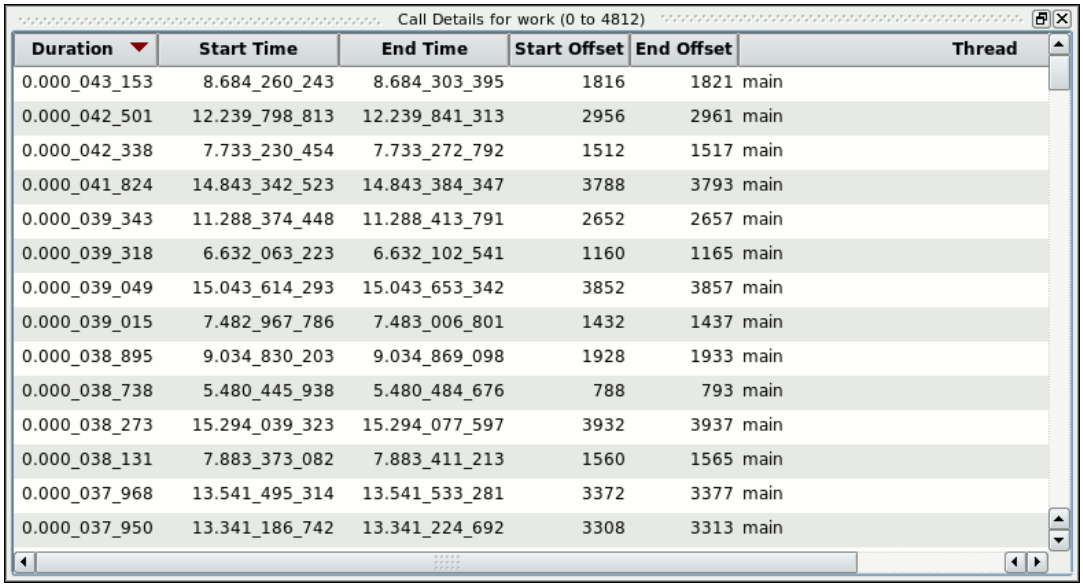
The context menu provides the following actions:



You can obtain details of a specific function by right-clicking its row in the table.

- Right click on the row for the `work` function and select Launch detailed summary of calls for this function.

A table appears with a row for every invocation of that function.



Duration	Start Time	End Time	Start Offset	End Offset	Thread
0.000_043_153	8.684_260_243	8.684_303_395	1816	1821	main
0.000_042_501	12.239_798_813	12.239_841_313	2956	2961	main
0.000_042_338	7.733_230_454	7.733_272_792	1512	1517	main
0.000_041_824	14.843_342_523	14.843_384_347	3788	3793	main
0.000_039_343	11.288_374_448	11.288_413_791	2652	2657	main
0.000_039_318	6.632_063_223	6.632_102_541	1160	1165	main
0.000_039_049	15.043_614_293	15.043_653_342	3852	3857	main
0.000_039_015	7.482_967_786	7.483_006_801	1432	1437	main
0.000_038_895	9.034_830_203	9.034_869_098	1928	1933	main
0.000_038_738	5.480_445_938	5.480_484_676	788	793	main
0.000_038_273	15.294_039_323	15.294_077_597	3932	3937	main
0.000_038_131	7.883_373_082	7.883_411_213	1560	1565	main
0.000_037_968	13.541_495_314	13.541_533_281	3372	3377	main
0.000_037_950	13.341_186_742	13.341_224_692	3308	3313	main

Figure 4-40. Function Details Table for the work function

This table has a context menu that is similar to the Function Summary table's context menu.

Batch Summary of Functions

You can also use **ntrace** in non-GUI mode to obtain summary information for all functions or for specific functions. Assuming you had captured some trace data for your application; perhaps like this:

```
./appAI &
ntraceud --join /tmp/data
sleep 5
ntraceud --quit-now /tmp/data
killall appAI
```

You could invoke **ntrace** with either of the following commands:

```
ntrace --verbose --summary=fs:* appAI /tmp/data
ntrace --verbose --summary=fs:work appAI /tmp/data
```

and it would generate output similar to the contents of the tables generated in the figures above, without presenting the graphical interface.

Shutting Down

- Select Exit Immediately from the File menu of NightTrace to terminate the NightTrace session.

- Issue the following command from a terminal shell to kill the **appAI** process which we left running:

  ```
  killall appAI 2>/dev/null
  ```

Conclusion - NightTrace

This concludes the NightTrace portion of the NightStar LX Tutorial.

5
Using NightProbe

NightProbe is a graphical tool for viewing and modifying data from independently executing programs as well as recording data for subsequent analysis.

This chapter assumes you have already built the **app** program and it is running under the control of NightView. If you have not built the program, do so using the instructions in "Building the Program" on page 1-2 and execute the application via the following command before proceeding:

```
./app &
```

Invoking NightProbe

Programs to be probed do not need to be instrumented with any special API calls. However, in order for NightProbe to refer to symbolic variable names, the program should be compiled with debug information (typically the **-g** compilation option).

NightProbe RT takes advantage of significant performance capabilities of the RedHawk or SLERT kernel, eliminating intrusion on the process by sampling and modifying variables in other programs using direct memory fetches and stores. However, those capabilities are not present on standard Linux kernels, and so NightProbe LX must control the process using ptrace and start and stop the process to obtain memory samples and to modify memory. As a result, NightProbe LX cannot probe a process under the control of a debugger.

- If the app program is still under control of NightView, which was the case in a previous chapter, locate that NightView session, stop the process, and exit NightView.
- The run the applicagtion from a shell session: **./app**

Invoke NightProbe by selecting NightProbe Monitor from the Tools menu of any of the NightStar Tools currently running. You may also invoke NightProbe by using the NightProbe desktop icon or type the following command:

```
nprobe &
```

at a command prompt.

The NightProbe main window is displayed.

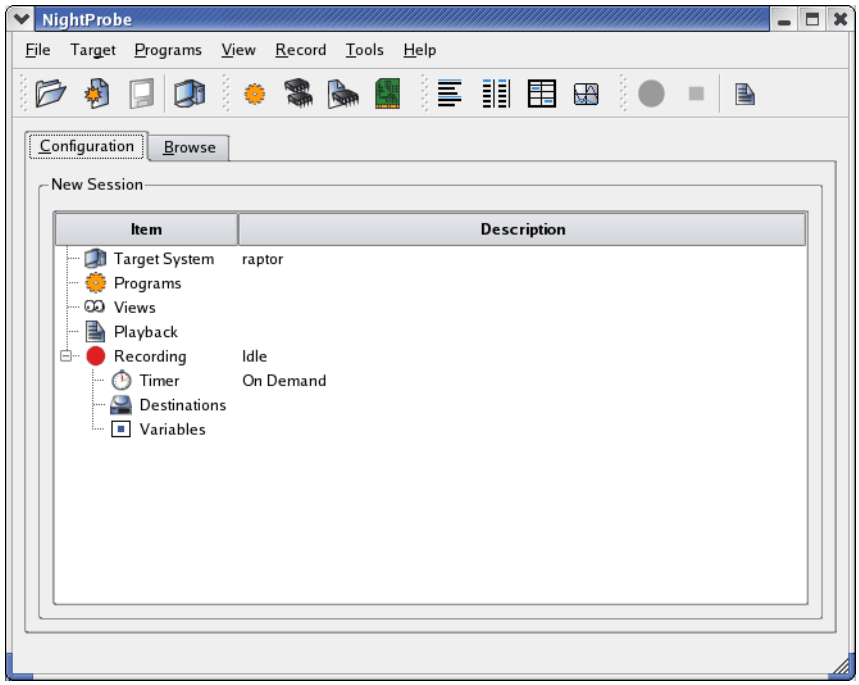


Figure 5-1. NightProbe Main Window

Selecting Processes

NightProbe has the ability to probe several kinds of resources, including programs, shared memory segments, memory mapped entities, and PCI devices.

- Right-click the Programs icon on the Configuration page and select the Program… menu option.

The Program Selection dialog is presented:

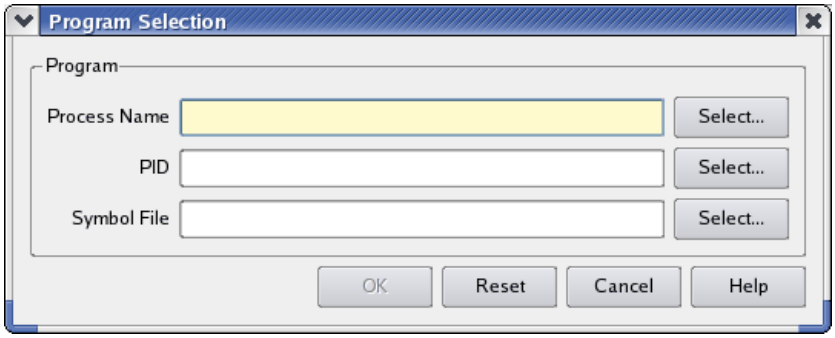


Figure 5-2. Program Selection Dialog

- Press the Select… button to the right of the PID field

The Process Selection dialog will appear.

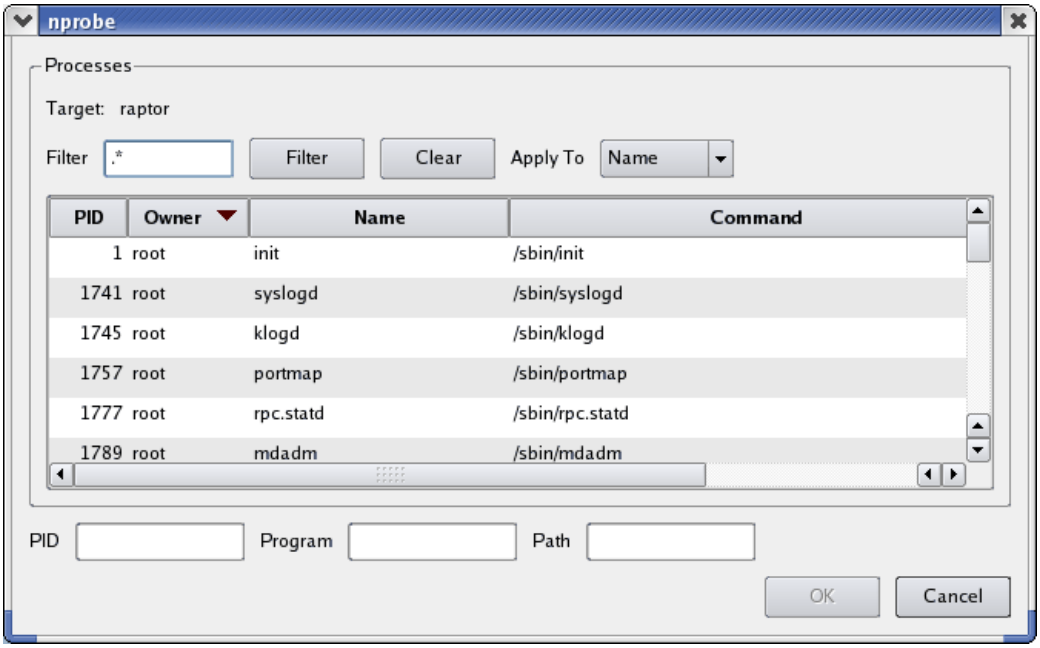


Figure 5-3. Process Selection Dialog

- Enter app in the Filter field and press the Enter key.

The list is filtered to only those process whose name includes **app** and an entry should be selected in the table.

- Ensure that a single item appears in the table and press Enter again to close the dialog. If multiple items appear in the table, double-click on the **app** process associated with your user name.

The process ID associated with the **app** program is placed in the PID text field and the Process Name and Symbol File text fields are updated accordingly.

- Press Enter to close the dialog.

The **app** program is added to the list of resources to be probed as is shown under the Programs item in the Configuration page.

Viewing Live Data

- Click on the Browse tab in the NightProbe main window.

The Live Browser is displayed.

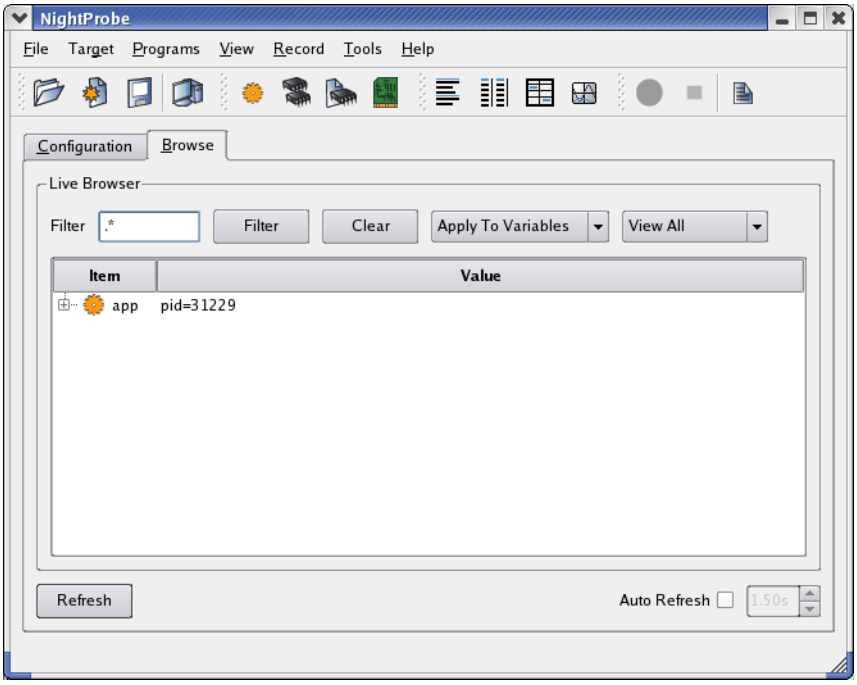


Figure 5-4. NightProbe Browse Panel

The Browse page serves two purposes. It allows you to browse your program to select variables of interest for recording or for viewing with alternative View panels.

It also provides you instant viewing of variables using the tree shown directly within the Browse page.

- Expand the **app** entry in the tree.

The items under a program's icon include all global variables as well as any nested scopes such as Ada packages, or functions that contain static data items.

Each variable item has an icon which indicates whether the variable is a scalar, a pointer, or a composite item such as an array or structure.

The `data` variable is a composite object and can be expanded.

- Expand the `data` variable.

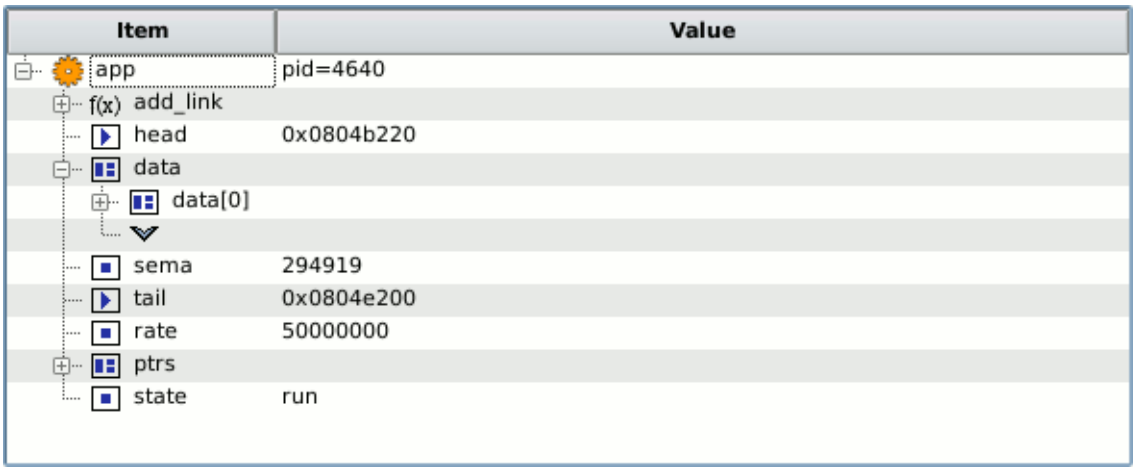


Figure 5-5. Expanded Data Item

The downward pointing arrow head is the array subscript expansion icon. By clicking the icon, an additional component of the array is shown.

- Click the array expansion icon so that `data[1]` is shown
- Expand both structures displayed, `data[0]` and `data[1]`.

In the Browse page, the current value of all variables shown in the tree is displayed whenever you press the Refresh button at the bottom of the page, whenever an automatic refresh occurs as controlled by the Auto refresh checkbox.

- Click the Auto Refresh checkbox.

This causes the display to automatically refresh at the rate shown in the spinbox to the right of the Auto Refresh checkbox.

Note the values of the count, angle, and value components of each component of the data array changing.

Modifying Variables

The app main program wakes each thread iteratively to do processing. The `state` variable controls whether this should occur or not.

Note that the current value of the state variable is the enumeration value `run`.

Double-click the value of the state variable.

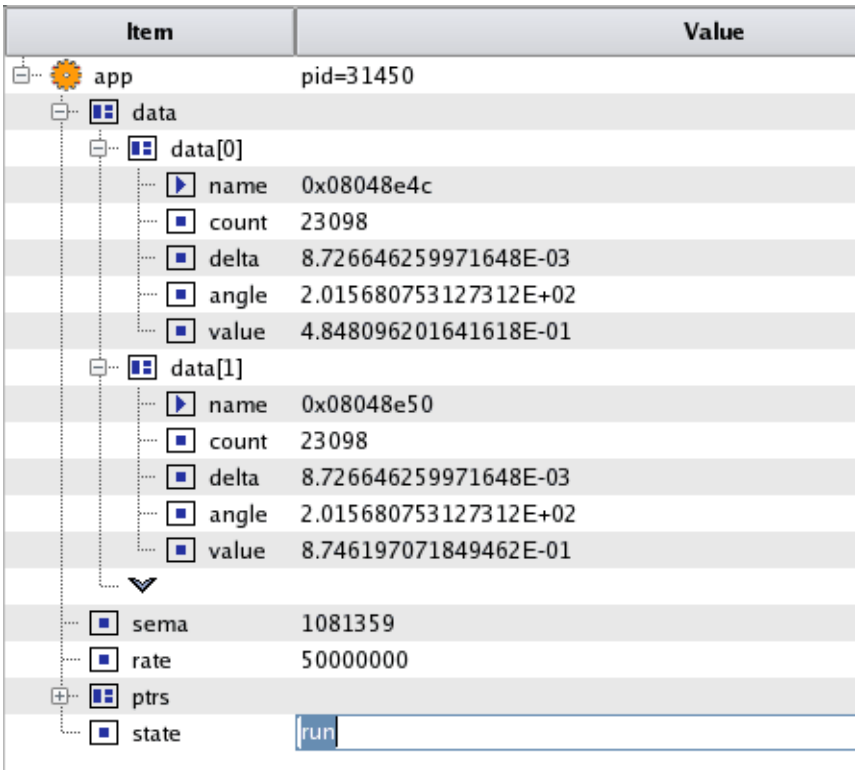


Figure 5-6. Variable Modification in Progress

The cell containing the value is frozen from updates and the current value is selected.

To change the value of a variable, all we need to do is supply a new value and commit the change to the program.

- Type the following in the cell:

  `hold`

- Press the Enter key to commit the value to the program.

The value of the state variable is now hold which prevents the program from waking the threads for computation, as shown in the source code snippet from **`app.c`**:

```
91      for (;;) {
92         struct timespec delay = { 0, rate };
93         nanosleep(&delay,NULL);
94         work(random() % 1000);
95         if (state != hold) semop(sema.&trigger,1);
96      }
```

- Change the value of the state variable back to `run` by double clicking the cell and then selecting `run` from the enumeration list and press Enter.

Selecting Variables for Recording and Alternative Viewing

Each variable has a Mark and a Record attribute. The Mark attribute, when set, indicates that the variable is of particular interest and may be viewed in other panels. The Record attributes specifies that the variable is to be included in recording sessions.

Double-clicking an item causes the color to turn a reddish color and sets its Mark and Record attributes. Alternatively, you can use an item's context menu to individually set its attributes.

- Double-click the `count`, `angle`, and `value` fields from both `data[0]` and `data[1]` structures.
- Double-click the `rate` variable.

The Browse page tree should look similar to the following:

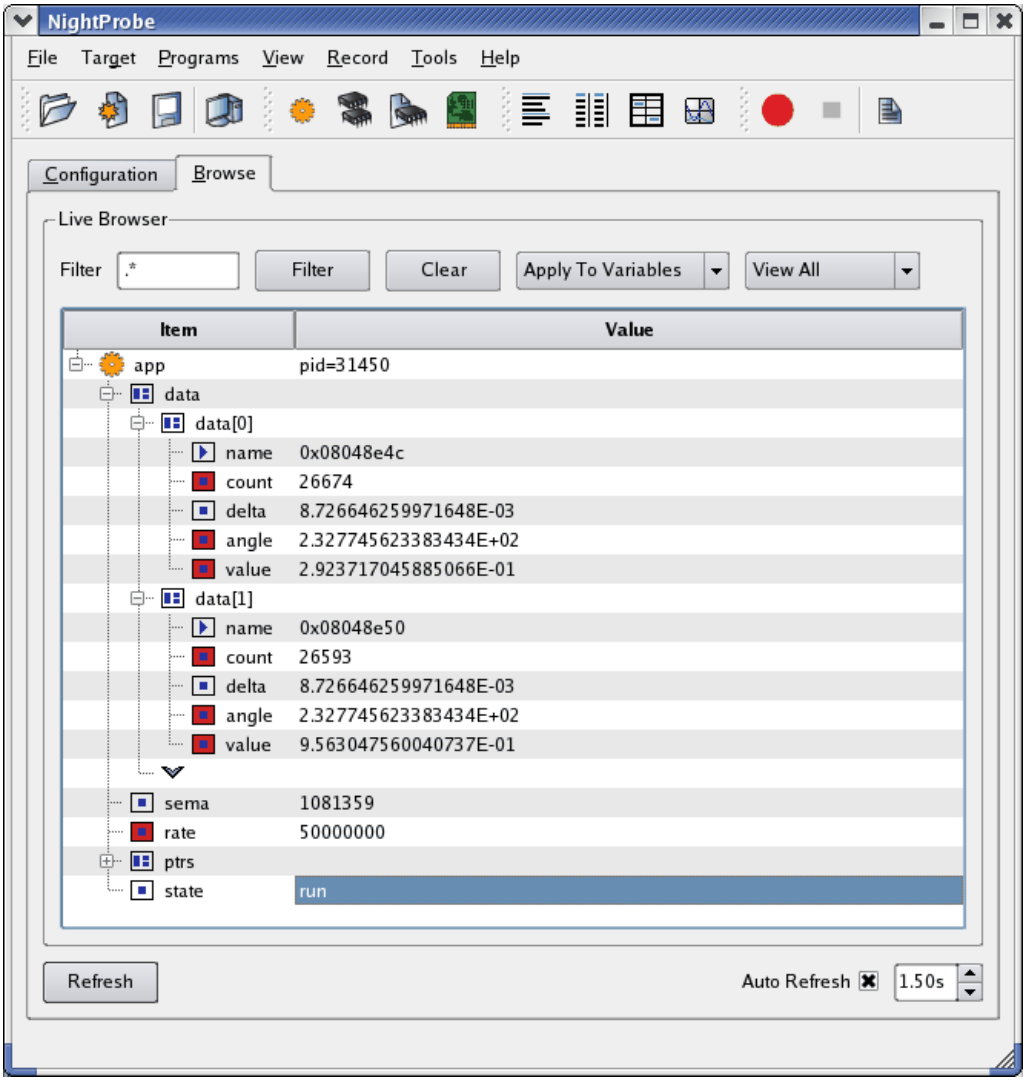


Figure 5-7. Mark and Record Attributes Set

Selection of Views

NightProbe provides various methods for viewing data:

- The Browse page
- List View
- Table View
- Spreadsheet View
- Graph View

Additionally, you can stream the output of a recording session to NightTrace or a user application for live analysis, or to a file for subsequent analysis within NightProbe.

Table View

A Table view provides a scrollable table with variables spread across the columns and rows containing the values of the variables, over time.

- Select the Table option from the View menu.

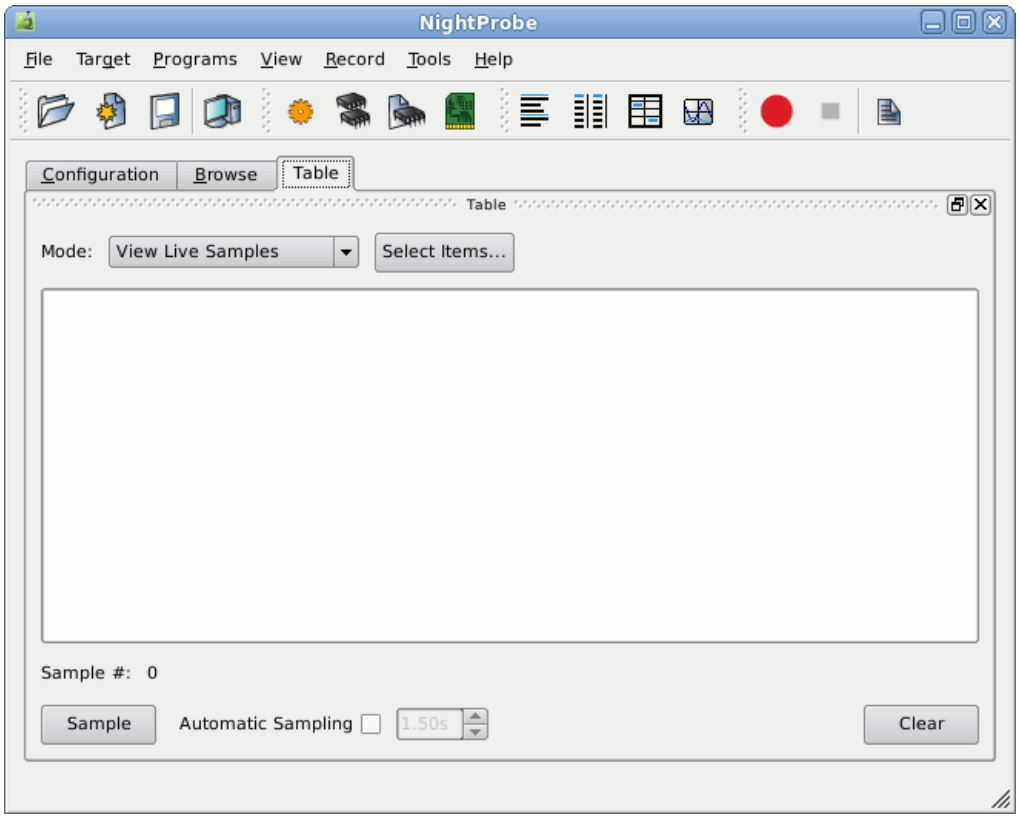


Figure 5-8. Table View

Initially, the table is empty. The first step is to select the items we wish to display in the table.

- Press the Select Items... button.

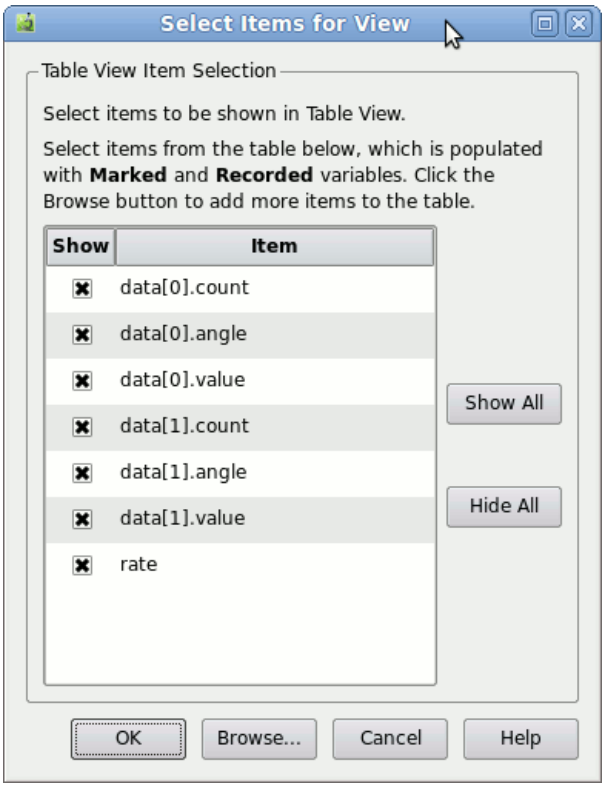


Figure 5-9. Item Selection Dialog

This dialog allows you to select items that have the Mark or Record attribute set.

By default, the dialog sets up defaults to display such variables.

- Hide all elements of the `data[1]` component by clicking their rows in the Hide column.
- Press the OK button.

The table now has five columns, one for the sample number and one for each of the variables we selected in the previous step.

- Check the Automatic Refresh checkbox

At the rate defined in the spinbox to the right of the Automatic Sampling checkbox, new samples are taken of the variables in the table.

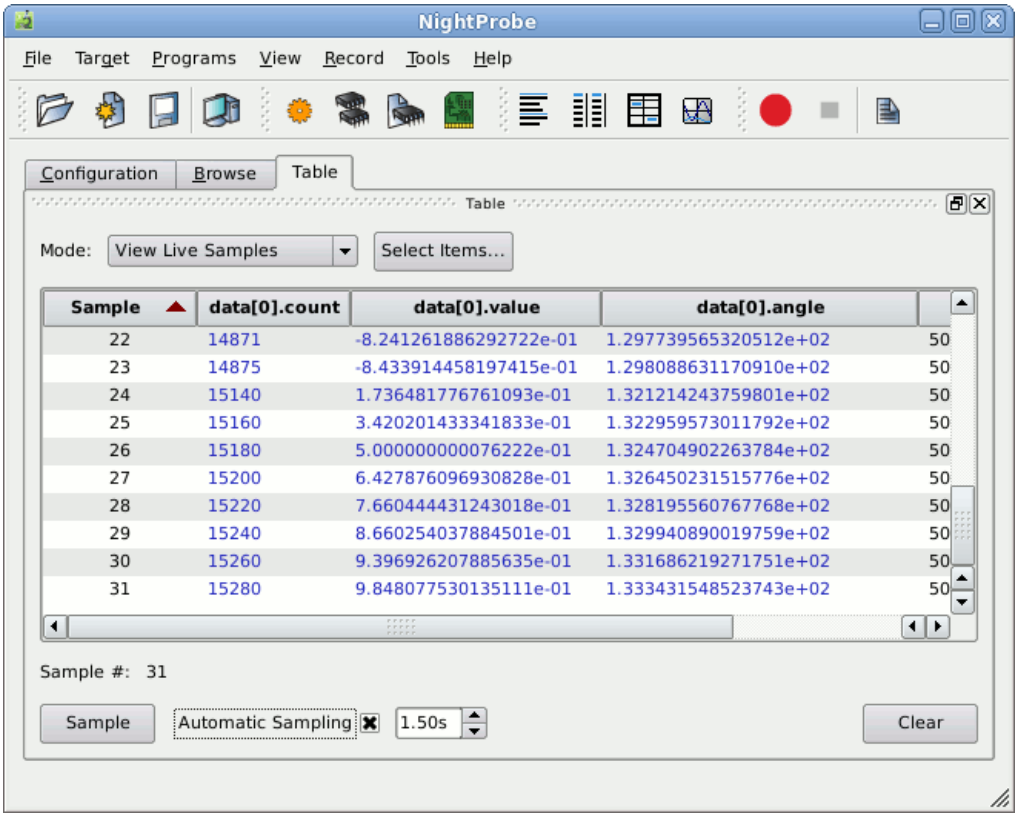


Figure 5-10. Table in Automatic Sampling Mode

Values are shown in blue if they have changed since the previous sample.

You can sort by variable value by clicking on a column header.

- Clear the Automatic Sampling checkbox
- Click on the column header for `data[0].value` and then click again so that the table is sorted from largest to smallest value.

The value shown at the top should be nearly 1.0 if enough samples have been taken (the value of data[0].value is that of a sine wave).

You can modify variables using the Table view in the same manner as described in “Modifying Variables” on page 5-5.

Graph View

The Graph panel presents individual variables as separate lines on a graph.

- Select the Add New Page option from the View menu.

- Select the Graph option from the View menu.

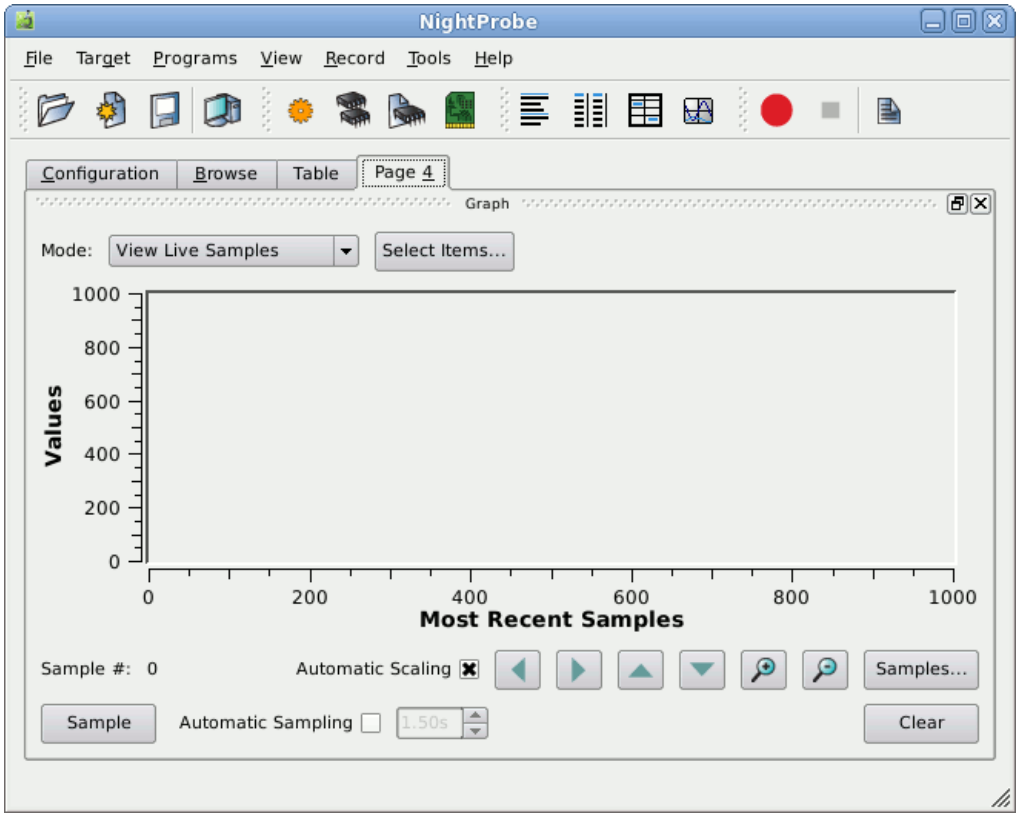


Figure 5-11. Graph Panel

Initially, the graph is empty.

- Press the Select items... button.

Unlike the table view, none of the items in the Select Item dialog are selected to be shown. Typically, only one or very few items are shown on a single graph.

- Mark the `data[0].value` and `data[1].value` items as Shown by clicking their respective rows in the Show column.
- Press the OK button.
- Check the Automatic Refresh checkbox.
- Change the refresh rate to 1.0 seconds in the spinbox to the right of the Automatic Sampling checkbox.

Two lines begin to be plotted as shown below.

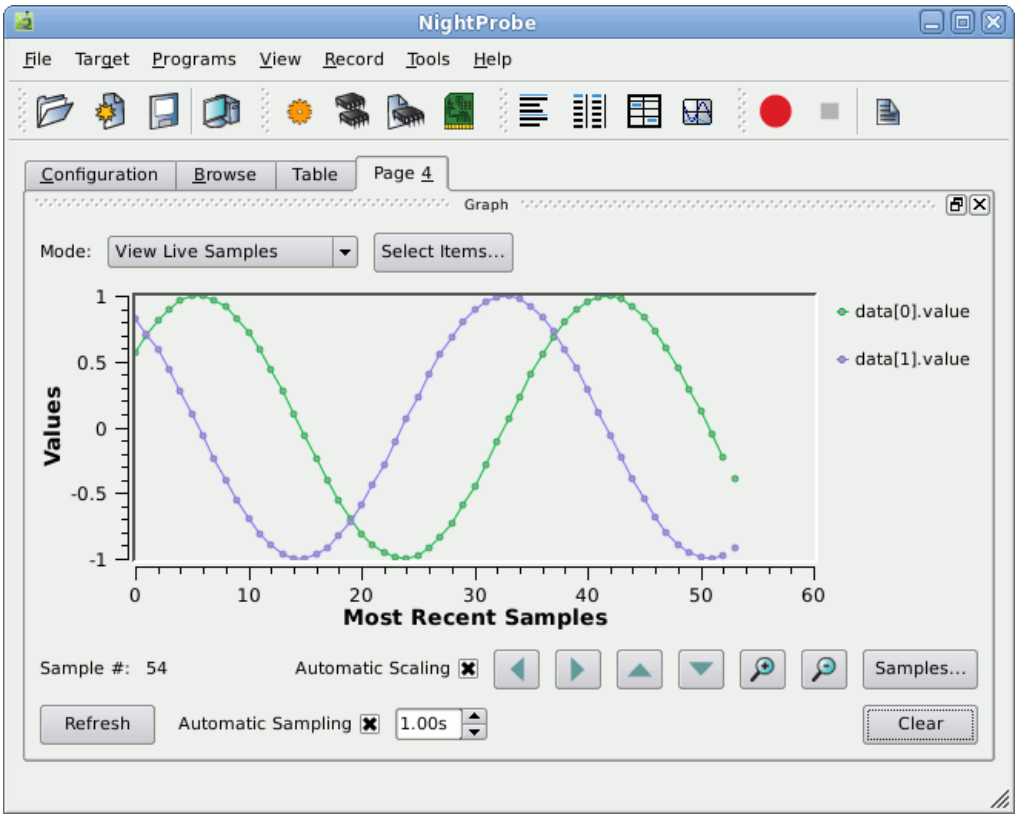


Figure 5-12. Graph Panel Actively Displaying Values

- Select the Edit… option from the context menu of one of the value items in the legend at the right-hand side of the graph panel (right-clicking activates the context menu).

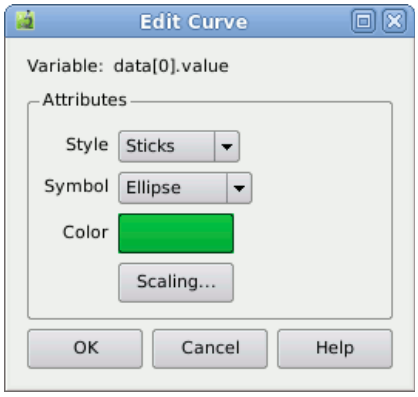


Figure 5-13. Edit Curve Attributes Dialog

- Select Sticks from the Style option list.

- Click on the colored block to activate a color selection dialog to change the color.
- Press the OK button to close the color selection dialog.
- Press the OK button to close the Edit Curve Attributes dialog.

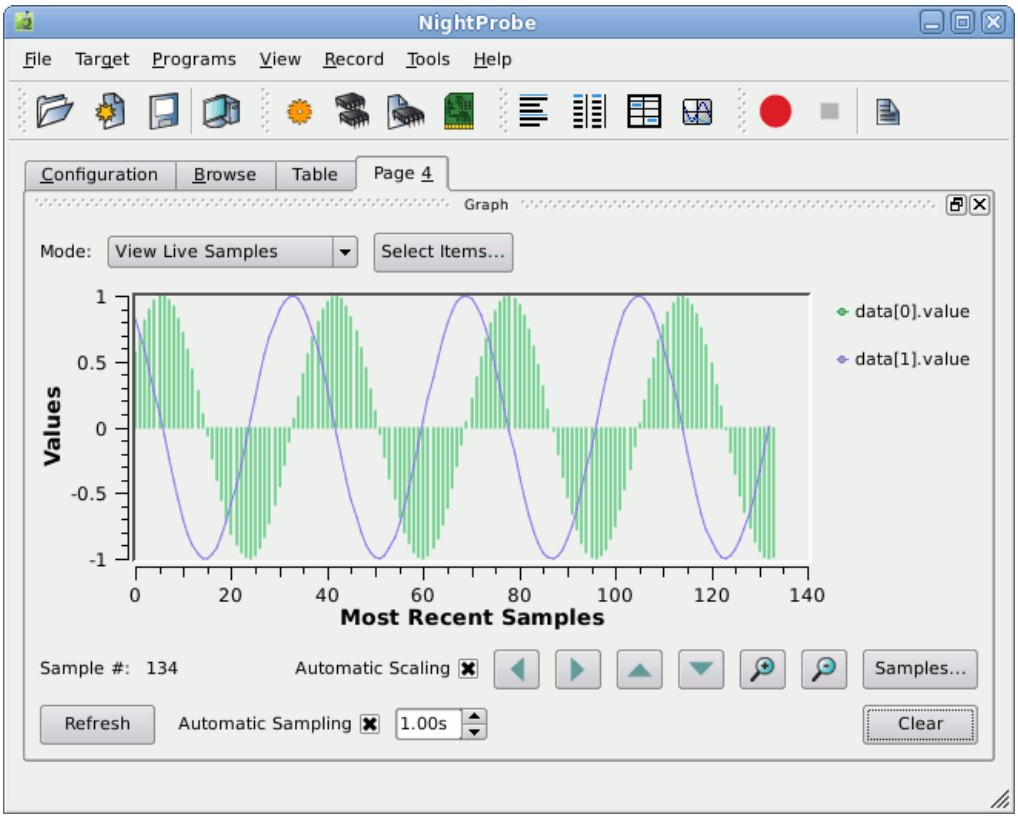


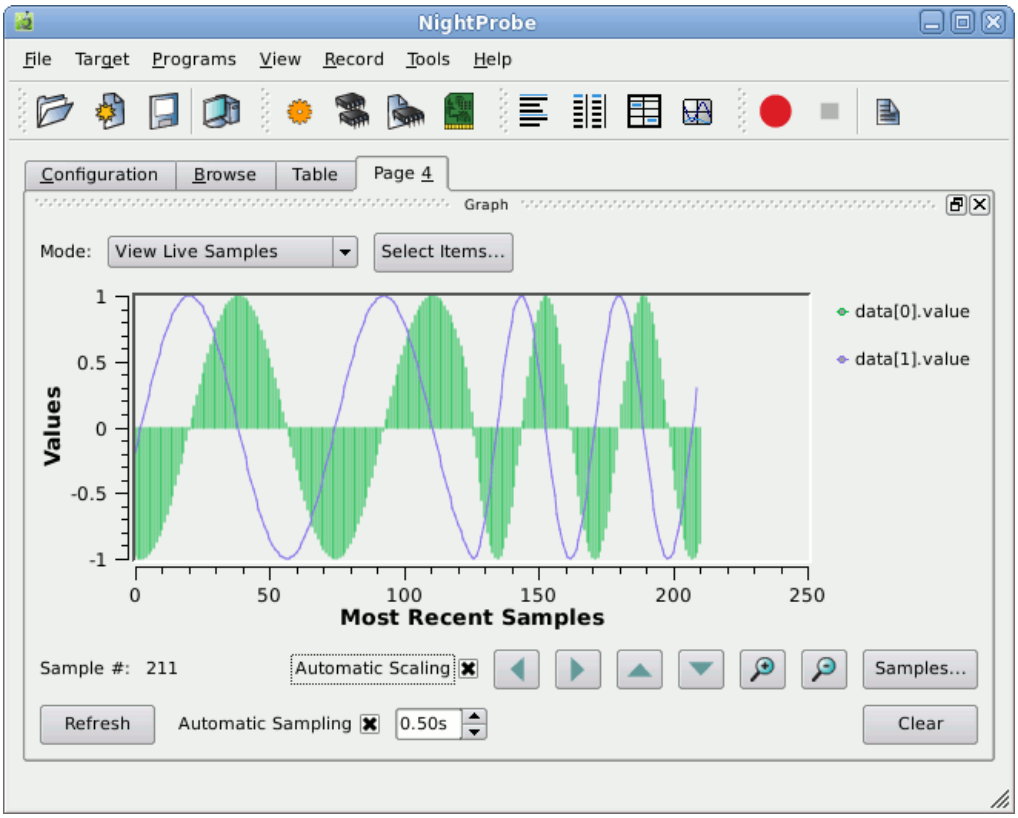
Figure 5-14. Graph Panel with Modified Curves

- Check the Automatic Scaling checkbox
- Change the refresh rate to 0.5 seconds

The program uses the rate variable to determine the frequency at which the threads are activated to do their calculations.

- Using the Browse page or the Table panel, change the value of the `rate` variable from `50000000` to `25000000`.

This change effectively doubles the frequency at which the threads operate, so the sine and cosine waves will change shape.



Sending Probed Data to Other Programs

Data values may be recorded to files for subsequent processing, or may be recorded and streamed to NightTrace for live processing.

Similarly, you can send recorded data to any process of choice.

- Raise the Configuration page by clicking on its tab.

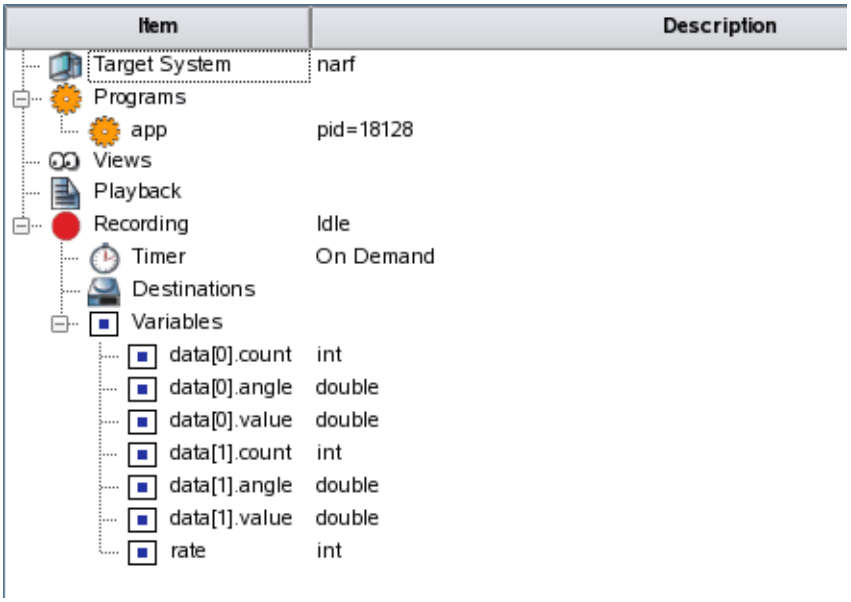


Figure 5-15. Recording area of Configuration Page

The Recording portion of the configuration tree indicates the Timing source for recording, the recording Destinations, and the list of variables whose Record attributes are set.

- Right-click on the Timer item in the Recording tree and select the Clock… option.

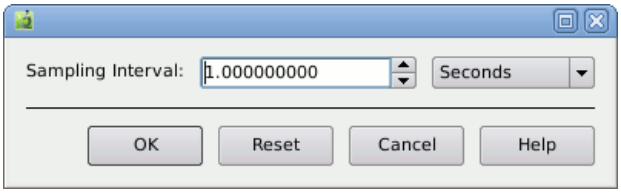


Figure 5-16. Clock Selection Dialog

This dialog controls the rate at which recording samples will be taken.

- Change the units to Milliseconds from the option list Sampling Interval option list.
- Change the Sampling Rate value to 100.0.
- Press the OK button.

The Timer item and description in the tree changes to reflect this activity.

The recording destination will be a user application.

- Right-click the Destinations item and select To Program…

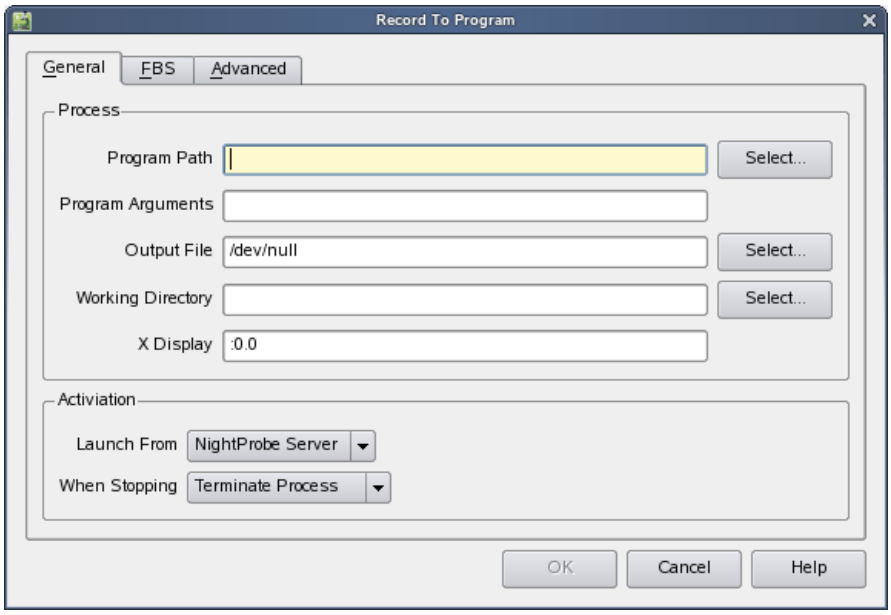


Figure 5-17. Record To Program Dialog

- Type **`api`** into the Program Path text field.
- Replace the **`/dev/null`** text in the Output File text field with the following.

  `/tmp/api.out`

- Press the OK button.

A simple application which uses the NightProbe API to consume and print the values of recorded samples was copied into the **`tutorial`** directory in “Creating a Tutorial Directory” on page 1-2.

- Type the following command in your terminal session to build the program:

  ```
  cc -g -o api api.c -lnprobe
  ```

The Recording area of the Configuration page should look similar to the following.

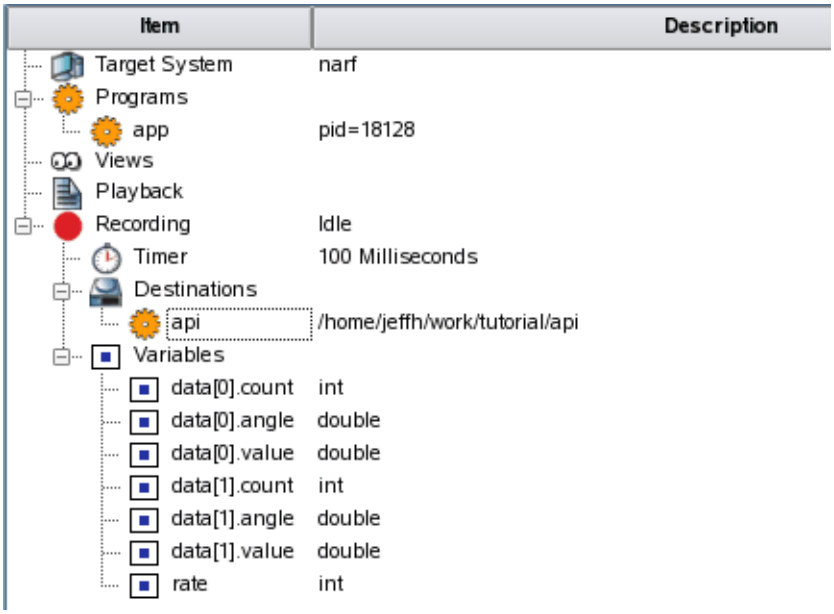


Figure 5-18. Recording Area of Configuration Page w/ Destination

Now that we have selected the variables to record, the recording timing source, and the recording destination, we can proceed to record samples and stream them to the **`api`** application.

- Press the Record icon on the toolbar:

- View the output of the api program as samples are recorded and passed to it.
- Enter the following command in a terminal session:

```
tail -f /tmp/api.out
```

The program will generate output similar to the following:

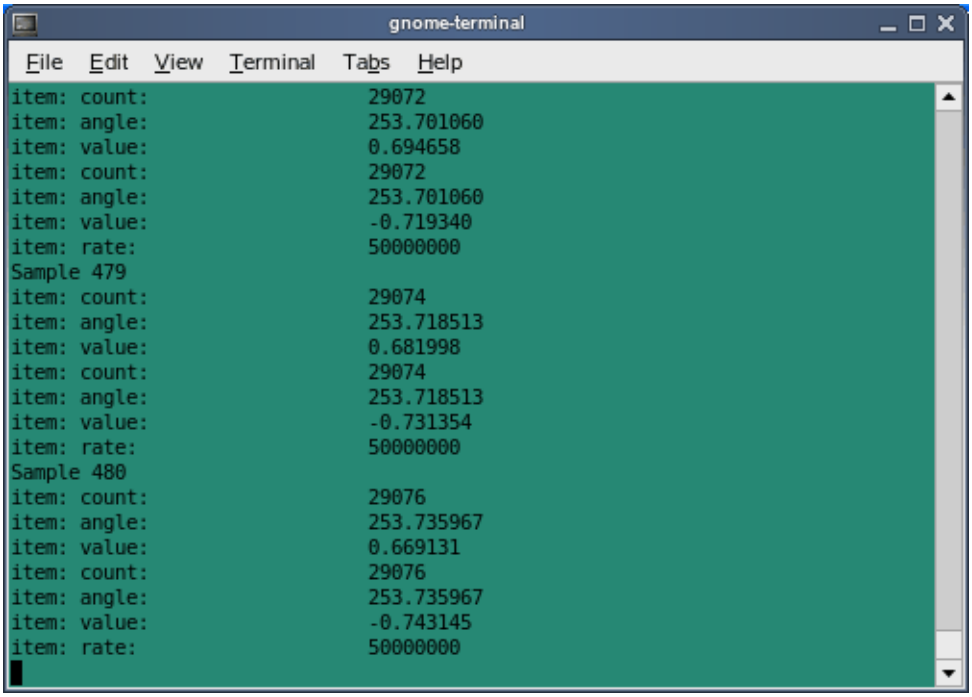


Figure 5-19. Example Output of Graph Program

- Stop the recording process by pressing the Stop icon on the Recording tool-bar:

For more information on the NightProbe API, refer to the “NightProbe API” chapter in the *NightProbe User’s Guide*.

Conclusion - NightProbe

To terminate NightProbe operations, execute the following steps:

- Select the Exit Immediately option from the File menu

This concludes the NightProbe portion of the NightStar LX Tutorial.

6
Using NightTune

NightTune is a graphical tool for analyzing and adjusting system activities.

This chapter assumes you have already built the **app** program and it is running. If you have not built the program, do so using the instructions in “Building the Program” on page 1-2 and execute the application before proceeding: **./app &**

Invoking NightTune

NightTune can be launched with the following command at a command prompt:

```
ntune &
```

Or it may be launched by double-clicking on the NightTune desktop icon.

For some aspects of this tutorial, it will be necessary to execute NightTune as the **root** user.

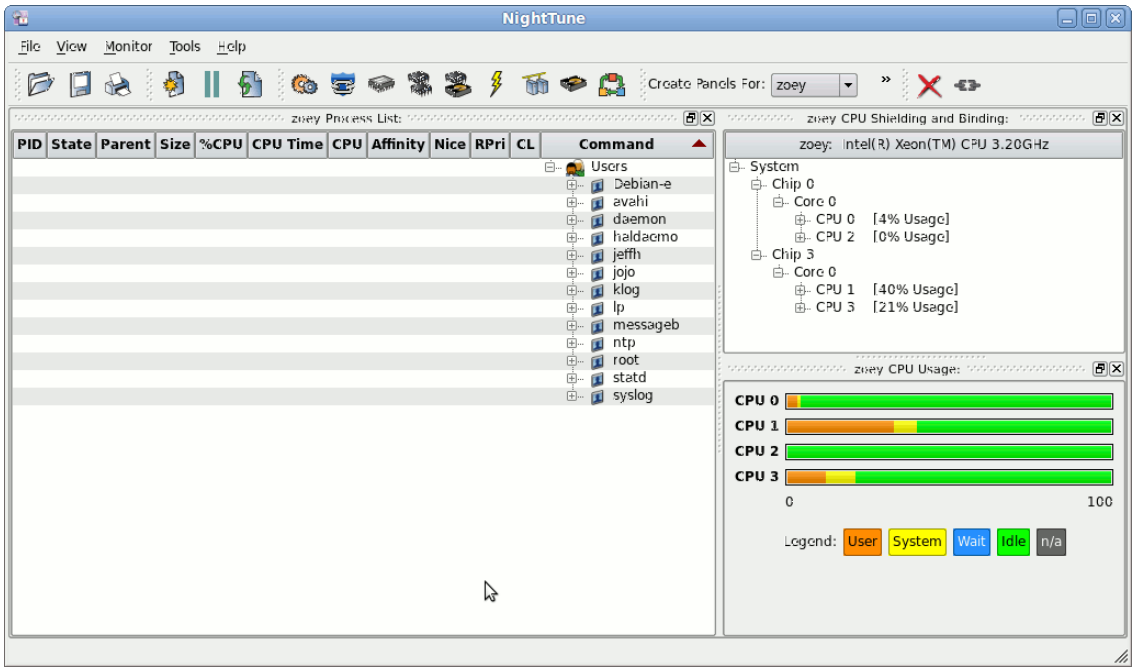


Figure 6-1. NightTune initial panels

Monitoring a Process

First monitor the running **app** process.

- In the Process List panel, click anywhere within the panel and the type Ctrl+F.
- A Find bar appears at the bottom of the panel. Type **app**, and the process list will be automatically expanded and the first process whose process name includes the word app will be selected.

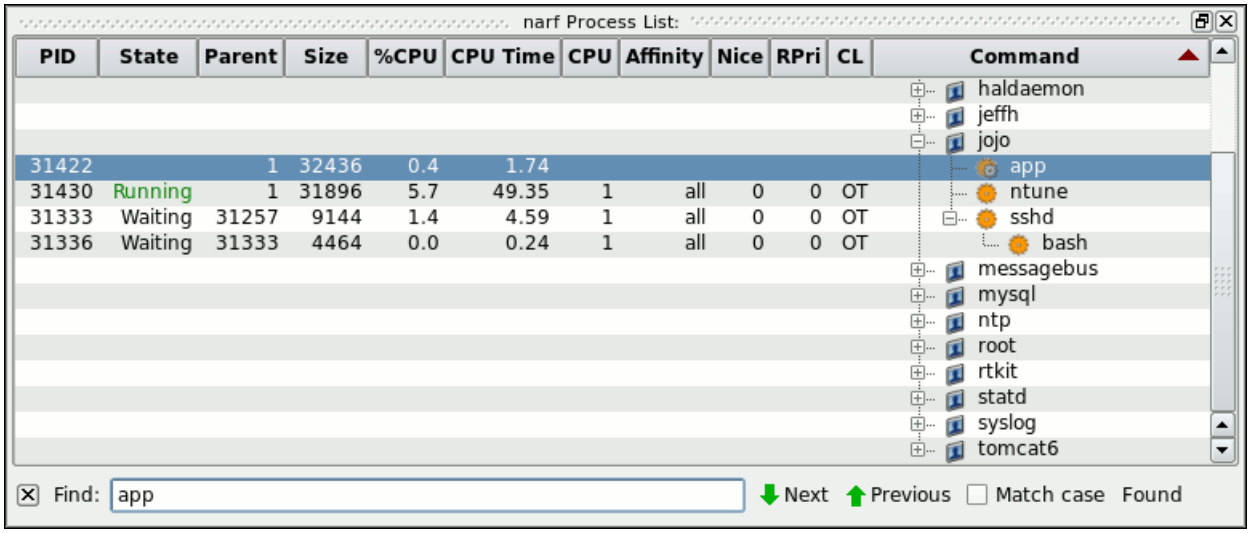


Figure 6-2. Expanded Process List

If the selected process is not our **app** process, press the Next icon in the Find bar until the correct process is selected.

Notice that the icon associated with the **app** process has a small gray gear superimposed on the orange process icon. This indicates that process is multi-threaded.

- Select the Show Threads option from the context menu associated with the **app** process.

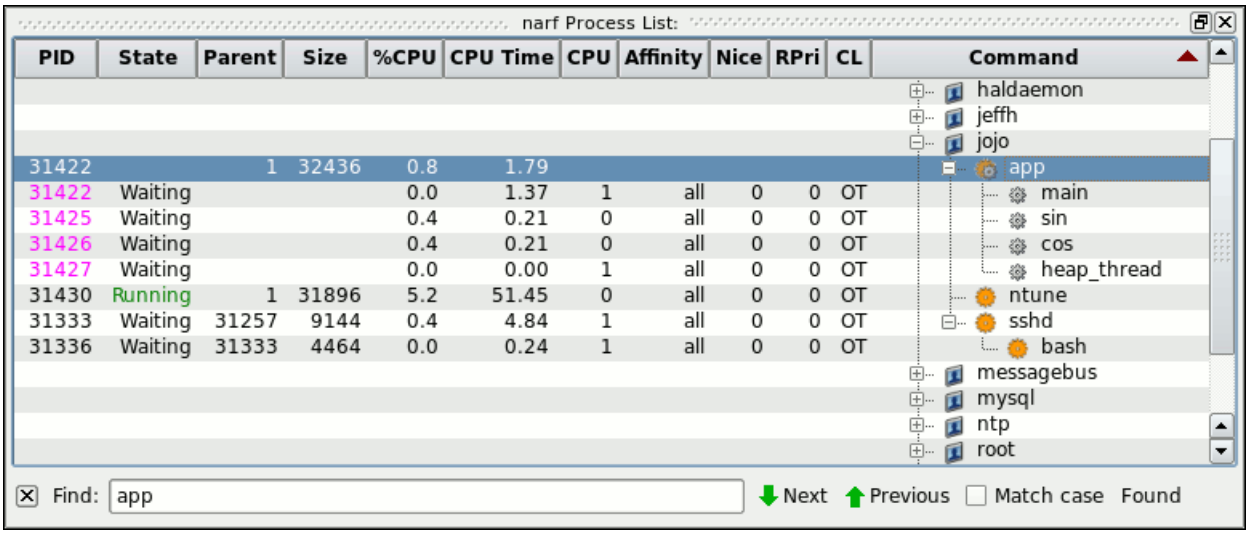


Figure 6-3. Process List with Threads

The panel shows characteristics of each thread and of the entire process. In particular, they include:

- the virtual memory size of the process
- the percentage and amount of CPU time used by each thread and by the whole process.
- CPU on which each thread ran most recently
- CPU affinity for each thread (the set of CPUs on which the thread is allowed to run)
- scheduling characteristics of each thread
- the thread name, if it is being debugged by NightView, or, if the application is using the NightTrace API and names its threads via a call to **`trace_set_thread_name(3x)`**.

The set of columns displayed can be modified by clicking the Display Fields option of the context menu for the panel, and then choosing individual fields by checking or unchecking their menu items.

Tracing System Calls

NightTune provides a handy interface for tracing system calls made by a process. This is essentially the same as using the strace(1) command, except that NightTune provides the output in a dialog which can be searched and controlled.

- Select the Trace System Calls... option from the context menu associated with the `sin` thread in the **`app`** program and press the run button.

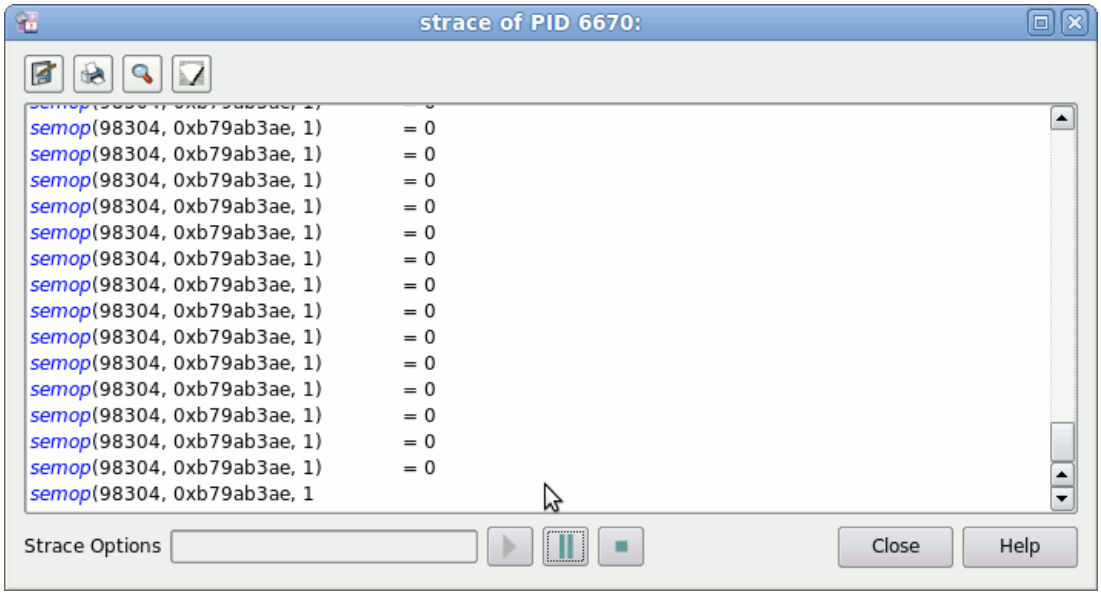


Figure 6-4. Strace Output of Thread

As shown in the figure above, the selected thread makes no system calls other than **`semop(2)`** which is associated with the line 46 of **`api.c`**, as shown in this code segment:

```
36 void *
37 sine_thread (void * ptr)
38 {
39    control_t * data = (control_t *)ptr;
40    struct sembuf wait = {0, -1, 0};
41    work(1);
42
43    trace_set_thread_name (data->name);
44
45    for (;;) {
46       semop(sema, &wait, 1);
47       data->count++;
48       data->angle += data->delta;
49       data->value = sin(data->angle);
50    }
51 }
```

- Press the Close button to stop the system call trace and close the dialog.

Process Details

NightTune provides detailed analysis of process attributes.

- Select the Process Details... option from the context menu of any thread in the **app** program.

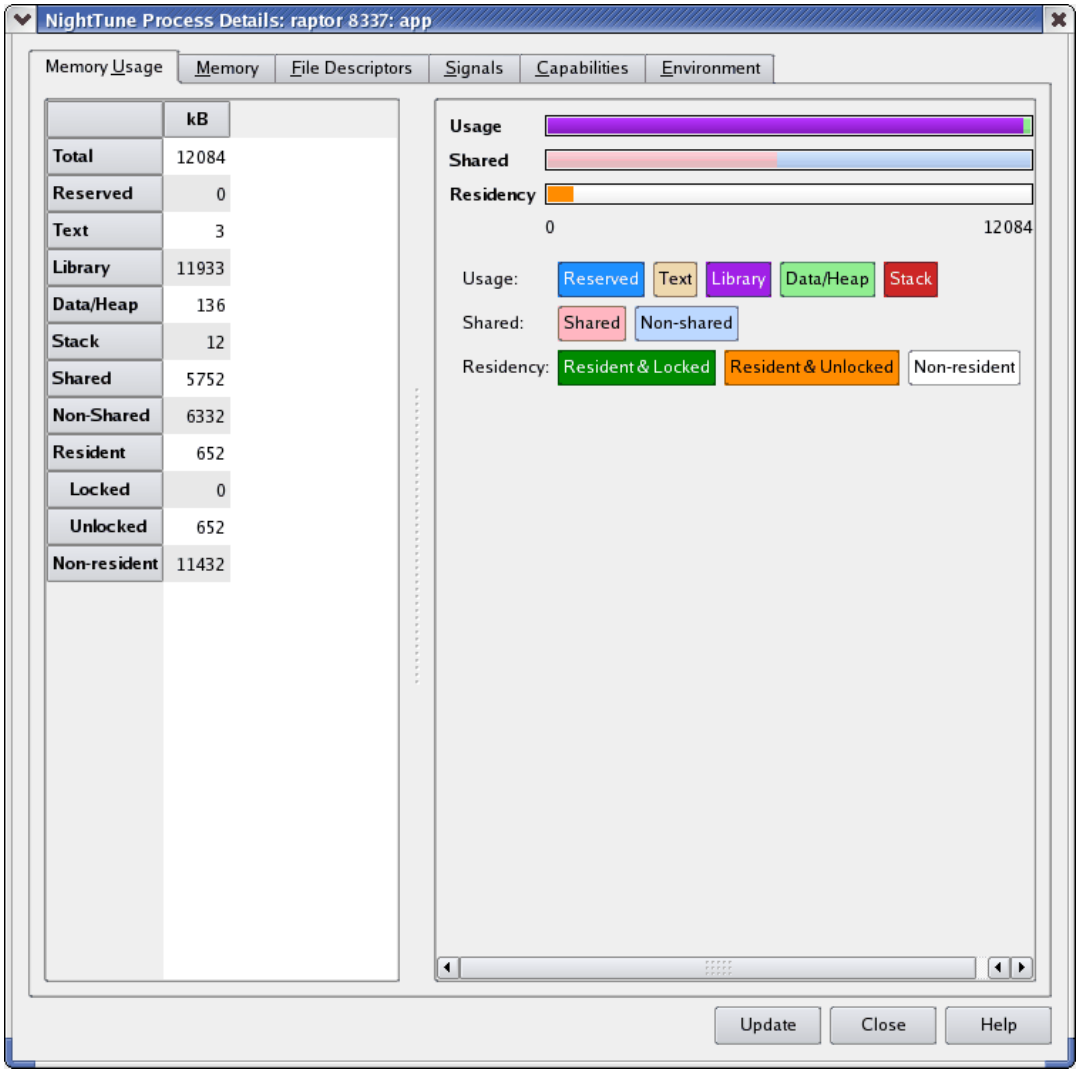


Figure 6-5. Process Details Dialog

All information displayed in this dialog is read-only in nature. You cannot make changes to process attributes using this dialog.

Seven tabbed pages provide detailed information about the process, including:

- Memory Usage
- Memory Maps (not shown)
- Memory details
- File Descriptors
- Signals

- Capabilities
- Environment

The Memory Usage page provides summary information of the virtual and resident usage of memory in both textual and graphical panes.

Process Details - Memory Details

- Click on the Memory tab to raise that page.

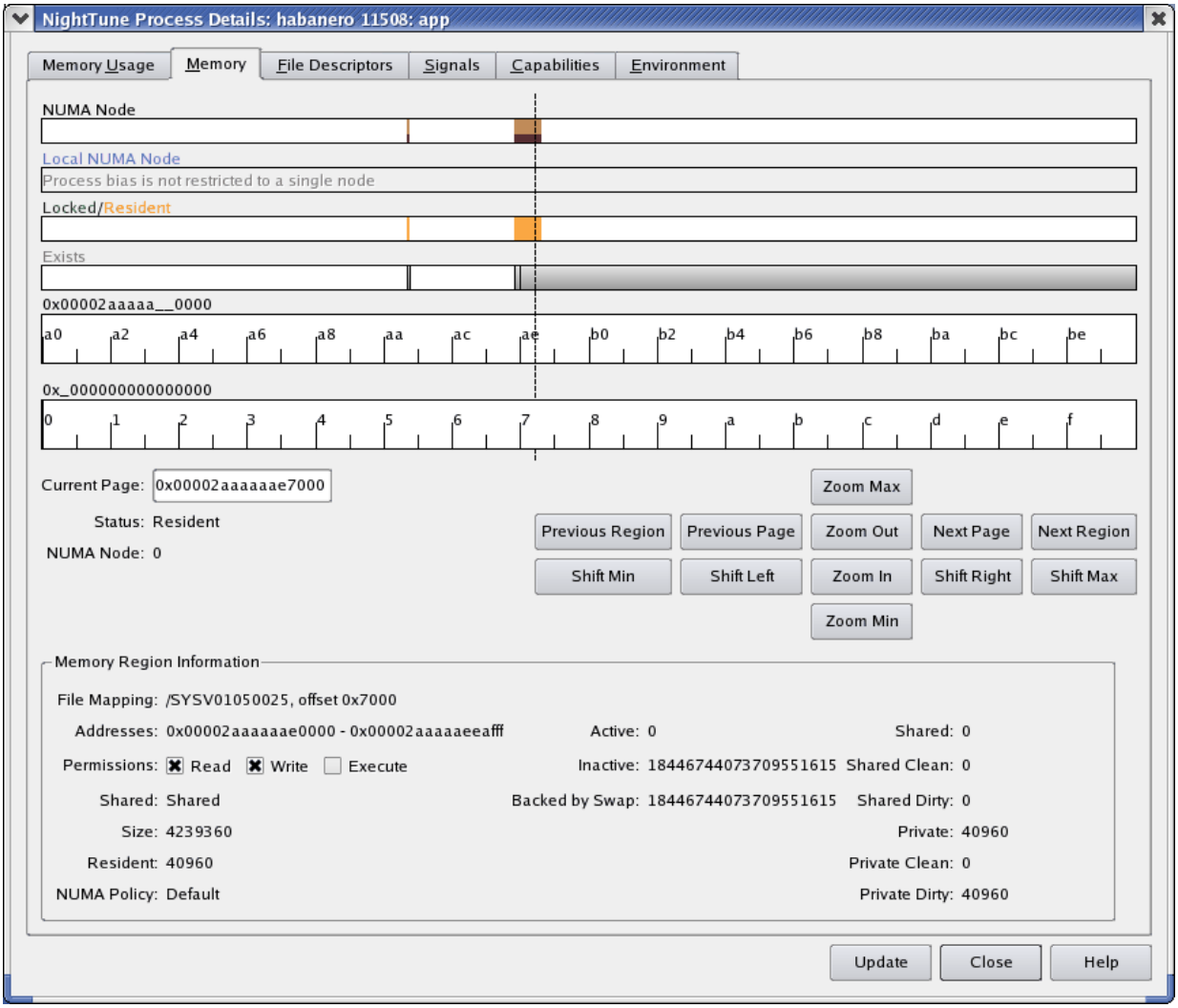


Figure 6-6. Process Memory Details Page

This dialog provides controls to allow you to get detailed memory information for any segment or page within the address space.

The controls in the graphical rows are similar to NightTrace in nature.

- Click anywhere on or above the rulers.
- Press Alt+UpArrow to zoom out completely.

The process's entire address space is now displayed. Each segment of the memory address space that is associated with pages in your process is indicated by at least a single vertical black line in the Exists row.

- Click on one of these lines
- Use the mouse wheel or the Zoom In button to zoom in until sufficient detail is available.

In the figure above, memory segments are shown as gray areas in the Exists row. The boundaries of memory segments are shown as vertical black lines. If the zoom factor is large enough, a memory segment may be portrayed as merely one or two vertical black lines.

Details about the memory segment are shown in the textual area in the bottom portion of the page.

The other rows show per-page information, including NUMA pools, and Locked and Resident attributes of the page.

NOTE

Locked and Resident information is not available in NightTune LX because the operating system support is not present in standard Linux.

Alternatively, you can select a specific address by typing it into the Current Page text field.

See the NightTune User's Guide for more information on the Memory page.

Process Details - File Descriptors

The File Descriptors page lists all open file descriptors associated with the process, and provides a description of each.

The figure below shows the file descriptors in use by an **ntune** process.

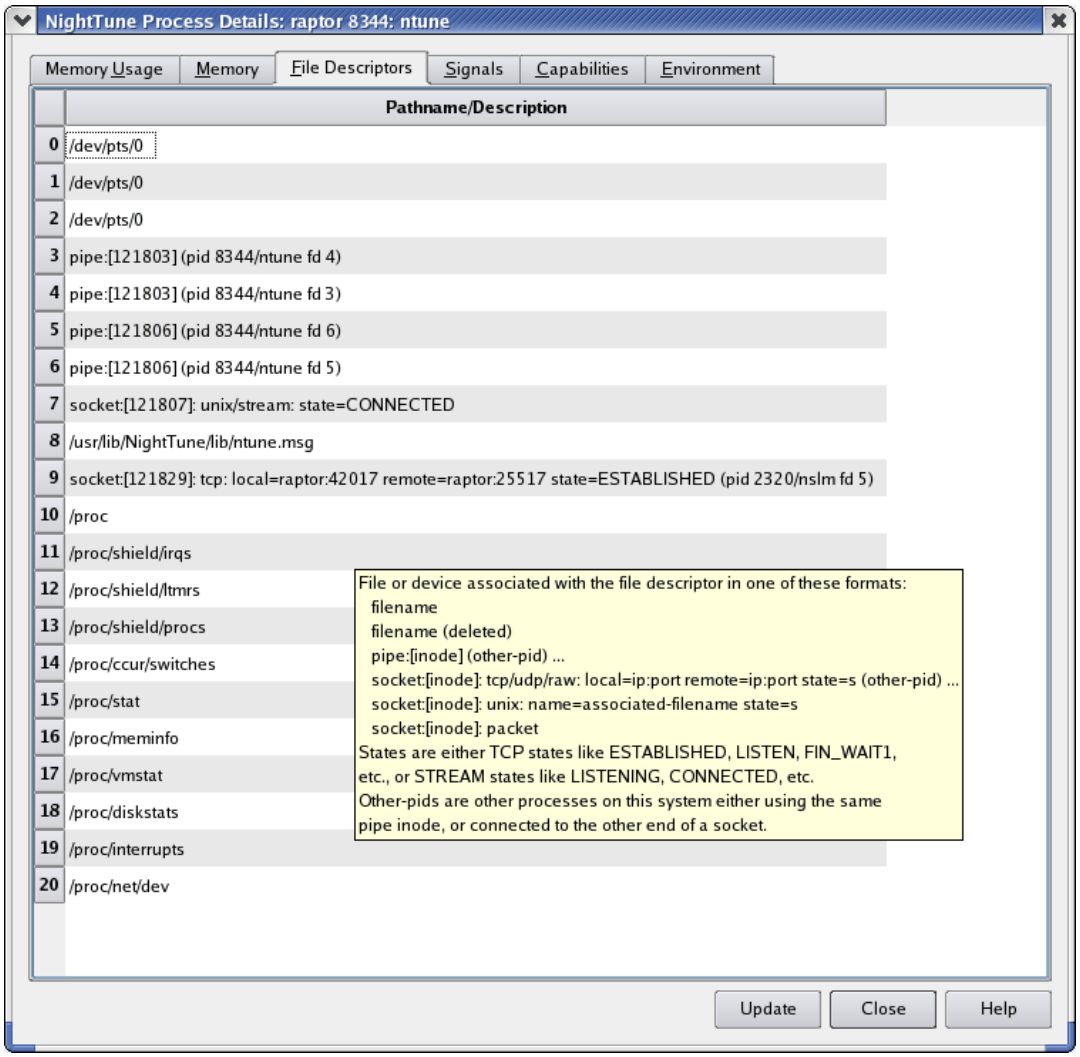
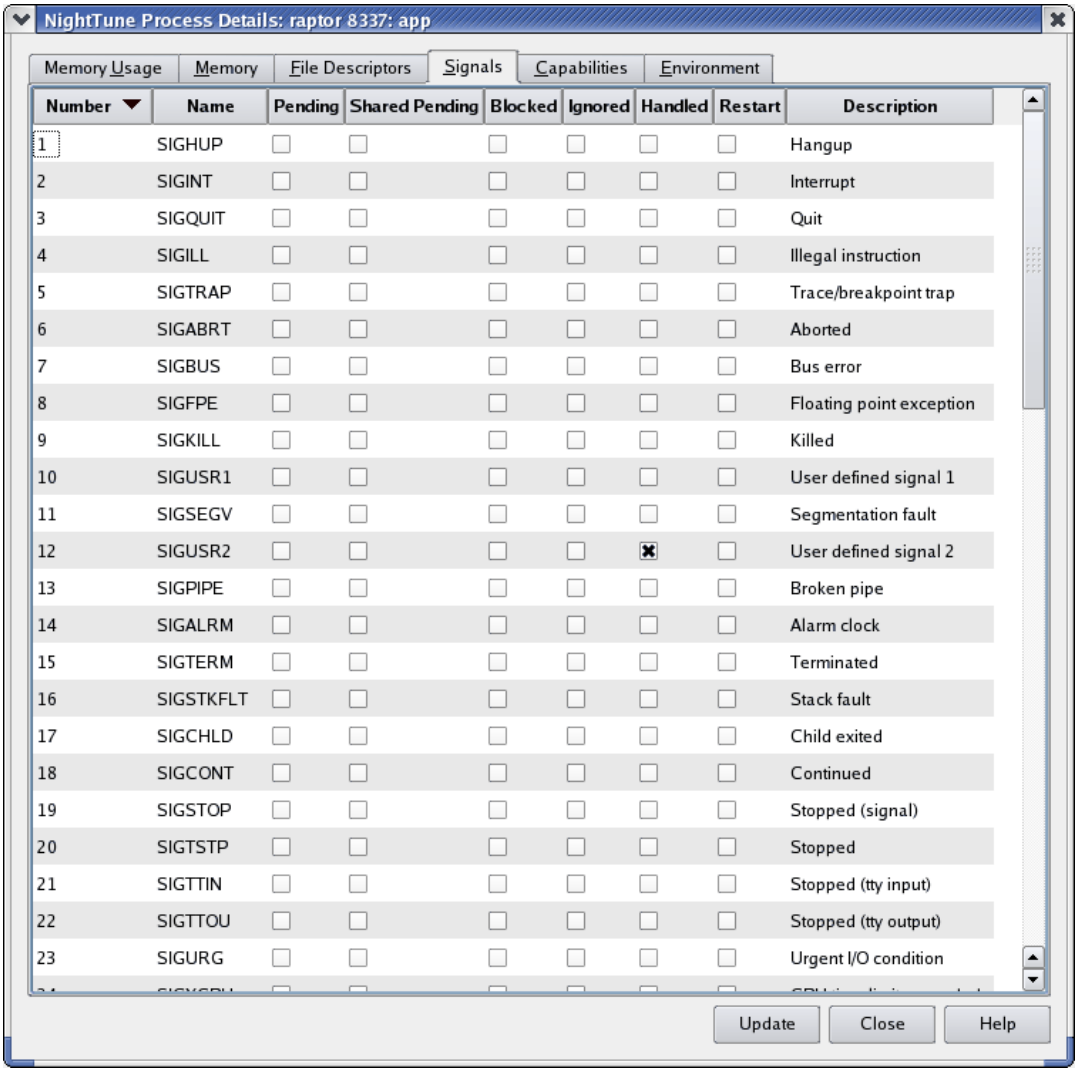


Figure 6-7. File Descriptors Page

The description includes the file name associated with a file descriptor (when relevant), connection information for a socket, and even identifies other processes using a pipe or socket when those processes are on the same system.

Process Details - Signals

The Signals table displays attributes of signals.



Number	Name	Pending	Shared Pending	Blocked	Ignored	Handled	Restart	Description
1	SIGHUP	☐	☐	☐	☐	☐	☐	Hangup
2	SIGINT	☐	☐	☐	☐	☐	☐	Interrupt
3	SIGQUIT	☐	☐	☐	☐	☐	☐	Quit
4	SIGILL	☐	☐	☐	☐	☐	☐	Illegal instruction
5	SIGTRAP	☐	☐	☐	☐	☐	☐	Trace/breakpoint trap
6	SIGABRT	☐	☐	☐	☐	☐	☐	Aborted
7	SIGBUS	☐	☐	☐	☐	☐	☐	Bus error
8	SIGFPE	☐	☐	☐	☐	☐	☐	Floating point exception
9	SIGKILL	☐	☐	☐	☐	☐	☐	Killed
10	SIGUSR1	☐	☐	☐	☐	☐	☐	User defined signal 1
11	SIGSEGV	☐	☐	☐	☐	☐	☐	Segmentation fault
12	SIGUSR2	☐	☐	☐	☐	☒	☐	User defined signal 2
13	SIGPIPE	☐	☐	☐	☐	☐	☐	Broken pipe
14	SIGALRM	☐	☐	☐	☐	☐	☐	Alarm clock
15	SIGTERM	☐	☐	☐	☐	☐	☐	Terminated
16	SIGSTKFLT	☐	☐	☐	☐	☐	☐	Stack fault
17	SIGCHLD	☐	☐	☐	☐	☐	☐	Child exited
18	SIGCONT	☐	☐	☐	☐	☐	☐	Continued
19	SIGSTOP	☐	☐	☐	☐	☐	☐	Stopped (signal)
20	SIGTSTP	☐	☐	☐	☐	☐	☐	Stopped
21	SIGTTIN	☐	☐	☐	☐	☐	☐	Stopped (tty input)
22	SIGTTOU	☐	☐	☐	☐	☐	☐	Stopped (tty output)
23	SIGURG	☐	☐	☐	☐	☐	☐	Urgent I/O condition

Figure 6-8. Signals Page

The information shown includes indicators of signals currently pending or blocked by the application, as well as whether the application has a handler installed for a signal.

In the figure above, the application has a handler registered for SIGUSR2.

Changing Process Scheduling Parameters

It may be desirable to change the scheduling properties of a thread or process while it is running to see how that changes the behavior of an application. For instance, perhaps one thread is being starved of CPU time by other threads. You may wish to change its scheduling class to a real-time class and/or its priority to a higher priority.

- Select the Process Scheduler... option of the context menu associated with the `sin` thread in the **`app`** process.

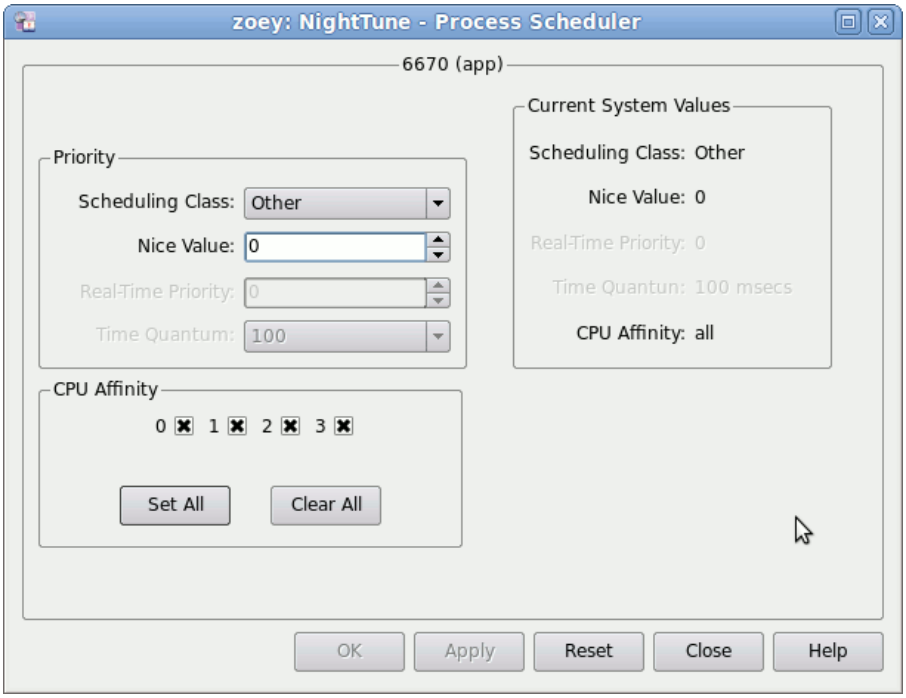


Figure 6-9. Process Scheduler Dialog

In this dialog, it is possible to change the Scheduling Class, Nice Value, Real-time Priority, and/or Time Quantum. On multi-processor systems, it also is possible to change the CPU Affinity. For each CPU on which the process or thread is allowed to run, the checkbox with the number of that CPU should be checked. See “Setting Process CPU Affinity” on page 6-11 for more on this topic.

- Change the Scheduling Class to Round Robin by selecting that from a drop down list.
- Change the Real-time Priority to 3.
- Press the OK button.

NOTE

To change the Scheduling Class to Round Robin and change the Real-time Priority, it is necessary that NightTune be run by the **`root`** user.

The Process List panel now reflects these changes to the thread.

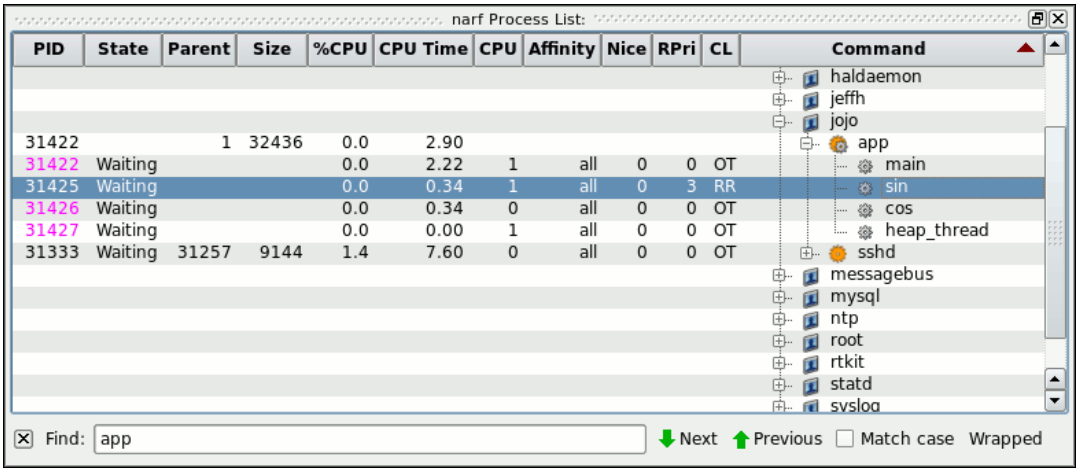


Figure 6-10. NightTune Process List with modified thread

For the modified thread, the CL (Scheduling Class) field displays the value RR (Round Robin), and the RPri (Real-time Priority) field displays the value 3.

Setting Process CPU Affinity

This section only is applicable if the system running NightTune is a multi-processor system. If not, skip to “Conclusion - NightTune” on page 6-17.

The CPU Shielding and Binding panel shows the CPU hierarchy, shielding status (on Concurrent RedHawk Linux only), CPU usage, and process and IRQ bindings.

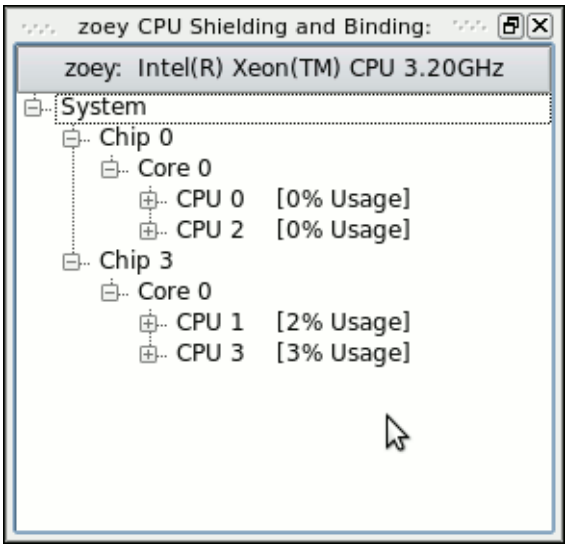


Figure 6-11. CPU Shielding and Binding Panel

The hierarchy is useful in visualizing the relationship of logical CPUs, especially in the presence of hyper-threaded and multi-core chips.

In the figure above, two chips each contain two local CPUs which are hyper-threaded siblings of each other. Hyper-threaded CPUs share some physical resources between them, yet operate in all user-visible ways as independent processors. Multi-core CPUs also share physical resources between their siblings, but much less so than with the hyper-threaded technology.

A process or thread has a CPU affinity, which determines the set of CPUs on which it may execute. It may even be restricted such that it may run on only a single CPU. Often this is called *binding* the process or thread. “Changing Process Scheduling Parameters” on page 6-10 described one way to change the CPU affinity. In addition, the CPU Status panel can be used to bind a process or thread quickly.

- Select Expand All from the context menu associated with the System item in the panel

The tree expands with leaves for bound processes and interrupts for each CPU.

- While the cursor is positioned over one of the threads in the **app** process, press and hold the *left* mouse button, then drag the thread to one of the CPUs in the CPU Shielding and Binding panel and release the mouse button.

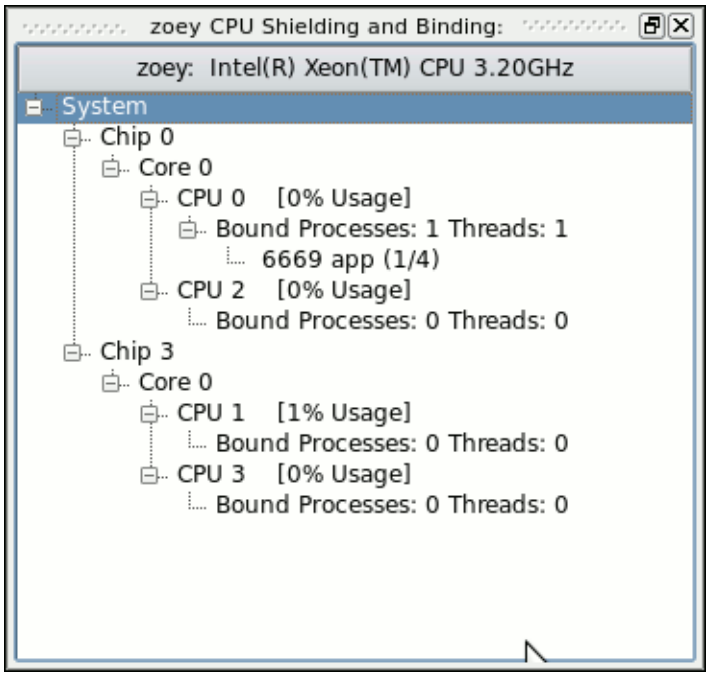


Figure 6-12. CPU Shielding and Binding Panel with Bound Thread

This action binds the selected thread to the particular CPU. That is, its CPU affinity is set to include only that single CPU. When a process' or thread's CPU affinity contains only a single CPU, that process or thread is listed in the CPU Status panel under the particular CPU's Processes tab. In this case, there is one entry under CPU 1. Because only one thread was bound to CPU 1 in this example, the entry includes the suffix (1/4), indicating that only 1 of the 4 threads is bound to that CPU.

The thread's new CPU affinity also is reflected in the Affinity field of the Process Monitor panel. That field displays a bit mask in hexadecimal, where the low order bit represents CPU 0, the next bit represents CPU 1, etc. In this case, the value 0x1 has only the lowest bit turned on, indicating CPU 0.

NightTune also can unbind a process quickly.

- While the cursor is over the thread entry in the CPU Status panel, press and hold the *left* mouse button, then drag the item to the Unbind icon at the upper right of the window (resembling a broken chain link) and release the mouse button.

The Process List panel will reflect that the thread is unbound once again.

Setting Interrupt CPU Affinity

The functionality described in this section only is available if NightTune was executed by the **`root`** user. If this is not the case, skip to “Conclusion - NightTune” on page 6-17.

In addition to being able to set the CPU affinity of a process, NightTune can control the CPU affinity of an interrupt.

It may be desirable to change the CPU affinity of an interrupt. For instance, an interrupt may be occurring frequently and, depending on the CPU which handles it, may be interfering with an application running on that same CPU.

- Close the Process List panel by clicking on the right-hand most box in its title bar.
- In its place, open the Interrupt Activity panel by selecting the Interrupt Activity option from the Monitor menu and then the Text Pane option from its sub-menu.

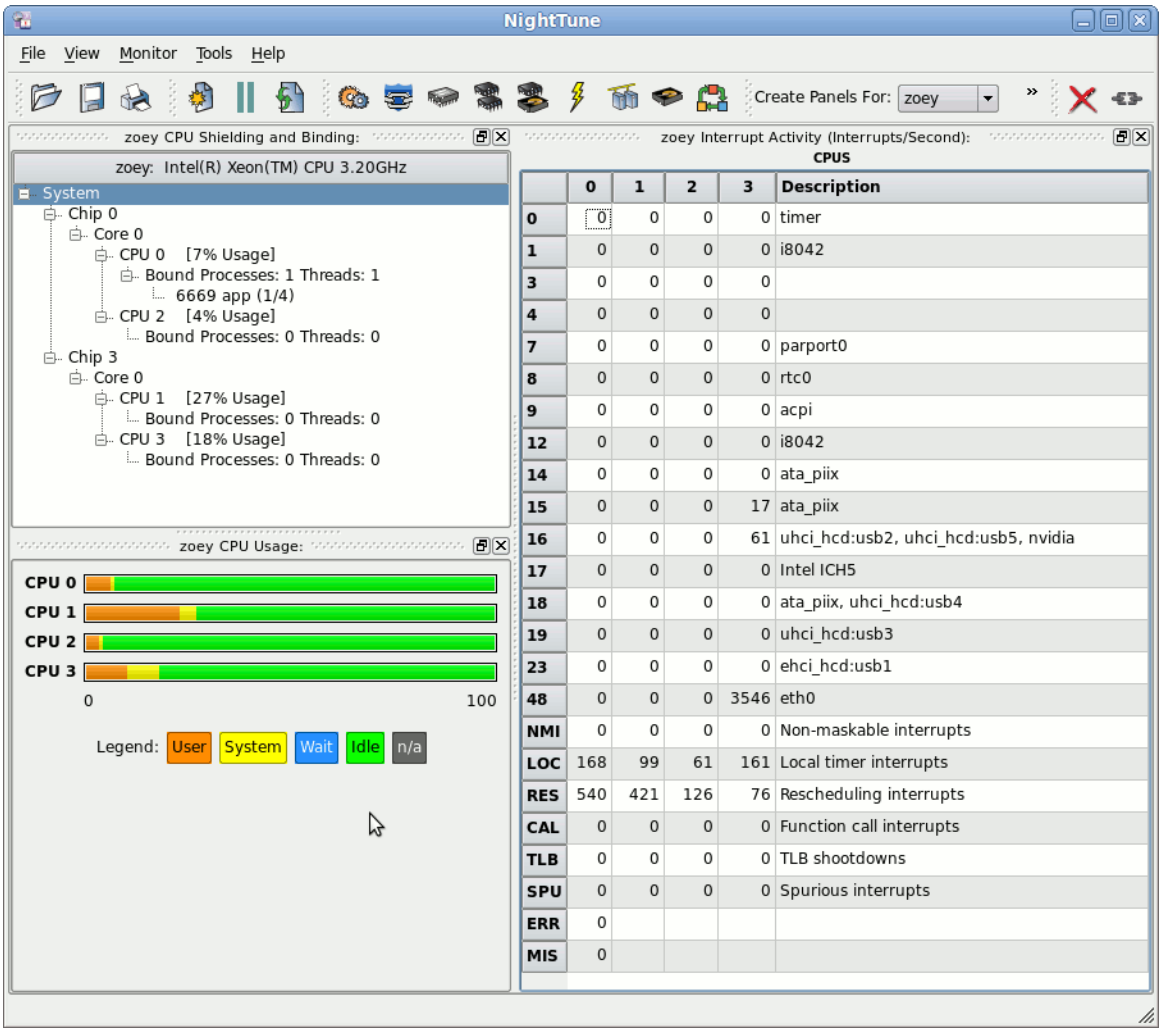


Figure 6-13. NightTune with Interrupt Activity Panel

The panel shows the number of interrupts per second for each interrupt as handled on each CPU (if on a multi-processor system).

The chain link icon in the Interrupt Activity panel indicates that an interrupt may be handled by that particular CPU. However, if an interrupt may be handled by all CPUs, then no icon appears for that interrupt. The same information is displayed in the Bound Interrupts items for each CPU in the CPU Shielding and Binding panel.

Some systems may employ IRQ balancing which automatically changes IRQ affinities over time. This interferes with attempts to control interrupt affinity manually. For purposes of this tutorial, ensure that IRQ balancing is currently disabled by executing the following command as the root user:

```
For SUSE:
    /sbin/service irq_balancer stop 2>/dev/null
For other Linux distributions:
    /sbin/service irqbalance stop 2> /dev/null
```

To bind an interrupt to a single CPU, it may be dragged in much the same way as a process.

While the cursor is over an interrupt in the Interrupt Activity panel, you may press and hold the *left* mouse button, then drag the interrupt to the particular CPU in the CPU Shielding and Binding panel. Similarly, while the cursor is over an interrupt in the Bound Interrupts list of a CPU in the CPU Shielding and Binding panel, you may press and hold the middle mouse button, then drag the interrupt to a different CPU in the CPU Shielding and Binding panel.

To change an interrupt's affinity to allow multiple CPUs, but possibly exclude one or more, select the Set CPU Affinity... option from the context menu of any interrupt row in the panel.

NOTE

If you are not running as the root user or your user lacks appropriate privileges, the Set CPU Affinity... option will not be present in the context menu.

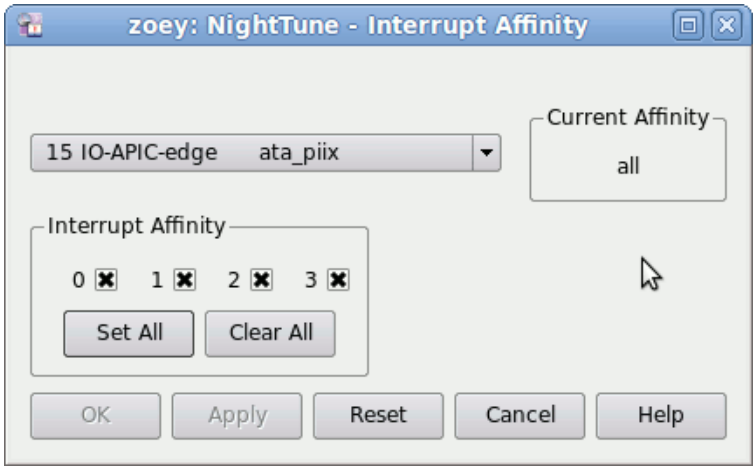


Figure 6-14. Interrupt Affinity Dialog

For each CPU on which the interrupt is allowed to be handled, the checkbox with the number of that CPU should be checked. The changes take effect when the OK or Apply button is pressed.

NOTE

For certain interrupts, such as NMI, it is impossible to control their CPU affinity.

Conclusion - NightTune

The remaining portion of the tutorial is unrelated to the execution of the **app** program. Terminate the program by executing the following steps:

- Drag the **app** process from the Process List panel using the left mouse button to the Kill icon on the toolbar and release.

- Terminate NightTune by selecting Exit from the File menu.

This concludes the NightTune portion of the NightStar LX Tutorial.

A
Tutorial Files

The following sections show the source listings for the files used in the *NightStar LX Tutorial*.

- **api.c**
- **app.c**
- **function.c**
- **report.c**

api.c

```
#include <stdio.h>
#include <unistd.h>
#include <stdlib.h>
#include <fcntl.h>
#include <errno.h>
#include <string.h>
#include <nprobe.h>



int cycles = 0;
int overruns = 0;
char * sample;


// Perform the work of consuming a single Data Recording
sample from NightProbe.
//
int
work (FILE * ofile, np_handle h, np_header * hdr) {
   np_item * i;
   int status;
   int which;

   // Read one sample, which may contain data for multiple
processes
   // and variables.
   //
   status = np_read (h, sample);
   if (status <= 0) {
      return status;
   }

   cycles++;

   fprintf (ofile, "Sample %d\n", cycles);
   for (i = hdr->items; i; i = i->link) {
      char buffer [1024];
      sprintf (buffer, "item: %s:", i->name);
      fprintf (ofile, "%-30s", buffer); // Nice formatting :-
)

      // Display the value of each item.
      // For arrays, format each individual item.
      //
      for (which = 1; which <= i->count; ++which) {
         char * image = np_format (h, i, sample, which);

         if (image != NULL) {
            fprintf (ofile, " %s", image);
```

```
         } else {
            fprintf (ofile, "\n<error: %s>\n", np_error (h));
            return -1;
         }

         free (image);
      }
      fprintf (ofile, "\n");
   }
   fflush (ofile);

   return 1;
}




int
main (int argc, char *argv[])
{
   np_handle h;
   np_header hdr;
   np_process * p;
   np_item * i;
   int fd;
   int status;
   FILE * ofile = stdout;


   fd = 0; // stdin

   status = np_open (fd, &hdr, &h);
   if (status) {
      fprintf (stderr, "%s\n", np_error (h));
      exit(1);
   }

   sample = (char *) malloc(hdr.sample_size);
   if (sample == NULL) {
      fprintf (stderr, "insufficient memory to allocate
sample buffer\n");
      exit(1);
   }

   for (p = hdr.processes; p; p = p->link) {
      if (p->pid >= 0) {
         fprintf (ofile, "process: %s (%d)\n", p->name, p-
>pid);
      } else {
         fprintf (ofile, "resource: %s (%s)\n", p->name, p-
>label);
      }
   }
   fprintf (ofile, "\n");
```

```
   for (i = hdr.items; i; i = i->link) {
      fprintf (ofile, "item: %s (%s), size=%d bits, count=%d,
type=%d\n",
             i->name, i->process->name, i->bit_size, i-
>count, i->type);
   }
   fprintf (ofile, "\n");

   for (;;) {
      status = work (ofile, h, &hdr);
      if (status <= 0) break;
   }

   fprintf (ofile, "Data Recording done: %d cycles fired, %d
overruns\n",
            cycles, overruns);

   if (ofile != stdout) {
      fclose (ofile);
   }

   if (status < 0) {
      fprintf (stderr, "%s\n", np_error (h));
   }

   np_close (h);

   // At this point, file descriptor 0 remains open, but is
no
   // longer a NightProbe Data File/Stream.
}
```

app.c

```
#include <stdlib.h>
#include <string.h>
#include <time.h>
#include <unistd.h>
#include <pthread.h>
#include <errno.h>
#include <ntrace.h>
#include <math.h>
#include <sys/ipc.h>
#include <sys/sem.h>

static void * heap_thread (void * ptr);
extern void work (int control);

typedef struct {
   char * name;
   int    count;
   double delta;
   double angle;
   double value;
} control_t;

control_t data[2] = { { "sin", 0, M_PI/360.0, 0.0, 0.0 },
                      { "cos", 0, M_PI/360.0, 0.0, 0.0 } };
enum { run, hold } state;
int rate = 50000000;
int sema;

extern double
FunctionCall(void)
{
   return data[0].value + data[1].value;
}

void *
sine_thread (void * ptr)
{
   control_t * data = (control_t *)ptr;
   struct sembuf wait = {0, -1, 0};
   work(1);

   trace_set_thread_name (data->name);

   for (;;) {
      semop(sema, &wait, 1);
      data->count++;
      data->angle += data->delta;
      data->value = sin(data->angle);
   }
}
```

```
void *
cosine_thread (void * ptr)
{
   control_t * data = (control_t *)ptr;
   struct sembuf wait = {0, -1, 0};
   work(1);

   trace_set_thread_name (data->name);

   for (;;) {
      semop(sema, &wait, 1);
      data->count++;
      data->angle += data->delta;
      data->value = cos(data->angle);
   }
}


int
main (int argc, char * argv[])
{
   pthread_t thread;
   pthread_attr_t attr;
   struct sembuf trigger = {0, 2, 0};

   trace_begin ("/tmp/data",NULL);

   sema = semget (IPC_PRIVATE, 1, IPC_CREAT+0666);

   pthread_attr_init(&attr);
   pthread_create (&thread, &attr, sine_thread, &data[0]);

   pthread_attr_init(&attr);
   pthread_create (&thread, &attr, cosine_thread, &data[1]);

   pthread_attr_init(&attr);
   pthread_create (&thread, &attr, heap_thread, NULL);

   for (;;) {
      struct timespec delay = { 0, rate } ;
      nanosleep(&delay,NULL);
      work (random() % 1000);
      if (state != hold) semop(sema,&trigger,1);
   }

   trace_end () ;
}

void * ptrs[5];

static void *
heap_thread (void * unused)
{
```

```
   int i = 5;
   int scenario = -1;
   void * ptr;
   int * * iptr;
   extern void * alloc_ptr (int size, int swtch);
   extern void free_ptr (void * ptr, int swtch);
   trace_set_thread_name("heap_thread");

   for (;;) {
      sleep (5);
      switch (scenario) {
      case 1:
         // Use of freed pointer
         ptr = alloc_ptr(1024,3);
         free_ptr(ptr,2);
         memset (ptr, 47, 64);
         break;
      case 2:
         // Double-free
         ptr = alloc_ptr(1024,3);
         free_ptr(ptr,2);
         free(ptr);
         break;
      case 3:
         // Overwriting past end of an allocated block
#define MyString "mystring"
         ptr = alloc_ptr(strlen(MyString),2);
         strcpy (ptr,MyString); // oops -- forgot the zero-
byte
         break;
      case 4:
         // Uninitialized use
         iptr = (int * *) alloc_ptr(sizeof(void*),2);
         if (*iptr) **iptr = 2778;
         break;
      case 5:
         // Leak -- all references to block removed
         ptr = alloc_ptr(37,1);
         ptr = 0;
         break;
      case 6:
         // Some more allocations we'll check on...
         ptrs[0] = alloc_ptr(1024*1024,3);
         ptrs[1] = alloc_ptr(1024,2);
         ptrs[2] = alloc_ptr(62,1);
         ptrs[3] = alloc_ptr(4564,3);
         ptrs[4] = alloc_ptr(8177,3);
         break;
      }

      (void) malloc(1);
      scenario = 0;
   }
}
```

```
void * func3 (int size, int count)
{
   return malloc(size);
}

void * func2 (int size, int count)
{
   if (--count > 0) return func3(size,count);
   return malloc(size);
}

void * func1 (int size, int count)
{
   if (--count > 0) return func2(size,count);
   return malloc(size);
}

void free3 (void * ptr, int count)
{
   free(ptr);
}

void free2 (void * ptr, int count)
{
   if (--count > 0) {
      free3(ptr,count);
      return;
   }
   free(ptr);
}

void free1 (void * ptr, int count)
{
   if (--count > 0) {
      free2(ptr,count);
      return;
   }
   free(ptr);
}

void * alloc_ptr (int size, int count)
{
   return func1(size,count);
}

void free_ptr (void * ptr, int count)
{
   free1(ptr,count);
}

void work (int control)
{
   volatile double calculations[2048];
```

```
   volatile double d = 0.0;
   int i;
   for (i=0; i<2048; ++i) {
      calculations[i] = 3.14159;
   }
   for (i=0; i<control*10; ++i) {
      d = d*d;
      calculations[i%2048] = d;
   }
}

struct node_t {
   int value;
   struct node_t * link;
};
struct node_t * head;
struct node_t * tail;

int add_link (void)
{
   static int count;
   count++;
   if (count > 5 && count < 1000) {
      struct node_t * n = (struct
node_t*)malloc(sizeof(struct node_t));
      n->value = count;
      n->link = NULL;
      if (tail) {
          tail->link = n;
      } else {
         head = n;
      }
         tail = n;
   }
}

#include <signal.h>
int nosighup (void)
{
   struct sigaction ignore;
   ignore.sa_flags = 0;
   ignore.sa_handler = SIG_IGN;
   sigemptyset(&ignore.sa_mask);
   sigaction(SIGHUP,&ignore,NULL);
}
```

function.c

```
double
FunctionCall(void)
{
   static double counter;
   return counter++;
}
```

report.c

```
#include <stdio.h>

void report (char * caller, double value)
{
   static int count;

   if (++count % 40) printf ("The value from %s is %f\n",
caller, value);
}
```