Shark User Guide

Tools & Languages: Performance Analysis Tools

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Introduction

Overview

Shark is a tool for performance understanding and optimization. Why is it called "Shark?" Performance tuning requires a hunter's mentality, and no animal is as pure in this quest as a shark. A shark is also an expert in his field — one who uses all potential resources to achieve his goals. The name "Shark" embodies the spirit and emotion you should have when tuning your code.

To help you analyze the performance of your code, Shark allows you to profile the entire system (kernel and drivers as well as applications). At the simplest level, Shark profiles the system while your code is running to see where time is being spent. It can also produce profiles of hardware and software performance events such as cache misses, virtual memory activity, memory allocations, function calls, or instruction dependency stalls. This information is an invaluable first step in your performance tuning effort so you can see which parts of your code or the system are the bottlenecks.

In addition to showing you where time is being spent, Shark can give you advice on how to improve your code. Shark is capable of identifying many common performance pitfalls and visually presents the costs of these problems to you.

Philosophy

The first and most important step when optimizing your code is to determine what to optimize. In a program of moderate complexity, there can be thousands of different code paths. Optimizing all of them is normally impractical due to deadlines and limited programmer resources. There are also more subtle tradeoffs between optimized code and portability and maintenance that limit candidates for optimization.

Here are a few general guidelines for finding a good candidate for optimization:

1. It should be time-critical. This is generally any operation that is perceptibly slow; the user has to wait for the computer to finish doing something before continuing. Optimizing functionality that is already faster than the user can perceive is usually unnecessary.

2. It must be relevant. Optimizing functionality that is rarely used is usually counter-productive.

3. It shows up as a hot spot in a time profile. If there is no obvious hot spot in your code or you are spending a lot of time in system libraries, performance is more likely to improve through high-level improvements (architectural changes).

Low-level optimizations typically focus on a single segment of code and make it a better match to the hardware and software systems it is being run on. Examples of low-level optimizations include using vector or cache hint instructions. High-level optimizations include algorithmic or other architectural changes to

your program. Examples of high-level optimizations include data structure choice (for example, switching from a linked list to a hash-table) or replacing calls to computationally expensive functions with a cache or lookup table.

Remember, it is critical to profile *before* investing your time and effort in optimization. Sadly, many programmers invest prodigious amounts of effort optimizing what their intuition tells them is the performance-critical section of code only to realize *no performance improvement*. Profiling quickly reveals that bottlenecks often lie far from where programmers might assume they are. Using Shark, you can focus your optimization efforts on both algorithmic changes and tuning performance-critical code. Often, even small changes to a critical piece of code can yield large overall performance improvements.

By default, Shark creates a profile of execution behavior by periodically interrupting each processor in the system and sampling the currently running process, thread, and instruction address as well as the function callstack. Along with this contextual information, Shark can record the values of hardware and software performance counters. Each counter is capable of counting a wide variety of performance events. In the case of processor and memory controller counters, these include detailed, low-level information that is otherwise impossible to know without a simulator. The overhead for sampling with Shark is extremely low because all sample collection takes place in the kernel and is based on hardware interrupts. A typical sample incurs an overhead on the order of 20µs. This overhead can be significantly larger if callstack recording is enabled and a virtual memory fault is incurred while saving the callstack. Time profiles generated by Shark are statistical in nature; they give a representative view of what was running on the system during a sampling session . Samples can include all of the processes running on the system from both user and supervisor code, or samples can be limited to a specific process or execution state. Shark's sampling period can be an arbitrary time interval (timer sampling). Shark also has the ability to use a performance event as the sampling trigger (event sampling). Using event sampling, it is possible to associate performance events such as cache misses or instruction stalls with the code that caused them. Additionally, Shark can generate exact profiles for specific function calls or memory allocations.

Organization of This Document

This manual is organized into four major sections, each consisting of two or three chapters, plus several appendices. Here is a brief "roadmap" to help you orient yourself:

- **Getting Started with Shark**— This introduction and "Getting Started with Shark" (page 17) are designed to give you an overall introduction to Shark. After covering some basic philosophy here, "Getting Started with Shark" (page 17) describes basic ways to use Shark to sample your applications, features of the *Session* windows that open after you sample your applications, and the use of Shark's global preferences.
- **Profiling Configurations**— Three chapters discuss Shark's default *Configurations* — its methods of collecting samples from your system or applications — and presentation of the sampled results in *Session* windows. These chapters are probably the most important ones. "Time Profiling" (page 29) discusses *Time Profiling*, the most frequently used configuration, which gives a statistical profile of processor utilization. *System Tracing*, discussed in "System Tracing" (page 59), provides an exact trace of user-kernel transitions, and is useful both to debug interactions between your program and the underlying system and to provide a "microscope" to examine multithreaded programming issues in detail. After the complete chapters devoted to these two configurations, the remainder are covered in "Other Profiling and Tracing Techniques" (page 91). *Time Profile (All Thread States)* is a variant of *Time Profile* that also samples blocked threads, and as a result is a good way to get an overview of locking behavior in multithreaded applications. *Malloc Trace* allows you to examine memory allocation and deallocation activity in detail. Shark can apply *Static Analysis* to your application in order to quickly examine rarely-traversed code paths. Equivalents

for *Time Profile*, *Malloc Trace*, and an exact *Call Trace*, all customized for use with Java applications, are also available. Finally, the chapter gives an overview of Shark's extensive performance counter recording and analysis capabilities.

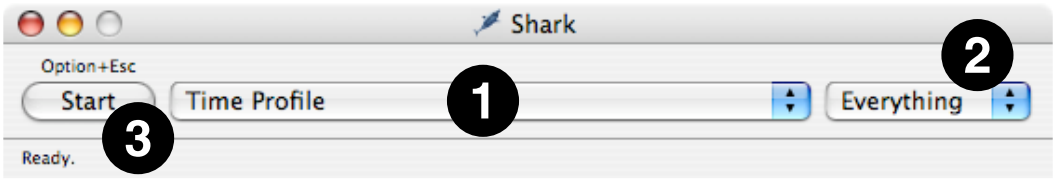
- **Advanced Techniques**— Shark's basic techniques for sampling and analysis are sufficient for most purposes, but with complex applications you may need more sophisticated techniques. "Advanced Profiling Control" (page 115) covers ways to start and stop Shark's sampling very precisely, allowing you to carefully control what is sampled, in advance. You can also learn how to control Shark remotely from other machines or even to control Shark running on iOS devices attached to your machine in this chapter. "Advanced Session Management and Data Mining" (page 133) looks at Shark's symbol management and *data mining* techniques, which are ways to very precisely select subsets of your samples for examination after they are taken.
- **Custom Configurations**— Shark is not just limited to its default configurations. If you want to save your own custom settings for a configuration or create a new one from scratch, then you will want to check out chapters "Custom Configurations" (page 171) and "Hardware Counter Configuration" (page 189). The first describes how you may make adjustments to the existing configurations, while the latter covers the many options relating to the use of hardware performance counters. Because there are so many different possible combinations of performance counters, only a limited number of the possibilities are covered by the default configurations. Hence, this is likely to be the main area where the use of custom configurations will be necessary for typical Shark users.
- **Appendices**— The first appendix, "Command Reference" (page 215), provides a brief reference to Shark's menu commands. The second, "Miscellaneous Topics" (page 225), describes several minor, miscellaneous options that do not really fit in anywhere else or are of interest only to a small minority of Shark users. The remainder of the appendices ("Intel Core Performance Counter Event List" (page 229), "Intel Core 2 Performance Counter Event List" (page 235), "PPC 750 (G3) Performance Counter Event List" (page 245), "PPC 7400 (G4) Performance Counter Event List" (page 247), "PPC 7450 (G4+) Performance Counter Event List" (page 253), "PPC 970 (G5) Performance Counter Event List" (page 263), "UniNorth-2 (U1.5/2) Performance Counter Event List" (page 291), "UniNorth-3 (U3) Performance Counter Event List" (page 295), and "Kodiak (U4) Performance Counter Event List" (page 299)) provide a reference for the performance counters that you can measure with Shark.

Getting Started with Shark

Starting to use Shark is a relatively simple process. You only need to choose one or two items from menus and press a big "Start" button in order to start sampling your applications. This chapter describes these basic steps and a few other general Shark features, such as its preferences.

Main Window

Figure 1-1 Main Window



After launching Shark, you will be presented with Shark's main window, as illustrated in Figure 1-1. The default sampling configuration is timer-based sampling (*Time Profile*) of everything running on the system. By default, the *Time Profile* configuration uses a 1 ms timer as the trigger for sampling and will record for 30 seconds (30,000 samples per processor). Opening the *Sampling Configuration* menu (#1) allows you to select from various built-in profiling configurations. Here is a list:

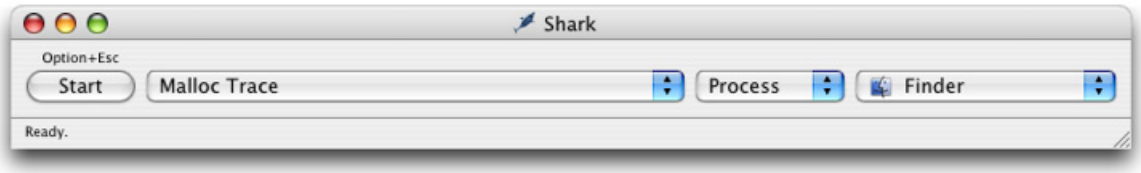
- **Time Profile**— This configuration, the default, performs timer-based sampling, interrupting your system after a regular interval and taking a sample of what is executing. It is a great starting point, as it allows you to very quickly see what code in your application is actually executing most frequently. Knowing this is the first step to successfully optimizing CPU-bound applications. See "Time Profiling" (page 29) for more information.
- **System Trace**— This configuration records an exact trace of calls into the Mac OS X kernel by your program, and which threads are running. It is useful for examining your program's interactions with Mac OS X and for visualizing how your threads are interacting in multithreaded programs. System Trace is discussed in depth in "System Tracing" (page 59).
- **Time Profile (All Thread States)**— This variation on time profiling also records the state of all blocked, inactive threads. As a result, it's a great way to see how much and why your threads are blocked. This is quite helpful in the development of multithreaded programs that do a lot of synchronization. This configuration is described in "Time Profile (All Thread States)" (page 91).
- **Malloc Trace**— If your program allocates and deallocates a lot of memory, performance can suffer and the odds of accidental memory leaks increase. Shark can help you find and analyze these allocations. "Malloc Trace" (page 94) talks about this more.
- **Static Analysis**— Shark can provide some basic optimization hints without actually running code. See "Static Analysis" (page 99) for more information.

- **Java Profiling**— Because Java programs run within the Java Virtual Machine (JVM), normally sampling them with Shark produces little useful information. However, Shark also includes several configurations that simulate the normal *Time Profile*, *Malloc Trace*, and even an exact trace of method calls, but while collecting information about what the JVM is executing instead of the native machine. A full description of these options and how to attach Shark to your Java programs is given in "Using Shark with Java Programs" (page 101).
- **Hardware Measurements**— The *L2 cache miss* and *Processor Bandwidth* (x86 systems) or *Memory Bandwidth* (PowerPC systems) configurations measure memory system activity using counters built into the hardware. They are a great way to see how your program is being slowed because of poor cache memory use. See "Event Counting and Profiling Overview" (page 103) for an overview of Shark's counter measurement capabilities.

These built-in configurations are adequate for sampling most applications. After you have used Shark for awhile, however, you may decide that you would like to sample something in your application that is not covered by the built-in collection of options. In particular, you may want to perform hardware measurements using counters that are not used by the default hardware measurement configurations. The process for building your own configurations is described in "Custom Configurations" (page 171). This process is complex enough that you should probably familiarize yourself with Shark before attempting the creation of configurations.

By default, Shark samples your entire system, as indicated by the "Everything" item selected for you in the *Target* pop-up menu (#2). Popping open this menu allows you to select a specific process or file (Figure 1-2). You may also choose different targets using the keyboard: *Command-1* for everything, *Command-2* for an executing process, and *Command-3* for a file. For a *Time Profile*, it is unnecessary to select a specific target, but others like *Malloc Trace* and *Static Analysis* require you to target a specific process or file. If you select the "Process" target, you can also choose to launch a new process. See "Process Attach" (page 115) and "Process Launch" (page 115) for full instructions on the process attaching and launching target selection techniques.

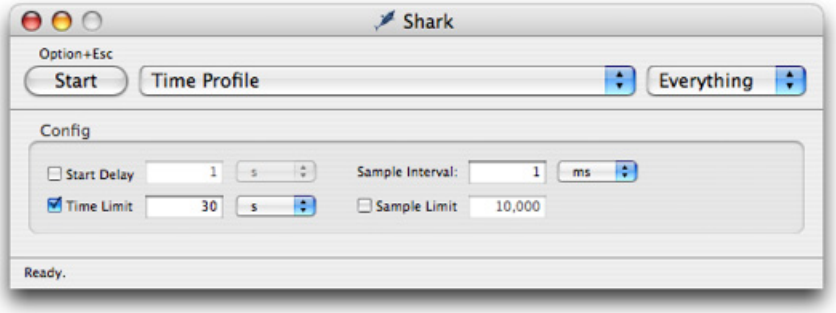
Figure 1-2 Process Target



Mini Configuration Editors

Each configuration typically has a few parameters that are frequently modified. Shark allows you to edit these easily using the *mini configuration editors* associated with each configuration. You can enable mini configuration editors by selecting the *Config*▯*how Mini Config Editor* menu item (*Command-Shift-C*). Most mini configuration editors are similar to the one depicted in "Shark Preferences," but all have small configuration-specific variations. The selection of controls available in each min configuration editor are described in the chapters associated with each type of configuration.

Figure 1-3 Mini Configuration Editor



Perform Sampling

After you choose what you would like to sample (or trace, with some configurations) and how, then actually using Shark to sample your program is extremely simple. There are two main ways to start sampling:

1. Click the *Start* button (#3 in "Main Window").
2. Press the current "Hot Key" (*Option-Esc*, by default).

Shark will emit a brief tone and the Shark icon in the dock will turn bright red to let you know that Shark is now actively sampling. At this point, you should exercise your program appropriately to trigger the execution of code that you want to measure. Sometimes this may require no active input on your part, but if you are measuring something like user interface performance then you may need to manually perform several steps while Shark samples.

Note: Occasionally you may notice a small delay while Shark allocates the sample buffers it needs to record data, due to time spent in the Mac OS X virtual memory system performing the necessary memory allocations. If this delay is long enough to cause you to miss the key events that you wanted to measure, you should just stop Shark and try to repeat your experiment, since memory allocation delays are usually much shorter for second and subsequent repeated Shark invocations.

After you have finished sampling the interesting portion of your program, you will need to stop Shark's sampling. Again, this is a simple process. You will typically use one of the following three options:

1. Click the *Stop* button, which is what the "Start" button becomes once sampling has started.
2. Press the current "Hot Key" (*Option-Esc*, by default).
3. Wait for the maximum profiling time or number of samples specified by the configuration to pass. When either of these conditions is met, Shark will automatically stop.

After Shark stops sampling, you will see a progress bar appear at the bottom of the main Shark window as samples are processed and symbols are gathered. During processing, Shark sorts samples both by process and by thread. Shark also looks up the symbols corresponding to each sampled address and caches any other information that may be needed for later browsing of your program. All of this work is done only *after* sampling is complete, in order to minimize the system overhead of Shark *during* sampling.

If you would like to use the "Hot Key" technique, but your application already uses *Option-Esc* for another purpose, then you should reassign Shark's "Hot Key" to another key combination. See "Shark Preferences" (page 23) for information on how to do this.

In addition to the basic timing options shown here, Shark also offers many other techniques for very fine selection of the time used for Shark's sampling, should you need more control. See "Advanced Profiling Control" (page 115) if you find that the basic start/stop operation described here is not enough to focus Shark's sampling on the parts of your application that you would like to measure.

Session Windows and Files

Once you've recorded samples or a trace, Shark will open up a new *session window* to display the results. Depending upon the configuration you chose, the appearance of this window will vary. See the chapter on the particular configuration that you chose for more information (in "Time Profiling" (page 29), "System Tracing" (page 59), and "Other Profiling and Tracing Techniques" (page 91)). Nevertheless, all session windows have some basic features in common.

Shark allows you to work with multiple sampling sessions at a time, displaying a separate window for each session. This is useful for comparing two or more sampling sessions side-by-side. The currently displayed session can be changed using the *Window* menu. By default, sessions are listed in the order they are loaded or created. In addition, each new session is given a unique name, in the format of "Session # - Configuration."

Session Files

Shark makes it easy to save any sessions to `.mshark` "session" files at any time. There are several reasons why you might want to do this: for later analysis, to keep as archives to track performance regressions, or to share your results. These files are particularly convenient when attached to performance bug reports, as a session file that records samples of slow code offers a simple and effective way to document the performance problem. Each session file contains all of the necessary data (symbols, source, and — optionally — even program text, see "Shark Preferences" (page 23)) needed to display and explore the session on *any* computer running Mac OS X, independent of that system's hardware or software configuration. Because of this, you can freely share your session files with any other coworkers using Shark, without regard to what type of Mac they might have.

A session is saved to disk as a single, compressed file when you use the *File Save* menu item (*Command-S*). The first time you save a session, you will need to name the new session. This name will be used to name the new session file and to replace the "Session #" part of the original window name. If you want to save the session again at any point in time using a new name, then just choose the *File Save as...* menu item (*Command-Shift-S*).

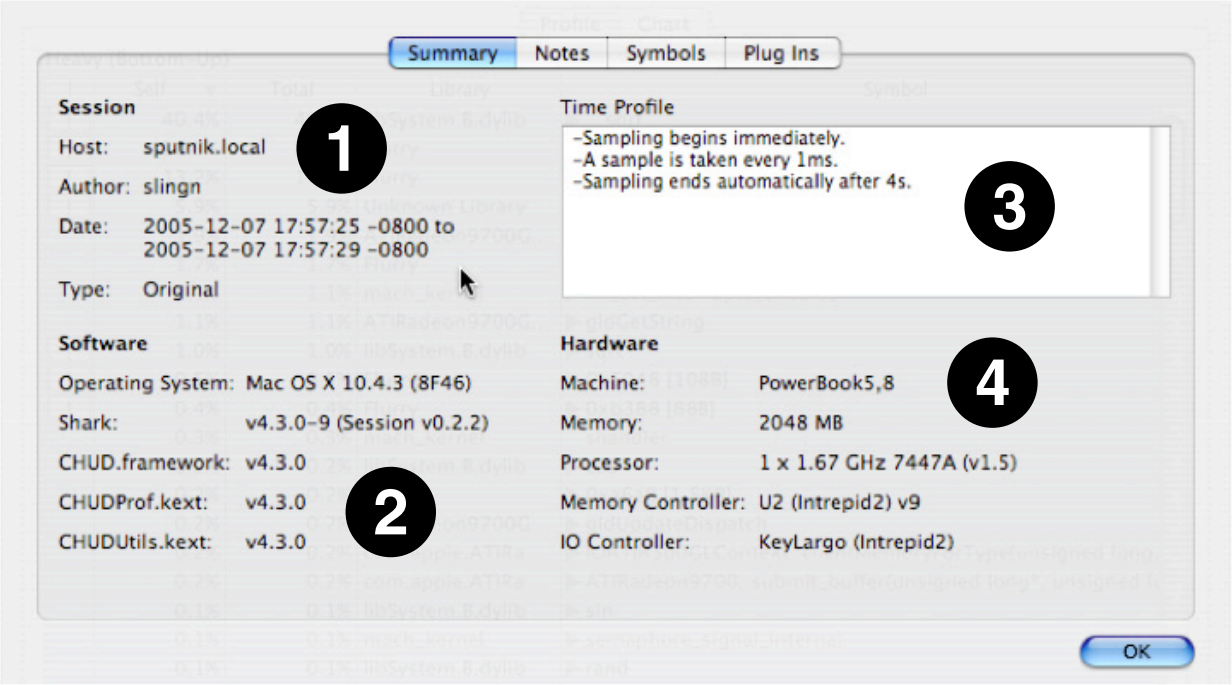
You may even choose to have Shark email your session file to someone else at any time, using the *File▷Mail This Session* menu item. When chosen, this will send your default email program a remote message asking it to start up a new email message for sending. Subsequently, Shark will automatically attach a session file of the current session (saving it first, if necessary). You may then finish composing your message and send it using the normal procedures for your email program.

Note: Shark's session files have slowly evolved and changed over time, as new features have been added that made it difficult to keep backwards-compatible file formats. The current file format (`.mshark`) is *only* compatible with Shark 4.6 and later. Shark 4.0–4.5 use a transitional file format (also called `.mshark`) that can still be read by more recent versions of Shark. However, users of these versions of Shark who need to read Shark 4.6 or later files will need to upgrade. Old `.shark` files from Shark 3 and before and the `.sample` files created by the Sampler application or command-line tool can only be read by Shark 4.3 or earlier.

Session Information Sheet

You can see many underlying details about the session by using *File▷Get Info* (*Command-I*). This will drop down the sheet shown in "Session Report" over the top of your session window.

Figure 1-4 Session Inspector Panel



This panel contains four tabbed panes:

- **Summary**— Because Shark records samples at a very low level, the configuration of the sampled system can often be critical when interpreting results. This pane, shown in "Session Report," displays many facts about the system setup when the session was originally recorded. This is very useful if you send a session file to another person, as they can call up your system's configuration with a single key combination. Four different types of information are presented in the four quadrants of the view:

1. *Basic Statistics*— This section of the pane contains basic information about the system at the time the session was recorded. The system's name, the current user, date, and time are available here.
2. *Software Configuration*— This shows version information about Shark and the underlying Mac OS X and frameworks.
3. *Sampling Configuration*— This shows a text description of the configuration used for recording the session. This is the same sort of summary description that you can see in the upper right corner of the custom configuration window (as shown in "The Config Editor" (page 171)).
4. *Hardware Configuration*— This shows key characteristics about the machine used for sampling and its underlying hardware components: processor, main memory, memory controller, I/O subsystem controller, and such.

- **Notes**— This pane is just a text box. You can type any notes and messages that you want here, and they will be saved with the session file. This is helpful when you would like to record some additional information about how the session was recorded, making notes about insights gained by you during analysis, and the like.
- **Symbols**— Here you can see a list of all binaries (application binaries, dynamic libraries, and the like) that were sampled during the session. It also provides controls for selecting and "symbolicating" (adding symbols to) samples taken from those binaries. See "Manual Session Symbolication" (page 134) for instructions on how to do this.
- **Plug Ins**— This pane displays a list of the Shark PlugIns that were used to record, analyze, and view the session. See "Custom Configurations" (page 171) for more information on these.

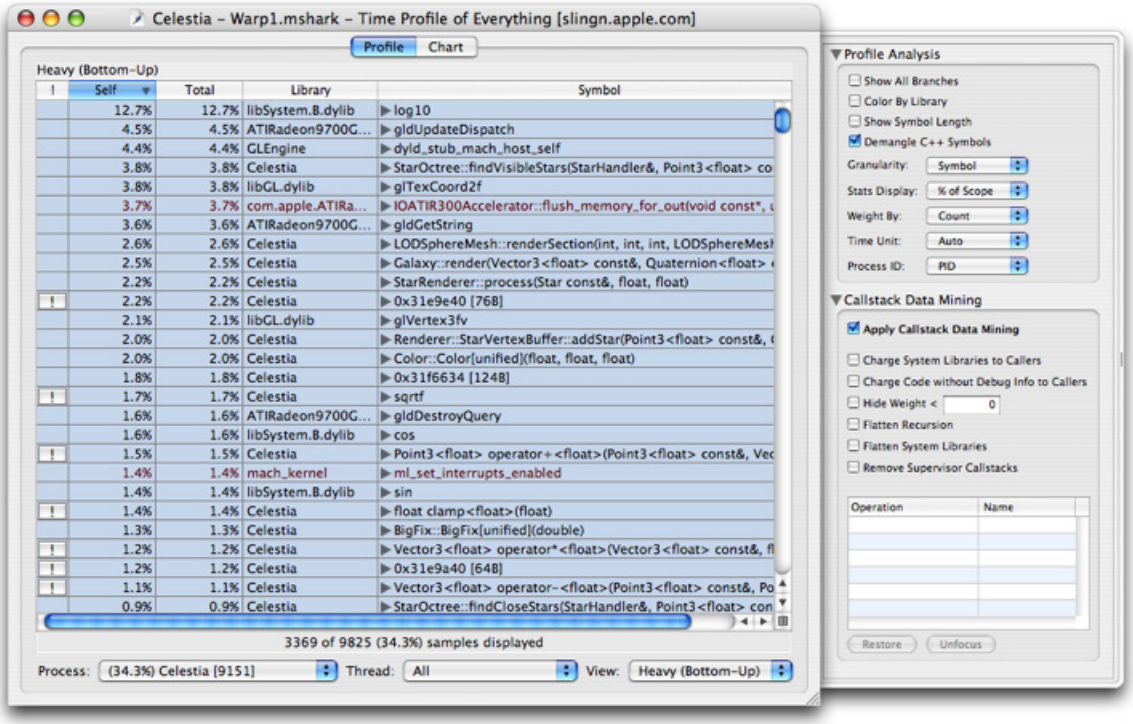
Session Report

At any time, you may open a window containing a brief text summary of your session's findings by using the *File*➤*Generate Report...* menu item (*Command-J*). This report includes some information about what the configuration was, the underlying system configuration, and a brief summary of the recorded samples. If you need to give a quick overview of a session to someone who does not have Shark on their computer, then this can be a useful command. Otherwise, it is probably easier just to send them your entire session file.

Advanced Settings Drawer

Most session windows in Shark have a variety of settings that can modify how the information in that window is presented. For consistency, the controls for these settings are always presented in the *Advanced Settings Drawer*, a drawer that can slide in and out of the right side of the session window by choosing the *Window*➤*Show Advanced Settings* menu item (*Command-Shift-M*). An example is depicted below in "Main Window." The controls presented will vary depending upon the current session viewer visible in the window, and so instructions on how to use these controls are provided in sections following the descriptions of the session viewers themselves.

Figure 1-5 Sample Window with Advanced Settings Drawer visible at right



Shark Preferences

Shark's global preferences are accessed from the *Shark Preferences...* menu item. This window allows you to set some global options that Shark uses while recording and displaying all of your sessions. Shark's preference panel is divided into four tabbed panes:

- **Appearance**— The first tab lets you control the appearance of Shark's main window (1–2) and session windows (3–5).

  1. *Sort Process Lists By*— Choose whether you want the process menu in Shark's main window to be sorted by name or process ID here.

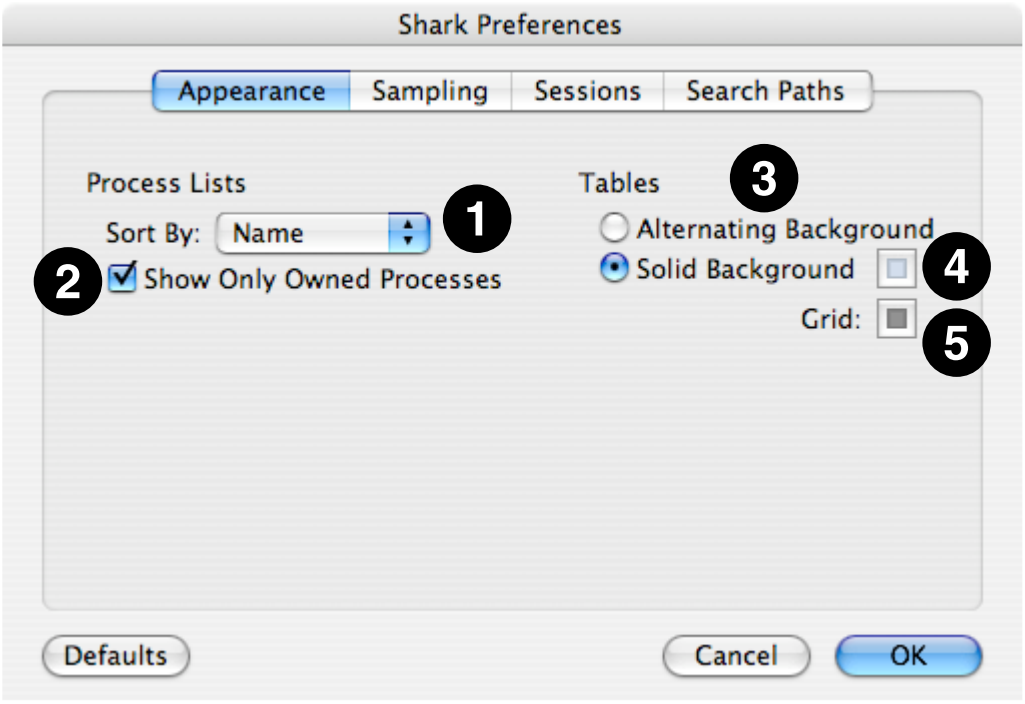
  2. *Show Only Owned Processes*— This option, selected by default, reduces clutter in the process menu by removing root (mostly daemon) processes and any processes from other users, on a multi-user system.

  3. *Alternating/Solid Table Background*— For tabular session window views, such as the profile browsers and code browsers described in "Profile Browser" (page 32) and "Code Browser" (page 43), Shark can use either a solid background color behind the text or alternate between a color and white on every row. Select the viewing option that you prefer here.

  4. *Background Color*— Choose either the solid background color or the color to alternate with white by clicking on this color well.

5. *Grid Color*— Choose the color to use as a grid between rows in tabular session views by clicking on this color well. If it is the same as the background color, previous, then the grid will essentially disappear.

Figure 1-6 Shark Preferences — Appearance



- **Sampling**— The options in this tab let you vary some of Shark's behaviors as it starts and stops sampling.

  1. *Play Alert Sound*— Choose whether or not you want to have Shark play an alert sound when you start and stop sampling. This is on by default, but if you are sampling for a very short time or are testing out something like an audio application, you may want Shark to stay quiet, instead. If you choose to have Shark play these alert sounds, then you can choose any alert sound installed on your system using the popup menu.

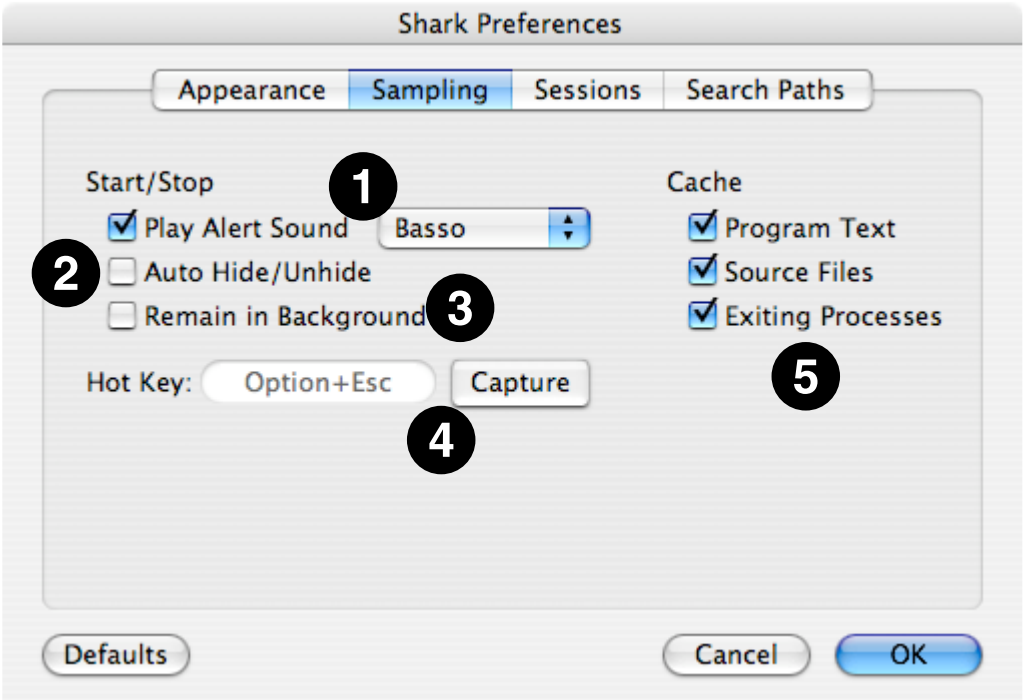
  2. *Auto Hide/Unhide*— When checked, this option causes Shark to automatically hide its windows whenever sampling starts and unhide them afterwards. It is useful if you need to see another application covering the entire screen during sampling. Because you cannot press the "Stop" button while Shark is hidden, this option is of most use if you use the "hot key" chosen below to start and stop Shark.

  3. *Remain in Background*— Shark normally brings itself to the front when sampling completes. This means that it will be the main application while it analyzes samples and then displays a session window. Generally, this is the desirable behavior, because most users want to examine their sampled sessions immediately. However, if you want to quickly capture several sessions in a row, then this option will force Shark to stay in the background while it processes samples. Because you cannot press the "Stop" button without bringing Shark to the front first, this option is of most use if you use the "hot key" chosen below to start and stop Shark.

4. *Hot Key Capture*— The current "hot key" used to start Shark, as described in "Perform Sampling" (page 19), can be set here. *Option-Esc* is the default, because it is rarely used by other programs, but you may want to use a different key if this collides with one of your own key combinations. Press the Capture button and then press the new key combination immediately afterwards to change the setting.

5. *Cache Options*— Caching of *Program Text*, *Source Files*, and *Exited Processes* allows Shark to provide useful information for short-lived processes after they complete, but may require more memory usage and increase sample processing time. You can disable these features if your applications of interest will not normally exit during sampling.

Figure 1-7 Shark Preferences — Sampling

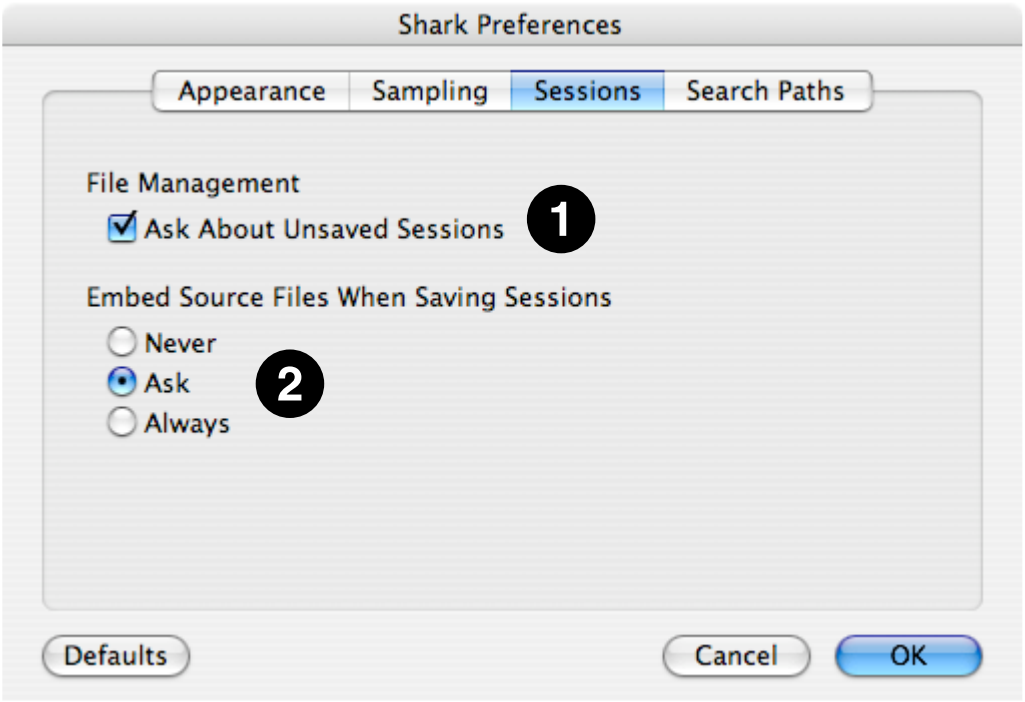


- **Sessions**— This tab contains some options about the saving of source files.

  1. *Ask About Unsaved Sessions*— With Shark, you can optionally disable the usual behavior of asking if you want to individually save each session file when closing it or quitting Shark. Some users tend to examine their data right after sampling, and therefore will rarely need to save Shark session files. If you tend to work this way, then you might find the default behavior annoying and wish to uncheck this box.

  2. *Embed Source Files*— Shark allows you to optionally embed source information right into your sessions when you save them, as discussed in "Session Files" (page 20), allowing anyone who opens the session to see source code, even if the source files are not actually available on their system at the time. This is usually very convenient, but may be problematic if you have a large amount of source code — since the session file can become enormous — or if you may be sending the file to a person who does not have permission to see all of the source. In these situations, you can choose not to include source code. For your convenience, this preference lets you tell Shark to never embed source, to always embed source, or to ask each time if you want to embed source (the default).

Figure 1-8 Shark Preferences — Sessions



- **Search Paths**— This tab lets you add (using the "+" button) or delete (using the "–" button) default directories where Shark will search for various types of files when it needs them. Shark lets you specify default paths for four different types of files:

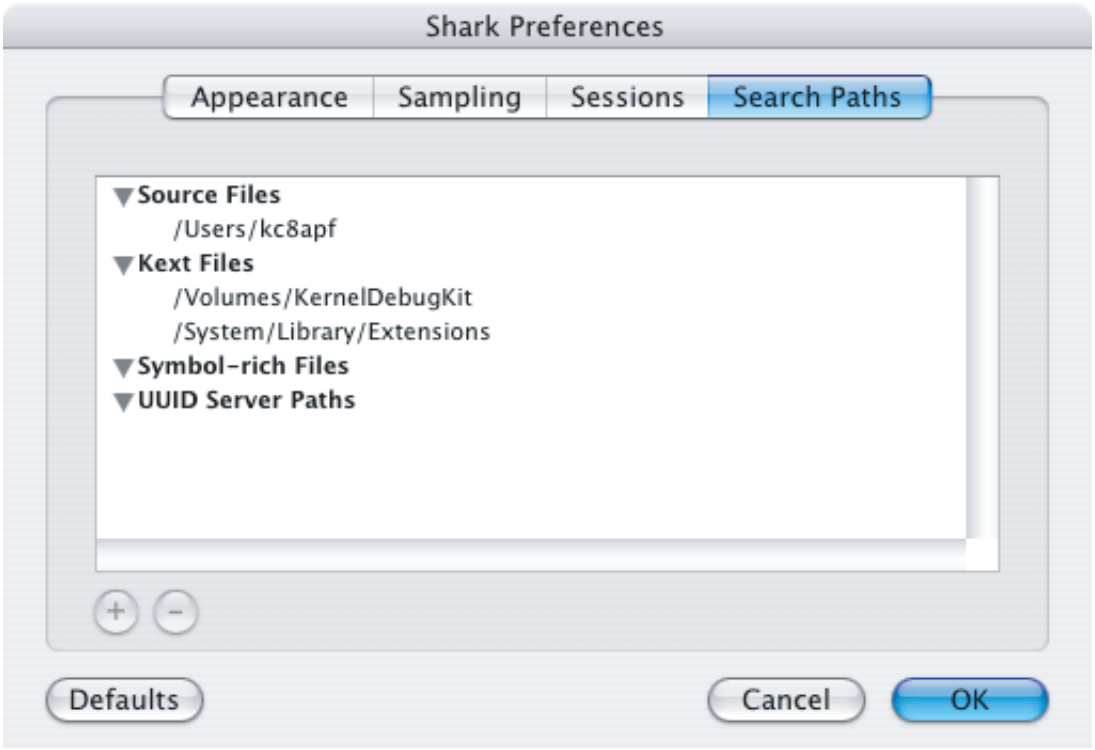
  1. *Source*— Shark will usually find source files automatically if they are not moved between compilation and session viewing times. If you must move the source at all, however, then you will need to specify a path to the new source location here so that Shark can find your source. Probably the most common reason why you might need to use this is if you compile the source on one system and then execute your code and examine your session on another.

  2. *Kext*— This tells Shark where to look for kernel extension binaries in order to find debugging information for non-user code. By default, the standard system paths for kernel extensions are included here.

  3. *Symbol-Rich*— Shark will use these paths when it looks for symbol-rich binary files during attempts at Symbolication of sessions, as described in "Automatic Symbolication Troubleshooting" (page 133).

  4. *UUID Server*— Shark can use these paths to automatically look up symbol-rich binary files and libraries by matching the UUID information in the stripped version of the binary to the symbol-rich versions of the files located here.

Figure 1-9 Shark Preferences — Search Paths



Time Profiling

The first and most frequently used Shark configuration is the *Time Profile*. This produces a statistical sampling of the program's or system's execution by recording a new sample every time that a timer interrupt occurs, at a user-specified frequency (1 KHz, for 1ms sampling intervals, by default). At each interrupt, Shark records a few key facts about the state of each processor for later analysis: the process and thread ID of the executing process, the program counter, and the callstack of the routine that was executing. From this sampled information, Shark reconstructs exactly what code from which functions was executing as samples were taken.

Statistical Sampling

This sampling process provides an approximate view of what is executing on the system. Figure 2-1 shows the worst case of an application with a sample interval greater than the lifespan of typical function calls, while Figure 2-2 shows the corresponding statistical sample, after post processing. In the first interval (marked #1), sampling correctly identifies long-running routines executing in the sample interval. However, when encountering short functions, two effects are seen because execution time is attributed to functions only at the granularity of the sampling rate:

- As seen in the third sample (marked #2), short-lived function calls can be missed entirely, so they are underrepresented in the samples.
- In contrast, when brief functions occur right on the sample points, as illustrated in the seventh sample (marked #3), they are recorded as taking an entire time quantum and hence overrepresented in the samples.

Luckily, over a large number of samples these errors average out in most cases, producing a collection of samples that fairly accurately represent the actual time spent executing each function in the application. In the example from Figure 2-1 and Figure 2-2, the rare occasions when the small subroutine `bar()` is measured as taking an entire time quantum balances out the numerous times that it is missed entirely, providing a fairly accurate measurement of the time spent executing the routine overall. As a result, execution time measurements for the most critical routines, where the program spends most of its time executing, are generally very good.

Figure 2-1 Execution Before Sampling

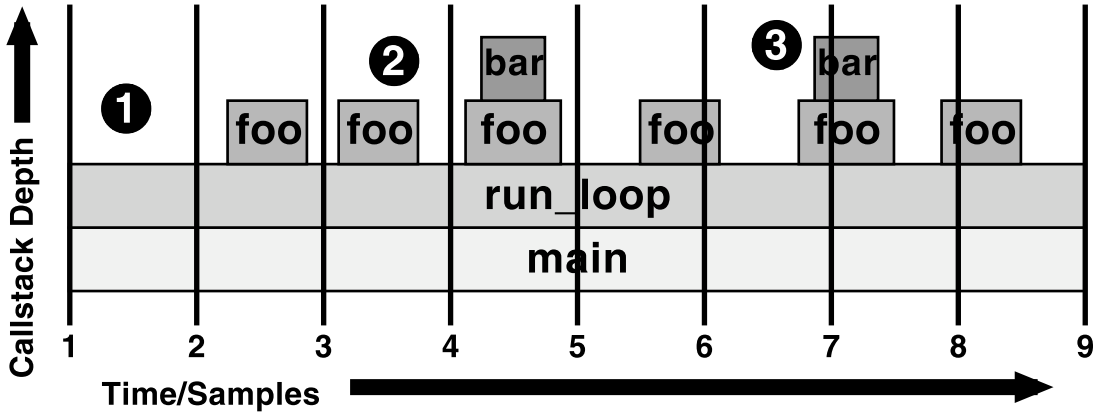
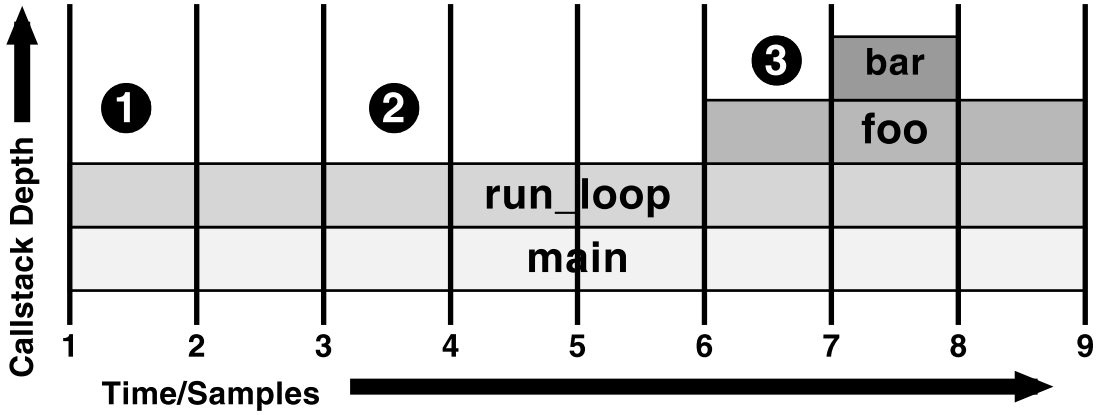


Figure 2-2 Sampling Results



In exchange for this inevitable measurement error, statistical sampling incurs very little overhead as it takes measurements, typically less than 2% with default settings. A major problem with performance-measuring tools is that the tool often affects the very performance it attempts to measure. The profiling tool requires a certain amount of processor time, system RAM, cache memory footprint, and other limited system resources in order to function. Inevitably, "stealing" these resources from the measured process adds artificial overhead to the program under test, sometimes skewing the performance measurements.

Statistical sampling minimizes this impact in two key ways. First, samples are taken at a relatively low frequency when compared with most event-monitoring mechanisms. The sampling mechanism's low intervention rate consumes only a small amount of processor time and memory, thereby minimizing the risk of skewed results. Second, and more subtly, samples can occur *anytime* during the execution of the program; side effects of the sampling mechanism are spread out to affect most areas of measured execution more or less equally. In contrast, most event counting-based mechanisms, such as function or basic block counting, record data at preset code locations, and therefore distort performance more near the preset sample points than elsewhere.

Statistical sampling provides helpful information about what executes most frequently, down to the level of individual assembly-language instructions, without the additional overhead required for an event-based profile at the instruction level. After sampling has ended, Shark correlates samples with the original binary to determine which assembly-language instructions or lines of original source code were executing when

each interrupt occurred. Shark then accumulates results across samples, determining which individual lines of code were executing most often. In contrast, the overhead from adding the necessary code to profile at this level of detail in a non-statistical way would distort the results enough to render them virtually useless.

Taking a Time Profile

Recording a *Time Profile* is generally very simple. Just use the general session-capture instructions presented in the previous chapter with the *Time Profile* configuration selected, and you will capture one. Because *Time Profile* is usually the default configuration, recording a session can be a matter of just starting Shark and pressing the "Start" button. Using the process selection menu, you may choose between capturing samples from just one process, or of the entire system at once. The former mode is usually better for analyzing most standalone applications, while the latter is better for seeing how applications interact.

If you need more control over the sampling behavior, the mini-configuration editor (Figure 2-3) contains the most common options. The list is reasonably short:

1. **Windowed Time Facility**— If enabled, Shark will collect samples until you explicitly stop it. However, it will only store the last N samples, where N is the number entered into the sample history field (10,000 by default). This mode is also described in "Windowed Time Facility (WTF)" (page 118).

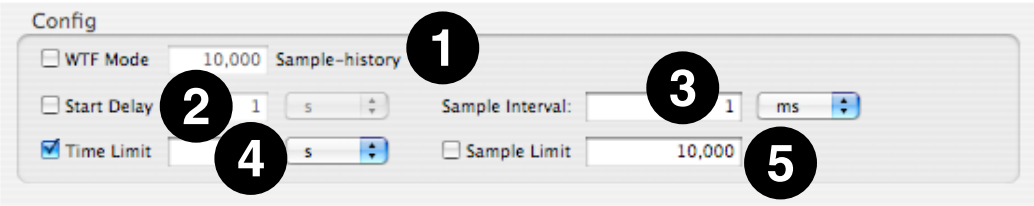
2. **Start Delay**— Amount of time to wait after the user selects "Start" before data collection actually begins. This helps prevent Shark from sampling itself after you press "Start."

3. **Sample Interval**— Enter a sampling period here to determine the sampling rate. The interval is 1 ms by default.

4. **Time Limit**— The maximum amount of time to record samples. This is ignored if WTF mode is enabled or if the sampling rate is high enough that the *Sample Limit* is reached first.

5. **Sample Limit** — The maximum number of samples to record. Specifying a maximum of *N* samples will result in at most *N* samples being taken, even on a multi-processor system, so this should be scaled up as larger systems are sampled. When the sample limit is reached, data collection automatically stops. With the *Windowed Time Facility* mode, its sample history field replaces this one, and if the *Time Limit* is very small it may be reached first.

Figure 2-3 Time Profile mini-configuration editor

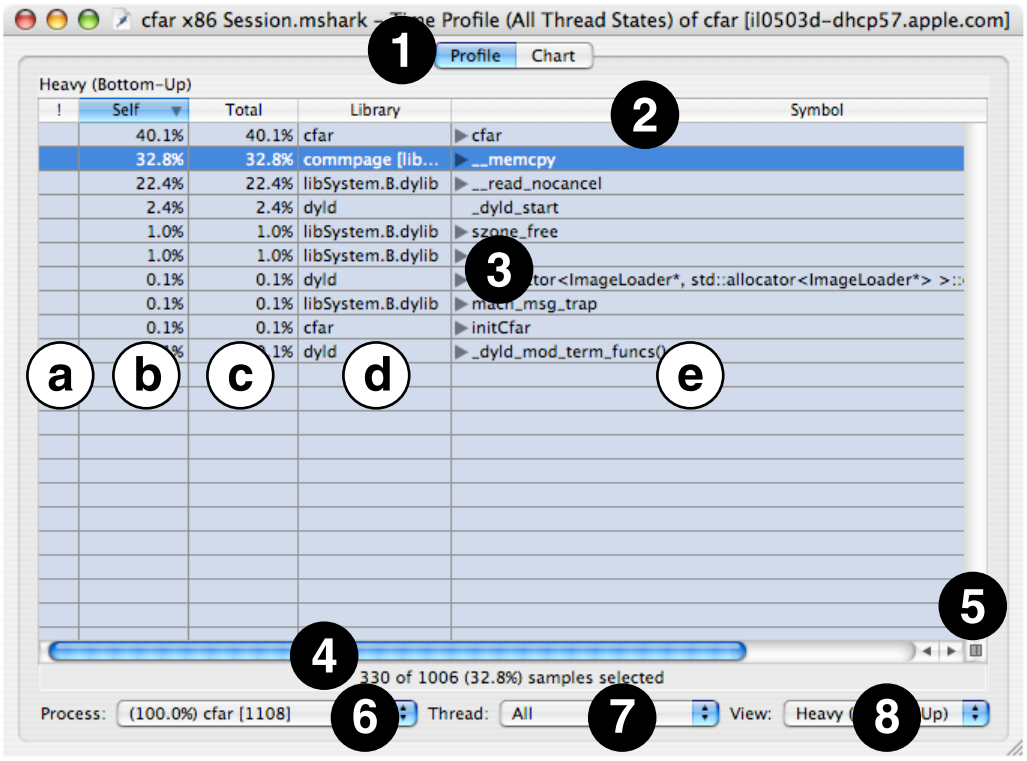


Note on short sample intervals: Shark will let you decrease the sample interval significantly, to a minimum of 20µs, but the very high sampling rates that result from these very short intervals are not recommended for most work, for several reasons. First, Shark will have a significant impact on system performance, since it needs some processor time when every sample is taken. Second, sample interval timing may be more erratic, because the inevitable sample timing error caused by interrupt response timing will be a larger percentage of each sample time. Finally, Shark may require significant amounts of memory to record the large number of samples that can quickly accumulate with short-interval sampling, adding significant memory pressure on systems with smaller amounts of main memory.

Profile Browser

After you record a *Time Profile* session, Shark displays the a summary of the samples from the dominant process in a tabular form called a *Profile Browser*. An example is shown in Figure 2-6. Samples are grouped (usually by symbol), and the groups with the most samples are listed first. This ordering is known as the "Heavy" view, and is described further below in "Heavy View" (page 36). This view can be modified using the *View* popup menu (#8), if you would rather see the "Tree" view, which is described in "Tree View" (page 36) and organizes the sample groups according to the program's callgraph tree, or "Heavy and Tree" view, which splits the window and shows both simultaneously.

Figure 2-4 The Profile Browser



The window consists of several main parts:

1. **Pane Tabs**— These tabs let you select to view your samples using this pane, the Chart view (see "Chart View " (page 39)), or from among one or more Code Browsers (see "Code Browser" (page 43)).

2. **Results Table Column Headers**— Click on any column title to select it, causing the rows to be sorted based on the contents of that column. You will usually want to sort by the "Self" or "Total" columns in this window. You can also select ascending or descending sort order using the direction triangle that appears at the right end of the selected header.

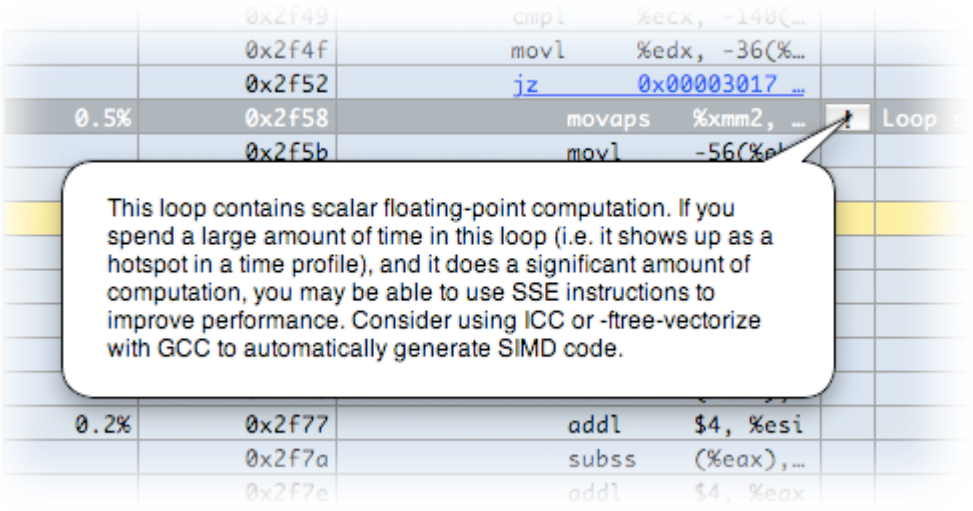
3. **Results Table**— The results table summarizes your samples in a simple, tabular form. User space code is normally listed in black text while supervisor code (typically the Mac OS X kernel or driver code) is listed in dark red text. However, this color scheme can be adjusted using the *Advanced Settings*, described below in "Profile Display Preferences" (page 37).

   The *Edit□in□Find□in□Find* command (*Command-F*) and the related *Edit□in□Find□in□Find Next* (*Command-G*) and *Edit□in□Find□in□Find Previous* (*Command-Shift-G*) commands are very useful when you are searching for particular entries in a profile browser listing many symbols. Simply type the desired library or symbol name into the *Find...* dialog box, and Shark will automatically find and highlight the next instance of that library or symbol.

   The table consists of five columns:

   a. *Code Tuning Advice*— When possible, Shark points out performance bottlenecks and problems. The availability of code tuning advice is shown by a ! button in the *Results Table*. Click on the button to display the tuning advice in a text bubble, as shown in "ISA Reference Window."

   Figure 2-5 Tuning Advice



   b. *Self*— The percentage of samples falling within this granule (i.e. symbol) *only*. Sorting on this column is a good way to locate the functions that were actively executing the most, and as a result is a good choice for use with the bottom-up "Heavy" view. By double-clicking on this, you can view the raw number of samples for each row in the table.

   c. *Total*— In the "Heavy" view, this column lists the portion of each leaf entry's time that passes through the given function (at the root level, therefore, it is equal to the *Self* column). In the "Tree" view this column lists the percentage of samples that landed in the given granule or anything called by it

(self plus descendants or "children"). Sorting on this column is a good way to locate the top of callstack trees rapidly, and as a result is a good choice for use with the top-down "Tree" view. By double-clicking on this, you can view the raw number of samples for each row in the table.

d. *Library*— The name of the library (binary file) where the code of the sampled symbol is located. If no library information is available — unlikely but not impossible — the address of the beginning of the library is shown, instead.

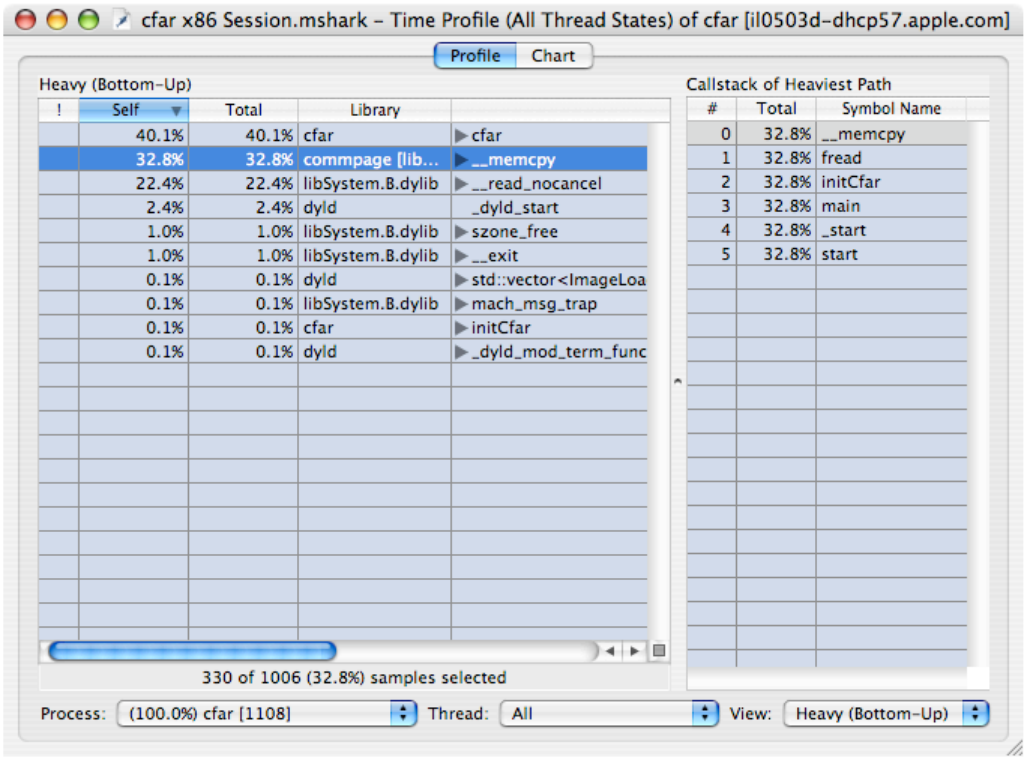
e. *Symbol*— The symbol where this sample was located. Most of the time, this is the name of the function or subroutine that was executing when the sample was taken, but the precise definition is controlled by the compiler. One particular area for wariness is with macros and inline functions. These will usually be labeled according to the name of the calling function, and not the macro or inline function name itself. If no symbol information is available, the address of the beginning of the symbol is shown, instead.

You may click the disclosure triangle to the left of the symbol name to open up nested row(s) containing the name of all caller(s) ("Heavy" view) or callee(s) ("Tree" view). If you Option-Click on the triangle, instead, then all disclosure triangles nested within will open, too, allowing you to open up the entire stack with a single click.

4. **Status Bar**— This line shows you the number of active samples, the number of samples in any selected row(s) of the *Results Table*, and the percent of samples that are selected. Note that the number of active samples being displayed can be reduced dramatically using controls such as the *Process* pop-up, *Thread* pop-up, and data mining operations (see "Data Mining" (page 139)).

5. **Callstack View Button**— Pressing this button opens up the function *Callstack Table*, shown in Figure 2-6, which allows you to view deep calling trees more easily. The most frequently occurring callstack within the selected granule (address/symbol/library) is displayed. Once open, you can click rows of the *Callstack Table* to navigate quickly to other granules that are present in the selected callstack.

Figure 2-6 Callstack Table



6. **Process Popup Menu**— This lists all of the sampled processes, in order of descending number of samples in the profile, plus an "All" option at the top. When you choose an option here, the *Results Table* is constrained to only show samples falling within the selected process. Each entry in the process list displays the following information: the percent of total samples taken within that process, process name, and process ID (PID). This information is similar to the monitoring information provided by tools such as the command-line `top` program.

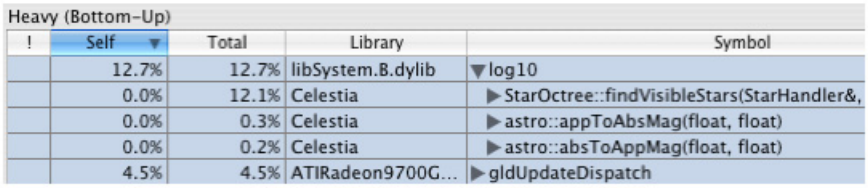
7. **Thread Popup Menu**— When you select a single process using the *Process Popup*, this menu lets you choose samples from a particular thread within that process. By default, the samples from all of the threads within the selected process are merged, using the "All" option.

8. **View Popup Menu**— This popup menu lets you choose from among the two different view options ("Heavy" and "Tree") described below, or to split the window and display both views at once ("Heavy and Tree").

Heavy View

The "Heavy" view is not flat – each symbol name has a disclosure triangle next to it (closed by default). Opening the disclosure triangles shows you the call path or paths that lead to each function. This allows you first to understand which functions are most performance-critical and second to see the calling paths to those functions.

Figure 2-7 Heavy Profile View Detail



For example, Figure 2-7 shows a close-up of the "Heavy" profile view `log10()` entry. The library function `log10()` represents 12.7% of the time spent in the `Celestia` process. The 12.7% of the overall time spent in `log10()` is distributed between three calling paths. The *Total* column shows that the first path (through `StarOctree::findVisibleStars()`) accounts for 12.1% of the overall time. The rest of the total time spent in `log10()` is through calls made by two other functions in the example shown above

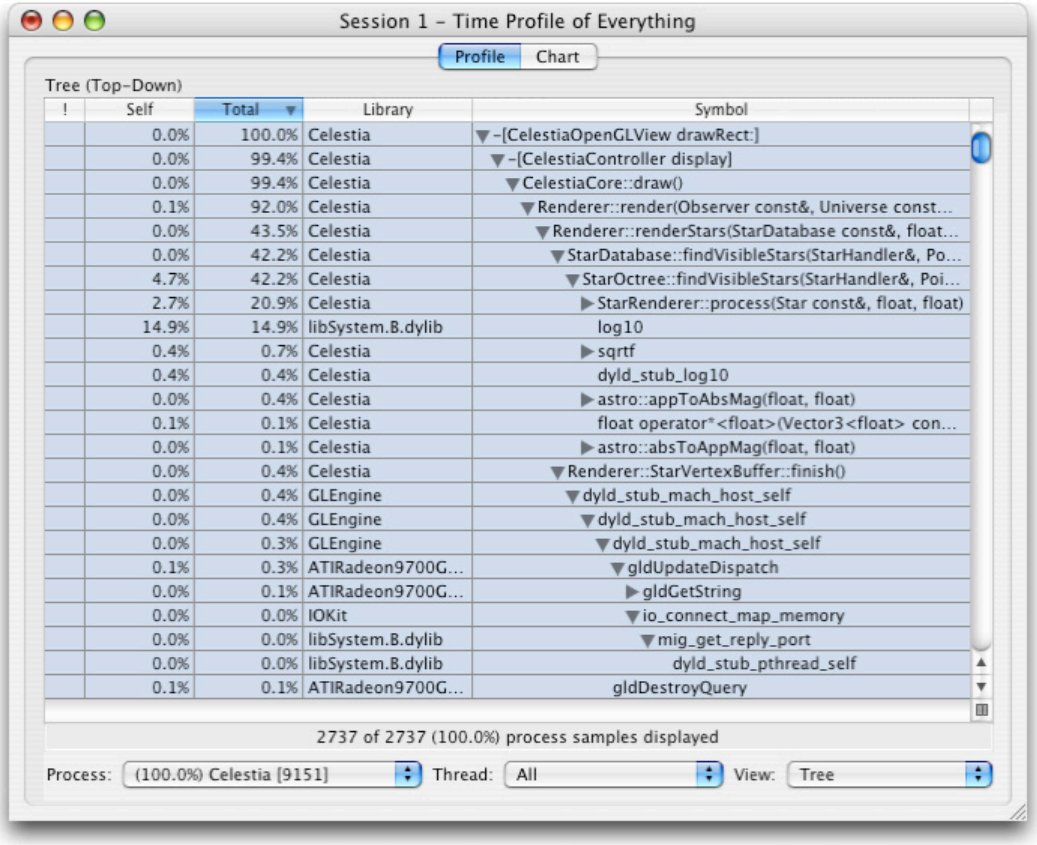
Tree View

In addition to the default "Heavy" or bottom-up profile view, Shark supports a call tree or top-down view (select "Tree" in the *Profile View* pop-up button).

The "Tree" view gives you an overall picture of the program calling structure. In the sample profile (Figure 2-8), the top-level function is `[CelestiaOpenGLView drawRect:]`, which in turn calls `[CelestiaController display]`, which then calls `CelestiaCore::draw()`, and so on.

In "Tree" view, the *Total* column lists the amount of time spent in a function and its descendants, while the *Self* column lists the time spent only inside the listed function.

Figure 2-8 Tree Profile View

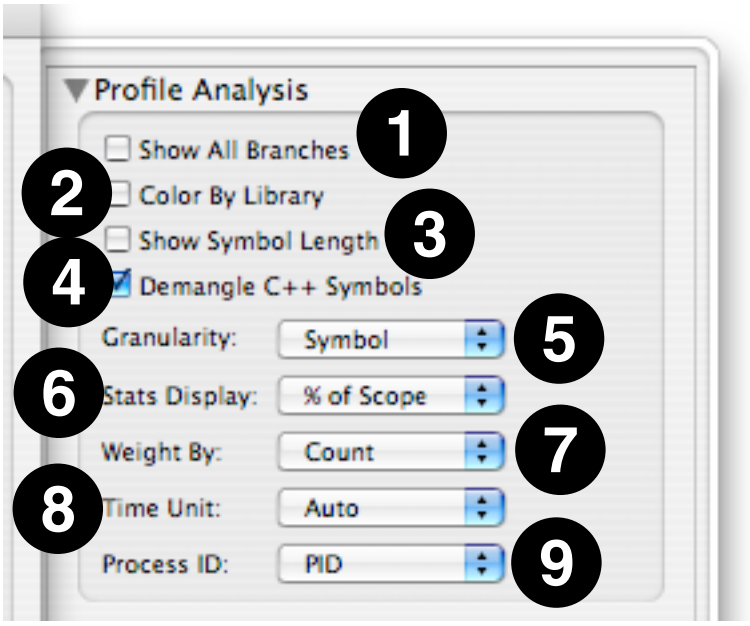


Note on Heavy/Tree comparisons: Please note that there may not be a one-to-one correspondence between entries in "Tree" view and "Heavy" view. If you select a function in "Heavy" view and then switch to "Tree" view, it will always select exactly one function in the tree. On the other hand, if you select a function in "Tree" view and then switch back to "Heavy" view, Shark will automatically select the "heaviest" symbol corresponding to that callpath. If several callpaths have similar weights, Shark may end up selecting one that is surprising to you.

Profile Display Preferences

Profile analysis can help you better understand the data presented in the *Profile Browser* by tailoring the formatting of the sampled information to suit your application's code. Analysis settings are controlled separately for each session. The analysis controls are accessed per session by opening a drawer on the Profile Window, shown in "Advanced Session Management and Data Mining," using *File*▸*Show Advanced Settings* (*Command-Shift-M*).

Figure 2-9 Profile Analysis Preferences



This part of the *Advanced Settings* drawer contains many different controls:

1. **Show All Branches**— The default "Heavy" view lists only the leaf entries (where samples landed) for the sampled callstacks. As a result, each sample only appears once in the profile. Opening disclosure triangles in the "Heavy" view reveals the contribution of each calling function to the "leaf" function's total, if you are interested in seeing what is calling those functions. With *Show All Branches* on, a "sample" is counted for *all* symbols (root, interior and leaf), rather than only leaf entries. This results in actual samples with deep callstacks being over-represented in the profile, since they are counted many times, but makes it easier to find symbols for frequently-occurring but non-leaf functions, since one no longer must drill down through multiple levels of disclosure triangles to find them.

   While Shark will allow you to use this mode with "tree" view, it is not recommended.

2. **Color By Library**— Uses colors to differentiate libraries in the *Results* table.

3. **Show Symbol Length**— Displays the sum of instruction lengths in bytes for each symbol.

4. **Demangle C++ Symbols**— Translates compiler-generated symbol names to user-friendly names in C++ code, stripping off the name additions required to support function polymorphism.

5. **Granularity**— Determines the grouping level that Shark uses to bind samples together.

   a. *Address*— Group samples from the same program address.

   b. *Symbol*— Group samples from the same symbol (usually there is a one-to-one correspondence between symbols and functions).

   c. *Library*— Group samples from the same library.

   d. *Source File*— Group samples from the same source file.

   e. *Source Line*— Group samples from the same line of source code.

6. **Stats Display**— Selects units and a baseline number of samples.
    a. *Value*— Shows raw sample counts rather than percentages.
    b. *% of Scope*— Shows percentages based on currently selected process and/or thread.
    c. *% of Total*— Shows percentages based on total samples taken.

7. **Weight By**— In Shark's default weighting method (weight by sample count), each sample contributes a count of one. During sample processing, any time a sample lands in a particular symbol's address range (in the case of symbol granularity) the total count (or weight) of the granule is incremented by one. In addition to context and performance counter information, each sample also saves the time interval since the last sample was recorded. When samples are weighted by time, each granule is weighted instead by the sum of the sampling interval times of all of its samples.

8. **Time Unit**— Selects the time unit (µs, ms, s) used to display time values. *Auto* will select the most appropriate time unit for each value when weighting by "Time."

9. **Process ID**— Shark normally differentiates between processes according to their process ID (PID) – a unique integer assigned to each process running on the system. Thus, Shark groups together samples from the same PID. Shark can also identify processes by name. In this case, samples from processes with the same name (and possibly different PIDs) would be grouped together. This is particularly useful for programs that are run from scripts or that fork/join many processes.

The remainder of the controls visible in the Advanced Settings Drawer, which control Data Mining, are described in "Data Mining" (page 139).

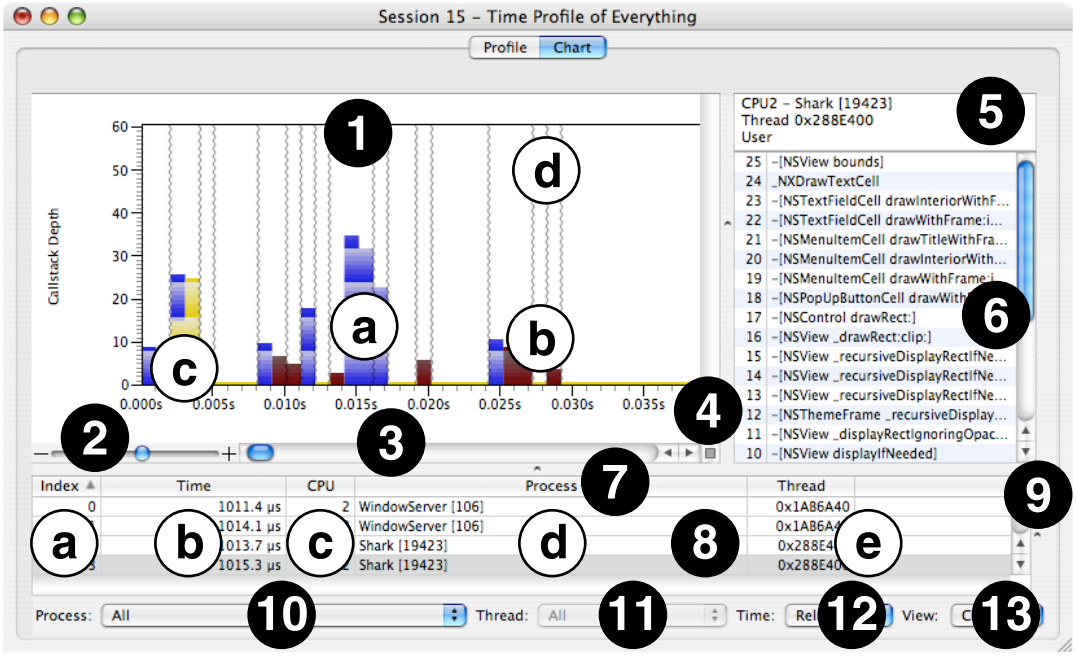
Chart View

Click Shark's *Chart* tab to explore sample data chronologically, from either a thread- or CPU-based perspective. This can help you understand the chronological calling behavior in your program, as opposed to the summary calling behavior shown in the *Results Table*. Using this chart, you can see at a glance if your program rarely/often calls functions and if there are any recurring patterns in the way your program calls functions. Based on this, you can often visually see different *phases* of execution — areas where your program is executing different pieces of its code. This information is useful, because each phase of execution will usually need to be optimized in a different way.

Shark's *Chart* and *Profile* views are tightly integrated. The same level of scope (system/process/thread) is always displayed on both. Selected entries in the *Results Table* are highlighted in the *Chart* view. Filtering of samples using the *Profile Analysis* or *Data Mining* panes (see "Data Mining" (page 139)) also affects the selection of samples shown in the *Chart* view. As with the *Callstack Table* shown in the *Profile* Browser, double clicking on any entry in the table opens a new *Code Browser* tab.

By default, Shark displays the currently selected scope (system, process, or thread) against an "absolute" time x-axis. This view displays gaps wherever the currently selected process or thread was not running. Use the *Time Axis* pop-up button to switch between absolute and relative time, which compresses out these out-of-scope areas.

Figure 2-10 Chart View



The chart view shown in Figure 2-10 has several parts:

1. **Callstack Chart**— This chart displays the depth (y-axis) of the callstack for each sample, chronologically from left-to-right over time (x-axis). The figure also clearly shows several key features of the chart:

    a. *User Callstack*— Most callstacks, in blue, represent user-level code from your program.

    b. *Supervisor Callstack*— Callstacks in dark red represent supervisor-level code stacks that were sampled.

    c. *Selected Callstack*— A yellow "pyramid" of callstacks is highlighted when you click on the graph to select a sample. Once you have chosen a sample, you can use the left and right arrow keys to navigate to the previous or next unique callstack "pyramid." After highlighting the chosen sample, Shark examines the callstacks to either side and automatically extends the selection outwards to the left and right wherever the adjacent callstacks have the same symbol. In this way, you can easily see the full tenures for each function (length of time that function is in the callstack). Because functions at the base of the callstack, like `main`, have much longer tenures than the leaf functions at the top of the callstack, the shape of the highlighted area will always be a pyramid of some sort.

    It is also possible to select one or more individual *symbols* within the chart view by selecting them in the Profile Browser and then switching over to the chart view. After you switch to the chart view, all of the dots on the chart representing calls to the selected symbol(s) will be highlighted in yellow, allowing you to find and examine samples containing those symbol(s) more easily in complex charts. It is usually easy to differentiate these "symbol selections" from the "sample selections" made by clicking within the chart view itself, because only elements of each callstack corresponding to the selected symbols are highlighted in the former case, and not entire samples or "pyramids," as in the latter.

   d. *Context Switch Lines*— These lines indicate where the operating system switched another process or thread into the processor. Note that because Shark uses statistical sampling, it is possible to miss very short thread contexts. They are only visible at high levels of magnification in "absolute" time mode (as chosen in #12, below), when you select the option to show them in the *Advanced Settings*.

   e. *Out-of-Scope Callstack*— (not shown) Callstacks in gray, visible only in "absolute" time mode, are just placeholders for samples that are outside the current process/thread scope. In "relative" mode, they are eliminated from the graph.

2. **Zoom Slider**— You can zoom in or out of the chart by dragging this slider towards the "+" and "–" ends, respectively. You can also use the mouse to zoom into a subset of the displayed samples by dragging the mouse pointer over the desired region of the chart. Zooming out can also be accomplished by *Option-Clicking* on the chart.

3. **Chart Scroll Bar**— If you have magnified the chart, then you can use this scroll bar to move left-and-right within it.

4. **Callstack Table Button**— Press this button to expose or collapse the *Callstack Table*, below.

5. **Callstack Table Header**— This area summarizes the CPU number, process ID, thread ID, and user/supervisor code status of the sample. This is displayed or hidden using the *Callstack Table Button* (#4).

6. **Callstack Table**— This displays the functions within the callstack for the currently selected sample, with the leaf function at the top and the base of the stack at the bottom. As you select different samples in the chart, this listing will update to reflect the location of the current selection. This is displayed or hidden using the *Callstack Table Button* (#4).

7. **Sample Table Headers**— Like most tables in Shark, you can click here to select the column used to sort the samples in this table, and then click on the arrow at the right end of the selected header cell to choose to sort in ascending or descending order. Choosing a column here has no other effect besides controlling the sort order, however.

8. **Sample Table**— This table lists a summary of all samples recorded within the session. It lists several key facts that are recorded with each sample:

   a. *Index*— Number of the sample within the session, starting from 1 and going up.

   b. *Time*— Time that has passed between this sample and the previous one. Normally, this will be a constant amount of time equal to the sampling period, but there are some sampling modes that allow variation here.

   c. *CPU*— Number of the CPU on your system where this sample was recorded, starting from 1 and going up.

   d. *Process*— Process ID for this sample's process, including the name of the application.

   e. *Thread*— Thread ID for this sample's thread.

9. **Sample Table Callstacks**— If you pull this window splitter to the left, you will expose a table listing all symbol names within the callstacks of each sample, in a large grid. Effectively, this is like looking at multiple *Callstack Table*s rotated 90 degrees and placed side-by-side. Most of the time, this level of detail about your samples is not necessary, but there may be some occasions when you might find this view helpful.

10. **Process Popup Menu**— This lists all of the sampled processes, in order of descending number of samples in the profile, plus an "All" option at the top. When you choose an option here, the *Callstack Chart* is constrained to only show samples falling within the selected process. Each entry in the process list displays the following information: the percent of total samples taken within that process, process name, and process ID (PID). This information is similar to the monitoring information provided by tools such as the command-line `top` program.

11. **Thread Popup Menu**— When you select a single process using the *Process Popup*, this menu lets you choose samples from a particular thread within that process. By default, the samples from all of the threads within the selected process are merged, using the "All" option.

12. **Time Popup Menu**— This popup lets you choose between two different viewing modes. The first, "absolute" time mode, shows *all* samples from a particular processor, no matter what was executing. Samples from outside the current process/thread scope are grayed out, but are still plotted. On the other hand, in "relative" time mode, all out-of-scope samples are eliminated and the chart's x-axis is adjusted to account for the smaller number of samples.

13. **View Popup Menu**— This popup lets you choose to view sets of samples from different processor cores.

Advanced Chart View Settings

The first pane of the *Advanced Settings* drawer displays a new set of options if you switch to a *Chart* view (Figure 2-11). These controls affect the appearance of the chart, and are generally fairly minor:

1. **Draw Context Switch Lines**— Enables or disables the drawing of gray lines between samples that are from different process and/or thread contexts. They are quite useful, but can clutter the display at low levels of magnification.

2. **Hide Samples Not In Scope**— When chosen, this hides all samples from processes or threads outside of the ones in the current scope, as chosen by the *Process* and *Thread* pop-up menus. Any remaining samples are compressed together to remove any gaps. This process is similar to switching to "Relative" time using the *Time* pop-up menu, but the results are slightly different.

3. **Coalesce Samples**— When chosen, this combines adjacent samples containing the same callstacks together, so they are no longer individually selectable. If your Time Profiles often contain large blocks of identical samples, the use of this option can make maneuvering through the samples using the arrow keys somewhat easier.

4. **Chart Type**— Selects which type of chart to plot. You will rarely need to change this, but other options are available:

    a. *Saturn*— The default chart type, this presents a graph consisting of a solid bar representing the callstack at each sample point.

    b. *Trace*— This chart type is similar to the Saturn graph type, except that it only draws an outline around the bars instead of coloring them completely. Selections are made only on a sample-by-sample basis, instead of in "pyramids."

    c. *Delta*— This is much like the trace view, including the point selections. However, it only shows *changes* in the callstacks, and not their exact depth. As a result, it is of most use when you are looking for rare changes in the callstack depth or trends over time.

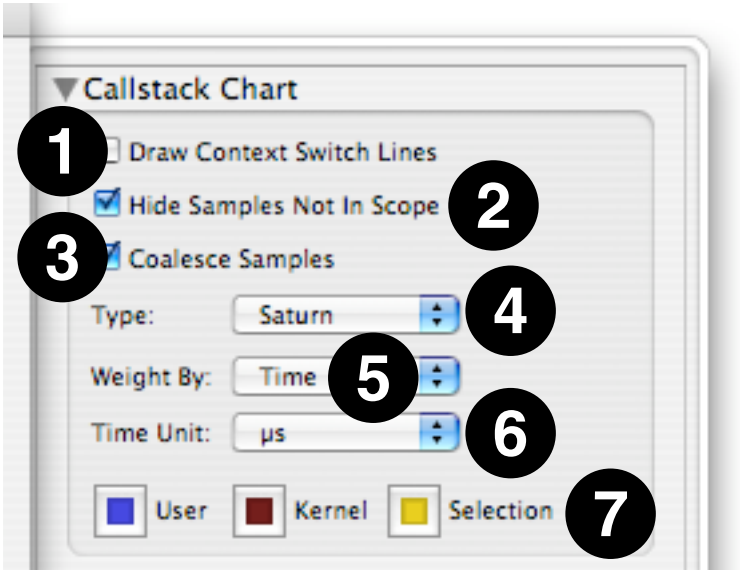
d. *Hybrid*— This graph looks like a Trace graph, but uses the full "pyramid" selection capability of the Saturn graph type.

5. **Weight By**— Choose how to present the x-axis scale for the chart view. You may have Shark present this axis in terms of sample count or by time. You may also use the keyboard equivalents *Command-1* to use sample counts or *Command-2* to use time.

6. **Time Unit**— Selects the time unit to use in the *Time* column of the *Sample Table*. Normally you should just leave this on the default, "Auto," but if you would prefer you may explicitly choose to have the numbers displayed in µs, ms, or s.

7. **Color Selection**— Choose colors to use for user sample callstacks, kernel sample callstacks, and the selection area by clicking on these color wells.

Figure 2-11 Advanced Settings for the Chart View

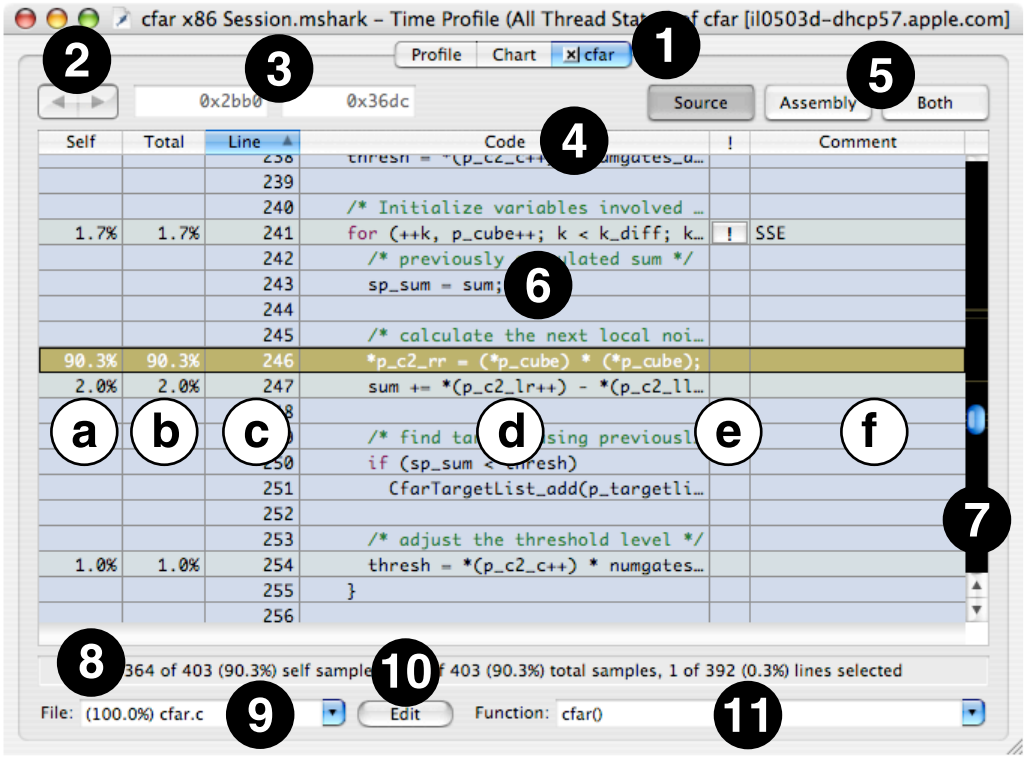


The remainder of the controls visible in the Advanced Settings Drawer, which control Data Mining, are described in "Data Mining" (page 139).

Code Browser

Double-clicking on an entry in the *Results Table* or *Callstack Table* will open a *Code Browser* view for that entry, as shown in Figure 2-12. If available, the source code for the selected function is displayed. Source line and file information are available if the sampled application was compiled with debugging information (see "Debugging Information" (page 134)). The *Code Browser* shows the code from the selected function and colorizes each instruction according to its reference count (the number of times it was sampled).

Figure 2-12 Code Browser



The Code Browser window consists of several different parts:

1. **Code Browser Tab**— When you double-click on an entry in a Profile Browser or Chart View, Shark dynamically adds a tab to the top of the window. This tab contains the code browser for the symbol that you double-clicked. If you return to one of the original browsers and double-click on another symbol, another tab will be added for that symbol. Unlike the default tabs, these additional tabs all have small close boxes on the left end. When clicked, the tab will be eliminated. If you open up more than about 3–5 code browsers, this may be necessary because of limited space at the top of the window.

2. **Browse Buttons**— You can use these buttons to maneuver through function calls. After you double-click on a function call (denoted by blue text) and go to the actual function, the "back" button here (left arrow) will be enabled. To return to the caller, just click on the "back" button. After you have maneuvered through a function call, you can navigate through code forward and backward just as you would navigate web pages in a web browser.

3. **Address Range**— This is used with the Assembly Browser (see "Assembly Browser" (page 46)).

4. **Code Table Headers**— Click on any column title to select it, causing the rows to be sorted based on the contents of that column. You will usually want to sort by the "Line" column in this window, so that you can view your code in the original sequence order. You can also select ascending or descending sort order using the direction triangle that appears at the right end of the selected header.

5. **View Buttons**— Use these buttons to choose between:, *Assembly View*, or a split-screen view showing both side-by-side.

- *Source View*: This displays the original source code for the function. It is the default, if Shark can find source code for the function. To make sure that Shark can find your source, you first need to have debugging information enabled in your compiler (see "Debugging Information" (page 134)). Also, it is best to avoid moving the files after you compile them, so all source paths embedded in debugging information will still be accurate. Otherwise, you may need to adjust Shark's source paths, as described in "Shark Preferences" (page 23).
- *Assembly View*: This displays the raw assembly language for the function. Because it is extracted directly from the program binary, this option is always available, even for library code. See the Assembly Browser section ("Assembly Browser" (page 46)) for more information.
- *Both*: This displays both views side-by-side, and is useful when you are comparing your source input to the compiler's output.

6. **Code Table**— This table allows you to examine your source code and see how samples were distributed among the various lines of code. Each row of the table is automatically color-coded based on the number of samples associated with that line — by default, hotter colors mean more samples — allowing you can see at a glance which code is executing the most.

   You can use the *Edit□in□Fd□in□d* command (*Command-F*) and the related *Edit□in□Fd□in□d Next* (*Command-G*) and *Edit□in□Fd□in□d Previous* (*Command-Shift-G*) commands to search through your code, much like you can in most text editors. Just type the desired text into the *Find...* dialog box, and Shark will automatically find and highlight the next instance of that text in your code. You can also use this to search for comments, if you need to look for repeated instances of a tip in the comments, for example.

   The table consists of several columns. Some of these are optional, and are enabled or disabled using checkboxes in the *Advanced Settings* drawer.

   a. *Self*— This optional column lists the percentage of displayed references for each instruction or source line, using only the samples that fell within this particular address range. To see sample counts instead of percentages, double-click on the column.

   b. *Total*— This optional column lists the percentage of displayed references for each instruction or source line, including called functions. To see sample counts instead of percentages, double-click on the column.

   c. *Line*— The line number for each line from your original source code file. This column is particularly useful for sorting the browser window, in order to keep the line numbers there in sequence.

   d. *Code*— This column lists your original source file, line-by-line. Double-clicking on this column will take you to the equivalent location in the *Assembly* display. Double-clicking on any function calls (denoted by blue text), will take you to the source code for that function.

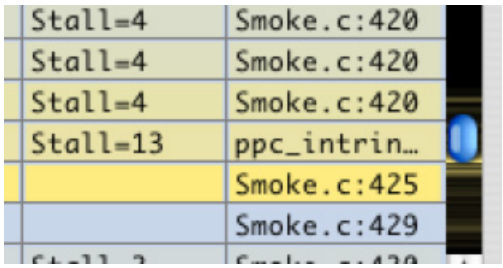
   e. *Code Tuning Advice*— When possible, Shark points out performance bottlenecks and problems. The availability of code tuning advice is shown by a  button in this column. Click on the button to display the tuning advice in a text bubble, as shown in "ISA Reference Window." The suggestions provided in the code browser will usually be more detailed and lower-level than the ones visible within the profile browser.

   f. *Comment*— This column gives a brief summary of the code tuning advice, allowing you to determine which code tuning suggestions are likely to be helpful without clicking on every last advice button.

g. *Performance Event Column*— (Not shown) This optional column, which is only available when you are looking at a code browser while using a configuration that uses performance counters (as described in "Event Counting and Profiling Overview" (page 103)), shows raw counts from those counters. It cannot be enabled with normal time profiles.

7. **Code Table Scrollbar**— This scrollbar (Figure 2-13) is customized to show an overview of sampling hot spots; the brightness of a location in the scrollbar is proportional to the sampling reference count of the corresponding instruction in the *Code Table*. Since programmer time is best spent optimizing code that makes up a large portion of the execution time, this visualization of hot spots helps you to quickly see and focus your development effort on the code that has the greatest influence on overall performance.

Figure 2-13 Hot Spot Scrollbar



8. **Status Bar**— This line shows you the number of active samples in the currently displayed memory range, the number of active samples in the entire session, and/or the number of samples in any selected row(s) of the *Code Table*. Either or both of the active samples will be eliminated from this line if the "Self" or "Total" columns in the code table are disabled. In addition, the percent of samples that are in each of these categories is displayed.

9. **Source File Popup Menu**—A given memory range can contain source code from more than one file because of inlining done by the compiler. You can select which source file to view using this menu.

10. **Edit Button**— You can open the currently displayed source file in Xcode by selecting the *Edit* button. The file will open up and scroll to your selected line, or the line with the most samples if nothing is selected.

11. **Function Popup Menu**— This pop-up menu allows you to jump quickly to different functions in the current source file. Please note that sample counts are only shown for the source lines in the current memory range — other functions not in the current memory range may be visible, and you can still look at them, but they will show no sample counts).

Assembly Browser

In addition to displaying the source code from the current memory range, Shark also provides a detailed assembly-level view (Figure 2-14) that can be enabled by clicking on the *Assembly* button or combined with a source browser by clicking on the *Both* button. This browser will also pop up in place of a source browser if Shark cannot find source code for the address range that you are examining. This will often be the case with common system libraries, the kernel, and precompiled applications.

Often, it is useful to examine the relationship between a line of source code and its compiler-generated instructions. Shark encourages this type of exploration: either use the *Both* button to view source and assembly simultaneously or double-click on a line in the *Source* or *Code* columns in the *Assembly Code Browser* to jump to the corresponding source line in the *Source Code Browser*. Conversely, double-click on a line of code in the *Source Code Browser* to jump back to the corresponding instructions in the *Assembly Code Browser*.

Many parts of this browser are identical to their counterparts in the *Source Browser*, including Self, Total, tuning advice, and Comment columns. However, there are a few differences:

1. **Browse Buttons**— You can use these buttons to maneuver through branches. After you double-click on a branch with a static target address (denoted by blue text) and go to the destination, the "back" button here (left arrow) will be enabled. To return to the branch itself, just click on the "back" button. After you have maneuvered through branches, you can navigate through code forward and backward just as you would navigate web pages in a web browser.

2. **Address Range**— Samples are displayed only for the address range between these two boxes (usually one symbol). Code outside of this range may have samples, but they will not be displayed.

3. **Code Table**— About half of the columns have functions that are identical to the basic source browser, but the others are new or slightly different:

    a. *Address Column*— This displays the address of the assembly-language instruction displayed on this row. With PowerPC, this value simply increases by 4 with every row, but with x86 this will change by 1–18 bytes per row, depending upon the variable length of each instruction. You can double-click on this column to switch to relative decimal or hexadecimal offsets from the beginning of the address range.

    b. *Code Column*— This column displays the assembly code used by your routine. Using *Advanced Settings*, you can choose to disable disassembly and to have Shark automatically find and indent loops based on backwards branches in the code (the default). Within this column, you can double-click on a branch with a static target address (denoted by blue text) to follow a branch to its target address; after double-clicking, the function containing the target instruction will be loaded, if necessary, and the target instruction will be highlighted. Finally, double-clicking on this column will take you to the equivalent location in the corresponding *Source* display.

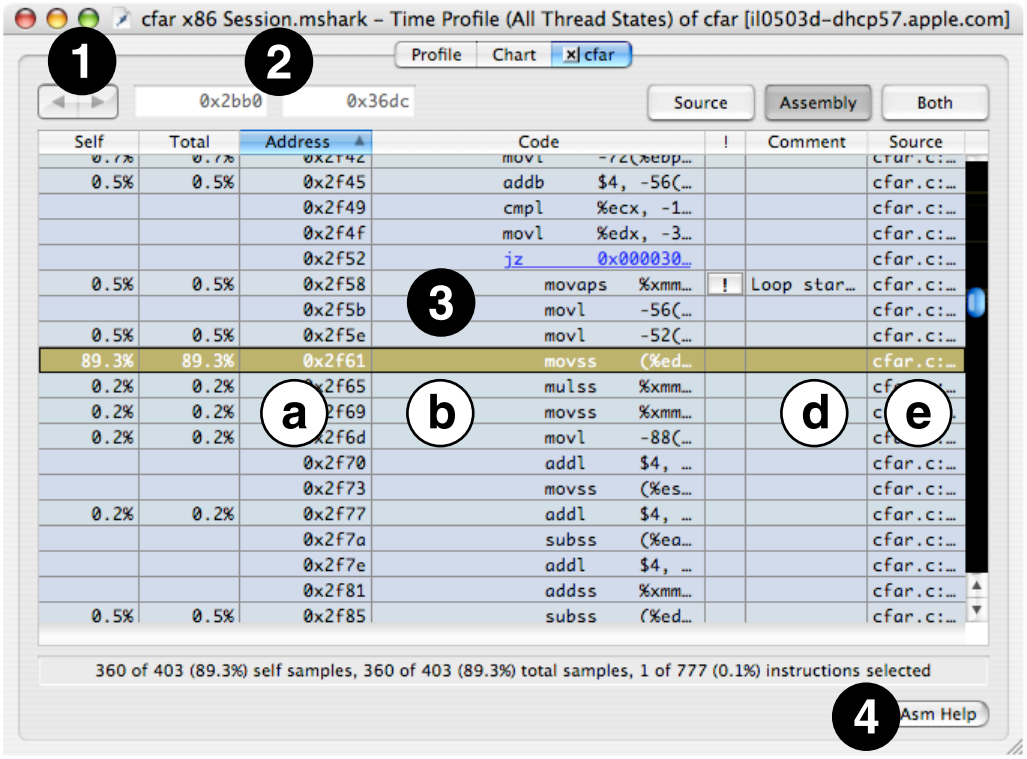
    c. *Cycles Column*— (not shown) This PowerPC-only column displays the latency (processor cycles before an instruction's result is available to dependent instructions) and repeat rate (processor cycles between completing instructions of this type when the corresponding pipeline is full) of the assembly instruction on this line, in processor cycles. In general, you will want to minimize the use of instructions with high latency, especially if the values that they produce are used by immediately following instructions. Use of instructions with poor (high number) repeat rates may also impact your performance if you try to issue them too frequently.

    d. *Comment Column*— In addition to its usual function of providing short versions of the code analysis tips, on PowerPC the comment column also displays information about how long the instruction must stall as a result of long latency by prior instructions. You will find that very low-level optimization hints, focused on particular assembly instructions, are provided here.

    e. *Source Column*— This shows the source file name and line number of where in the source code this instruction originated, when this is available. As with the *Code Column*, you can double-click here to get back to the *Source* display, scrolled to the line listed here.

4. **Asm Help Button**— Press this button to get help for the selected assembly-language instruction, as described in "ISA Reference Window" (page 51).

Figure 2-14 Assembly Browser



Advanced Code Browser Settings

The *Advanced Settings* drawer displays a new set of options if you switch to a *Code Browser* view ("Manual Session Symbolication"). These options allow you to customize the viewing of source and assembly code and turn on and off various features of the browser. These are many controls in this view:

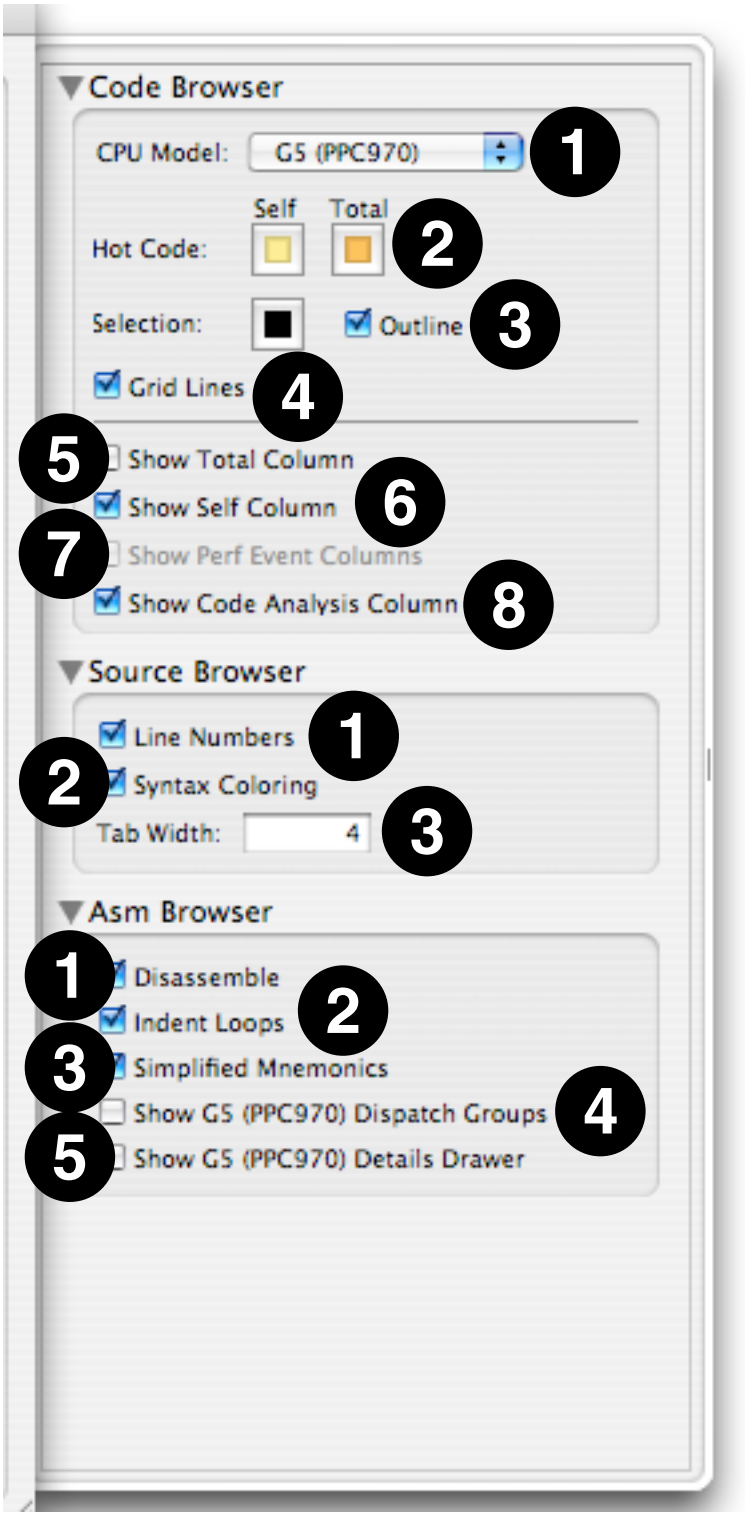
- **Code Browser**— This section affects the display of both source and assembly-language browsers.
  1. **CPU Model**— By default, Shark uses a model of the current system's CPU architecture when analyzing code sequences in order to determine instruction latencies and hints. You can select other CPU architectures by changing this setting.
  2. **Hot Code Colors**— Choose the colors that Shark uses to display the "hotness" of code here.
  3. **Selection Formatting**— Choose the color and whether or not an outline is used for code selections.
  4. **Grid Lines**— Adds grid lines between each line of code when checked (the default).
  5. **Show Total Column**— Toggles display of the column that lists the percentage of displayed references for each instruction or source line, including called functions.
  6. **Show Self Column**— Toggles display of the column that lists the percentage of displayed references for each instruction or source line, but *not* including called functions.
  7. **Show Perf Event Column(s)**— If the current profile contains performance counter information, this setting toggles display of that data within the browser. Otherwise, it will be disabled.

8. **Show Code Analysis Columns**— Toggles display of the columns that provide optimization tips.

- **Source Browser**— This section affects the display of the source browser only.
  1. **Line Numbers**— Toggles display of the column that lists the line number from the source code.
  2. **Syntax Coloring**— Enable this to have Shark color source code keywords, constants, comments, and such.
  3. **Tab Width**— Shark auto-indents loops by this number of spaces for every loop nest level.

- **Asm Browser**— This section affects the display of the assembly-language browser only.
  1. **Disassemble**— Choose whether to display disassembled mnemonics or raw hexadecimal values for the instructions.
  2. **Indent Loops**— Choose whether or not to have Shark auto-indent loops in the code here. Loops are found based on analysis of backwards branches in typical compiled code.
  3. **Simplified Mnemonics**— (PowerPC-only) Choose whether or not to enable full disassembly of instructions with constant values that specify special instruction modes, or to only disassemble to fundamental opcodes and leave the modifying constants intact for your examination.
  4. **Show G5 (PPC970) Dispatch Groups**— (PowerPC-only) Displays outlines on the main assembly-language grid showing the breakdown of the instructions into dispatch groups. Further details on is can be found in "Code Analysis with the G5 (PPC970) Model" (page 225). This function is always disabled for sessions recorded on Macs with other processor architectures.
  5. **Show G5 (PPC970) Details Drawer**— (PowerPC-only) Shark can display graphs of instruction dispatch slot and functional unit utilization in an additional, G5-specific "details" drawer. Further details on is can be found in "Code Analysis with the G5 (PPC970) Model" (page 225). This function is always disabled for sessions recorded on Macs with other processor architectures.

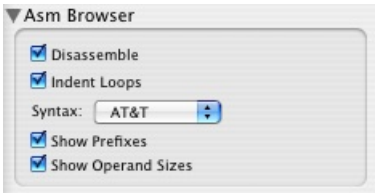
Figure 2-15 Advanced Settings for the Code Browser



Other architectures have slightly different options for items 3–5 of the **Asm Browser** settings. For x86-based systems, illustrated in , these options are:

- **Syntax**— Chooses whether to display the x86 instructions in Intel assembler syntax or AT&T syntax (the default).
- **Show Prefixes**— If checked, instruction prefixes (like `lock` and temporary mode shifts) will be displayed.
- **Show Operand Sizes**— If checked, each instruction explicitly encodes its operand size into the mnemonic (AT&T syntax) or operand list (Intel syntax). Otherwise, the code will be streamlined but it may not be possible to tell 8, 16, 32, and 64-bit versions of instructions apart.

Figure 2-16 x86 Asm Browser Advanced Settings



For ARM-based systems, illustrated in , the only option is:

- **ISA**— Selects to decode the instructions in the block as ARM (32-bit) instructions or Thumb (16-bit) instructions. The iOS uses both types of ARM instructions for different functions, so you may need to use this menu to switch from one to the other on a symbol-by-symbol basis.

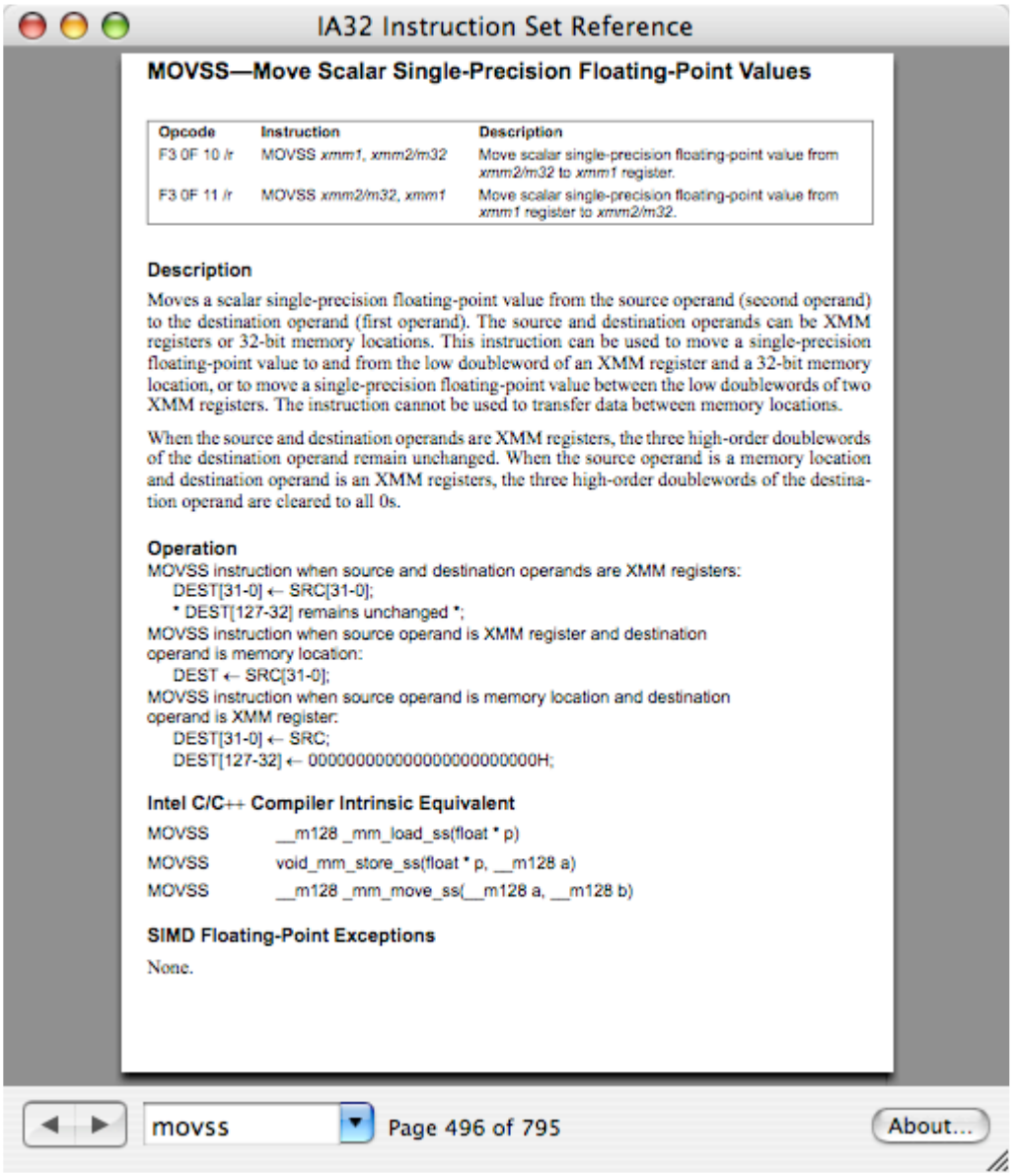
Figure 2-17 ARM Asm Browser Advanced Settings

ISA Reference Window

In order to understand the low-level analysis displayed in Shark's *Assembly Browser*, it may be helpful to view the underlying machine's instruction set architecture (ISA). You can display the PowerPC or Intel ISA Reference Manual (Figure 2-18) by clicking on the *Asm Help* button in the *Assembly Browser* or choosing the appropriate command from the *Help* menu: *Help*□*o*P*werPC ISA Reference*, *Help*□ *I*2*3SA Reference*, or *Help*□ *EM*6*4 ISA Reference*.

The *ISA Reference Window* provides an indexed, searchable interface to the PowerPC, IA-32 (32-bit x86), or EM64T (64-bit x86) instruction sets. The reference is also integrated with selection in the Shark *Assembly Browser* – selecting an instruction in the table causes the *ISA Reference Window* to jump to that instruction's definition in the manual.

Figure 2-18 ISA Reference Window



Tips and Tricks

This section points out a few things that you might see while looking at a *Time Profile*, what they may mean, and how to optimize your code if you see them. The tips and tricks listed herein are organized according to the view most commonly used to infer the associated behavior.

- **Profile Browser**
  - *Where should I start? :*

When first presented with a Profile Browser, you will want to begin in "Heavy View" sorted by "Self" and see what pops to the top. These will be the functions that execute the most, and probably have inner loops that may be susceptible to optimization. Do not forget to pop open disclosure triangles to see what functions are calling these functions; sometimes it is easier to optimize outer loops in these calling functions, instead of inner loops in the leaf functions. If any of these outer functions look promising, you may want to consider flipping to "Tree" view in order to see the caller-callee relationships a little more clearly.

- *No Samples Taken:*

  Shark will come up and report that it has not taken any samples if all of the threads in your application are blocked when you choose to sample one process using "Process Attach" (page 115) or "Process Launch" (page 115). In this case, you probably want to use *Time Profile (All Thread States)* (see "Time Profile (All Thread States)" (page 91)) to see where your threads are blocking.

  If you are using programmatic control of Shark's start and stop points (see "Programmatic Control" (page 125)), having no samples taken may also indicate that you are starting and stopping so quickly that there was simply no chance to take any meaningful samples. In this case, you should either adjust your start and stop points to increase the amount of time between them, increase the sampling rate (see "Taking a Time Profile" (page 31)), or both.

- *Too many symbols displayed:*

  If there is just too much clutter in the profile browser, then you need to use data mining. See "Data Mining" (page 139) for details on how to do this. Sometimes, switching between "Tree" and "Heavy" view can help organize the symbols in a more helpful way, also.

  If you are looking for a small number of known symbols in a large browser window, the *Edit□inFd□inFd* command (*Command-F*) and the related *Edit□inFd□inFd Next* (*Command-G*) and *Edit□inFd□inFd Previous* (*Command-Shift-G*) commands are probably your best bet. With these commands, Shark will automatically find and highlight the next instance of that library or symbol for you.

- *Lots of symbols have almost equal weight:*

  If you have many symbols popping up to the top of the list, the best thing is to quickly examine several of them using the Code Browser, while keeping an eye out for functions with loops that look easy-to-optimize.

Chart View

- *Different parts of the chart look visibly different:*

  Different-looking areas were probably created by different code in your program as it executes different program *phases* of execution. In most applications, each of these will need to be optimized separately. As a result, you may want to sample these with different Shark sessions, so that you can examine the different phases separately. Alternately, you may sample them all in one session and then use data mining (see "Data Mining" (page 139)) to focus more selectively on each phase as you examine the session.

- *What is executing at a point in the chart? :*

  Click on the chart at the point of interest and then open up the Callstack Table to see the stack for that sample (#4–6 in Figure 2-10 (page 40)). You can also double-click on the chart to open a Code Browser for the function executing at that point.

Code Browser

- *The assembly browser shows lots of MOV (x86) or LD/ST (PowerPC) instructions:*

If well over half of the instructions in your Assembly Browsers are memory access instructions, instead of actual computation, then it is quite likely that you forgot to turn on compiler optimization. One of the most important compiler optimizations is *register allocation*, which assigns variables to processor registers temporarily between operations. Without this — such as when you use Xcode's `gcc` with `-O0` optimization — the compiler will typically load and store all values to-and-from memory with every operation, resulting in multiple data movement instructions per computation instruction. WIth register allocation, however, the compiler will use registers to route data right from one computation instruction directly to another, resulting in significantly fewer instructions and hence faster code.

As a result of the significant "free" performance improvement possible using this and other optimizations, we suggest that you always use compiler optimization *before* using Shark (with Xcode's `gcc` we suggest `-O2`, `-Os`, or `-O3`).

- *I do not see any source:*

  Shark finds source code based on the full path to the source at the time it was compiled, but it recovers this source as you examine the session. If your source code moved or changed between compilation and session examination, or if you are recording and examining your session on a different Mac than you used for compilation, then you are likely to have trouble finding source. In this case, you will want to either recompile your source, in order to reset the paths correctly, or add the path to your source to Shark's list of source search paths, in "Shark Preferences" (page 23).

  Another common source of this problem is omitting the `-g` flag when you compile. You should only use Shark on fully-optimized, release-quality code, but default settings in development environments such as Xcode often turn off debugging options like `-g` when set to produce optimized code. As a result, you will often need to manually adjust the build settings to enable this option when using Shark. Please note that in Xcode you will need to adjust the build settings for the *Target* that you are testing and the correct (optimized) *build configuration*. Unfortunately, it is quite easy to set options for the wrong target or build configuration accidentally.

- *I want to see code coloring based on time spent here and in functions called by this code:*

  By default, the code browser only shows the *Self* value column, and code is colored based on these values, which are the percent of samples spent executing each line of code within the displayed function. If you are examining your code line-by-line, this is generally how you will want to see the weighting displayed. However, you may also be interested in seeing time spent within the function *and* all descendant functions that it calls. In this case, you will want to enable the *Total* column using the *Advanced Settings* drawer. The code browser's color scheme will then change to show weight coloring based on the values in this column, instead.

Example: Optimizing MPEG-2 using Time Profiles

In this section, Shark is used to increase the performance of the reference implementation of the MPEG-2 decoder (from mpeg.org) by 5.7x on a Mac Pro with 3.0 GHz Intel® Core 2™ processor cores.

Before beginning any performance study, it is critical to define your performance metric and to justify its relevance. Measurement of your metric should be both precise and consistent. Our performance metric for MPEG-2 was defined as the frame rate, in frames per second, of the decoder when decoding a reference movie. Unlike most video decoders, our test harness for the mpeg.org reference code let it decode as quickly as possible, without trying to keep the frame rate fixed at the rate at which it was originally recorded. As a result, the frame rate was a direct function of how fast the processor was able to do the actual decoding.

This kind of unlimited decoding speed is used for offline video decoding/encoding, a task performed almost constantly by video editing programs as they read and write video clips. In addition, higher decoding speed in playback settings where the processor is limited to a fixed frame rate is still a useful metric, because means that the processor will have more time between frames to do other tasks, decode larger frames, or simply shut down and save power for a longer time between frames.

Base

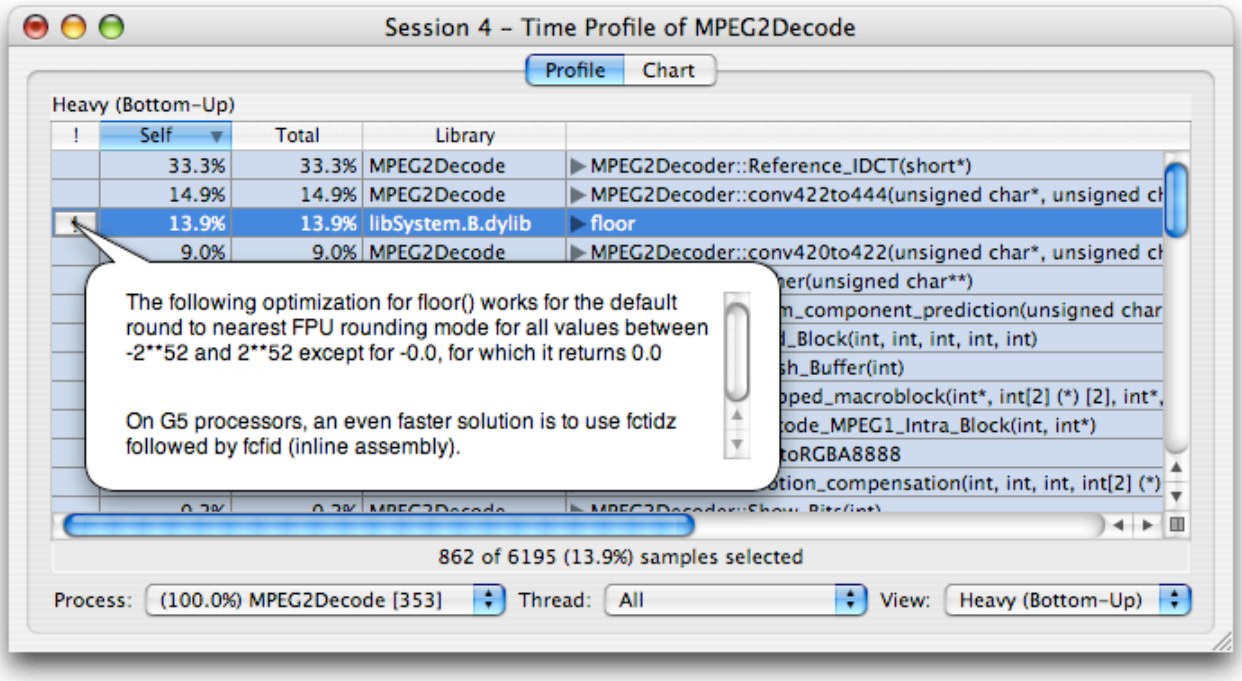
The reference MPEG-2 decoder source code consists of over 120 densely coded functions spread across more than 20 files. As a result, if one were handed the code and told to optimize it, the task would appear virtually hopeless — there is simply too much code to review in a reasonable amount of time! However, as in many programs, a large majority of the code handles initialization tasks and unusual corner cases, and is therefore only rarely executed. As a result, the actual quantity of code that needs modification in order to dramatically speed up the application is probably small, but Shark is required to locate it efficiently.

After compiling and running the reference decoder, Shark generated the session displayed in Figure 2-19. Just by pressing the "Start" and "Stop" button, we get a session that lets us see that about half the execution time is spent in a combination of the `Reference_IDCT()` function and the `floor()` function. By clicking the callout ( ) button to the left of the `floor()` function in the display, we see that Shark suggests we replace the `floor()` function with a simple, inline replacement. Following this advice garners a **1.12x** performance increase. This is not a huge improvement, but is very good for something that only takes a few minutes to perform.

Looking at the code more closely shows *why* `floor()` was required: the IDCT (Inverse Discrete Cosine Transform) function takes short integer input, converts to floating point for calculation, and then converts the results back to short integers. While this is a good way to keep the mathematics simple in the sample "reference" platform, the numerous type conversions and slow floating point arithmetic make this routine slow.

Converting to integer mathematics throughout avoids expensive integer□ FP□ger conversions and slow FP mathematics, at the expense of more convoluted math in the code. This code is available in the mpeg2play implementation (also available on mpeg.org). Switching the implementation to integer math resulted in a much more dramatic speedup over the original code of **1.86x**.

Figure 2-19 Original Time Profile, with Tuning Advice



Vectorization

Optimizing the `Reference_IDCT()` function by converting it from floating point to integer also presented another possible optimization that could be helpful: SIMD vectorization. All Intel Macintoshes support the SSE instruction set extensions, allowing them to process 128-bit vectors of data, and most PowerPC Macintoshes support the very similar AltiVec™ extensions. Although the methodology for vectorizing your code is beyond the scope of this document, there is a plethora of documentation and sample code available to you online at http://developer.apple.com/hardwaredrivers/ve/index.html. The very regular, mathematically intensive inner loops of the IDCT routine are perfect candidates for this kind of vectorization. Following the suggestion supplied by Shark in Figure 2-20 led to converting the IDCT routine to use SSE. Surprisingly, performance only increased to **2.05x**, with only a 10% improvement from vectorization.

At a point like this, where our optimization efforts result in non-intuitive results, it is generally a good idea to use Shark again to see how conditions have changed since our first measurement. This additional run of Shark produced the session in Figure 2-21. The vectorized IDCT function, `IWeightIDCT()`, now takes up less than 5% of the total execution time. The mystery is solved: as the IDCT function was optimized while other routines were not modified, those other, unoptimized routines became the performance bottleneck instead. Further examination with Shark quickly identified the key loops in several new functions. Because, like IDCT, they were performing complex math in tight inner loops, most of the new bottlenecks were also good targets for vectorization. As seen in Table 2-1, final optimization of motion compensation (`Flush_Buffer()` and `Add_Block()`), colorspace conversion (`dither()`), and pixel interpolation (`conv420to422()` and `conv422to444()`) achieved a speedup of **5.69x** over the original code — a dramatic improvement made possible in a relatively short amount of time thanks to the feedback provided by Shark.

Figure 2-20 Code Browser with Vectorization Hint

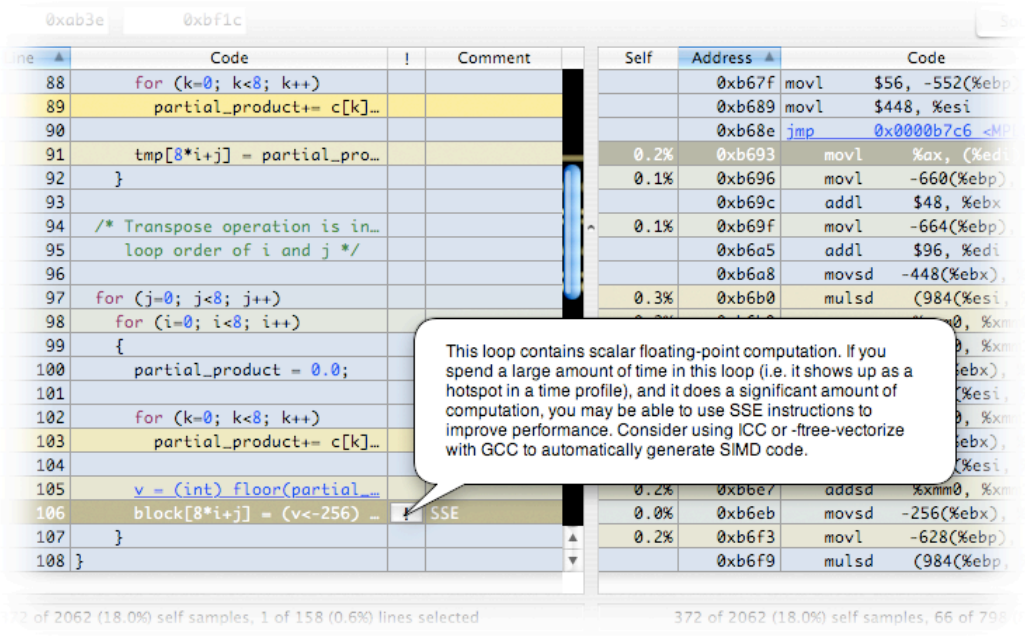


Figure 2-21 Time Profile after Vectorizing IDCT

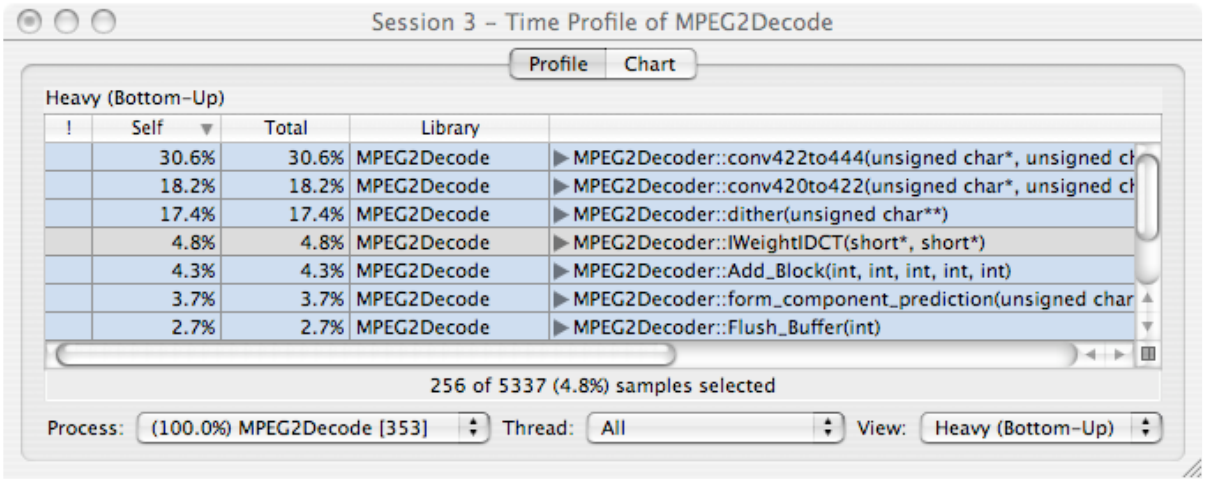


Table 2-1 MPEG-2 Performance Improvement

Optimization Step	Speedup
Original	1.00x
Fast `floor()`	1.12x
Integer IDCT	1.86x
Vector IDCT	2.05x

Optimization Step	Speedup
All Vector	5.69x

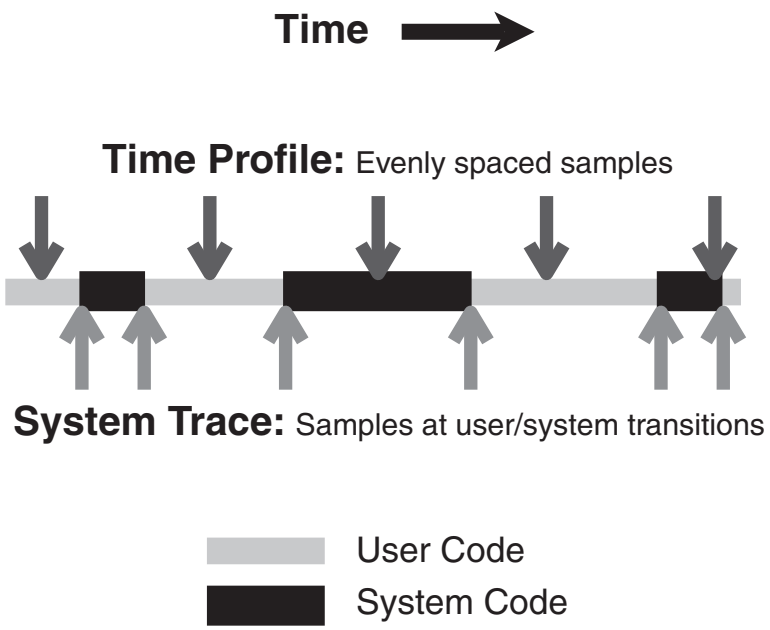
System Tracing

Shark's *System Trace* configuration records an exact trace of system-level events, such as system calls, thread scheduling decisions, interrupts, and virtual memory faults. *System Trace* allows you to measure and understand how your code interacts with Mac OS X and how the threads in your multi-threaded application interact with each other. If you would like to gain a clear understanding of the multi-threaded behavior of a given program, characterize user vs. system processor utilization, or understand the virtual memory paging behavior of your application, then *System Trace* can give you the necessary insight.

Tracing Methodology

System Trace complements Shark's default *Time Profiling* configuration (see "Time Profiling" (page 29)) by allowing you to see *all* transitions between OS and user code, a useful complement to the statistical sampling techniques used by *Time Profiling*. For example, in "Basic Usage" we can see an example of a thread of execution sampled by both a *Time Profile* (on top) and a *System Trace* (on the bottom). Time profiling takes evenly-spaced samples over the course of time, allowing us to get an even distribution of samples from various points of execution in both the user and system code segments of the application. This gives us a statistical view of what the processor was doing, but it does not allow us to see all user-kernel transitions — the first, brief visit to the kernel is completely missed, because it falls between two sample points. System tracing, in contrast, records an event for each user-kernel transition. Unlike time profiling, this does not give us an overview of *all* execution, because we are looking only at the transition borders and never in the execution time between them, but we gain an *exact* view of all of the transitions. This precision is often more useful when debugging user-kernel and multithreading problems, because these issues frequently hinge upon managing the precise timing of interaction *events* properly in order to minimize the time that threads spend waiting for resources (blocked), as opposed to minimizing execution time.

Figure 3-1 Time Profile vs. System Trace Comparison



As with most other profiling options available from Shark, System Trace requires no modification of your binaries, and can be used on released products. However, it is possible to insert arbitrary events into the System Trace Session using *Sign Posts*, which are discussed in detail in "Sign Posts" (page 84), if the built-in selection of events simply does not record enough information.

Basic Usage

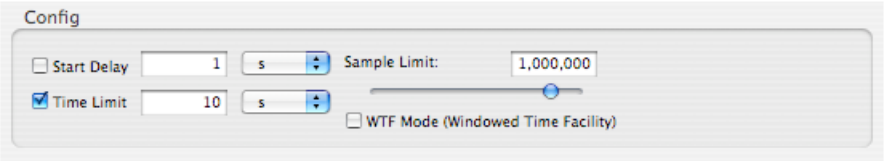
In its simplest usage, all you need to do is select System Trace from the Configuration Popup and start sampling. Shark will then capture up to 1,000,000 system events per-processor (a user-tunable limit), process the results, and display a session (see "Interpreting Sessions" (page 61)). In most cases, this should be more than enough data to interpret. Note that you cannot select a single process before you start tracing using the standard pop-up menu (from "Main Window" (page 17)); instead, if you only want to see a trace for a specific process or thread, you must narrow the *scope* of the traced events *after* the session is recorded (see "Interpreting Sessions" (page 61)).

In order to allow direct correlation of system events to your application's code, Shark records the following information with each event:

- Start Time
- Stop Time
- A backtrace of the user-space function calls (callstack) associated with each event
- Additional data customized depending on the event type that triggers recording (see "Trace View In-depth" (page 68) for details)

In the course of profiling your application, it may become necessary to trim or expand the number of events recorded. Most of the typical options are tunable by displaying the Mini Config Editor, depicted in Figure 3-2.

Figure 3-2 System Trace Mini Config Editor



The Mini Config Editor adds the following profiling controls to the main Shark window:

1. **Start Delay**— Amount of time to wait after the user selects "Start" before data collection actually begins.

2. **Time Limit**— The maximum amount of time to record samples. This is ignored if *Windowed Time Facility* is enabled, or if Sample Limit is reached before the time limit expires.

3. **Sample Limit** — The maximum number of samples to record. Specifying a maximum of *N* samples will result in at most *N* samples being taken, even on a multi-processor system, so this should be scaled up as larger systems are sampled. On the other hand, you may need to reduce the sample limit if Shark runs out of memory when you attempt to start a system trace, because it must be able to allocate a buffer in RAM large enough to hold this number of samples. When the sample limit is reached, data collection automatically stops, unless the *Windowed Time Facility* is enabled (see below). The Sample Limit is always enforced, and cannot be disabled.

4. **Windowed Time Facility**— If enabled, Shark will collect samples until you explicitly stop it. However, it will only store the last N samples, where N is the number entered into the Sample Limit field. This mode is described in "Windowed Time Facility (WTF)" (page 118).

If the user-level callstacks associated with each system event are of no interest to you, it is possible to disable their collection from within the Plugin Editor for the System Trace Data Source (see "System Trace Data Source PlugIn Editor" (page 179)), further reducing the overhead of system tracing. With callstack recording disabled, Shark will still record the instruction pointer associated with each event, but will not record a full callstack. Since most system calls come from somewhere within library code, you may lose some ability to relate system events to your code with callstack recording disabled.

Out of memory errors?: If you see these when starting a system trace, then just reduce the *Sample Limit* value until Shark is able to successfully allocate a buffer for itself.

Interpreting Sessions

Upon opening a System Trace session, Shark will present you with three different views, each in a separate tab. Each viewer has different strengths and typical usage:

- The *Summary View* provides an overall breakdown of where and how time was spent during the profiling session, and is very analogous to the *Profile Browser* used with Time Profile. You can use this information to ensure your application is behaving more-or-less as expected. For example, you can see if your program

is spending approximately the right amount of time in system calls that you were expecting. You can even click on the System Call Summary to find out *which* system calls are being used and open the disclosure triangles to see where, *in your code*, these calls are happening.

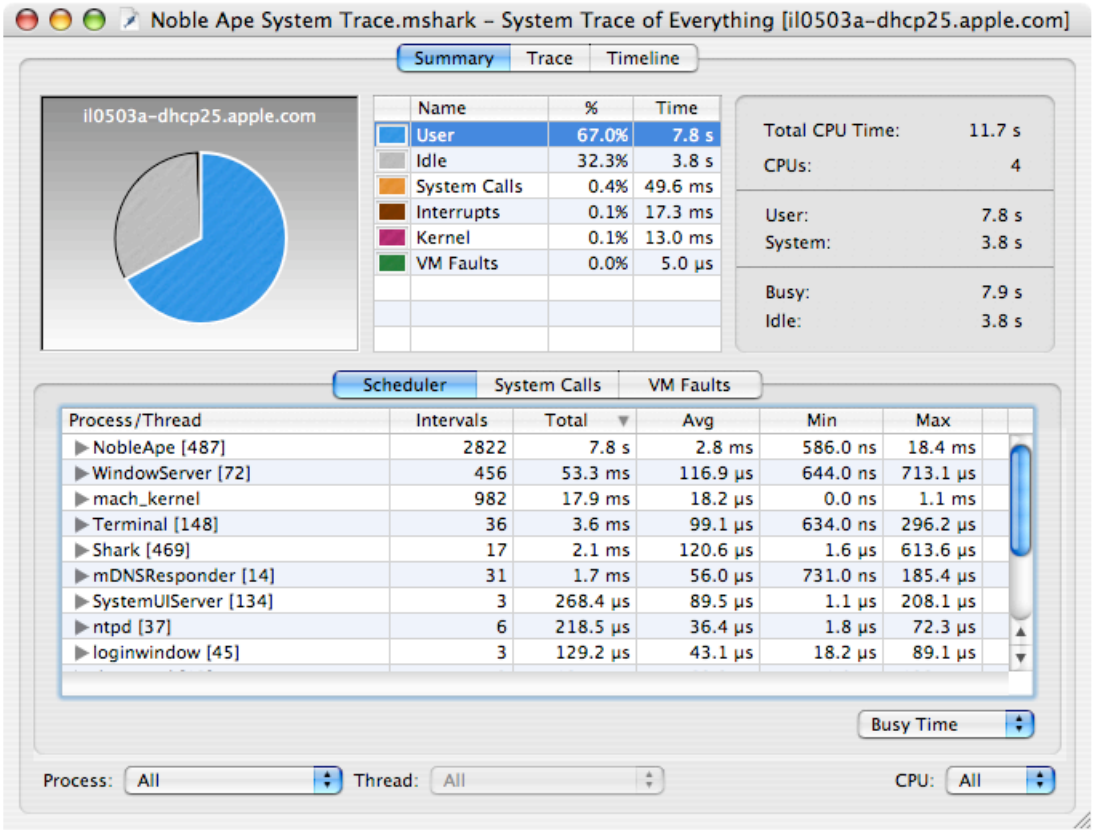
- The *Trace View* provides a complete trace of system events during the profiling session. Does the Summary View show that your CPU-bound threads are only getting an average of 200 microseconds of processor time every time they are scheduled? Flip to the Trace View to see why your threads are blocking so soon.
- The *Timeline View* provides a complete picture of system activity over the course of a session, similar to Time Profile's *Chart View*. You can use it to verify that your worker threads are running concurrently across all the processors in your system, or to visually inspect when various threads block.

All views show trace events from a configurable *scope* of your System Trace. The default scope is the entire system, but you can also focus the session view on a specific process, and even a specific thread within that process. Independently, you can choose to only view events from a single CPU. For example, when focusing on CPU 1 *and* thread 2, you will see only the events caused by thread 2 that also occurred on CPU 1. The current settings for the scope are set using the three popup menus at the bottom of all System Trace session windows, which select process, thread, and CPU, respectively.

Summary View In-depth

The *Summary View* is the starting point for most types of analysis, and is shown in Figure 3-3. Its most salient feature is a pie chart that gives an overview of where time was spent during the session. Time is broken down between user, system call, virtual memory fault, interrupt, idle, and other kernel time.

Figure 3-3 Summary View

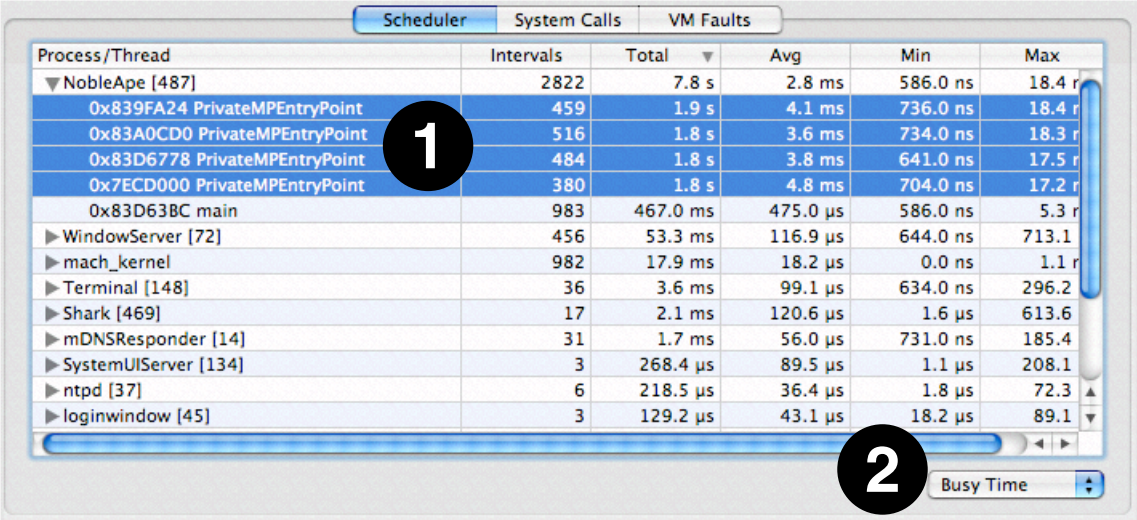


Underneath the pie chart, there are individual summaries of the various event types. Each of these is discussed in turn in the following subsections.

Scheduler Summary

The *Scheduler Summary* tab, shown in Figure 3-4, summarizes the overall scheduling behavior of the threads running in the system during the trace. Each thread is listed in the outline underneath its owning process, as shown at (1). To the left of each thread's name, Shark displays the number of run intervals of that thread (or all threads within a process) that it recorded in the course of this session.

Figure 3-4 Summary View: Scheduler



The *Total*, *Avg*, *Min* and *Max* columns list the total, average, minimum, and maximum values for the selected metric. A popup button below the outline (2) lists the supported metrics:

- **Busy Time**— Total time spent running, including both user and non-idle system time
- **User Time**— Total time spent running in user space
- **System Time**— Total time spent running in supervisor space (kernel and driver code)
- **Priority**— Dynamic thread priority used by the scheduler

Information about how your application's threads are being scheduled can be used to verify that what is actually happening on the system matches your expectations. Because the maximum time that a thread can run before it is suspended to run something else (the maximum *quantum* or *time slice*) is 10ms on Mac OS X, you can expect that a CPU-bound thread will generally be scheduled for several milliseconds per thread tenure. If you rewrite your CPU-bound, performance-critical code with multiple threads, and System Trace shows that these threads are only running for very short intervals (on the order of microseconds), this may indicate that the amount of work given to any worker thread is too small to amortize the overhead of creating and synchronizing your threads, or that there is a significant amount of serialization between these threads.

Note on Thread IDs: Thread IDs on Mac OS X are not necessarily unique across the duration of a System Trace Session. The Thread IDs reported by the kernel are not static, single use identifiers - they are actually memory addresses. When you destroy a thread, and then create a new one immediately thereafter, there is a very high probability that the new thread will have the same thread ID as the one you just destroyed. This can lead to some confusion when profiling multithreaded applications that create and destroy many threads.

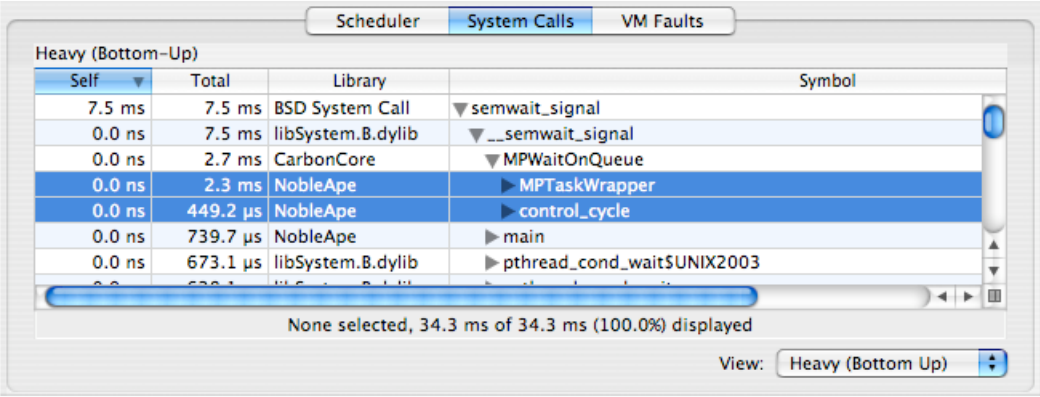
There are a couple of distinct ways to avoid this confusion. Your first option is to *park* your threads when you are profiling; if you don't let any new threads exit for the duration of profiling, it is not possible to get duplicate thread IDs. A better option is to utilize a work queue model: create enough threads to fully populate the processors in your system, and instead of destroying the threads when they are out of work, put them on a work queue to be woken up later with more work.

System Calls Summary

The *System Calls Summary* tab, shown in Figure 3-5, allows you to see the breakdown of system call time for each specific system call. Because System Trace normally records the user callstack for each system call, you can use this view to correlate system call time (and other metrics) directly to the locations in your application's code that make system calls. This view is quite similar to Time Profile's standard profile view, described in "Profile Browser" (page 32). In fact, many of the same tools are available. For example, the system call profile can be viewed as either a heavy or tree view (selected using the popup menu at the bottom). Similarly, data mining can be used to simplify complex system call callstacks (see "Data Mining" (page 139)).

More settings for modifying this display are available in the *Advanced Settings* drawer, and are described in "Summary View Advanced Settings" (page 67).

Figure 3-5 Summary View: System Calls



Note on System Trace callstacks: In rare cases, it is not possible for System Trace to accurately determine the user callstack for the currently active thread. In this case, it may just copy the callstack from the previous sample. While it occurs so rarely that it is usually not a problem, this "interpolation" can occasionally result in bad callstack information. As a result, you should carefully analyze Shark's system trace callstacks when the callstack information seems unusual or impossible.

Virtual Memory (VM) Faults Summary

The *VM Faults Summary* tab, depicted in Figure 3-6, allows you to see what code is causing virtual memory faults to occur. The purpose of this view is to help you find behavior that is normally transparent to software, and is obscured in a statistical time profile. Functionally, it acts just like the *System Calls Summary* tab.

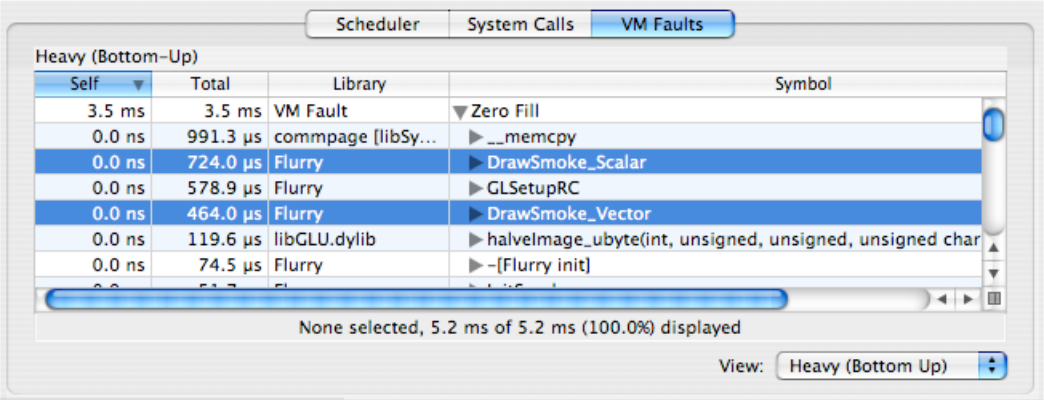
By default, virtual memory faults are broken down by type:

- **Page In**— A page was brought back into memory from disk.
- **Page Out**— A page was pushed out to disk, to make room for other pages.
- **Zero Fill**— A previously unused page marked "zero fill on demand" was touched for the first time.
- **Non-Zero Fill**— A previously unused page *not* marked "zero fill on demand" was touched for the first time. Generally, this is only used in situations when the OS knows that page being allocated will immediately be overwritten with new data, such as when it allocates I/O buffers.
- **Copy on Write (COW)**— A shared, read-only page was modified, so the OS made a private, read-write copy for this process.
- **Page Cache Hit**— A memory-resident but unmapped page was touched.
- **Guard Fault**— A page fault to a "guard" page. These pages are inserted just past the end of memory buffers allocated using the special MacOS X "guard malloc" routines, which can be used in place of normal memory allocations during debugging to test for buffer overrun errors. One of these faults is generated when the buffer overruns.
- **Failed Fault**— Any page fault (regardless of type) that started and could not be completed. User processes will usually die when these occur, but the kernel usually handles them more gracefully in order to avoid a panic.

In some cases, virtual memory faults can represent a significant amount of overhead. For example, if you see a large amount of time being spent in zero fill faults, and correlate it to repeated allocation and subsequent deallocation of temporary memory in your code, you may be able to instead reuse a single buffer for the entire loop, reallocating it only when more space is needed. This type of optimization is especially useful in the case of very large (multiple page) allocations.

More settings for modifying this display are available in the *Advanced Settings* drawer, and are described in "Summary View Advanced Settings" (page 67).

Figure 3-6 Summary View: VM Faults

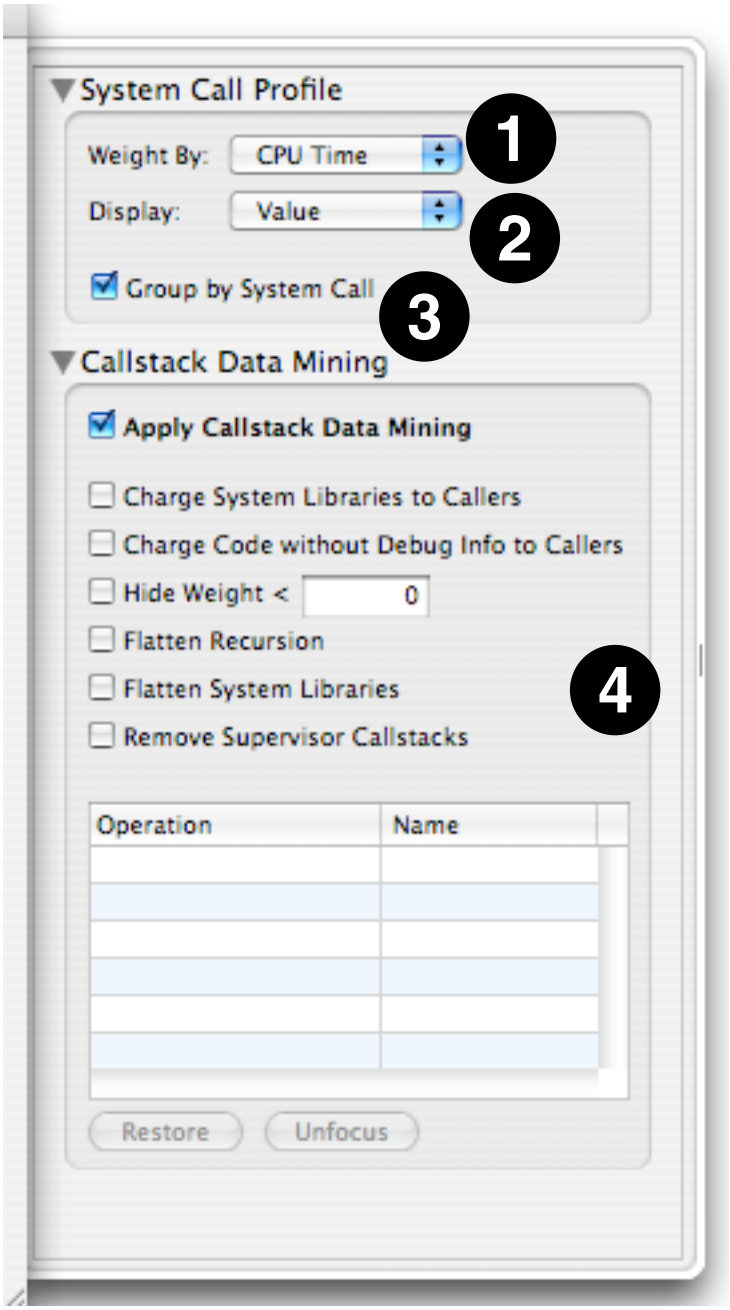


Summary View Advanced Settings

When you are viewing the *System Calls Summary* and *VM Faults Summary* tabs, several options are available in the *Advanced Settings* drawer (see "Advanced Settings Drawer" (page 22)), as seen in Figure 3-7:

1. **Weight By Popup**— the summary can construct the profile of system calls using several metrics. The following metrics can be selected:
   - *CPU Time*— Total system call or fault time spent actively running on a processor
   - *Wait Time*— Total system call or fault time spent blocked waiting on a resource or event
   - *Total Time*— Total system call or fault time, including both CPU and waiting time
   - *Count*— Total system call or fault count
   - *Size*— (VM fault tab only) Total number of bytes faulted, since a single fault can sometimes affect more than one page
2. **Display Popup**— This lets you choose between having the *Self* and *Total* columns display the raw *Value* for the selected metric or the percent of total system call or fault time. You can also change the columns between these modes individually by double clicking on either column.
3. **Group by System Call/VM Fault Type**— By default, the metrics are listed for each of the different *types* of system calls or faults in the trace. You can see summary statistics for all system calls or faults by deselecting this.
4. **Callstack Data Mining**— The System Call and VM Fault summaries support Shark's data mining options, described in "Data Mining" (page 139), which can also be used to customize the presentation of the data.

Figure 3-7 Summary View Advanced Settings Drawer



Trace View In-depth

The *Trace View* lists *all* of the events that occurred in the currently selected scope. Because events are most commonly viewed with "System" scope (all processes *and* all CPUs), each event list has a *Process* and a *Thread* column describing the execution context in which it took place.

As with the *Summary View*, the *Trace View* is sub-divided according to the class of event. The events in each *event class* (scheduler events, system calls, and VM Faults) are separately indexed, starting from 0. Each tab in the *Trace View* lists the index of the event (specific to each event class) in the *Index Column*.

Each tab in the *Trace View* supports multi-level (hierarchical) sorting of the event records, based on the order that you click column header row cells. This provides an extremely flexible means for searching the event lists. For example, clicking on the "CPU Time" column title will immediately sort by CPU Time. If you then click on the "Name" column title Shark will group events by Name, and then within each group of identically named events it will sort secondarily by CPU Time.

You may click on events in the table to select them. As with most Mac tables, you may Shift-click to extend a contiguous selection or Command-click to select discontiguous events. Below the main *Trace View* table, Shark presents a line summarizing key features of the selected trace event(s). This is particularly convenient if you select multiple events at once, because Shark will automatically add up key features of the selected events together and present the totals here.

You should note that double-clicking on any event in the trace list will jump to that event in the *Timeline View*. This is a helpful way to go directly to a spot of interest in a System Trace, because you can reliably scroll to the same point by double-clicking on the same trace element.

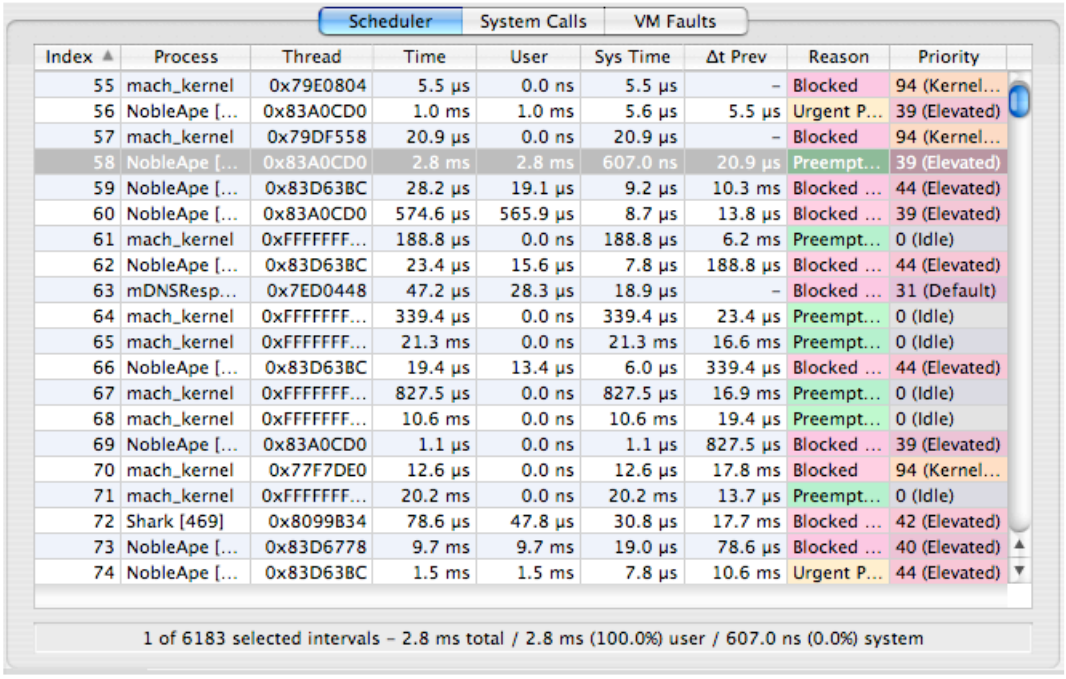
The remainder of this section will examine the three different tabs in the trace view window.

Scheduler Trace

The *Scheduler Trace* Tab, shown in Figure 3-8, lists the intervals that threads were running on the system. The meanings of the columns are as follows:

- **Index**— A unique index for the thread interval, assigned by Shark
- **Process**— Shows the process to which the scheduled thread belongs. The process' PID is in brackets after the name, which can be helpful if you have multiple copies of a process running simultaneously.
- **Thread**— The kernel's identifier for the thread
- **Time**— Total time (the sum of user and system time) that the thread ran
- **User Time**— Time that the thread spent executing user code during the interval
- **Sys Time**— Time that the thread spent executing system (kernel) code during the interval
- **Prev**— Time since this thread was previously scheduled
- **Reason**— Reason that the thread tenure ended (described in "Thread Run Intervals" (page 74))
- **Priority**— Dynamic scheduling priority of the thread

Figure 3-8 Trace View: Scheduler



Index	Process	Thread	Time	User	Sys Time	Δt Prev	Reason	Priority
55	mach_kernel	0x79E0804	5.5 µs	0.0 ns	5.5 µs	–	Blocked	94 (Kernel…
56	NobleApe […	0x83A0CD0	1.0 ms	1.0 ms	5.6 µs	5.5 µs	Urgent P…	39 (Elevated)
57	mach_kernel	0x79DF558	20.9 µs	0.0 ns	20.9 µs	–	Blocked	94 (Kernel…
58	NobleApe […	0x83A0CD0	2.8 ms	2.8 ms	607.0 ns	20.9 µs	Preempt…	39 (Elevated)
59	NobleApe […	0x83D63BC	28.2 µs	19.1 µs	9.2 µs	10.3 ms	Blocked …	44 (Elevated)
60	NobleApe […	0x83A0CD0	574.6 µs	565.9 µs	8.7 µs	13.8 µs	Blocked …	39 (Elevated)
61	mach_kernel	0xFFFFFFF…	188.8 µs	0.0 ns	188.8 µs	6.2 ms	Preempt…	0 (Idle)
62	NobleApe […	0x83D63BC	23.4 µs	15.6 µs	7.8 µs	188.8 µs	Blocked …	44 (Elevated)
63	mDNSResp…	0x7ED0448	47.2 µs	28.3 µs	18.9 µs	–	Blocked …	31 (Default)
64	mach_kernel	0xFFFFFFF…	339.4 µs	0.0 ns	339.4 µs	23.4 µs	Preempt…	0 (Idle)
65	mach_kernel	0xFFFFFFF…	21.3 ms	0.0 ns	21.3 ms	16.6 ms	Preempt…	0 (Idle)
66	NobleApe […	0x83D63BC	19.4 µs	13.4 µs	6.0 µs	339.4 µs	Blocked …	44 (Elevated)
67	mach_kernel	0xFFFFFFF…	827.5 µs	0.0 ns	827.5 µs	16.9 ms	Preempt…	0 (Idle)
68	mach_kernel	0xFFFFFFF…	10.6 ms	0.0 ns	10.6 ms	19.4 µs	Preempt…	0 (Idle)
69	NobleApe […	0x83A0CD0	1.1 µs	0.0 ns	1.1 µs	827.5 µs	Blocked …	39 (Elevated)
70	mach_kernel	0x77F7DE0	12.6 µs	0.0 ns	12.6 µs	17.8 ms	Blocked	94 (Kernel…
71	mach_kernel	0xFFFFFFF…	20.2 ms	0.0 ns	20.2 ms	13.7 µs	Preempt…	0 (Idle)
72	Shark [469]	0x8099B34	78.6 µs	47.8 µs	30.8 µs	17.7 ms	Blocked …	42 (Elevated)
73	NobleApe […	0x83D6778	9.7 ms	9.7 ms	19.0 µs	78.6 µs	Blocked …	40 (Elevated)
74	NobleApe […	0x83D63BC	1.5 ms	1.5 ms	7.8 µs	10.6 ms	Urgent P…	44 (Elevated)

System Call Trace

The *System Call Trace* Tab, shown in Figure 3-9, lists the system call events that occurred during the trace. In most respects, this Tab behaves much like the scheduler tab described previously, but it does have a couple of new features.

You can inspect the first five integer arguments to each system call by selecting an entry in the table and looking at the `arg` fields near the bottom of the window.

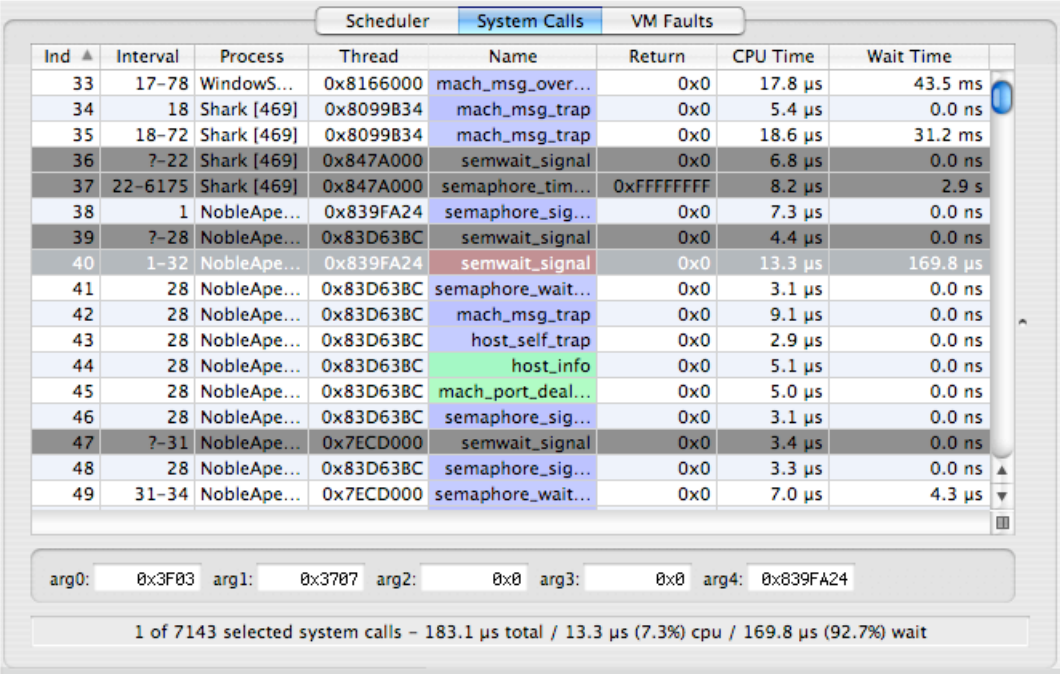
The current user callstack is recorded for each system call. You can toggle the display of the *Callstack Table* by clicking the  button in the lower right corner of the trace table. When visible, the *Callstack Table* displays the user callstack for the currently selected system call entry.

The meanings of the columns are as follows:

- **Index**— A unique index for the system call event, assigned by Shark
- **Interval**— Displays thread run interval(s) in which the system call occurred. Each system call occurs over one or more thread run intervals . If the system call begins and ends in the same thread interval, the *Interval Column* for that event lists only a single number: the index of the thread interval in which the event occurred. Otherwise, the beginning and ending thread interval indices are listed. Because it is possible for an event to start before the beginning of a trace session, or end after a trace session is stopped, event records may be incomplete. Incomplete events are listed with "?" for the unknown thread run interval index, and have a gray background in the event lists.
- **Process**— Shows the process in which the system call occurred. The process' PID is in brackets after the name, which can be helpful if you have multiple copies of a process running simultaneously.
- **Thread**— Thread in which the system call occurred

- **Name**— Name of the system call
- **Return**— Shows the return value from the system call. Many system calls return zero for success, and non-zero for failure, so you can often spot useless system calls by looking for multiple failures. Eliminating streams of these can reduce the amount of time an application spends in wasted system call overhead.
- **CPU Time**— Time spent actively running on a processor
- **Wait Time**— Time spent blocked waiting on a resource or event

Figure 3-9 Trace View: System Calls



VM Fault Trace

The *VM Fault Trace* Tab, illustrated in Figure 3-10, lists the virtual memory faults that occurred. The current user callstack, if any, is recorded for each VM fault.

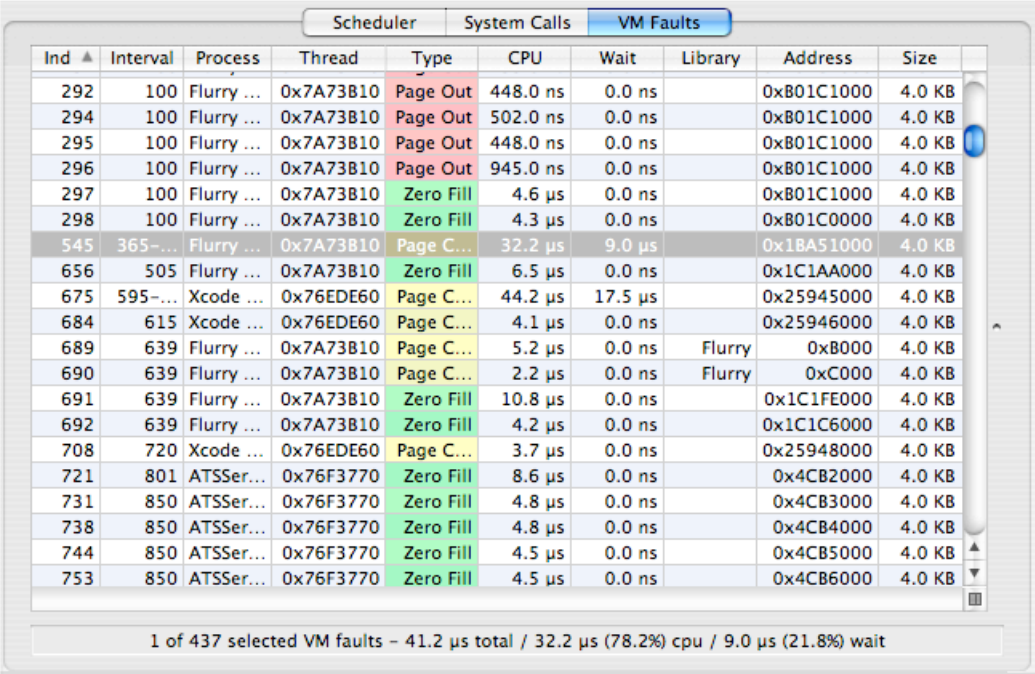
You can toggle the display of the *Callstack Table*, which displays the user callstack for the currently selected VM fault entry, by clicking the  button in the lower right corner of the trace table.

The columns in the trace view have the following meanings in this tab:

- **Index**— A unique index for the VM fault event, assigned by Shark
- **Interval**— Displays thread run interval(s) in which the VM fault occurred. Each fault occurs over one or more thread run intervals. If the fault begins and ends in the same thread interval, the *Interval Column* for that event lists only a single number: the index of the thread interval in which the event occurred. Otherwise, the beginning and ending thread interval indices are listed. Because it is possible for an event to start before the beginning of a trace session, or end after a trace session is stopped, event records may be incomplete. Incomplete events are listed with "?" for the unknown thread run interval index, and have a gray background in the event lists.

- **Process**— Shows the process in which the VM fault occurred. The process' PID is in brackets after the name, which can be helpful if you have multiple copies of a process running simultaneously.
- **Thread**— Thread in which the VM fault occurred
- **Type**— Fault type (see "Virtual Memory (VM) Faults Summary " (page 66) for descriptions)
- **CPU Time**— Time spent actively running on a processor
- **Wait Time**— Time spent blocked waiting on a resource or event
- **Library**— In the case of a code fault, this lists the framework, library, or executable containing the faulted address. In contrast, it is blank for faults to data regions, such as the heap or stack.
- **Address**— Address in memory that triggered the fault
- **Size**— Number of bytes affected by the fault, an integral multiple of the 4096-byte system page size

Figure 3-10 Trace View: VM Faults



Ind	Interval	Process	Thread	Type	CPU	Wait	Library	Address	Size
292	100	Flurry ...	0x7A73B10	Page Out	448.0 ns	0.0 ns		0xB01C1000	4.0 KB
294	100	Flurry ...	0x7A73B10	Page Out	502.0 ns	0.0 ns		0xB01C1000	4.0 KB
295	100	Flurry ...	0x7A73B10	Page Out	448.0 ns	0.0 ns		0xB01C1000	4.0 KB
296	100	Flurry ...	0x7A73B10	Page Out	945.0 ns	0.0 ns		0xB01C1000	4.0 KB
297	100	Flurry ...	0x7A73B10	Zero Fill	4.6 µs	0.0 ns		0xB01C1000	4.0 KB
298	100	Flurry ...	0x7A73B10	Zero Fill	4.3 µs	0.0 ns		0xB01C0000	4.0 KB
545	365-...	Flurry ...	0x7A73B10	Page C...	32.2 µs	9.0 µs		0x1BA51000	4.0 KB
656	505	Flurry ...	0x7A73B10	Zero Fill	6.5 µs	0.0 ns		0x1C1AA000	4.0 KB
675	595-...	Xcode ...	0x76EDE60	Page C...	44.2 µs	17.5 µs		0x25945000	4.0 KB
684	615	Xcode ...	0x76EDE60	Page C...	4.1 µs	0.0 ns		0x25946000	4.0 KB
689	639	Flurry ...	0x7A73B10	Page C...	5.2 µs	0.0 ns	Flurry	0xB000	4.0 KB
690	639	Flurry ...	0x7A73B10	Page C...	2.2 µs	0.0 ns	Flurry	0xC000	4.0 KB
691	639	Flurry ...	0x7A73B10	Zero Fill	10.8 µs	0.0 ns		0x1C1FE000	4.0 KB
692	639	Flurry ...	0x7A73B10	Zero Fill	4.2 µs	0.0 ns		0x1C1C6000	4.0 KB
708	720	Xcode ...	0x76EDE60	Page C...	3.7 µs	0.0 ns		0x25948000	4.0 KB
721	801	ATSSer...	0x76F3770	Zero Fill	8.6 µs	0.0 ns		0x4CB2000	4.0 KB
731	850	ATSSer...	0x76F3770	Zero Fill	4.8 µs	0.0 ns		0x4CB3000	4.0 KB
738	850	ATSSer...	0x76F3770	Zero Fill	4.8 µs	0.0 ns		0x4CB4000	4.0 KB
744	850	ATSSer...	0x76F3770	Zero Fill	4.5 µs	0.0 ns		0x4CB5000	4.0 KB
753	850	ATSSer...	0x76F3770	Zero Fill	4.5 µs	0.0 ns		0x4CB6000	4.0 KB

Timeline View In-depth

The *Timeline View*, displayed in Figure 3-11, allows you to visualize a *complete* picture of system events and threading behavior in detail, instead of just summaries. Each row in the timeline corresponds to a traced thread, with the horizontal axis representing time. At a glance, you can see when and why the threads in your system start and stop, and how they interact with the system when they are running.

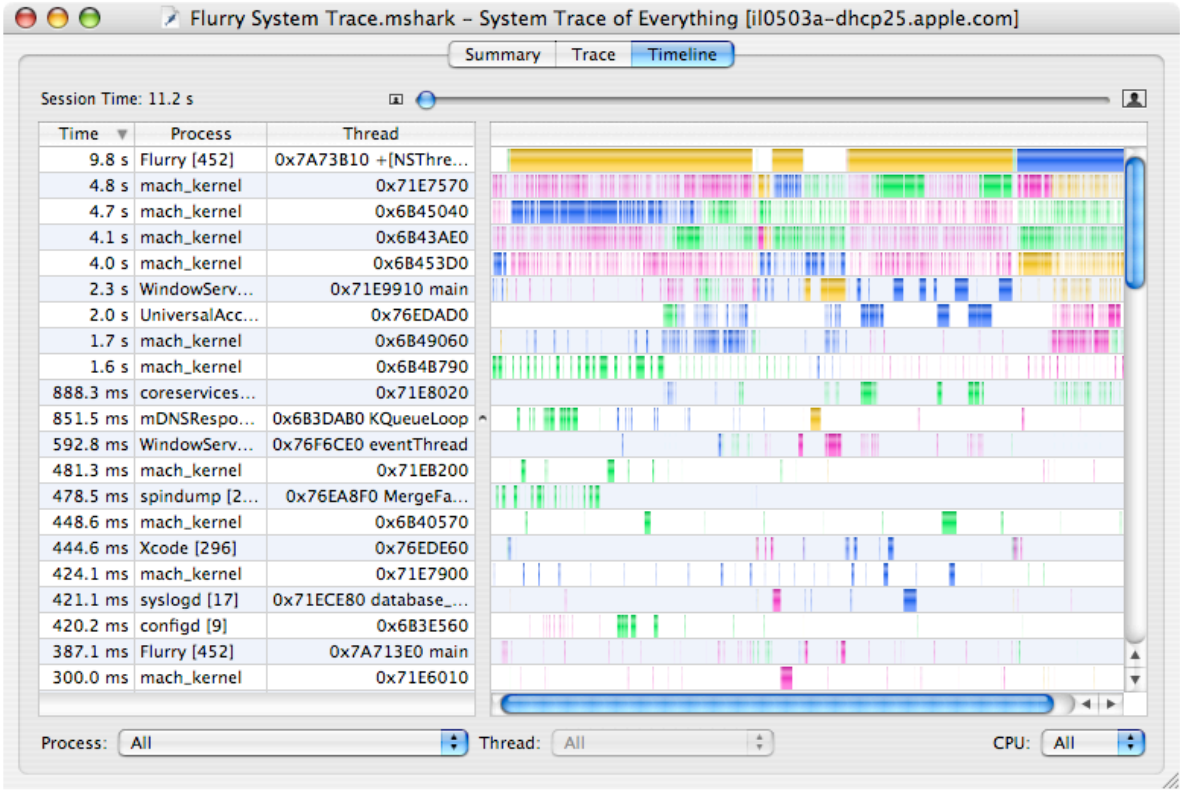
Session timelines are initially shown in their entirety. Because a typical session has thousands or millions of events in it, this initially means that you can only see a broad overview of when threads are running. Events such as system calls and VM faults are labeled with icons, but these icons are automatically hidden if there

is insufficient space to display them, as is usually the case when the trace is completely zoomed out. Hence, to see and examine these events, you will need to zoom in on particular parts of the timeline display and then maneuver around to see other parts of the display. There are 3 main ways to perform this navigation:

- **Scroll/Zoom Bars**— Use the scroll bar at the bottom of the window to scroll side to side, and zoom with the slider at the top of the window.
- **Mouse Dragging**— Click and drag anywhere (or "rubber-band") within the main Timeline View to form a box. When you release the mouse bottom, the Timeline View will zoom so that the horizontal portion of the box fits on screen (until you reach the maximum zoom level).
- **Keyboard Navigation**— After highlighting a Thread Run Interval by clicking on it, the Left or Right Arrow keys will take you to the previous or next run interval from the same thread, respectively. If you highlighted a System Call, VM Fault, or Interrupt, the arrow keys will scroll to the next event of any of these types. Holding the Option key, however, will scroll to the next event of the *same* type. For example, if you had clicked on a Zero Fill Fault, the Right Arrow would take you to the next event on the same thread, whether it was a System Call, VM Fault, or Interrupt, but Option-Right Arrow would take you to the next Zero Fill Fault on the same thread.

If you have too many threads, the *Timeline View* allows you to limit the scope of what is displayed using the standard scope-control menus described in "Interpreting Sessions" (page 61), at the bottom of the window. There are also many options for filtering out events in the *Advanced Settings* drawer, as described in "Timeline View Advanced Settings" (page 81).

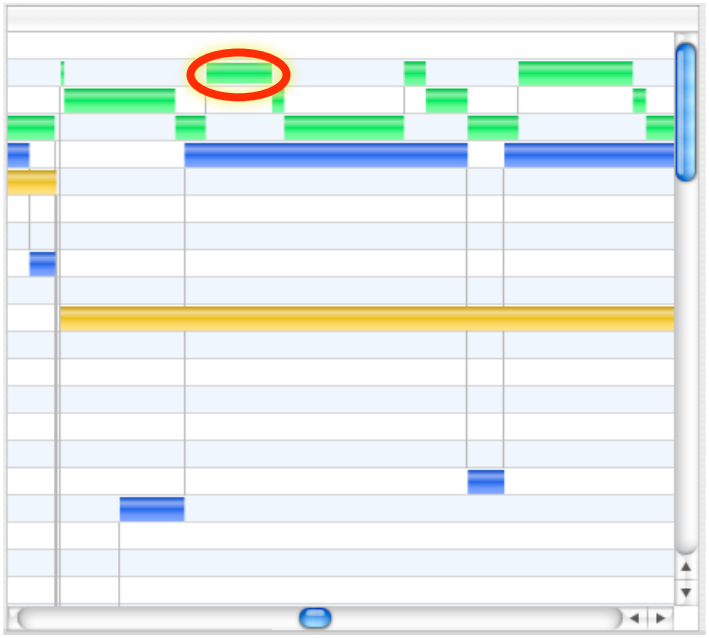
Figure 3-11 Timeline View



Thread Run Intervals

Each time interval that a thread is actively running on a CPU is a *thread run interval*. Thread run intervals are depicted as solid rectangles in the *Timeline View*, as is shown in Figure 3-12, with lines depicting context switches joining the ends of the two threads running before and after each context switch.

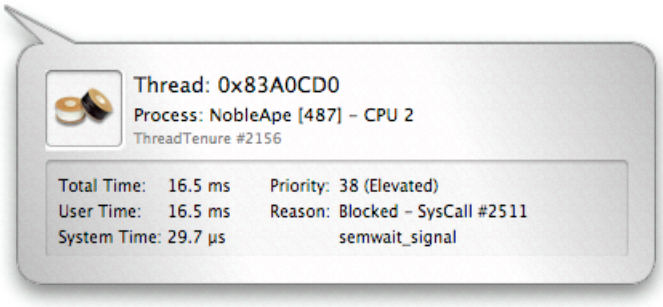
Figure 3-12 Timeline View: Thread Run Intervals



Thread interval lines can be colored according to several metrics, including the CPU on which the thread ran, its dynamic priority, and the reason the thread was switched out. See "Timeline View Advanced Settings" (page 81) for more information on how to control this.

You can inspect any thread run interval in the Timeline View by clicking on it. The inspector (see Figure 3-13) will indicate the amount of time spent running in user mode and supervisor mode, the reason the thread was switched out, and its dynamic priority.

Figure 3-13 Thread Run Interval Inspector



There are five basic reasons a thread will be switched out by the system to run another thread:

Blocked— The thread is waiting on a resource and has voluntarily released the processor while it waits.

Explicit Yield— The thread voluntarily released its processor, even though it is not waiting on any particular resource.

Quantum Expired— The thread ran for the maximum allowed time slice, normally 10ms, and was therefore interrupted and descheduled by the kernel.

Preemption— A higher priority thread was made runnable, and the thread was interrupted in order to switch to that thread. It is also possible to be "urgently" preempted by some real-time threads.

Urgent Preemption— Same as previous, except that the thread preempting us *must* have the processor immediately, usually due to real-time constraints.

System Calls

System calls represent explicit work done on behalf of the calling process. They are a secure way for user-space applications to employ kernel APIs. On Mac OS X, these APIs can be divided into four groups:

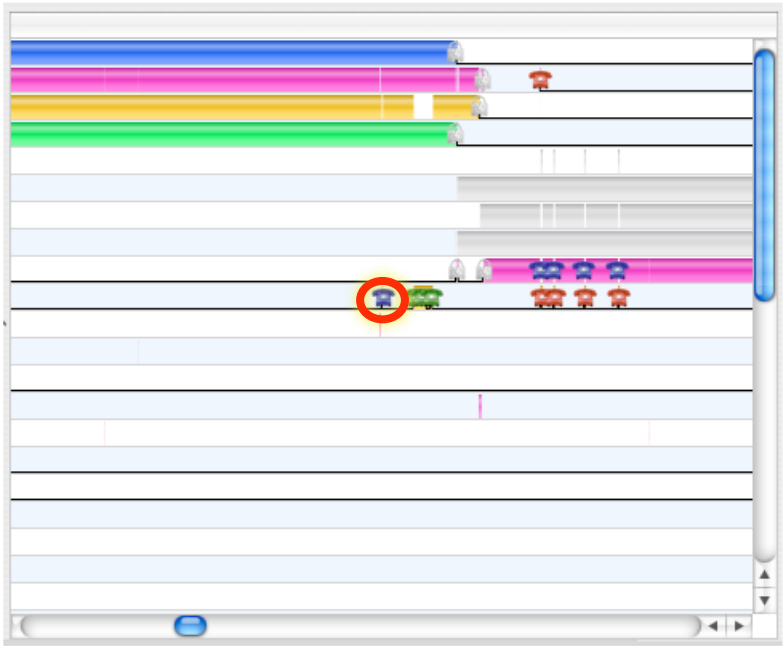
BSD— Syscall, ioctl, sysctl APIs

Mach— Basic services and abstractions (ports, locks, etc.)

Locks— *pthread mutex* calls that trap to the kernel. These are a subset of Mach system calls.

MIG Message— Mach interface generator routines, which are usually only used within the kernel

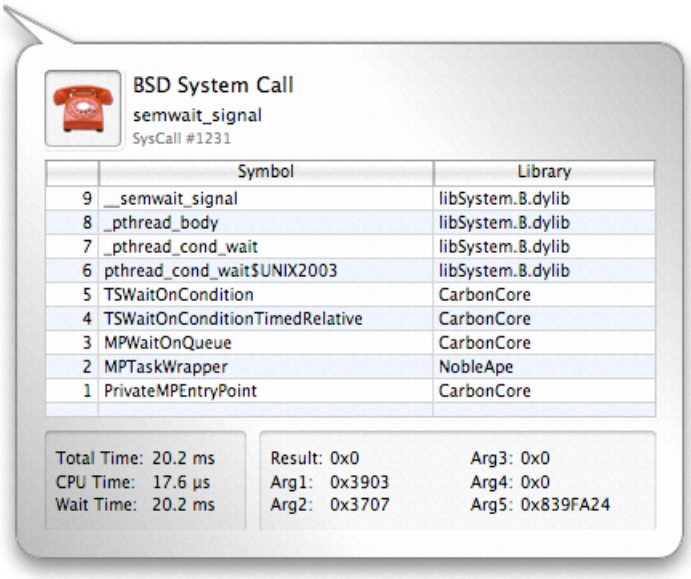
Figure 3-14 Timeline View: System Calls



Calls from all of these groups are visible in Figure 3-14. Clicking on the icon for a system call will bring up the System Call Inspector, as seen in Figure 3-15. The resulting inspector displays many useful pieces of information which you can use to correlate the system call to you application's code. The listed information includes:

- **Type**— The system call icon and a textual description
- **Name**— The system call name
- **Number**— The system call's event index number (its number in the Trace View)
- **Callstack**— A backtrace of user space function calls that caused the system call
- **Time** — Total, CPU, and wait time
- **Result**— The return value from the call
- **Arguments**— The first four integer arguments

Figure 3-15 System Call Inspector



VM Faults

As is the case with almost all modern operating systems, Mac OS X implements a virtual memory system. Virtual memory works by dividing up the addressable space (typically 4GB on a 32-bit machine, currently 256 TB on 64-bit machines) into pages (typically 4 KB in size). Pages are brought into available physical memory from a backing store (typically a hard disk) on demand through the page fault mechanism. In addition to efficiently managing a system's available physical memory, this added level of indirection provided by the virtual to physical address mapping allows for memory protection, shared memory, and other modern operating system capabilities. There are five virtual memory events on Mac OS X, all of which are faults (running code is interrupted to handle them the first time the page is touched) except for page outs, which are completed asynchronously.

Page In— A page was brought back into memory from disk.

Page Out— A page was pushed out to disk, to make room for other pages.

Zero Fill— A previously unused page marked "zero fill on demand" was touched for the first time.

Non-Zero Fill— A previously unused page *not* marked "zero fill on demand" was touched for the first time. Generally, this is only used in situations when the OS knows that page being allocated will immediately be overwritten with new data, such as when it allocates I/O buffers.

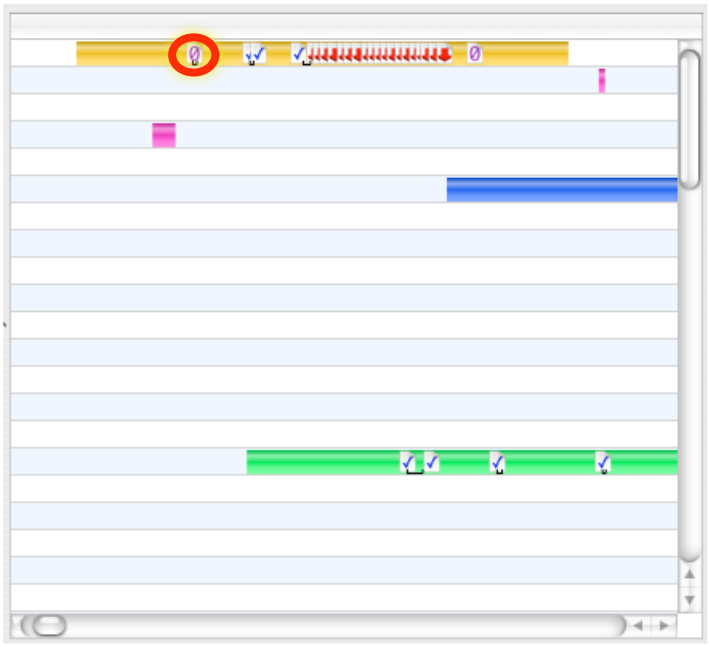
Copy on Write (COW)— A shared, read-only page was modified, so the OS made a private, read-write copy for this process.

Page Cache Hit— A memory-resident but unmapped page was touched.

Guard Fault— A page fault to a "guard" page. These pages are inserted just past the end of memory buffers allocated using the special MacOS X "guard malloc" routines, which can be used in place of normal memory allocations during debugging to test for buffer overrun errors. One of these faults is generated when the buffer overruns.

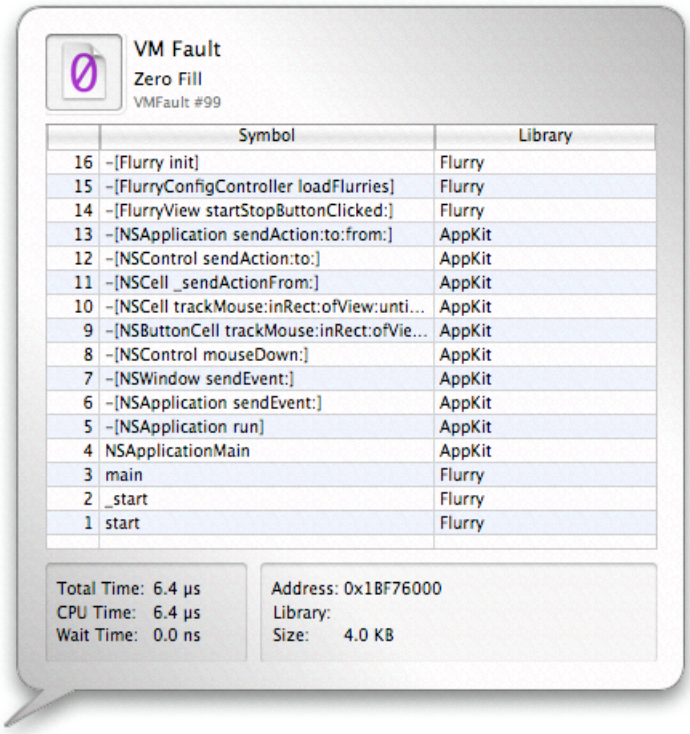
Failed Fault— Any page fault (regardless of type) that started and could not be completed. User processes will usually die when these occur, but the kernel usually handles them more gracefully in order to avoid a panic.

Figure 3-16 Timeline View: VM Faults



Three of these types of faults are visible in Figure 3-16. A zero-fill fault is circled to highlight it. Clicking on a VM Fault Icon will bring up the VM Fault Inspector, as seen in Figure 3-17. This inspector functions much like the System Call Inspector, except instead of listing arguments and return values, the VM Fault Inspector lists the fault address, size, and — for code faults — the library in which it occurred.

Figure 3-17 VM Fault Inspector



Interrupts

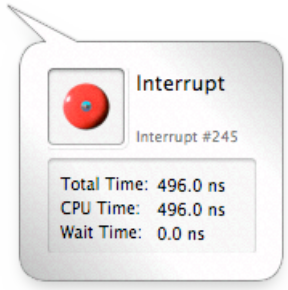
Interrupts are asynchronous signals that external hardware devices use to communicate to the processor that they require servicing. Most are associated with I/O devices, and signal either that new data has been received by an input device or that an output device needs more data to send. However, there are also other sources of interrupts inside of the computer system, such as DMA controllers and clock timers.

Here is an interrupt icon: 

Because interrupts occur asynchronously, there is no correlation between the source of the interrupt and the thread being interrupted. As a result, and because most users of System Trace are primarily interested in examining the threading behavior of their own programs, the display of interrupt events in the *Timeline View* is disabled by default. See "Timeline View Advanced Settings" (page 81) for instructions on how to enable these.

Clicking on an Interrupt icon will bring up the Interrupt Inspector. This inspector lists the amount of time the interrupt consumed, broken down by CPU and wait time.

Figure 3-18 Interrupt Inspector



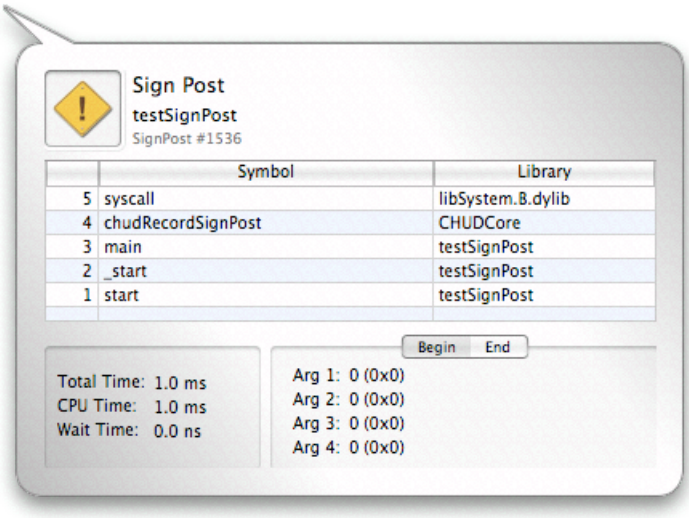
Sign Posts

You can often get a good idea of your application's current state by inspecting the user callstacks associated with the built-in VM fault and system call events that occur in your application. But an even more precise technique is to instrument your application with *Sign Post* events at critical points in your code (see "Sign Posts" (page 84) for instructions as to how you can do this). For example, if you are developing an application that operates on video frames, you can insert a sign post marker whenever the processing of a new frame starts.

Here is a sign post icon: 

Sign posts are displayed in the timeline alongside the other events. You can inspect each sign post by clicking its icon in the timeline. The inspector will indicate which thread it came from, its event name, the 4 user-specified ancillary data values for both the begin and the end point, and the associated user callstack (if any). If the sign post is an "interval" sign post, an under-bar will indicate its duration on the timeline, and the inspector will list the amount of time spent on the CPU and time spent Waiting between the begin and end event. Since you can supply different arguments to the start and end points of an interval sign post, the inspector supplies "Begin" and "End" tabs that display the arguments supplied to the start and end points, respectively.

Figure 3-19 Sign Post Inspector



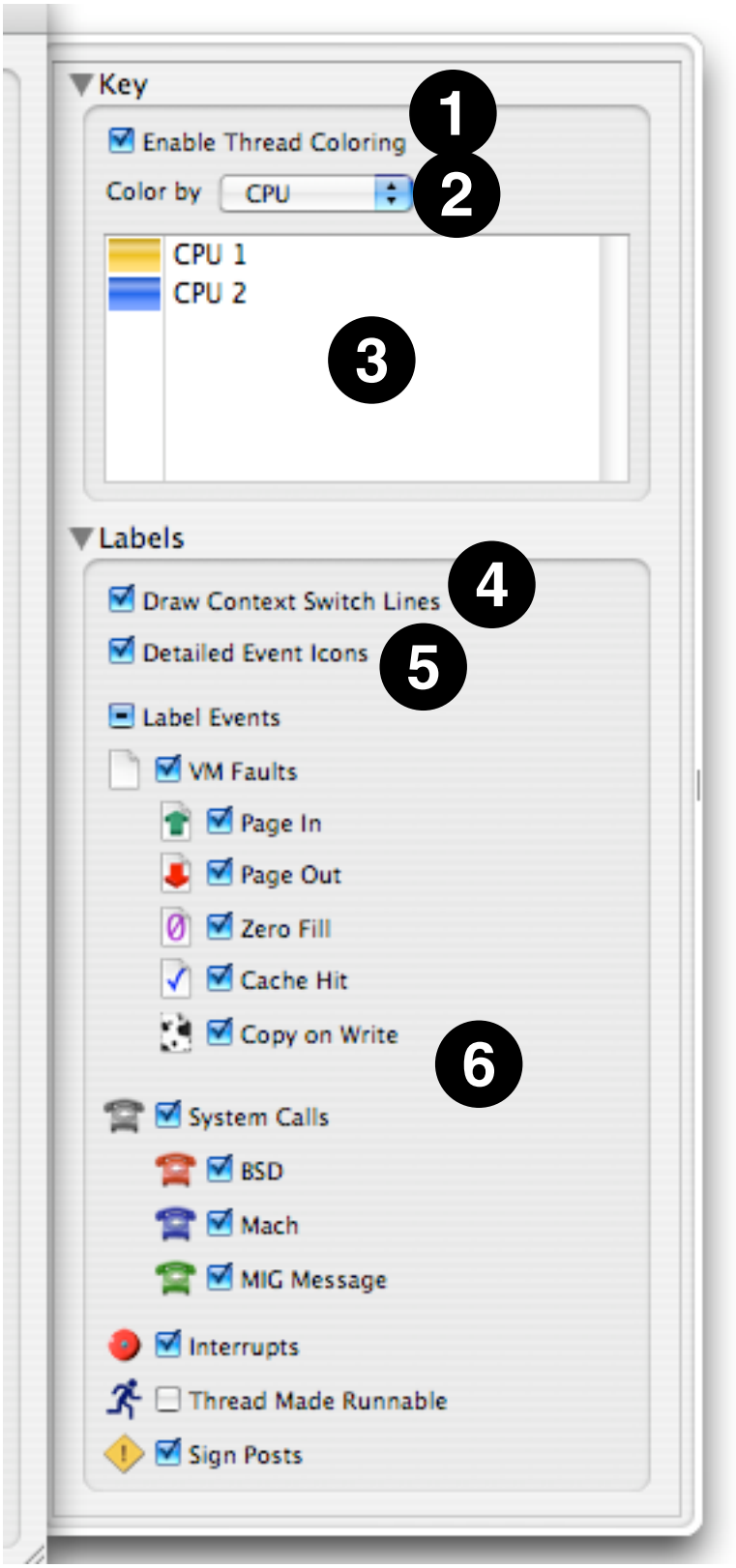
Timeline View Advanced Settings

While you are in *Timeline View*, several options are available in the *Advanced Settings* drawer (see "Advanced Settings Drawer" (page 22)), as seen in Figure 3-20.

1. **Enable Thread Coloring**— When enabled (the default), Shark attempts to color-code the threads in the timeline display using one of the algorithms selected below.
2. **Color By**— Assuming that you do choose to use thread coloring, this menu allows you to choose from among several different color schemes that allow you to see different trends:
   - **CPU**— Each CPU is assigned a different color, so you can see both how a processor is bouncing from one thread to another or, alternately, how a thread is bouncing from one processor to another. This is the default, and usually the most useful coloration.
   - **Priority**— Thread priority is assigned a color on a gradient from deep blue-violet colors (low priority) to bright, hot yellows and oranges (high priority). Mac OS X changes thread priority dynamically, depending upon how much CPU time each thread gets, so this color scheme is useful to see the effects of these dynamic changes over time.
   - **Reason**— Colors each thread run tenure based on the reason that it ended. See "Thread Run Intervals" (page 74) for a list of the possible reasons that are used to color-code thread tenures.
3. **Color Key**— Displays the colors that Shark is currently using to display your threads.
4. **Draw Context Switch Lines**— Check this to enable (default) or disable the thin gray lines that show context switches, linking the thread tenures before and after the switch that ran on the same CPU core.
5. **Detailed Event Icons**— Deselecting this instructs Shark turn off the icons that identify the various types of VM faults and system calls and just replace them with generic "plain page" VM fault and "gray phone" system call icons.

6. **Label Events**— These checkboxes allow you to enable or disable the display of event icons either entirely, by type group, or on an individual, type-by-type basis. For example, you can use them to enable interrupt icons or to remove icons for events, such as VM faults, that you may not be interested in at the present time.

Figure 3-20 Timeline View Advanced Settings Drawer



Sign Posts

Even with all of the system-level instrumentation already included in Mac OS X, you may sometimes find that it is helpful or even necessary to further instrument your code. Whether to orient yourself within a long trace, or to time certain operations, *Sign Posts* can be inserted in your code to accomplish these and other tasks.

Shark supports two types of Sign Posts:

- Point events (no duration)
- Interval events (with beginning *and* ending points)

Point events can be used to orient yourself within a larger trace. For example, if you are developing an application that operates on video frames, you can insert a sign post marker whenever the processing of a new frame has begun. Interval events can be used to time operations, such as the length a particular lock is held, or how long it takes to decode a frame of video.

In order to use Sign Posts, you must first make Shark aware of your Sign Posts' definitions. Do so by creating a *Sign Post File*. In your home directory, Shark creates a folder in which you can place Sign Post Files: `~/Library/Application Support/Shark/KDebugCodes`. A Sign Post File is *any* file that contains specially formatted lines which associate a code value with a Sign Post name. This name can be anything you like. To create a Sign Post File, simply create a new text file in the above directory and edit it, adding one Sign Post definition per line. Each line should only contain a hexadecimal value followed by an event name, as illustrated in the following example:

Listing 3-1 ~/Library/Application Support/Shark/KDebugCodes/myFirstSignPosts

```
0x31 LoopTimer
0x32 LockHeld
```

Sign Post values can take any value from 0x0 to 0x3FFF, inclusive.

Note on changes to Sign Post Files: If you created your Sign Post File while Shark was running, you might need to relaunch Shark for your new Sign Posts to appear in a System Trace. If you've already taken a System Trace that generated Sign Posts, but no Sign Posts are displayed in the Viewers, then save your session and relaunch Shark with your Sign Post Definition file(s) in place.

Once you've added your Sign Post File(s) to the `KDebugCodes` directory, you can add Sign Posts to your code. There are two ways to accomplish this, depending on where your code runs:

- **User Applications using CHUD Framework:** User Applications that link with the `CHUD.framework`, and can simply call `chudRecordSignPost()`, which has the following API:

  ```
  int chudRecordSignPost(unsigned code, chud_signpost_t type,
      unsigned arg1, unsigned arg2, unsigned arg3, unsigned arg4);
  ```

- **User Applications not using CHUD Framework:** User Applications for which you prefer not to link with the `CHUD.framework` can still create signposts using explicit system calls. You will need to include `<sys/syscall.h>` and `<sys/kdebug.h>`, and then use the following call (with a "type" suffix of `NONE` for a point signpost, `START` for begin interval, and `END` for end interval):

  ```
  syscall(SYS_kdebug_trace, APPSDBG_CODE(DBG_MACH_CHUD, <your code number>) |
      DBG_FUNC_<<type>>, arg1, arg2, arg3, arg4);
  ```

- **Kernel Extensions:** Kernel Extensions *must* call `kernel_debug()` directly, using the `APPS_DEBUG()` macro as the `debugid` argument. Using this function and macro requires you to include `<sys/kdebug.h>`, and then make your call like this (the "type" suffixes are the same as in the `syscall` case):

```
KERNEL_DEBUG(APPSDBG_CODE(DBG_MACH_CHUD, <your code number>) |
    DBG_FUNC_<<type>>, arg1, arg2, arg3, arg4, 0);
```

In both cases, the caller can record up to 4 values of user-defined data with each Sign Post that will be recorded and displayed with the session.

The Sign Post `type` must be one of the following:

- `chudPointSignPost` for a point event with no duration.
- `chudBeginIntervalSignPost` for the start point of an interval Sign Post.
- `chudEndIntervalSignPost` for the end point of an interval Sign Post.

When using interval Sign Posts, the start and end points will be coalesced into one Sign Post with a duration equal to the elapsed time between the two events. You must ensure that the same `code` value is given for both the start and end points of the interval Sign Post. It is possible to "nest" sign posts - just be sure you match the code value for each start and end point.

The example uses the Sign Post defined in the above Sign Post File to create an interval Sign Post that times a loop in a user-space application:

Listing 3-2 signPostExample.c

```
#include <CHUD/CHUD.h>
#include <stdint.h>

/* This corresponds to the sign post defined above, LoopTimer */
#define LOOP_TIMER 0x31
#define ITERATIONS 1000

uint32_t ii;

/* The last 4 arguments are user-defined, ancillary data */
chudRecordSignPost(LOOP_TIMER, chudBeginIntervalSignPost, ITERATIONS, 0, 0, 0);
for(ii = 0; ii < ITERATIONS; ii++) {
    do_some_stuff();
    do_more_stuff();
}

/* notice that the code value used here matches that used above */
chudRecordSignPost(LOOP_TIMER, chudEndIntervalSignPost, 0, 0, 0, 0);
```

Note: To compile the above example, you'll need to instruct `gcc` to use the `CHUD.framework`:

```
gcc -framework CHUD -F/System/Library/PrivateFrameworks signPostExample.c
```

To accomplish the same task in a kernel extension, use `kernel_debug()` as follows:

Listing 3-3 testKernelSignPost.c

```
#include <sys/kdebug.h>
#define LOOP_TIMER 0x31
#define ITERATIONS 1000

uint32_t ii;

/*
 * Use the kernel_debug() method when in the kernel (arg5 is unused),
 * DBG_FUNC_START corresponds to chudBeginIntervalSignPost.
 */
kernel_debug(APPS_DEBUG(DBG_MACH_CHUD, LOOP_TIMER) | DBG_FUNC_START,
    ITERATIONS, 0, 0, 0, 0);
for(ii = 0; ii < ITERATIONS; ii++) {
    do_some_stuff();
    do_more_stuff();
}

/* remember to use the same debugid value, with DBG_FUNC_END */
kernel_debug(APPS_DEBUG(DBG_MACH_CHUD, LOOP_TIMER) | DBG_FUNC_END,
    0, 0, 0, 0, 0);
```

You should note that when using Sign Posts in the kernel, it is not necessary to add CHUD to the list of linked frameworks. Adding the above code to your drivers will cause Sign Posts to be created in the System Trace session without it. Similar code using the `syscall(SYS_kdebug_trace,...` invocation instead of `kernel_debug` does exactly the same thing, but works from user code, instead.

Tips and Tricks

This section will list common things to look for in a *System Trace*, what they may mean, and how to improve your application's code using the information presented. The tips and tricks listed herein are organized according to the view most commonly used to infer the associated behavior.

- **Summary View**
  - *Short average run intervals for worker threads:*

    This can indicate that the amount of work given to each worker thread is too small to amortize the cost of creating and synchronizing your threads. Try giving each thread more work to do, or dynamically tune the amount of work given to each thread based on the number and speed of processors present in the system (these values can be introspected at runtime using the `sysctl()` or `sysctlbyname()` APIs).

    It can also indicate that your threads frequently block while waiting for locks. In this case, it is possible that the short intervals are inherent to your program's locking needs. However, you may want to see if you can reduce the inter-thread contention for locks in your code so that the locks are not contested nearly as much.

  - *Inordinate count of the same system call:*

Sometimes, things like `select()` are called too often. For system calls such as this, try increasing the timeout value. You might also want to rethink your algorithm to reduce the number of system calls made, if possible. Because System Trace records the user callstack associated with each system call by default, it's relatively easy to find the exact lines of code that cause the frequent system call(s) in question.

- *Large amount of time spent in Zero Fill Faults:*

  This can indicate that your application is frequently allocating and deallocating large chunks of temporary memory. If you correlate the time spent in Zero Fill Faults to allocation and deallocation of temporary memory, then try eliminating these allocation/deallocation pairs and just reuse the chunks of memory whenever possible. This optimization is especially useful with very large chunks of memory, since a large amount of time can be wasted on zero-fill faults after every reallocation.

- **Trace View**

  - *System calls repeatedly failing:*

    As above, when system calls repeatedly return failure codes, inspect your algorithm and ensure that you still need to be calling them. The overhead of a system call is considerable, and any chance to avoid making a system call, such as checking for known failure conditions prior to making the call, can improve the performance of your code considerably.

  - *System calls repeated too frequently (redundant system calls):*

    This can be indicated either by the same system call being called multiple times in a row as displayed in the Trace View, or by a large count value when *Weight By* is set to *Count* in the *Summary View*. Inspect your algorithm to ensure the repeated system call needs to be called as often as reported — there's a good chance you could be doing redundant work.

  - *Sign Posts were generated during session, but are not displayed:*

    If you've already taken a System Trace session in which your application or driver generated Sign Posts, but no Sign Posts are displayed in the Trace view, it is possible that the correct Sign Post definition file(s) were not in place when you launched Shark. First, save your session — if Sign Posts were generated, they will be saved in the session regardless of whether or not they are displayed. Ensure the correct Sign Post Files are in place in `~/Library/Application Support/Shark/KDebugCodes/` and relaunch Shark. Opening your session should now display the Sign Posts.

- **Timeline View**

  - *Multi-threaded application only has only one thread running at a time:*

    First of all, ensure you've performed the System Trace on a multiprocessor machine. You can do this by pressing *Command+I* to bring up the session inspector, which will list the pertinent hardware information from the machine on which the session was created. Usually, this is not an issue.

    Second, ensure your selected scope is not limited to a single CPU.

    Once you've verified the session was taken on a multi-processor machine and is displaying data for all processors, look in the timeline for *Lock* icons (see "System Calls" (page 75)). Their presence indicates *pthread mutex* operations that have resulted in a trap to the kernel, usually as a result of lock contention. This may indicate a serialization point in your algorithm.

Locking Note: Currently, only *pthread mutex* operations are given a distinct icon. However, you can still view semaphore system calls in the *Trace* and *Timeline* views under their Mach system calls. In either case, only contention that results in a trap to the kernel is indicated; user space contention will not show up in a System Trace.

Correlate the locking operations to your application's code using the inspector (single-click the icon). If the serialization point is not necessary, remove it. Otherwise, try to reduce the amount of time spent holding the lock. You might also instrument your code with "Sign Posts" (page 84) in order to characterize the amount of time spent holding the lock.

- *Worker thread run intervals are shorter than expected:*

  Remember, the default scheduling quantum on Mac OS X is 10ms. If the thread run intervals are near 10ms, there may not be any benefit to continuing this investigation.

  If the thread run intervals are much shorter than 10ms, single-click the short thread run intervals, making sure not to click any event icons. The resulting inspector will list the reason why the thread in question was switched out. If it blocked, the inspector will list the blocking event and its index. Use the trace view to correlate this event (usually a system call) to your application's code.

  An alternate approach is to look for event icons which have an underbar that extends past the end of the thread run intervals. This generally indicates that the event in question — such as an I/O system call or mutex lock — caused the thread to block. Clicking the event icon will display the associated user callstack (if any), allowing you to correlate it directly to your application's code.

  If you find your threads are frequently blocking on system calls such as `stat(2)`, `open(2)`, `lseek(2)`, and the like, you may be able to use smarter caching for file system actions. If you see multiple threads context switching back and forth, identify their purpose. If they are CPU-bound, this is not necessarily a problem. However, if these threads are communicating with each other, it may be prudent to redesign your inter-thread communication protocol to reduce the amount of inter-thread communication.

  Another possibility is that you've simply not given your worker threads enough work to do. Verify this theory using the tip from the summary view suggestions above.

- *One processor doesn't show any thread run intervals until much later than another:*

  If this happens, chances are you are using the Windowed Time Facility. This is due to a fundamental difference in how the data is recorded when using this mode. When using *WTF* Mode, the user-specified number of events are right-aligned, as described in "Windowed Time Facility (WTF)" (page 118). Because of this right-alignment, you'll notice that all the CPUs tend to end around the same point in time in the timeline, but may start at vastly different times.

  This difference in start time is expected, and most likely means that any CPU which starts later in the timeline was generating system events at a higher rate (on average) than CPUs that start earlier.

- *My application is supposed to be creating and destroying more threads than are shown:*

  On Mac OS X, thread identifiers (thread IDs) are not always static, unique numbers for the duration of a profiling session. In fact, thread IDs are merely addresses in a zone of memory used by the kernel. When your application creates and destroys threads in rapid succession, the kernel must also allocate and free threads from this zone of memory. Not only is this a huge amount of overhead, but it makes it possible to create a new thread that will have the exact same thread ID as a thread which you just destroyed.

  There are a couple of ways to avoid this confusion. The first, simple option is to "park" your threads when profiling. Simply don't let your threads exit, and your thread IDs are guaranteed to be unique. A second, arguably better option is to utilize a work queue model for your threads. Create just

enough worker threads to fully populate the number of processors in your system, and two queues: one to hold IDs of free threads and another to hold task records describing new "work" to be completed. When a worker thread completes a task, do not destroy it. Either assign it a new task from the task queue, or place it on the free thread queue until another task is available. This not only reduces the overhead of allocating and freeing memory in the kernel, but also ensures that your thread IDs will be unique while profiling.

- *I see an inordinate amount of interrupt icons:*

  If you see a large number of interrupt icons during the run intervals of your threads, you may be communicating with the underlying hardware inefficiently. Sometimes, it is possible to assemble your hardware requests into larger batch requests for better performance. Inspect your algorithm and find any places to group hardware requests.

- *I need to return to a particular point X on the timeline:*

  If you might be returning to a location later, take a moment to note the index number and type of a nearby event, by clicking on that event and reading the event inspector. To return, or to send someone else there, look up that event in the *Trace View* and double-click on it. This will bring you directly back to the interesting spot.

Other Profiling and Tracing Techniques

Not every performance problem stems from computation in a program or a program's interaction with the operating system. For these other types of problems, Shark provides a number of profiling and tracing configurations that focus on individual types of performance problems. Any of them may be chosen using the configuration list in the main Shark window before pressing "Start."

Time Profile (All Thread States)

When doing certain types of operations, a program can temporarily stop running while it waits on some other event to finish. This is commonly referred to as *blocking*. Blocking can be the source of many performance problems. Portions of programs, such as startup routines, making heavy use of library calls can accidentally waste a significant amount of time blocked at various points within those calls. In heavily multithreaded programs, time spent blocking at locks and barriers is another serious source of performance loss.

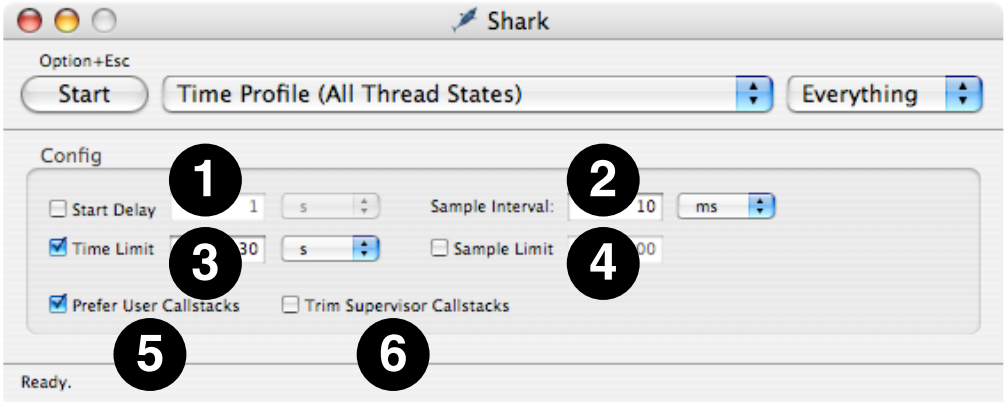
Since a program is not running while it is blocked, *Time Profile* will not take many samples in routines that spend large amounts of time being blocked. To provide some insight into blocking, Shark offers the *Time Profile (All Thread States)* configuration. This configuration is similar to *Time Profile*, but with one key difference: it takes samples of *all* threads, whether they are blocked or running. With this information, you can get a good idea about how often your threads are blocked, and where in your code the blocking calls are being made.

Like *Time Profile*, *Time Profile (All Thread States)* can be used to look at blocking behavior of a single application or the whole system by selecting the appropriate option in the target list in Shark's main window. While the default settings for this configuration are often sufficient, you can also select many useful options in the mini-configuration editor (see "Mini Configuration Editors" (page 18)), as shown in Figure 4-1. Here is a list of options:

1. **Start Delay**— Amount of time to wait after the user selects "Start" before data collection actually begins.
2. **Sample Interval**— Determine the trigger for taking a sample. The interval is a time period (10 ms default).
3. **Time Limit**— The maximum amount of time to record samples. This is ignored if Sample Limit is enabled and reached before the time limit expires.
4. **Sample Limit** — The maximum number of samples to record. Specifying a maximum of *N* samples will result in at most *N* samples being taken, even on a multi-processor system, so this should be scaled up as larger systems are sampled. When the sample limit is reached, data collection automatically stops. This is ignored if the *Time Limit* is enabled and expires first.
5. **Prefer User Callstacks**— When enabled, Shark will ignore and discard any samples from threads running exclusively in the kernel. This can eliminate spurious samples from places such as idle threads and interrupt handlers, if your program is not affected by these.

6. **Trim Supervisor Callstacks**— When enabled, Shark will automatically trim the recorded callstacks for threads calling into the kernel down to the kernel entry points, and discarding the parts of the stack from within the kernel itself. These shortened stacks are usually sufficient, since most performance problems in your programs can be debugged without knowing about how the kernel is running internally. You just need to know how and when your code is blocking, and not how Mac OS X is actually processing the blocking operation itself.

Figure 4-1 Time Profile (All Thread States) mini configuration editor

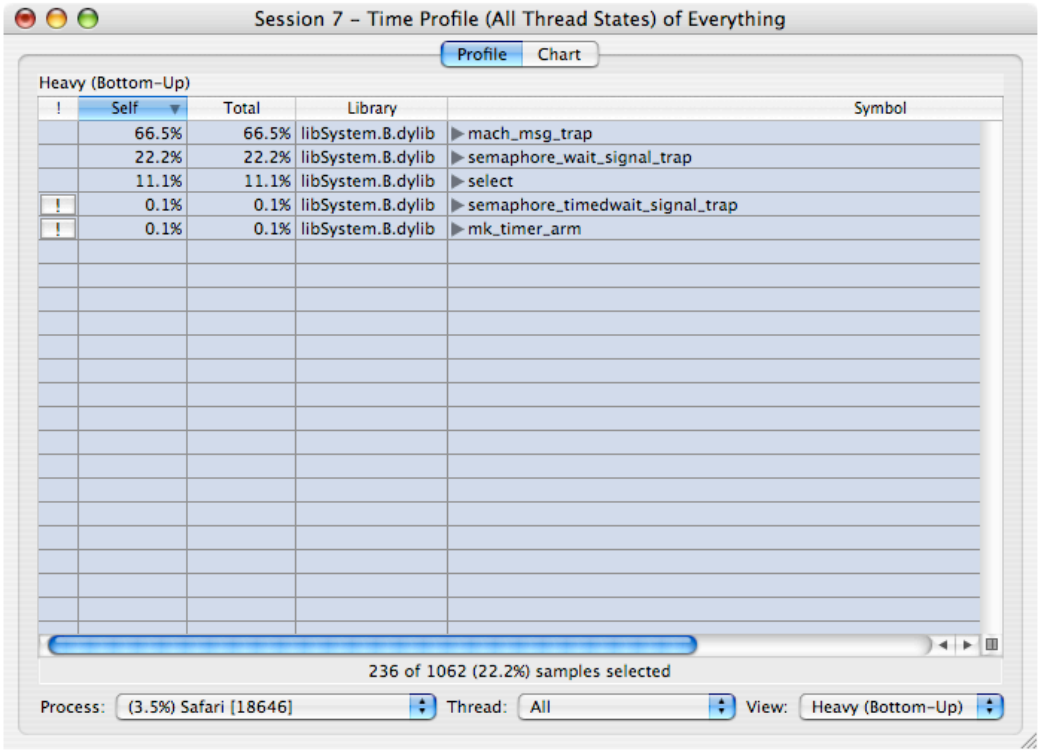


After you record a *Time Profile (All Thread States)* session, you will be presented with a profile browser window that looks almost exactly like one you might see after recording a conventional *Time Profile*. However, there are some subtle differences, as you can see in the profile of "Safari" while idle in Figure 4-2 and Figure 4-3.

All threads have exactly the same number of samples, since Shark recorded samples for them whether they were running or not. With 9 threads, as we have in this example, all threads have exactly 1/9 of the samples, or 11.1%. This "even-division-of-samples" rule will always hold true for *Time Profile (All Thread States)* sessions, unless you happen to sample an application that is actively creating and destroying threads while it is being measured, because *Time Profile (All Thread States)* always records samples for all threads at each sample point, whether they are blocking or not. This trend can be less obvious if your threads are actively calling many different routines over the course of the measurement, but it generally holds. This kind of behavior is much less common in conventional *Time Profiles*, because almost all threads block occasionally during the time that Shark samples them.

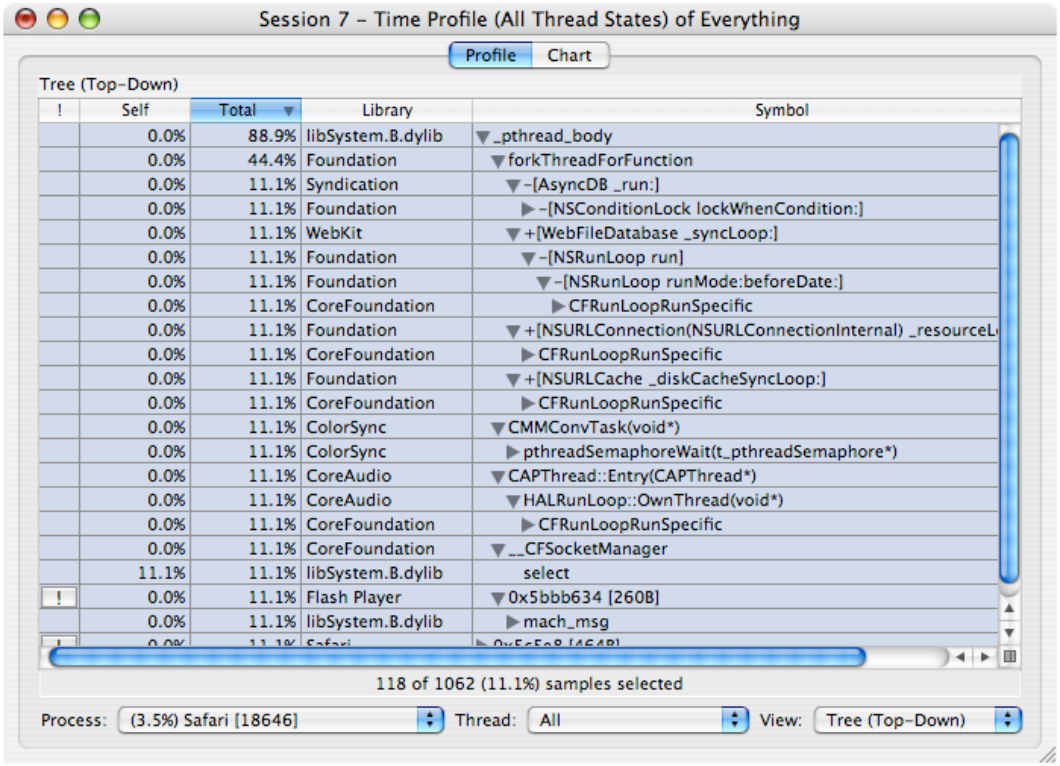
With "Heavy" view, as shown in Figure 4-2, you will mostly see Mac OS X's primitive blocking routines like `pthread_mutex_lock`, `pthread_cond_wait`, `mach_msg_trap`, `semaphore_timedwait_signal_trap`, `select`, and similar functions popping up to the top of the browser window. This view is mostly useful for showing you how much time your threads are blocked and how often they are running. As a result, it is a good "sanity check" technique to make sure that threads that are supposed to be CPU-bound are not accidentally wasting time blocked, and that threads that are supposed to be blocked really are idle.

Figure 4-2 Time Profile (All Thread States) session, heavy view



Unfortunately, this does not tell you the most important information: why *your* code is calling these routines and hence blocking. It is possible to get this information by opening up disclosure triangles in "Heavy" view, but generally "Tree" view, as shown in Figure 4-3, is the best way to track down this information. By flicking a few disclosure triangles open, this view lets you logically follow your code paths until you reach a point where they call blocking library routines. At that point, and possibly with the help of a code browser, you should be able to get a good idea of which parts of your code are blocking, and how frequently this blocking is occurring.

Figure 4-3 Time Profile (All Thread States) session, tree view



Time Profile (All Thread States) can often allow you to track down and solve multithreaded blocking problems in your applications by itself. However, it also works well in conjunction with *System Trace*. After you identify *which* code that is blocking too often with *Time Profile (All Thread States)*, if you cannot determine *why* the code is blocking, then the precise recording of blocking timing provided by *System Trace* can often help by letting you see the precise timing of blocks as multiple threads compete for resources. Conversely, using *System Trace* without *Time Profile (All Thread States)* can often be difficult, because it is fairly easy to get overwhelmed with data while examining a *System Trace*. Performing a *Time Profile (All Thread States)* first can be very helpful, since it can let you know *which* bits of blocking code are the most important before you look for them in a *System Trace*.

Note regarding launched target processes: When launching a process (as described in "Process Launch" (page 115)) with *Time Profile (All Thread States)*, you may notice samples in `_dyld_start`. Since Shark starts sampling the process before the launched process begins executing, some samples will fall in this method. When profiling launch time in this way, you will want to make sure that you skip past all these samples before paying attention to the results or use data mining to remove all callstacks with this symbol.

Malloc Trace

In today's large and complex software applications, it is often informative to understand the scope and pattern of memory allocations and deallocations. If you understand how your software objects are being created and destroyed, you can often improve the overall performance of your application significantly, since

memory allocation is a very expensive operation in Mac OS X, especially for large blocks of memory. If your program suffers from memory leaks, *Malloc Trace* is also a good way to identify locations in your program that may be the culprits.

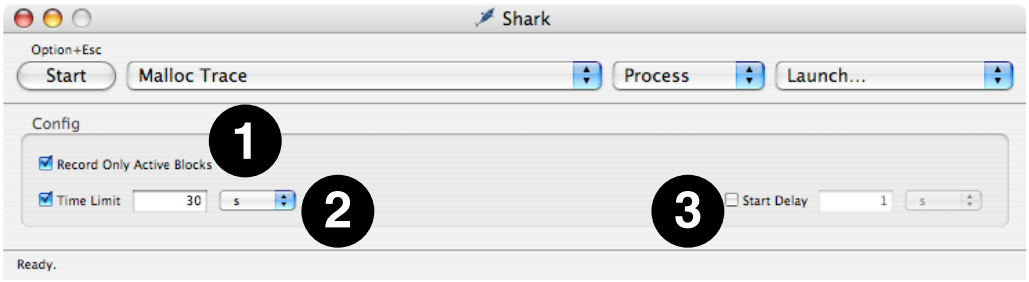
To collect an exact trace of memory allocation and freeing function calls, select *Malloc Trace* in the configuration list. Unlike with most configurations in Shark, you *must* choose a particular process to examine with this configuration. In its mini configuration editor (see "Mini Configuration Editors" (page 18)), shown in Figure 4-4, *Malloc Trace* offers the following tuning options to help refine the memory events that are collected:

1. **Record Only Active Blocks**— Collect only memory allocations that were not released during the collection period (the default). It is most useful for catching memory leaks. If turned off, any allocation or deallocation that takes place is recorded, an option that is more useful when you are just attempting to reduce the overall number of allocations that occur.

2. **Time Limit**— Specify a maximum length of time to collect a profile. After this amount of time has elapsed since the start of collection, Shark will automatically stop collecting the profile.

3. **Start Delay**— Specify a length of time that Shark should wait after being told to start collecting a profile before the collection begins. If the program action to be profiled requires a sequence of actions to start, this option can be used to delay the start until after the setup actions have been completed.

Figure 4-4 Malloc Trace mini configuration editor

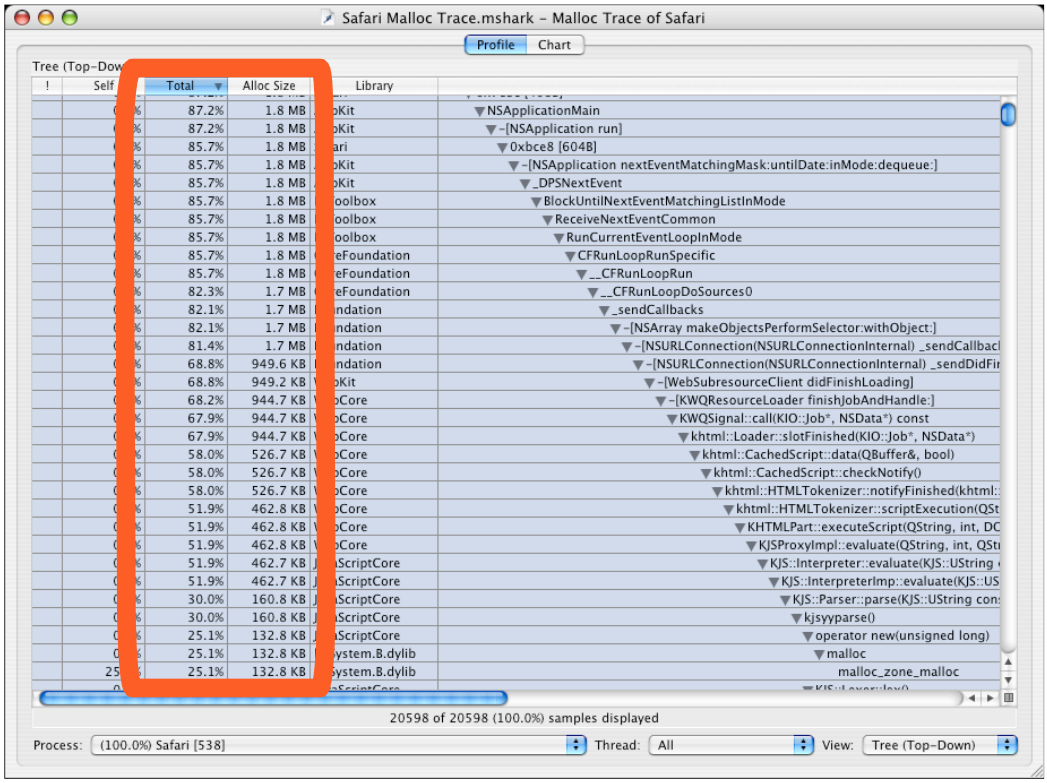


Using a Malloc Trace

Once you have recorded a *Malloc Trace*, there are several ways that you can analyze the resulting trace, which comes up in a window that superficially resembles a standard time profile. Here are a few of the most common techniques:

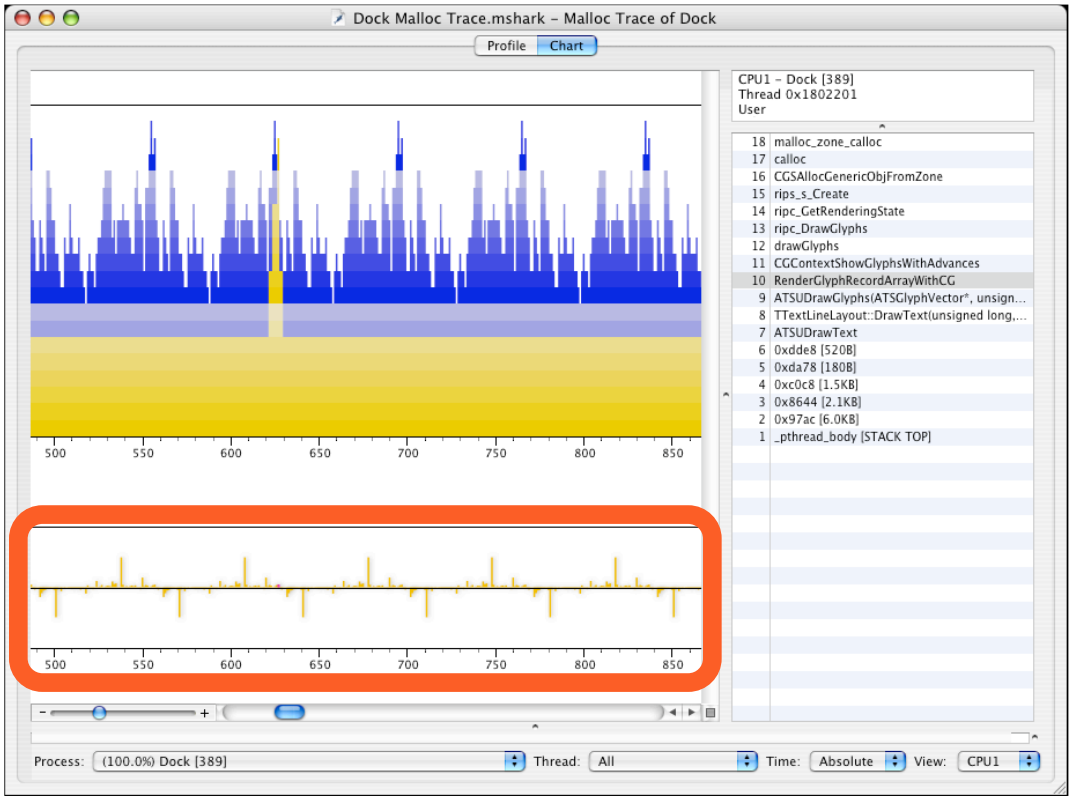
- **Profile Browser: Get an Overview**— The profile browser from a *Malloc Trace*, as shown in "Using a Malloc Trace," looks a lot like what you might obtain with a normal *Time Profile*, but it contains an extra column listing the amount of memory allocated. In addition, the "Self" and "Total" columns are based on the number of allocations made using that call instead of execution time. These figures are highlighted in the figure. By sorting on the "Total" or "Alloc Size" columns in a "Heavy" view, you can see which routines in your program either make the largest number of allocations or allocate the most memory at a glance. It is often a good idea to look over the routines near the top of this list and make sure that both the routines allocating memory are the ones you *think* should be allocating memory, and that the amount of memory allocated by each routine makes sense.

Figure 4-5 Malloc Trace session, profile browser



- **Code Browsers: Locate Allocating Code**— If you see a potentially troublesome routine, double-clicking it will bring it up in a code browser window. Unlike the code browsers associated with *Time Profile* sessions, lines in a *Malloc Trace* session are colored based on how many memory allocations they perform. With this feedback, you can see *exactly* which lines of code were the cause of memory allocation. Often these lines will be fairly obvious, but with object-oriented languages like Objective-C and C++ it is surprisingly easy to accidently allocate and free memory implicitly, as a side effect of object method calls. Using a code browser from a *Malloc Trace* session can allow you to identify which method calls are performing memory allocation and focus your optimization efforts on these. In addition, knowing what code is performing memory allocation implicitly can help you track down memory leaks, as these allocations are easy to forget about when one is cleaning up and freeing memory allocations.
- **Chart View: Look for Patterns**— The chronological view of allocations presented by the extra memory allocation graph added below the usual callstack plot in *Chart* view can easily reveal unexpected repetitive allocation and deallocation activity in your software, like the pattern shown in the highlighted part of Figure 4-5. When you see patterns like this, it can be helpful to try and adjust your code to move memory allocation and deallocation operations outside of loops, so that you can reuse the same memory buffers repeatedly without reallocating them each time through the loop. Similarly, if you see repetitive allocation without matching deallocations, then you are most likely seeing a major memory leak in progress!

Figure 4-6 Malloc Trace session, chart view

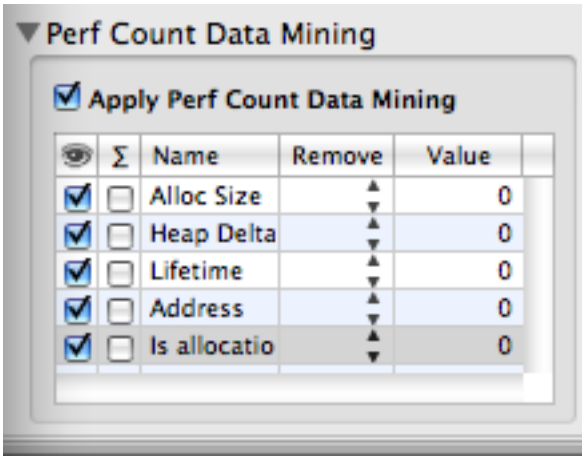


Using techniques like these, you can identify and isolate memory allocation locations and patterns within your code. This is the first step to actually eliminating these memory problems from your code, and hopefully improving performance in the process.

Advanced Display Options

Each Malloc Trace records a few additional pieces of information at each allocation event. These are not displayed by default, but can be useful in some situations. Display of these values can be enabled by using the "Performance Counter Data Mining" pane in the Advanced Settings Drawer of the session window (see "Advanced Settings Drawer" (page 22)), as shown below in Figure 4-7, and then clicking on the check boxes in the "eye" column of each row to show that data element.

Figure 4-7 Enabling Malloc Trace Advanced Options

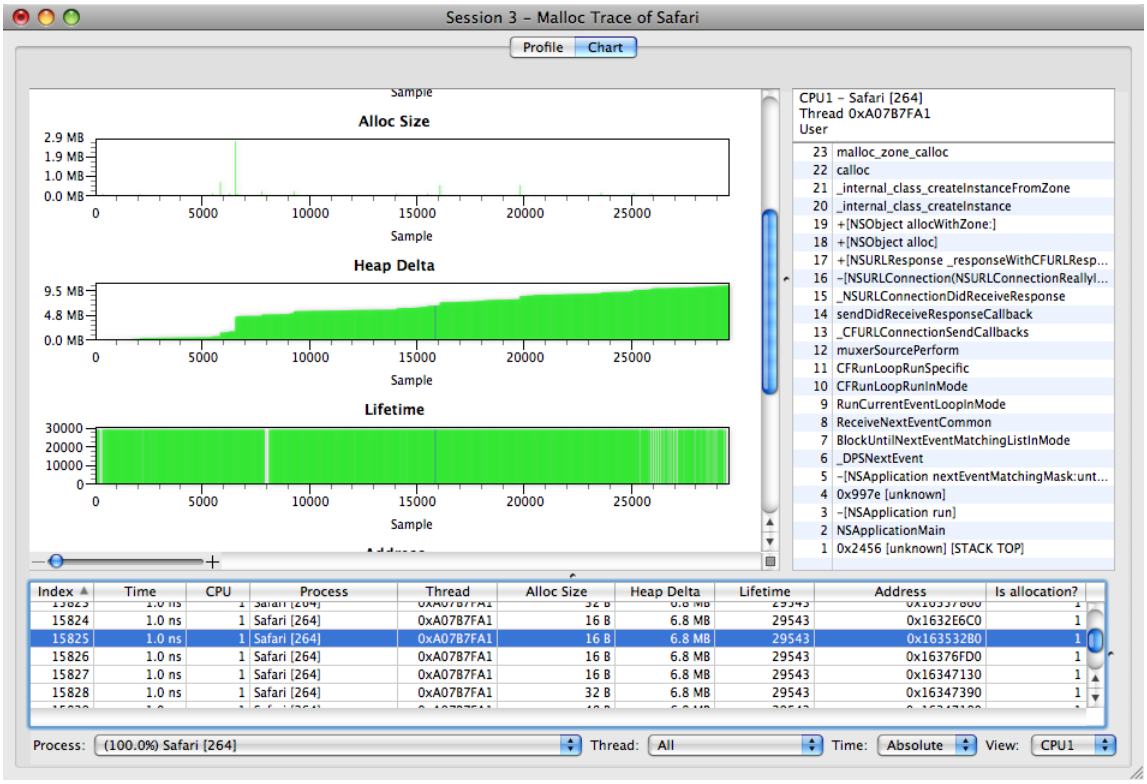


Five different types of information can be enabled or disabled in this manner:

- *Alloc Size*— The size in bytes of each memory allocation. This is enabled by default, as it is almost always useful.
- *Heap Delta*— The change in size of the heap since the start of the trace. This is sometimes useful for spotting memory leaks, which can be seen when the heap grows but never shrinks. Note that it is also possible to get this data by using the "summation" option (as described in "Perf Count Data Mining" (page 145)) with *Alloc Size*.
- *Lifetime*— The number of allocation/deallocation events between matched allocation and deallocation pairs. This option is only useful if you disabled the "Record Only Active Blocks" option before taking your Malloc Trace, because otherwise that option automatically screens out all matched pairs from the trace and leaves no interesting lifetimes remaining in the trace.
- *Address*— The address of the memory block allocated or freed. For performance analysis purposes, this is only rarely helpful, but it can sometimes be useful during debugging of memory allocation behavior.
- *Is allocation?*— This binary value records a 1 for allocations and 0 for frees.

When you enable display of a particular type of data, it will appear in several places. First, columns displaying it will appear in the Profile Browser (as shown previously in Figure 4-5 (page 96)), although this type of display is really only meaningful for *Alloc Size*. Raw values are displayed in the list of samples at the bottom of the Chart View (as shown in Figure 4-8), and all types of displays are useful here. Finally, charts appear in the main part of the chart view displaying all of the sample values graphically for your inspection. These are useful with *Alloc Size* (enabled by default), *Heap Delta*, and *Lifetime*.

Figure 4-8 Additional Malloc Trace Charts



The rest of the "Performance Counter Data Mining" pane, which is described more fully in the context of performance counter analysis in the section "Perf Count Data Mining" (page 145), also has other features that can be useful. For example, if a Malloc Trace contains allocations of wildly varying size, use of these options may be necessary in order to make the allocation size chart readable, as no means for vertical scaling or scrolling are provided by Shark. A particularly quick way of focusing the view on allocations of particular sizes is to use the "remove !=," "remove <," or "remove >" screening options to chop off most allocations that are vastly different in size from the ones that you are trying to examine.

All other features accessible through the Advanced Settings Drawer work just like they do for Time Profiling (see "Profile Display Preferences" (page 37) for the "Profile Analysis" pane and "Data Mining" (page 139) for the "Callstack Data Mining" pane).

Static Analysis

Most of Shark's profiling methods limit their code analysis to those functions that appear dynamically in functions that are executed during the profiling. Dead or otherwise unused code is not analyzed or presented for optimization precisely because it has very little effect on the measured performance. However, it can sometimes be useful to statically analyze and examine infrequently used code paths in a piece of code to look for problems that might crop up if those code paths *do* become important at some point, such as with a different input data set.

Shark is capable of statically analyzing either a running process or a binary file with the *Static Analysis* configuration, but not your entire system. To analyze a running application, select *Process* in the target list and then select the process you wish to analyze in the process list. To analyze an executable file, select *File* in the target list and then select the file in file selection window.

Static Analysis' mini config editor (see "Mini Configuration Editors" (page 18)), shown in Figure 4-9, offers a number of tuning options to refine what types of problems to look for and where in the program to look for them. The available options are:

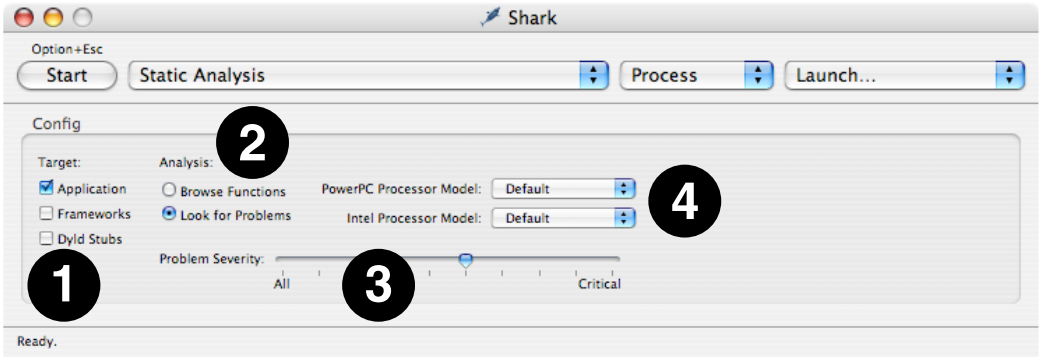
1. **Target Selection**— These options allow you to narrow down the area of memory examined by Shark.
    - *Application*— Looks for potential performance issues in the main text segment of the target process
    - *Frameworks*— Looks for potential performance issues in the frameworks that are dynamically loaded by the target process.
    - *Dyld Stubs*— Looks for any potential performance or behavior anomalies in the glue code inserted into the binary by the link phase of application building.

2. **Analysis Options**— These allow you to enable or disable analysis.
    - *Browse Functions*— Gives each function in the text image of a process a reference count of one. This allows you to browse all of the functions of a given process with Shark's code browser. No analysis (or problem weighting) is performed.
    - *Look For Problems* — search all functions in the text image of a process for problems of at least the level of severity specified by the Problem Severity slider. Any address with a problem instruction or code is given a reference count equivalent to its severity.

3. **Problem Severity Slider**— This slider acts as a filter, adjusting the minimum "importance" of problems to report using a predefined problem weighting built into Shark. The further to the right the slider, the less output is generated, as more and more potential problems are ignored because their "importance" is not high enough.

4. **Processor Settings**— Shark needs to know which model of processor is your target before it can examine code and find potential problems. Separate menus are provided for PowerPC and Intel processors because it can analyze for one model of each processor family simultaneously.
    - *PowerPC Model*— Selects the PowerPC model to use when searching for and assigning problem severities .
    - *Intel Model*— Selects the Intel model to use when searching for and assigning problem severities .

Figure 4-9 Static Analysis mini configuration editor



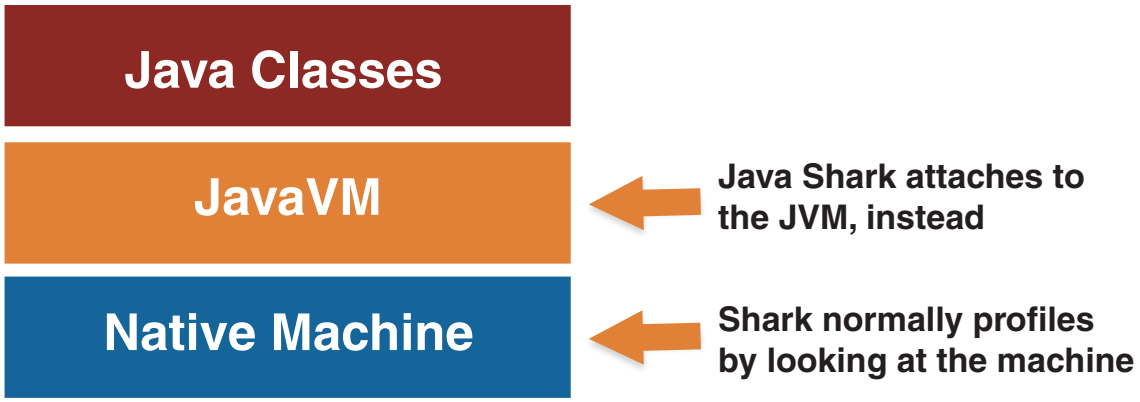
Once you have created a *Static Analysis* session, you can examine it to see Shark's optimization suggestions for your program. Both the profile browser and code browser views offer optimization hints similar to those you can see after a normal *Time Profile* run, and they can be used to help you analyze your application in much the same manner.

Using Shark with Java Programs

Shark's profiling and tracing techniques will work just fine with programs written in virtually any compiled language. Your compiler processes your source code in these languages and creates binary files where the various instructions in the binary are PowerPC or x86 instructions that correspond closely with your original source code operations. Shark records program counters and callstacks from the native machine execution as it profiles, and can use this information to reference back to your source code. Because Mac OS X imposes requirements on how its binaries are formatted, compilers for any language use the same techniques to record which machine instructions correspond with which source files, making it possible for Shark to show you symbol information and source code in languages as disparate as C and Fortran.

This system breaks down when your source code is written in a compiled language that runs within a runtime virtual machine, such as Java, or interpreted scripting languages. In these cases, Shark's samples will only tell you what code is executing *within* the virtual machine or interpreter, which will not help you optimize *your* programs. For Shark to return useful information, it must move "up" a level in the software hierarchy (as shown in Figure 4-10) and record the location within the virtual machine code or script that is executing, instead. While support for recording this information is unavailable with most script interpreters, recent versions of Sun's Java virtual machine included with Mac OS X *do* provide an interface that Shark can use. As a result, Shark includes some special, Java-only configurations that use this interface to allow you to usefully profile your Java applications.

Figure 4-10 How Shark-for-Java differs from regular Shark configurations



Java Tracing Techniques

Shark supports three different techniques for examining your Java applications:

- **Java Time Profile:** This is the Java version of *Time Profile*. The targeted Java program is periodically interrupted and Shark records the method that was running and the callstack of method calls leading up to the current method. You may examine the results using browsers that are almost identical to the normal *Time Profile* ones described in "Profile Browser" (page 32), except that they only list Java methods and libraries. Note that, because a fair amount of code must be executed to communicate with the JVM, overhead requirements for a Java Time Profile are somewhat higher than for a conventional time profile. Using the mini-config editor (see "Mini Configuration Editors" (page 18)), you can adjust the sampling rate at the millisecond level.
- **Java Call Trace:** This is the Java analog to the separate Saturn program. Java Call Trace records each call into and exit from *every* Java method during the execution of your program. As a result, it records an *exact* trace of all the method calls, much like a normal *System Trace* records an exact trace of all system calls. The amount of time spent in each method is also recorded. While this provides very exact and detailed information about the execution of your program, with no potential for sampling error, it also incurs a significant amount of system overhead due to the frequent interruptions of your code to pass information back to Shark. As a result, Shark's overhead may distort the timing of your program to a certain extent, and this factor should be considered if you have code that is sensitive to external timing adjustments. Also, due to the large amount of data that can be collected very quickly, you probably want to limit the use of this to relatively short timespans. When complete, Shark presents the information that it has collected in a browser virtually identical to one produced by a Java Time Profile.
- **Java Alloc Trace:** This records memory allocations and the sizes of the objects allocated, and is analogous to a regular *Malloc Trace* ("Malloc Trace" (page 94)). Not surprisingly, the resulting session window produced by Shark is very similar to one produced by *Malloc Trace*. As with *Malloc Trace*, the display is just that of a *Time Profile* — albeit a Java Time Profile, in this case — with an added "allocation size" column. As with the previous two techniques, the overhead imposed by the Shark while doing a Java Alloc Trace is large enough that it may affect some programs that are very sensitive to external timing adjustments. Also, due to the large amount of data that can be collected very quickly, you probably want to limit the use of this to relatively short timespans.

Linking Shark with the Java Virtual Machine

In order to let Shark connect to your JVM and access its internals, to get the detailed information used by all of the techniques described earlier, the Java Virtual Machine first needs to load the "Shark for Java" extension. The method for doing this varies, depending upon which version of the JVM you're using (use the command `java -version` to see which one you are running):

- **JVM 1.3 or earlier:** Shark will not work with these, as they do not have the necessary external debugging support.
- **JVM 1.4:** Add the following flag to your Java VM command line options: `-XrunShark`.
- **JVM 1.5 or later:** Add the following flag to your Java VM command line options: `-agentlib:Shark`.

If you are using Xcode to build your Java application, edit the program's target. Under the *Info.plist Entries*, select *Pure Java Specific*. In the *Additional VM Options* field, add `-XrunShark` or `-agentlib:Shark` as appropriate.

When you run a Java program with Shark for Java, the program will output to the shell (or console for a double-clickable target) a message similar to the following:

```
2004-06-27 03:33:24 java[4489] Shark for Java is enabled...
```

As soon as you see this message you can begin sampling with Shark. When you choose one of the Java tracing configurations in Shark's main window, the process list will change to only display Java processes that are running with Shark for Java loaded. Non-Java processes and Java processes that have been started without Shark support will both be eliminated.

To use source navigation, the program's source must be on disk in package hierarchy structure. Shark does *not* support inspection within jar files. If you have a jar such as `/System/Library/Frameworks/JavaVM.framework/Home/src.jar`, you will need to extract it into a directory hierarchy (`jar -xvf src.jar` for the example). When adding a path to the *Source Search Path* (see "Shark Preferences" (page 23)), add only the path to the root of the source tree.

Event Counting and Profiling Overview

After analyzing an application using a *Time Profile*, you may find it informative to count system events or even sample based on system events in order to understand why your application spends time where it does. The best way to do this is to take advantage of the performance counters built into your Mac's processors (usually called PMCs) and Mac OS X itself. Shark provides built-in configurations to help you access this information in meaningful ways:

- *Processor Bandwidth* (x86) or *Memory Bandwidth* (PowerPC): These configurations track off-chip memory traffic over time. Because of differences in the implementation of the counters, the PowerPC version measures memory bandwidth only, while the x86 version measures processor bus bandwidth, including traffic to memory, I/O, and other processors.
- *L2 (Data) Cache Miss Profile:* This configuration provides an event-driven profile of L2 cache misses. As each L2 cache miss causes the processor to stall for a significant amount of time while it accesses main memory, algorithms that arrange accesses to memory in ways that minimize these misses will tend to run faster than ones that do not.

The rest of this section attempts to describe how you can use these default configurations to get useful information about your system with Shark, and learn about performance counters in the process. However, the default configurations only scratch the surface of what Shark's counter recording mechanisms can do. Using the mini-configuration editor (see "Mini Configuration Editors" (page 18)) associated with each of these configurations, you can adjust the same parameters used with a normal *Time Profile* mini-config editor (see "Taking a Time Profile" (page 31)) to control things like sampling rate, time limit, and the like. Beyond this, using the full *Configuration Editor*, you can set up a variety of other configurations to count or sample a variety of hardware or software events, such as instruction stalls or page misses. See "Custom Configurations" (page 171) and "Hardware Counter Configuration" (page 189) for more information.

Timed Counters: The Performance Counter Spreadsheet

This section uses the built-in *Processor Bandwidth* and *Memory Bandwidth* configurations as an example of how to use Shark's Performance Counter Spreadsheet, its mechanism for analyzing and displaying sessions that record performance counters in a regular, timed fashion.

After you perform sampling with one of these configurations, you will be presented with a session window containing a *Performance Counter Spreadsheet* like the one shown in Figure 4-11. This window contains many features:

1. **Column Control Table**— This optional table lists the columns in the Results and PMC Summary tables to the right, providing longer names and allowing you to hide columns. It may be hidden or exposed using the window splitter on its right edge or a checkbox in the *Advanced Settings* drawer (see "Performance Counter Spreadsheet Advanced Settings" (page 107)). Selecting rows in this list also selects the corresponding columns in the counter table, graphing them. Use *Command-clicks* (for discontiguous selection) and/or *Shift-clicks* (for contiguous selection) to select multiple rows simultaneously.

    a. *"Eye" Column*— Uncheck the checkboxes in this column to hide columns in the results table(s). This is very helpful if you have a large number of columns.

    b. *Term Column*— Contains the short names for the columns, which can be used as terms in "shortcut equations," as described below.

    c. *Description Column*— Contains the long names for the columns, for your reference. This can be useful when you have many columns with long names that do not fit into the name cells at the tops of the columns.

2. **Results Table**— This table shows the actual results from performance counters and any derived results calculated from them. You can Control-click (or right click) anywhere on this table to bring up the *Counters* menu, described in "The Counters Menu" (page 106).

    a. *Column Names*— These provide a brief description of the contents of the column. If you find a name too terse, then you may want to open up the *Column Control Table* and see the longer description there. In addition, clicking on these names selects one or more columns of data to be graphed below in the *Results Chart*. Use *Command-clicks* (for discontiguous selection) and/or *Shift-clicks* (for contiguous selection) to select multiple columns simultaneously. By default, the first performance counter column ("M/C Read/write request beats," in this example) is automatically selected and graphed when the window is first opened. Finally, you can resize any columns by clicking-and-dragging on the lines separating these cells from each other.

b. *Index Column*— Lists an integer value associated with each sample, counting from 1 on up, for your reference. This column can be hidden from display using the appropriate checkbox in the *Advanced Settings* drawer (see "Performance Counter Spreadsheet Advanced Settings" (page 107)). This column may not be selected or graphed.

c. *Timebase Column(s)*— Contains the time between each sample, with one column for each processor in the system. Normally, these should be essentially constant, but you may see occasional glitches where a sample took slightly longer than normal to record due to interrupt contention on a processor. The first and/or last samples may also show some timing variation. In addition, you will see significant variation here if you choose to view results from an event-driven counter run (see "Event-Driven Counters: Correlating Events with Your Code" (page 111)) using the counter "spreadsheet." These columns may be shown or hidden using checkboxes in the *Column Control Table* to the left.

d. *Counter Result Column(s)*— These columns show the "raw" results recorded from performance counters, one column per active counter. These columns may be shown or hidden using checkboxes in the *Column Control Table* to the left.

e. *Shortcut Result Column(s)*— These columns show the performance counter results after they have been processed by the math in any "shortcut" equations. These columns may be shown or hidden using checkboxes in the *Column Control Table* to the left, and the "shortcut" equations may be viewed or edited using the controls in the *Advanced Settings* drawer (see "Performance Counter Spreadsheet Advanced Settings" (page 107) and "Adding Shortcut Equations" (page 111)).

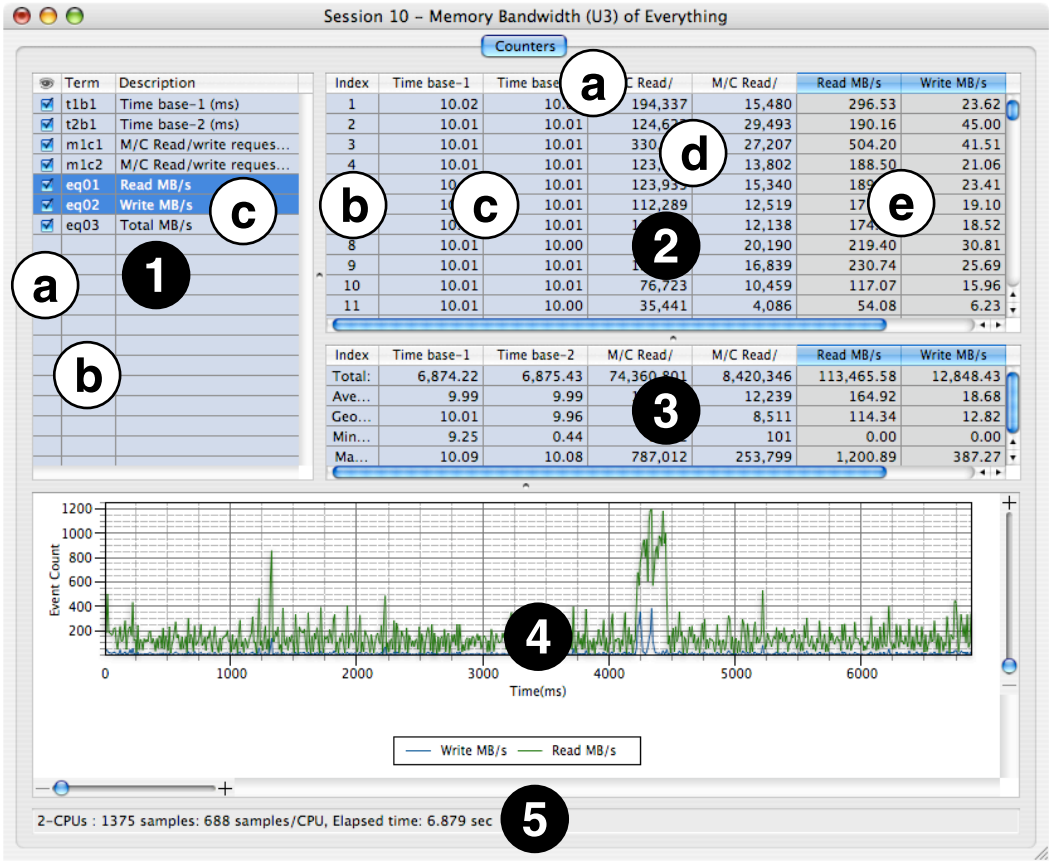
3. **PMC Summary Table**— This window pane extends the *Results Table* with additional rows that list the total, average (arithmetic mean), geometric mean, minimum, and maximum values for each column. This pane can be hidden from display using the appropriate checkbox in the *Advanced Settings* drawer (see "Performance Counter Spreadsheet Advanced Settings" (page 107)) or the window splitter at the top of the pane.

4. **Results Chart**— This graph charts the values in the selected column(s) in the Results Table. There are many options for controlling this graph in the *Advanced Settings* drawer (see "Performance Counter Spreadsheet Advanced Settings" (page 107)). The chart starts out scaled so that it fits entirely within the window allocated, but you can also magnify the chart and the scroll to any part of the magnified chart using the magnifier sliders and scroll bars along both the right side and bottom. In addition, you can print the contents of this graph using a command in the *Counters* menu (see "The Counters Menu" (page 106)) and vary the percentage of the window's space allocated to the chart using the window splitter at its top edge.

5. **Session Summary**— This line of text summarizes key facts about the session, including the number of processors, the number of samples taken, and the total time that elapsed during counter sampling.

In Figure 4-11, the last two columns have been selected and their contents displayed together in the chart. These last two columns are not actual event counts, but the results of "Shortcut Equations." These equations are simple mathematical combinations of the "raw" counts recorded by Shark. Shortcut equations can be added to the configuration before a profile is taken, or just as easily be added to a session afterwards. In this session, the "Read MB/s," and "Write MB/s" columns were generated by performing some simple arithmetic on the entries in the two "M/C Read/write request beat" columns (reads to left, writes to right). Every counter sample is multiplied by 16 (bytes per beat), multiplied by 100 (samples per second) and divided by 2^{20} (bytes per megabyte), which yields MB/s in each new column. For a brief introduction to adding equations to your sessions, see "Adding Shortcut Equations" (page 111), below. For a complete description of how to write performance counter equations, including how to add them permanently to your configurations, see "Counter Spreadsheet Analysis PlugIn Editor" (page 182).

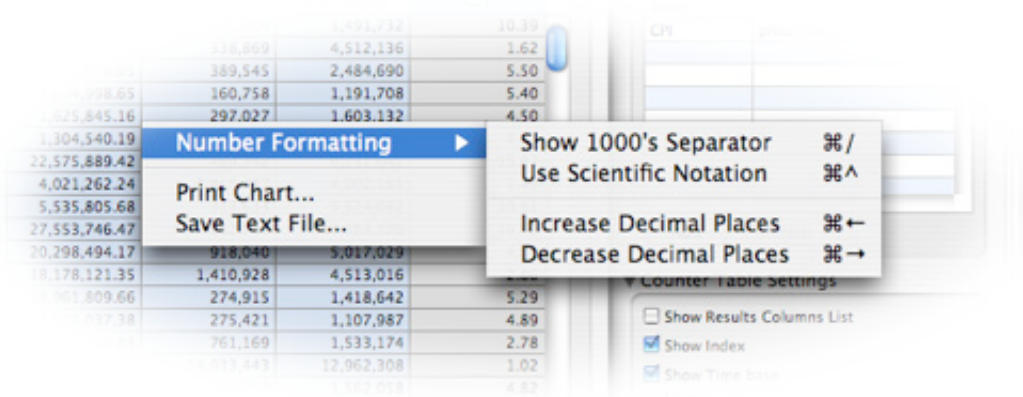
Figure 4-11 Performance Counter Spreadsheet



The Counters Menu

When you switch to the *Counters* tab in a session made with timed performance counters, a *Counters* menu will appear in the menu bar. You can also access this menu by control-clicking (or right-clicking, with a 2-button mouse) in the *Results table*, as shown in Figure 4-12.

Figure 4-12 Counters Menu



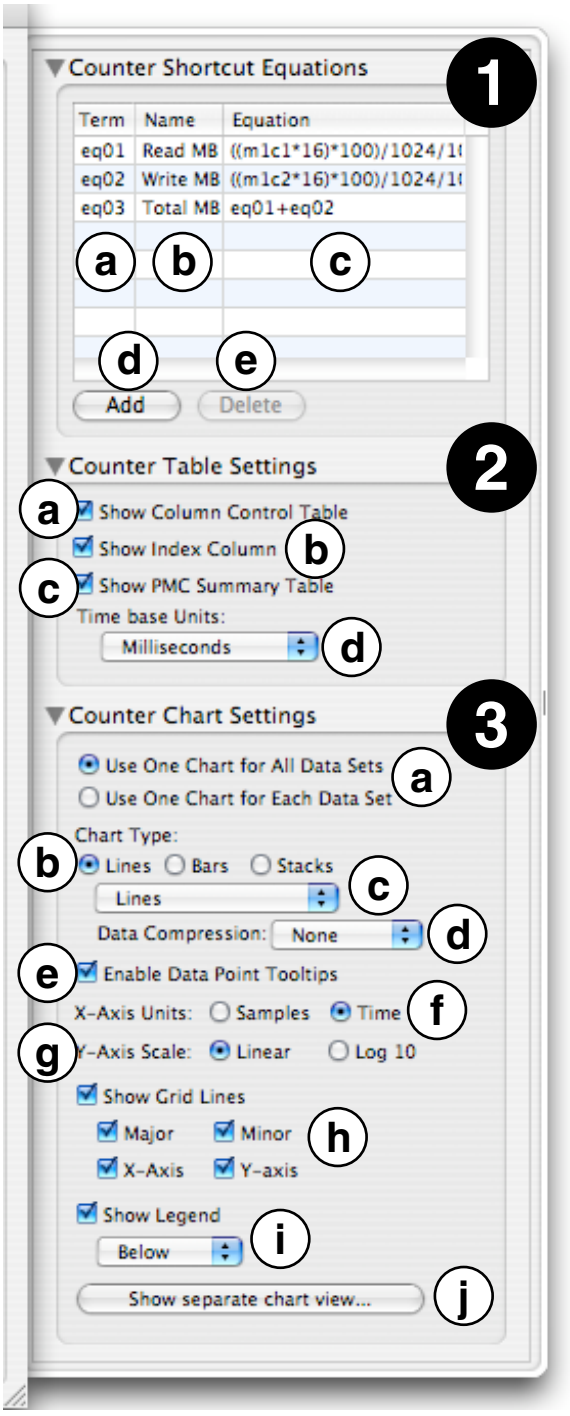
This menu contains several commands that allow you to work with the performance results:

- **Number Formatting**— This submenu lets you adjust how the (often quite large) numbers are displayed in the *Results Table*:
  - *Show 1000's Separator*— Add thousands separators (typically commas) to the values. You can also choose this using the keyboard shortcut *Command-/*.
  - *Use Scientific Notation*— Toggles between standard (e.g. 100) and scientific (1.0E2) notation. You can also choose this using the keyboard shortcut *Command-^*.
  - *Increase Decimal Places*— Increases the number of digits of precision used to display floating-point values by one decimal place. Because performance event counts are integers, this normally only affects shortcut equation results and timebase columns. You can also choose this using the keyboard shortcut *Command-*.
  - *Decrease Decimal Places*— Decreases the number of digits of precision used to display floating point values by one decimal place. Because performance event counts are integers, this normally only affects shortcut equation results and timebase columns. You can also choose this using the keyboard shortcut *Command-*.
- **Print Chart…**— Allows you to print the currently displayed chart, using a standard Mac *Print* dialog box.
- **Save Text File…**— Exports the current *Results Table* values as a comma-separated value (CSV) format text file. This resulting text can be imported into an application like Excel for further analysis.

Performance Counter Spreadsheet Advanced Settings

With the session window in the foreground, select *Window*▸*Show Advanced Settings* (*Command-Shift-M*), as we described earlier in "Advanced Settings Drawer" (page 22). The palette of advanced controls will appear ("Performance Counter Spreadsheet Advanced Settings").

Figure 4-13 Performance Counter Spreadsheet: Advanced Settings



This drawer contains three main panels, each with many different controls that affect the presentation of results:

1. **Counter Shortcut Equations**— This table displays the "Shortcut Equations" used to generate each of the computed results columns in the *Results Table*, one equation per row. Both equations that were included right in the configuration and ones that you add yourself after the session has been recorded are listed here, and you can freely edit any of them here. The table consists of a few fairly straightforward parts:

    a. *Term column*— This column lists the "term" name for this equation (usually eq01, eq02, etc.). This is the shorthand name that you can use to include the results of this equation in a subsequent, dependent equation. These "term" names, plus the "term" names for the original performance counter data, are also listed in the *Column Control Table* described previously in "Timed Counters: The Performance Counter Spreadsheet" (page 104).

    b. *Name column*— Here is where you may edit the label that will appear as the column header for this shortcut equation's results.

    c. *Equation column*— You can define or edit the equation used to calculate the entries in the shortcut column here, using the techniques described below in "Adding Shortcut Equations" (page 111).

    d. *Add button*— Creates a new "shortcut equation" and a *Results Table* column for it..

    e. *Delete button*— Removes the selected shortcut(s) and their associated columns from the *Results Table*.

2. **Counter Table Settings**— This section of the drawer lets you adjust the appearance of the tables within the counter spreadsheet window.

    a. *Show Column Control Table*— Toggles display of the *Column Control Table* to the left side of the *Results Table*.

    b. *Show Index Column*— Toggles view of the index column in the *Results Table*.

    c. *Show PMC Summary Table*— Toggles display of the *PMC Summary Table* below the *Results Table*.

    d. *Timebase Units popup*— Allows you to change the units used in the time base column(s) to something more appropriate. Selections are listed in order of increasing size: CPU cycles, bus cycles, microseconds, milliseconds (default), and seconds.

3. **Counter Chart Settings**— This section of the drawer lets you adjust the appearance of the chart within the counter spreadsheet window.

    a. *Multiple Data Set Chart Mode*— These buttons select how you would like the chart to display when multiple columns are selected:

        - One combined chart for all selected result columns
        - Separate charts for each selected column

    b. *Chart Type*— Selects the type of chart that will be displayed:

        - *Lines*— Display results as line charts. There are several sub-options for displaying these charts, which can be selected using the two menus below.
        - *Bars*— Display results using a vertical bar chart. Bars from multiple selected columns will be superimposed over one another.

- *Stacks of Bars*— Display results as stacked vertical bar charts, with the values from all selected columns added together at each sample point. This chart is identical to the standard bar chart if only one column is selected

c. *Line Chart Subtype*— This menu fine-tunes line charts by controlling the display of symbols at data points on the line charts:

- *Lines and Markers*— Display both symbols at each data point and lines to join them up.
- *Lines*— (default) Only displays lines joining the data points together.
- *Markers*— Only displays symbols at each data point.
- *Small Markers*— Same as previous, but the symbols are significantly smaller.

d. *Line Chart Data Compression*— This menu lets you apply filters to smooth out the data plotted using a line chart. These filtering options are not allowed with bar and stacked bar charts.

- *Average*— Applies a moving average (FIR) filter to the data in order to smooth it out.
- *IIR Filter*— Applies an IIR averaging filter to the data to smooth it out.
- *None*— (default) No smoothing applied, so you see only actual values.

e. *Enable Data Point Tool Tips*— When enabled, hovering the mouse pointer over a data point in a data set shows the x- and y-values for that point in a pop-up window.

f. *X-Axis Units*— The horizontal scale can be plotted in two ways:

- *Elapsed Time*— The elapsed time since the beginning of the session, in the units specified with the *Timebase Units popup* above.
- *Sample count*— The sample index, or values from the index column.

g. *Y-Axis Scale*— Data can be plotted vertically on a linear or logarithmic (base 10) scale.

h. *Show Grid Lines*— This lets you control the display of grid lines within the chart. You can toggle all grid lines together or independently toggle major grid lines, minor grid lines, x-axis (all vertical) grid lines, and y-axis (all horizontal) grid lines.

i. *Show Legend*— Toggles whether or not to show a legend, displaying color-to-data column associations, along with the chart. When enabled, you can select the position of the legend for the chart — above, to the right, or below — using the popup menu just below.

j. *Show/Hide Separate Chart View...*— This opens or closes a separate window for the chart view, freeing it from its normal position below the *Results Table*. While it does not enable any new functionality, this option can be useful if you have a widescreen display, and want to position the *Results Table* and *Results Chart* side-by-side instead of top-and-bottom, or if you have multiple monitors attached to your Macintosh and would like to put the *Results Table* and *Results Chart* on different screens.

Adding Shortcut Equations

This section gives a brief summary of how to add new "shortcut equation" results columns to your performance counter spreadsheet. For a full description of all the capabilities of shortcut equations, see "Using the Editor" (page 183).

1. Open up the *Advanced Settings* drawer, if you do not already have it open.
2. Click the "Add" button, in the *Counter Shortcut Equations* palette, and enter a name for your new equation.
3. Double-click on the "Equation" field in the row for your new equation, and enter your equation. You may use any terms from previous columns (using the short names in the term list from the *Column Control Table*) and numeric constants, combined using simple 4-function arithmetic — addition (+), subtraction (-), multiplication (*), and division (/).
4. Press *Enter* when you are done editing your equation. A new column will immediately appear in the Results Table with the results from your computation. You may then examine, graph, or use the numbers in that column in subsequent equations, just as if they had been there from the start.

Event-Driven Counters: Correlating Events with Your Code

Like Time Profiling, using performance counters in "timed counter" mode only performs timed sampling of the various counters, giving you a set of samples with a statistical view of how your application works. However, you may want record more exact information, more like what you can record using System Trace. This is possible using *event sampling*, which is used by the default *L2 Cache Miss Profile* configurations. In this case, you set up a performance counter to interrupt the processor and record a new sample after it has counted a predetermined number of events. Because hardware events happen quickly, you will usually want to have this be a fairly large number, but with some lower-frequency counters it is possible to set the value as low as 1, allowing you to get an exact event trace.

When complete, a standard profile browser will appear, which looks much like the ones created for *Time Profiling* (see "Profile Browser" (page 32)). However, the results must be interpreted quite differently. Because of the unusual way that sampling is triggered, the sample percentages (or counts) do not represent *time* percentages, but instead show *event* percentages. This distinction is *not* clearly marked on the columns, so you must be careful when reading and interpreting the results. With these results presented in this way, you can get a good idea about which routines and even which lines of code are responsible for causing the largest number of performance-draining events, such as L2 cache misses, in a manner that is completely analogous to interpreting a conventional *Time Profile*.

Note: The built-in L2 cache miss profile configuration is a great way to find lines in your code that access memory in ways that cause very slow L2 cache misses, events which can significantly slow down processors like the ones in modern Macs. Optimizing this code to reduce the number of cache misses by adjusting your algorithms and/or memory access patterns can be a very helpful way to improve performance significantly.

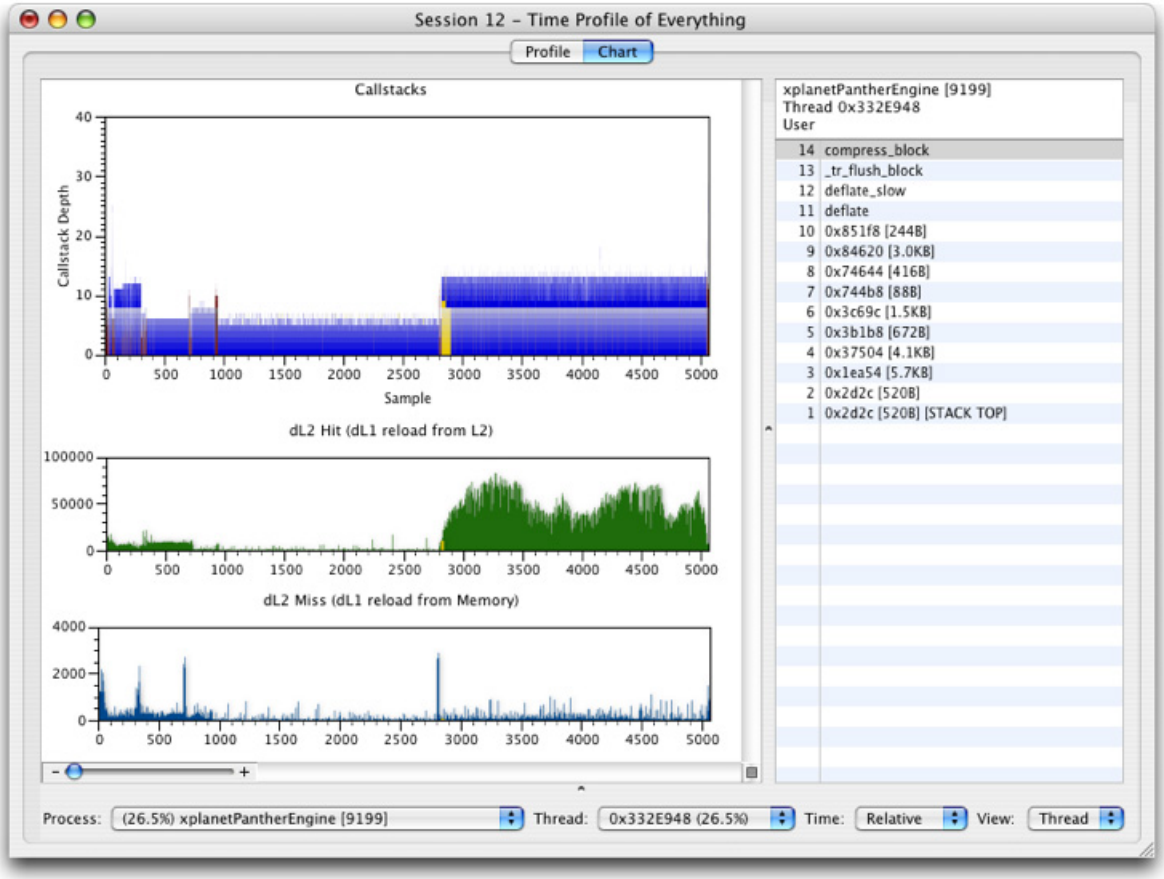
Event sampling can only be triggered by a single PMC at a time, so you can only trigger on a single event type (such as L2 misses or off-chip data movement) per session. The value of other counters can be recorded at the same time, but they cannot be used as triggers. While this can be a serious disadvantage, it is balanced out by the fact that you are able to capture your program's callstack *exactly* where the event is occuring, allowing you to see exactly which lines of code are causing the events, instead of the approximate locations returned by "counter" mode profiling. In general, if you need to visualize system-wide or process-wide

performance events over time without associating performance events to a specific piece of code, the timed counter method is appropriate. On the other hand, if you need to associate performance events precisely with source code that is causing the event to occur, then event sampling is the better choice. These various pros and cons are summarized below:

	Timer Sampling	Event Sampling
Pros	■ Measure multiple performance events over time. ■ Produce meaningful system and process level chart of performance events. ■ Works with any processor. ■ Results are easy to interpret on multiprocessors.	■ Very precise; can relate performance events to a small window of instructions.
Cons	■ Normally no correlation with your code. ■ With callstack recording enabled (see below), event-code correlation is very approximate.	■ Trigger on only a single performance event per session. ■ No chart of performance events. ■ It is harder to interpret results on multiprocessors, since events do not occur simultaneously on all processors. ■ Not available on older PowerPC processors (G3 and G4).

While none of the default configurations use this capability, it is also possible to essentially record callstacks like a *Time Profile* simultaneously with timed counter information, giving you timed counter recording with a way to approximately correlate results with your code, by building your own custom configuration. In this case, the chart view adds new graphs that allow you to look for correlations between performance monitor counts and what code was running at the time a sample was taken, merging elements of the Counters viewer in with the standard *Time Profile* chart view. An example of using the Chart view with PMCs in counter mode (raw values graphed over time) is shown in Figure 4-14. With these graphs, you can click on them at any point to see the callstacks that correspond with that part of the profile. However, be aware that the callstack locations only record *approximately* what code was executing at the time the counts were recorded, and may not be representative if the sampling rate is significantly lower than the rate at which your program calls functions. This potential defect is the reason why none of the default configurations use this technique, even though it can sometimes be useful if used judiciously.

Figure 4-14 Chart View with additional timed counter graphs



Advanced Profiling Control

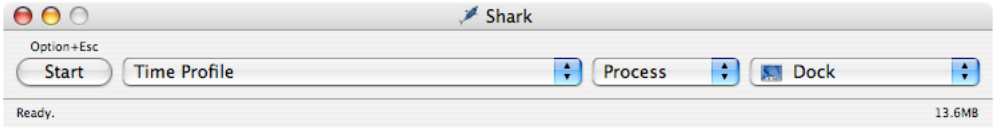
Although the *Start* button makes starting and stopping Shark quite simple, sometimes it can be impractical, or even impossible to use. For example, how can you press the start button on a headless server? Profiling application launch can be hard to accomplish by hand as well. And what if you are only interested in profiling one particular "hot" loop, buried somewhere deep within your application?

This section discusses various advanced ways to control *what* Shark profiles, *when* it profiles, and *how* the resulting profile relates to your target execution.

Process Attach

It's not always beneficial to profile the entire system — often there is just too much information. For this reason, Shark allows you to target any process in the system individually, further focusing your profile. In this mode, Shark will only save samples from the target process, while discarding any others.

Figure 5-1 Process Attach

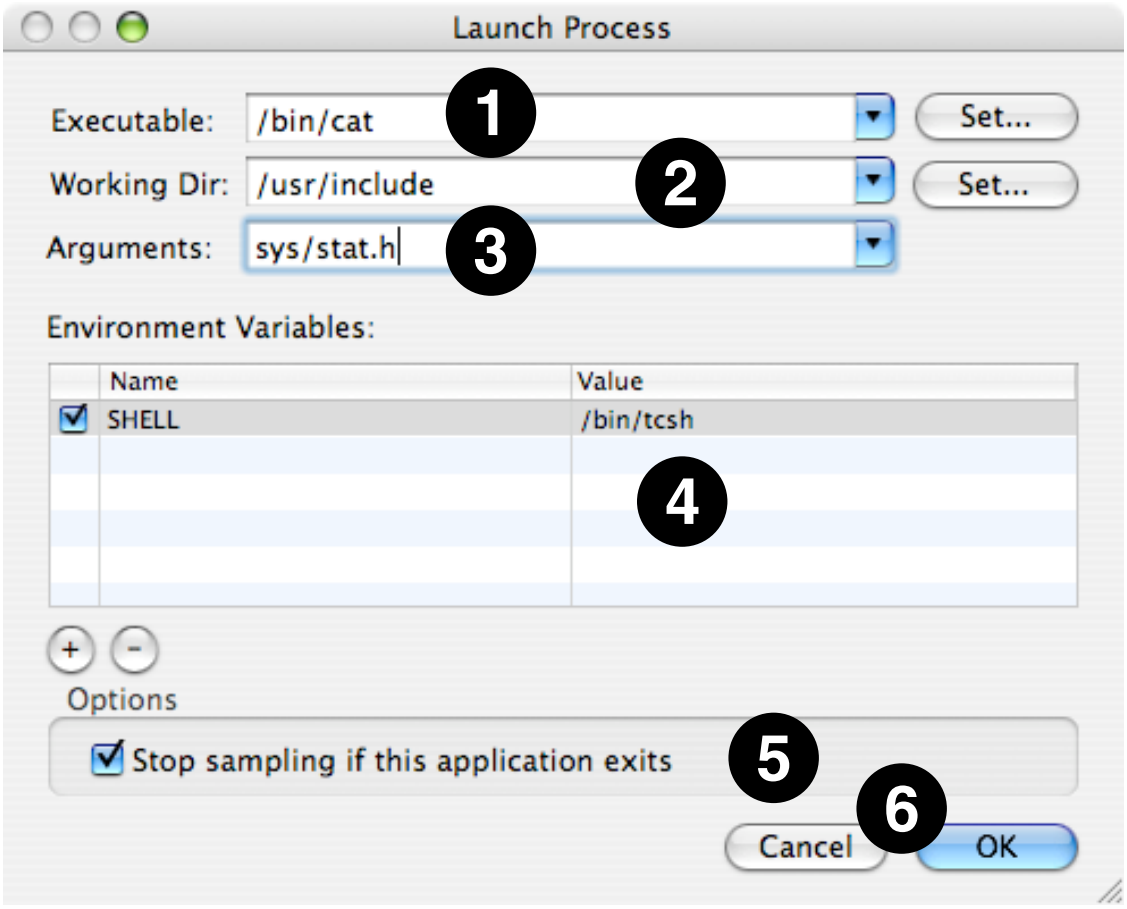


When you enter this mode by selecting *Process* from the Target popup in Shark's main window(or use *Command-2*), the Shark window will expand, adding a new popup — the *Process List*, as we show in Figure 5-1. By default, the Process List is sorted by process name, and you will only see processes that you own. To change these defaults, open the preferences by selecting the *Shark*▯*references* menu item (*Command-Comma*) and adjust the values for the Process List under the "Appearance" tab "Shark Preferences" (page 23).

Process Launch

Attempting to profile launch times for your application by hand can be a frustrating endeavor. Profiling an application (or part of one) that only runs for a short time can be similarly difficult. For this reason, Shark allows you to launch your application directly, from within Shark. To instruct Shark to launch your process, enter *Process Attach* mode, by selecting *Process* from the Target popup (*Command-2*). Now, select the "Launch..." target from the top of the process list (or use *Command-Shift-L*). Choosing this "process" and then pressing "Start" will bring up the Process Launch Panel, shown below in Figure 5-2.

Figure 5-2 Launch Process Panel



Once the Process Launch Panel has appeared, you need to "fill in the blanks" in order to tell Shark how to launch your application. If you reach here by choosing *Debug*▷*Launch Using Performance Tool*▷*Shark* in Xcode, most of these blanks will be completed for you. At the very least, you must choose an executable file before pressing "OK" and continuing. However, you can also supply many other bits of information to Shark in order to simulate the launching of your application from a command-line shell prompt, and specify a couple of options to help limit capture of spurious samples.

1. **Executable**— The *full* path to the executable. You can either type it here or press the "Set..." button and then find it using a normal Mac "Open File..." dialog box. For Mac applications, you can set this to be either the entire application or the core binary file inside of it.

2. **Working Dir**— The *full* path to the working directory that the application will start using. By default, this is the path where the executable is located, but you may point it anywhere else that you like. When the application is executed, it will appear to have been started from a shell that had this directory as its working directory (i.e. the output of `pwd`) just before executing the command. Hence, relative paths to data files will start being determined from this directory.

3. **Arguments**— Enter any arguments here that you would have normally entered onto your shell command line after the name of the executable. Shark will feed them into the application just as if they had come from a normal shell. Note that since Shark's "shell" does not have any text I/O, you will need to provide `< stdin.txt` and `> stdout.txt` redirection operations here if your executable expects to use `stdin` and/or `stdout` "files."

4. **Environment Variables**— Supply *any* environment variables that must be set before your application starts in this table. Otherwise, Shark will start your application with *no* environment variables set (it even clears out any "defaults" that you may have had before invoking Shark). Pressing the "+" and "–" buttons below the table allows you to add or remove environment variables, respectively. Once added, you can freely edit the names of the variables and their value in the appropriate table cells.

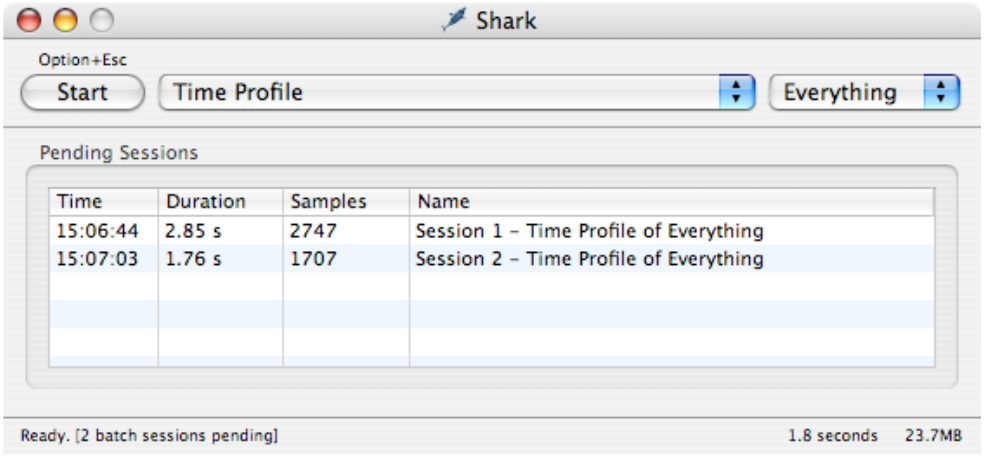
5. **Stop sampling if this application exits**— If checked, Shark stops sampling immediately after your application completes. Hence, this will prevent Shark from capturing a bunch of samples that have nothing to do with your application if it completes quickly.

6. **Cancel & OK**— Shark will start your application and sample it *immediately* after you hit OK. If you change your mind, Cancel will return you back to the main Shark window.

Batch Mode

Batch mode queues up any sessions recorded without displaying them. Pending sessions are listed in the main Shark window. Batch mode allows multiple sessions to be recorded in quick succession, by not immediately incurring the overhead of displaying the viewers for each session. To enter Batch Mode, select the *Sampling*□*aBatch Mode*menu item (or *Command-Shift-B*).

Figure 5-3 Batch Mode



Batch mode is most useful when paired with remote control from within your application's code, profiling multiple hot loops in quick succession, during a single program execution. Using a different session label for each loop, you can rapidly obtain multiple profiles for later investigation. See "Performance Counter Spreadsheet Advanced Settings" (page 107) for information on using this technique.

Windowed Time Facility (WTF)

For measuring hard to repeat scenarios, Shark provides the Windowed Time Facility (abbreviated as *WTF*) with the Time Profile and System Trace configurations. The Windowed Time Facility directs Shark to only record and process a finite buffer of the most recently acquired samples, allowing it to run *continuously* for long periods of time in the background. This continuous behavior allows you to stop profiling just *after* something interesting occurs. At this point, Shark processes the samples in the *window* of time just before profiling was terminated. This allows you to determine what part of your program's execution is "interesting" *after* it occurs, instead of trying to anticipate it in advance. Now, you effectively have the benefit of hindsight for finding hard to repeat problems.

Another way of describing how WTF mode works is how it modifies Shark's normal "start" and "stop" behavior. Generally, Shark processes *all* the data between the "start" and "stop" trigger events, as is shown in Figure 5-4. Most commonly, users start Shark just before entering an "interesting" period of execution and stop it when leaving the area of interest. However, you may not always know when you will encounter the "interesting" region of your program in advance. WTF mode sidesteps this problem by eliminating the need to "start" normally. While Shark stops in the normal way, as we show in Figure 5-5, the starting position is just a fixed number of samples (or effectively amount of time, with Time Profiling) before the end, instead of at a user-specified point.

Figure 5-4 Normal Profiling Workflow

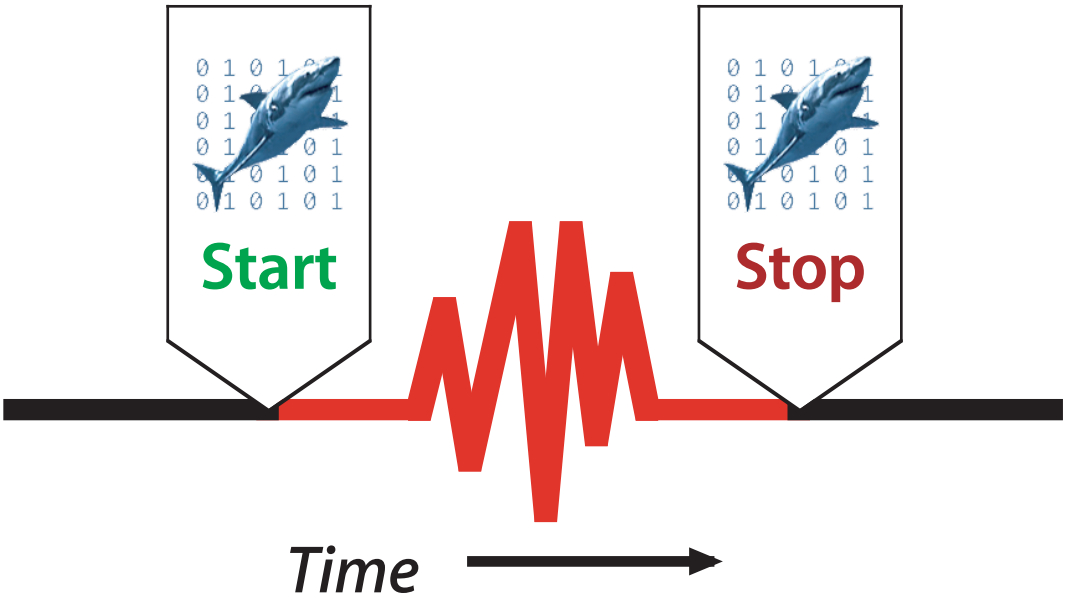
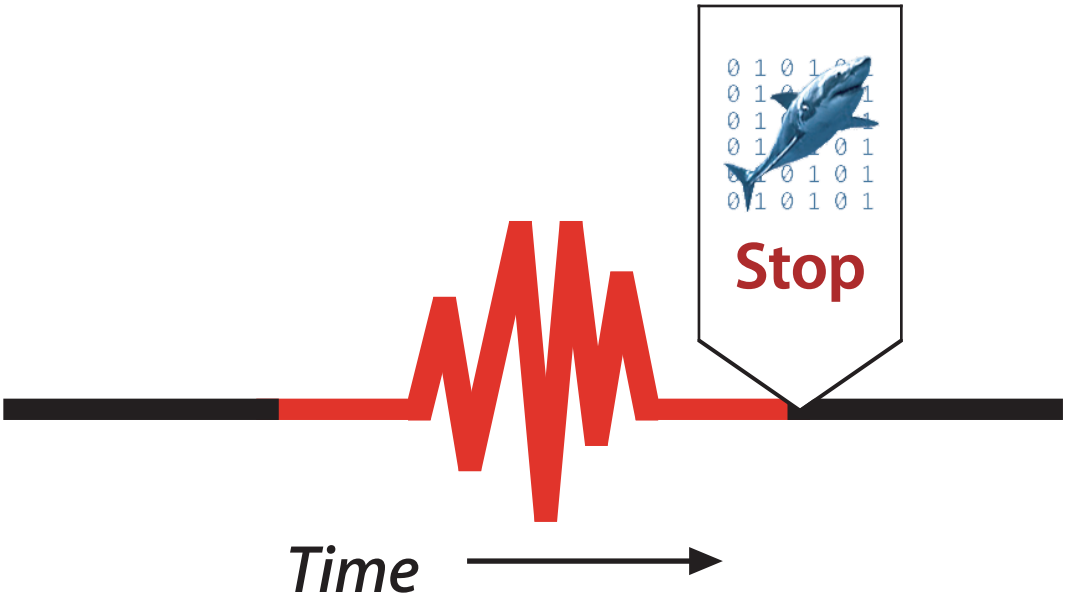


Figure 5-5 Windowed Time Facility Workflow



Tracing the execution around an asynchronous event, such as inter-thread communication, the arrival of a network packet, or OS event such as a page fault, are all situations when WTF mode can make profiling easier, especially when these "glitches" occur at hard-to-predict times.

This mode of profiling is especially useful for game programming; often, the timing of calls to performance-critical code regions is highly dependent upon a player's actions, which can be hard to reproduce. For example, assume you are developing a video game engine and occasionally see the frame rate drop and/or video glitches. If the conditions for causing the glitch are unpredictable and inconsistent, then you would normally have to start sampling, attempt to reproduce the problem, and then stop sampling afterwards. If the glitch is rare, then odds will be low that you will catch the glitch within the limited sampling window, creating an extremely frustrating workflow. With WTF mode, in contrast, you can just start Shark and forget about it — until the glitch actually occurs, when a quick press of the "stop" button will capture the sequence of samples involving the glitch.

WTF mode can be enabled in several different ways. In order of increasing complexity, it can be turned on through any of the following three options:

- You can select the *Time Profile* and *System Trace* configurations with "WTF" included in the name from the Configuration popup (see "Main Window" (page 17)).
- WTF is an option for the "normal" *Time Profile* and *System Trace* configurations which may be enabled by checking the "WTF Mode" check boxes in the mini-configuration editors associated with these configurations (see "Taking a Time Profile" (page 31) and "Basic Usage" (page 60)).
- You may include this option in your own configurations that use the "Timed Samples & Counters" or "System Trace" data source plugins (see "Simple Timed Samples and Counters Config Editor" (page 174) and "System Trace Data Source PlugIn Editor" (page 179)).

In addition, WTF mode works perfectly well with *all* of the different ways to effectively press "start" and "stop" described in this chapter. For example, instead of manually pressing "stop" at the end of your WTF region, you might have code in your program detect "glitch" conditions and programmatically fire a "stop" signal using the techniques described in "Programmatic Control" (page 125).

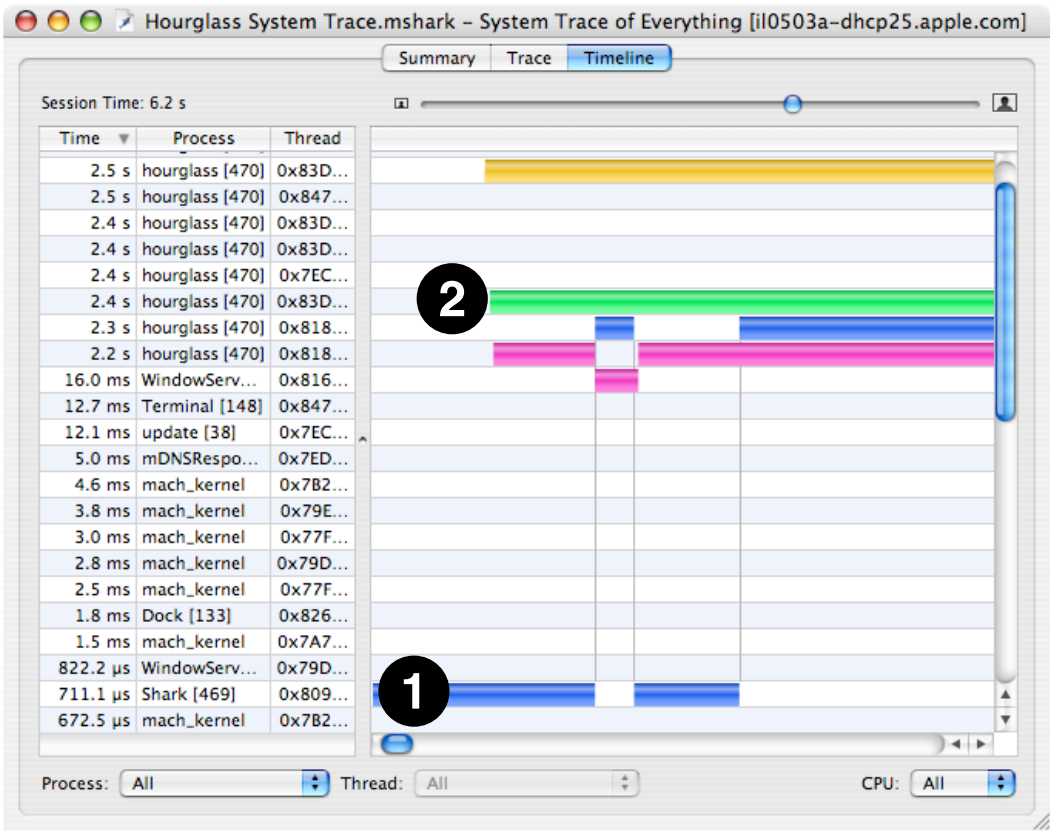
WTF with System Trace

In most ways, WTF mode functions exactly the same when used with both the Time Profile and System Trace configurations. However, there are two notable differences.

First, since System Trace is event-driven, and not time interval-driven, the "window" is actually a fixed number of *system events* per processor, and not a fixed window of time. Therefore, the actual period of time represented by the window is highly dependent on the rate that system events occur for each processor. If these events occur very rapidly, the window might be quite short in time; if these events occur infrequently, the window might represent a long interval.

Second, the beginning of a WTF System Trace Timeline (see Figure 5-6) can appear a bit strange; different processors might first appear at vastly different points in the timeline. In the figure below, the timeline for the processor at (1) begins well before the other three processor timelines at (2). This occurs because each processor maintains its own "window" of samples, and system events can occur at vastly different rates on each processor. As a result, each processor's window of samples can correspond to different periods of time. Since all processors' timelines end at the same time, the effect of this is that some processors won't show up in the timeline until much later than other processors.

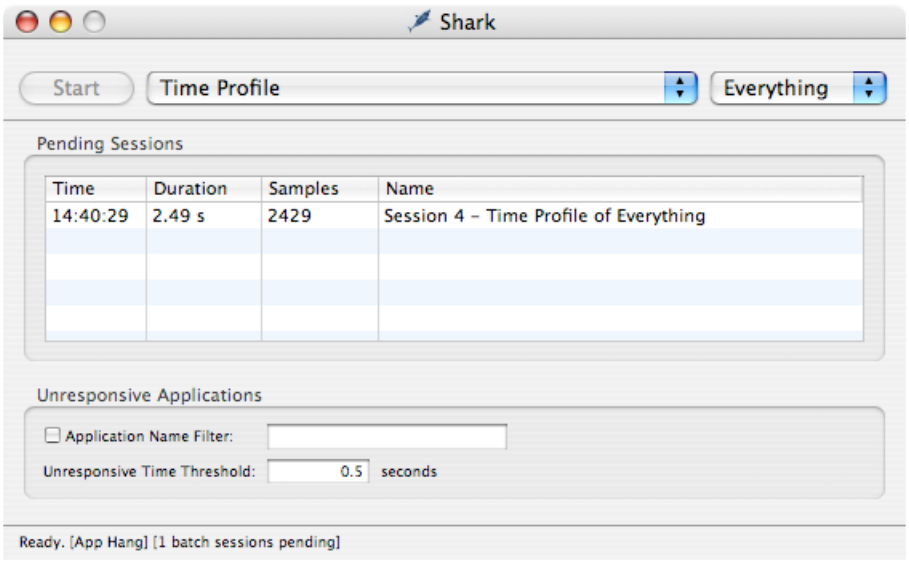
Figure 5-6 The Windowed Time Facility Timeline



Unresponsive Application Measurements

During the development process, there may come a point where your application goes unresponsive, and the dreaded spinning rainbow cursor is displayed (). Often, the situations in which this happens can be hard to repeat. For these situations, Shark provides *Unresponsive Application* Triggering, allowing you to automatically sample whenever an application becomes unresponsive. This method of triggering is enabled by selecting the *Sampling→Unresponsive Applications* menu item (*Command-Shift-A*). When Unresponsive Application Triggering is enabled, Shark will automatically switch to Batch Mode and display unresponsive application triggering options, as shown below.

Figure 5-7 Unresponsive Application Triggering



Unresponsive application profiling can be limited to a single application by setting the *Application Name Filter* check box and filling in a name or partial name in the associated text field. The threshold for the amount of time an application is unresponsive (does not respond to mouse or keyboard events) can be set by entering a value (in seconds) in the *Unresponsive Time Threshold* text field. With this, you can eliminate sampling of expected, brief bits of unresponsive time and focus instead on the really long and painful occurrences.

Note: The *Unresponsive Time Threshold* value modifies the system-wide definition of what an "unresponsive application" actually is, and will consequently change the amount of time from the last time the application was responsive to the first time that the system presents the spinning rainbow cursor for it.

Command Line Shark

In some situations, such as profiling on headless servers, it is not possible to use the graphical user interface at all. For these cases, use `/usr/bin/shark`. Command line `shark` supports the major features of its graphical counterpart for data collection, but does not do much with the recorded data beyond saving sessions. In

general, it is intended that you use it to collect sessions and then review your results with a graphical copy of Shark later. This section will discuss some common ways to use command line `shark`. A more complete description of the options available when using command line `shark` is available in its man page, `shark(1)`.

Basic Methodology

There are four main ways to use command-line `shark`. With the exception of network mode, which can run along with interactive and remote modes, any one invocation of `shark` is locked into using only one of these modes for its entire duration.

Interactive Mode

By default, command-line `shark` works in a simple interactive mode. After starting up, it records sessions on demand through a simple, three-step process:

1. `shark` waits in the background until it spots a "hot key" press, and then it starts sampling. On your local system, the hot key same as graphical Shark (*Option-Escape*, by default), while on remote terminals it defaults to *Control*-\, since this key combination can be transmitted through a generic terminal.
2. When you press the same "hot key" again, `shark` will stop sampling and begin analyzing its samples to produce a standard Shark session file. It displays progress as this occurs, and then writes out the session file to disk, using the name `session_XX.mshark` (XX = a number) and the current terminal directory by default. When complete, shark waits for another "hot key" press.
3. If you press *Control-c* instead of a "hot key," then `shark` will terminate and return you to the shell prompt.

After `shark` completes, you will have a sequence of Shark session files that you may then examine at your leisure with graphical Shark. Of course, there are many ways to modify this basic methodology, described in the next few sections.

Immediate Mode

Command line `shark` also supports *immediate* mode, where it starts sampling immediately after it is launched with no user interaction, and quits after it finishes profiling — usually after 30 seconds, or when the user presses *Control-C*. This is often useful for invocation from shell scripts. To launch `shark` in this mode, use the `-i` option, as follows:

```
shark -i
```

Remote Mode

A third way to use command line `shark` is *remote* mode, which works much like the remote mode supported by graphical Shark and described in "Interprocess Remote Control" (page 125). Once started in this mode, `shark` will wait for start/stop signals from other processes to arrive in any one of three ways:

1. A program instrumented with `chudStartRemotePerfMonitor()` and `chudStopRemotePerfMonitor()` calls can start and stop `shark`, respectively. This works the same as the equivalent functionality described in "Programmatic Control" (page 125).

2. The utility program `chudRemoteCtrl` can start and stop `shark`. This works the same as the equivalent functionality described in "Command Line Remote Control" (page 127).

3. The UNIX `SIGUSR1` and `SIGUSR2` signals can be sent to `shark`'s PID by your program or the UNIX `kill` utility with the "`-s USR1`" and "`-s USR2`" options. It will interpret `SIGUSR1` as a start/stop toggle and `SIGUSR2` as a command to stop sampling and generate a session.

To launch `shark` in this mode, use the `-r` option, as follows:

```
shark -r
```

Network Mode

Finally, command line `shark` supports *network* mode, where it is controlled remotely by graphical Shark running on another computer. When enabled, `shark` starts up in interactive (or remote) mode, and works normally that way. However, it also listens for network connections from graphical Shark running on different Macintoshes. You can then use a combination of local start/stop operations and network start/stop operations while `shark` is running. To launch `shark` in this mode, use the `-N` option, as follows:

```
shark -N
```

A full description of network shark usage is in "Network/iPhone Profiling" (page 128).

Common Options

Many of Shark's configurations, such as *Time Profile* and *System Trace*, support common options such as time and sample limits. Command line `shark` allows you to change these limits for configurations that support them. These common options include:

- *Time Limit*— `shark -T` allows you to change the time limit. Valid times are any integer followed by "u," "m," or "s," corresponding to microseconds, milliseconds, and seconds, respectively.
- *Time Interval* — `shark -I` allows you to change the sampling interval for configurations that support a sampling interval. Valid times are entered the same way as for time limits.
- *Sample Limit* — `shark -S` allows you to specify the maximum number of samples to record during each session.

Some other, less commonly used options change the behavior of `shark`:

- *Quiet Mode*— `shark -q` will limit terminal output to reporting of errors only.
- *Ignore task exits*— `shark -x` will instruct shark to ignore task exit notifications. Normally, shark gets notified when tasks are about to exit while it is profiling. This allows shark to collect some basic information about the task just before it is allowed to quit. It is possible, though not likely, that this can cause gaps in profiling. Use of this option is discouraged. This is equivalent to the use of the similarly named preference in "Shark Preferences" (page 23).
- *Change default filename*— `shark -o` allows you to change the default session file name from `session_XX.mshark` to a user supplied name. This name will be appended with a unique number to create a unique file name. For example, `shark -o myfile` will result in session files names `myfile_01.mshark`, `myfile_02.mshark`, and so on.

- *Change session file path*— `shark -d` allows you to specify the directory where shark will save session files, instead of the current working directory.

Target Selection

With command line `shark`, you can choose to launch and attach `shark` to a process, or attach `shark` to a currently running process, using options similar to the ones described previously in "Process Attach" (page 115) and "Process Launch" (page 115) for graphical Shark. To launch a process, simply append the process invocation as you normally would to the end of the shark command line. The following example would launch `/bin/ls ~/Documents`, and start `shark` profiling immediately:

```
shark -i /bin/ls ~/Documents
```

Instead, if you wanted to attach to a running *Apache* daemon process, you might try this line:

```
shark -i -a [pid of httpd]
```

Making things even simpler, if you do not know the PID of the process in which you are interested, you can specify a full or partial name as the argument to the `-a` option. If there are multiple matches to a partial name, Shark will take its best guess. For these situations, it is often best to supply a PID instead.

Reports

Command line shark supports generation of textual reports, either from session files that you've already created, or from new sessions as they are generated. These reports can be simple summaries (`-g` or `-G` options), or complete analysis reports (`-t` option).

When creating a summary report, you can either create one from a session that is already saved on disk, with `shark -g`, or create it for new sessions, with `shark -G`. Both options result in the creation of a sidecar file, whose name will be the original session file name with `-report.txt` appended.

Creating a full analysis, either from previously saved sessions, or for any new sessions, requires passing the `-t` flag to `shark`. The `-t` flag optionally takes a filename as an argument. If no file name is specified, `shark` will allow you to take sessions as normal, except it will write one additional file per session — the full analysis report. If you specify a file name, `shark` will instead only generate the full analysis report sidecar file, and immediately quit. In both cases, the report filename will be the session file name, with `-full.txt` appended.

Custom Configurations

Because of its command line nature, `shark` can only operate on configurations already created by its graphical counter-part as discussed in "Custom Configurations" (page 171). To use a custom configuration on a headless server, export it from Shark by opening the Configuration Editor, selecting the desired Configuration, and clicking the "Export..." button in the Configuration Editor (as described in "The Config Editor" (page 171)). Copy the resulting `.cfg` file to `~/Library/Application Support/Shark/Configs` on the target machine so that command-line `shark` can find it.

Running `shark -l` will list all installed configurations, including any custom configurations (which will be near the bottom of the list). Using a capital `-L` instead will additionally list a short summary of what each configuration does, what plugins are active with each one, and their settings.

Instruct `shark` to use your custom config by passing its corresponding number to the `-c` argument. For example, if your new configuration was listed as number 13, you might use the following command line to load that configuration into command line `shark`:

```
shark -c 13
```

Alternatively, you can specify the configuration file to use directly, using `-m`:

```
shark -m custom.cfg
```

For more information on creating and using custom profiling configurations, see "Custom Configurations" (page 171).

More Information

This section has presented some of the most common options and techniques for using command-line `shark`. For more detailed information on all available options, please read the man page: `shark(1)`.

Interprocess Remote Control

In some cases, it is best to have your programs start and stop Shark's sampling at precisely chosen points in their execution. Shark supports two major forms of start/stop "remote control" from other processes: *programmatic control* allows you to insert code directly into your application to start and stop profiling, while command line remote control allows you to insert commands in your `perl` or shell scripts to start and stop profiling. In order for a remote client to activate Shark, Shark must first be placed in remote mode using the *Shark*→*Sampling*→*Programmatic (Remote)* menu item. Similarly, you can use `shark -r` to start command line `shark` in remote mode (as mentioned in "Remote Mode" (page 122)).

Programmatic Control

It may be useful to narrow down what is profiled by Shark to a particular section of code within your application. You can start and stop sampling from within your application's code by calling the `chudStartRemotePerfMonitor()` and `chudStopRemotePerfMonitor()` functions, defined in the `CHUD.framework`. This can be accomplished in one of two ways:

1. *Remote Profiling*— instrument your code with calls to `chudStartRemotePerfMonitor()`/`chudStopRemotePerfMonitor()`. Shark should then be placed in remote monitoring mode via the *Sampling*→*Programmatic (Remote)* menu item (*Command-Shift-R*) before running your instrumented program. For every pair of start/stop calls, Shark will create a new sampling session. This can be especially useful with "Adding Shortcut Equations" (page 111).

2. *Thread Marking*— When using Hardware Performance Counters on a PowerPC machine, as discussed in "Hardware Counter Configuration" (page 189), you can use `chudMarkPID()` to mark your process or `chudMarkCurrentThread()` to mark the current thread around your critical sections of code. If you configure Shark to sample only marked performance events, only code in the critical sections will be profiled.

Note: Currently, Intel machines do not support process or thread marking for performance monitoring. Consequently, this technique is only useful for PowerPC machines.

It is important to keep in mind that many profiling techniques used by Shark employ statistical sampling in order to generate a profile. If the sampling interval is longer than the time it takes to execute the instrumented section of code, you may see few or no samples in the resulting profile. Statistical sampling is most useful when at least several hundred samples are taken.

Example: Towers of Hanoi

We will use the Towers of Hanoi puzzle as an example of controlling Shark from within source code. The French mathematician Edouard Lucas invented the Towers of Hanoi puzzle in 1883 . The puzzle begins with a tower of N disks, initially stacked in decreasing size on one of three pegs. The goal is to transfer the entire tower to one of the other pegs, moving only one disk at a time and never a larger one onto a smaller one. A common solution to the Towers of Hanoi problem is a recursive algorithm (see Listing 5-1, below).

Listing 5-1 Towers of Hanoi Source Code

```
/* This functions takes a tower of n disks and moves from peg   */
/* 'source' to peg 'destination'.  Peg 'temp' may be used       */
/* temporarily.                                                 */
void Hanoi(char source, char temp, char destination, int n){
   if(n>0) {
      Hanoi (source, destination, temp, n-1);
      Hanoi (temp, source, destination, n-1);
   }
}
```

As a demonstration of source code instrumentation, we insert calls to start and stop Shark into the Towers of Hanoi test program (see Listing 5-2, below). Shark is then placed in *Remote Monitoring* mode and set to use the standard *Time Profile* configuration. The test program is run for N=10..20 disks. Shark records a session for each pair of start and stop calls.

Listing 5-2 Instrumented Towers of Hanoi

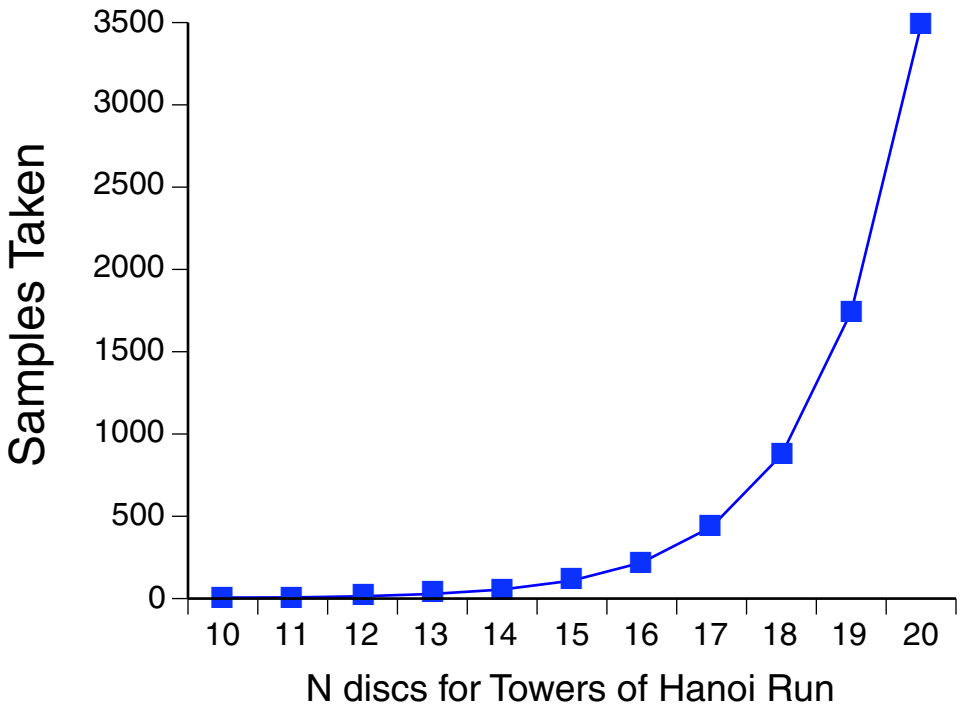
```
#include <CHUD/CHUD.h>

   chudInitialize();

   chudAcquireRemoteAccess();

    for(i=n_min; i<=n_max; i++) {
      sprintf(label_str, "Hanoi #%d", i);
      chudStartRemotePerfMonitor(label_str);

      Hanoi('A','B','C',i);

      chudStopRemotePerfMonitor();
   }

   chudReleaseRemoteAccess();
```

Note: To compile this example program, you must instruct `gcc` to link with the CHUD framework:

```
gcc -framework CHUD -F/System/Library/PrivateFrameworks towersOfHanoi.c
```

The Towers of Hanoi test program demonstrates the need for a sampling interval that is much shorter than the time between the calls to start and stop Shark (see Figure 5-8). Less than 100 samples are taken unless the problem size is at least 15 disks. As a result, you will often find that it is better to sample your entire application and use Shark's powerful "Data Mining" (page 139) mechanisms to narrow down what is displayed after sampling.

Figure 5-8 Samples Taken for Towers of Hanoi N=10..20



Command Line Remote Control

You can also start sampling remotely through the command-line using the `chudRemoteCtrl` command-line tool. Again, in order for remote clients to activate Shark, Shark must first be placed in remote mode using the *Shark*▸*Sampling*▸*Programmatic* (*Remote*) menu item.

To start profiling from within your shell scripts (or by hand), issue the following command:

```
chudRemoteCtrl -s MySessionLabel
```

The argument to `-s`, above, is an arbitrary, user-specified label that will be applied to the generated session. To stop profiling, issue the following command:

```
chudRemoteCtrl -e
```

When used to stop profiling, `chudRemoteCtrl` will not return until Shark has stopped profiling. In the case of command-line `shark`, `chudRemoteCtrl` will not exit until the session file is written to disk. More information on chudRemoteCtrl is available from its man page, `chudRemoteCtrl(1)`.

Network/iPhone Profiling

Shark allows you to share computers for profiling over a network and to discover other computers sharing their copies of Shark using *Bonjour* or manual IP address entry. This allows you to record profiles on two separate Macs on your desk (good for fullscreen application profiling), Macs in another room (useful when you are profiling servers), or even Macs halfway around the world (for travelers).

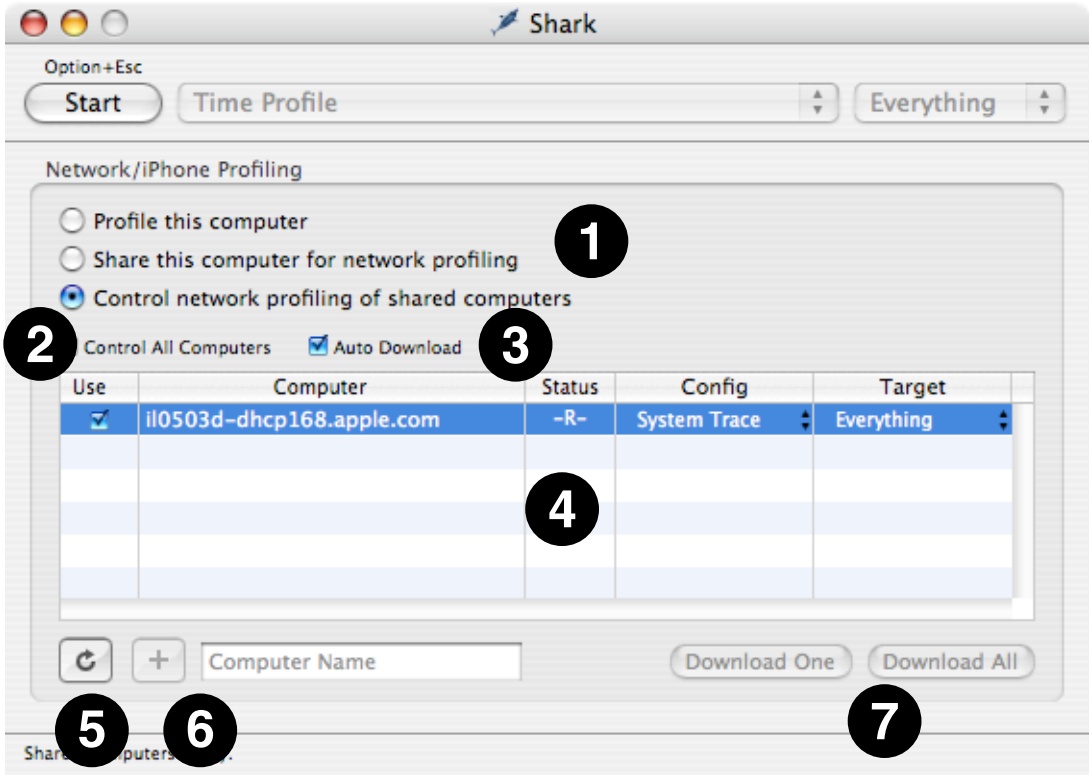
Note: Because of changes required to add iOS support to Shark 4.6, the networking protocol software changed between versions 4.5 and 4.6 of Shark. As a result, you cannot control computers running versions of Shark 4.5 or earlier from a machine running 4.6 or later, and vice-versa. Hence, it is a good idea to keep copies of Shark that may be communicating with each other remotely synchronized to the same version.

In addition, the same user interface can be used to control Shark running on any iPhone (or other device that runs the iOS, such as the iPod Touch). Shark is included by default in the iOS developer tools, so once they are installed onto your device it can be controlled by Shark running on any Mac simply by docking the device and attaching the dock to one of the Mac's USB ports.

Important: Shark cannot capture *symbol* information on the iPhone itself, so "raw" sessions recorded from an iPhone will appear in Shark labeled only based on sample address ranges. This can make it very difficult to understand the results that Shark returns. Instead, you must tell Shark to recover symbol information afterwards from a copy of your iOS application which is stored locally on your Macintosh. As a result, anybody profiling an iPhone will definitely want to check out "Manual Session Symbolication" (page 134) for more information about how to tell Shark where your application's symbols are located.

To use Network Profiling, select the *Shark*▸*Sampling*▸*Network/iPhone Profiling...* menu item (*Command-Shift-N*), and the main window will expand to show the *Network/iPhone Manager* pane below the main controls, as shown in Figure 5-9.

Figure 5-9 Network/iPhone Manager



The controls in this window are described below:

1. **Modes of Operation**— Choose the overall network operation mode here:

   - *Profile this computer*— Profile the system that is running this instance of Shark; this is the "normal" way of running Shark, and effectively disables Network/iPhone Mode.
   - *Share this computer for network profiling*— Shark will advertise itself as a shared profiling service to networked computers. In this shared profiling mode, the user interface for starting and stopping profiling on the local machine is disabled.
   - *Control network profiling of shared computers*— Any computers on the network (in the local domain) running Shark in "shared" network mode will automatically be listed as available for control by this instance of Shark. In addition, all iOS devices in docks attached directly to this computer will also appear as "shared computers" if they have Shark installed (because it cannot be controlled directly on the device, Shark is automatically started in "shared" mode on these devices when necessary). In "Control" mode, clicking on Shark's *Start* button triggers profiling on the selected shared computer(s). "Distant" computers that are outside of the local network domain can be added to the list of controlled computers by entering the computer's network name in the field below the shared computer table and clicking the Add (+) button.

2. **Control All Computers checkbox**— When selected, *all* of the currently listed shared computers will be automatically selected for control. Any new computers that become available in the list (either by Bonjour auto-discovery or by being manually added by name to the table) will be automatically selected for control, as well. All computers will start and stop sampling together, at approximately the same time.

Additionally, changing the config or target of *any* shared computer causes all the controlled computers' settings to change to the same setting, if it is available. This option is very useful when you are attempting to control a large cluster of identical computers.

3. **Auto Download checkbox**— When selected, the shared computers controlled by this copy of Shark will automatically deliver sessions to the the controller. The name of the system that generated each session is included in the title of each session document window. Otherwise, the sessions will be saved locally on the controlled machines for later download. This can be a better policy if you are taking many sessions in quick succession, and network bandwidth becomes a limiting factor or impacts your measurements adversely.

4. **Computer table**— This is the list of all the Macs running the Shark application in shared profiling mode and attached iOS devices. These computers can be selected for profiling control by this Shark application. Columns are discussed in the order they are presented onscreen, left-to-right:

   - *Use*— Toggles whether or not to control Shark on a shared computer.
   - *Computer*— The name of each shared computer
   - *Status*— This shows the current "state" of Shark running on the remote system. There are several different possible states of a shared computer running Shark in network mode:
     - Unknown (–?–): Computer is not connected.
     - Ready (–R–): Shark can start sampling.
     - Sampling (–S–): Shark is actively collecting profile data.
     - Processing (–P–): Shark is creating a profile session.
     - Transmitting (–T–): The new session is being sent.
   - *Config*— The currently active *Sampling Configuration* on the shared computer. The entries in this column are menus, just like the one in Shark's main window (see "Main Window" (page 17)). The selected configuration on the remote shared computer can be changed by changing the selection in the menu
   - *Target*— The currently active *Profiling Target* on the shared computer. The entries in this column are menus, just like the one in Shark's main window (see"Main Window" (page 17)). The targeted process (if any) on the remote shared computer can be changed by changing the selection in the menu.
   - *Cached Sessions (not pictured)*— This column is only visible if "Auto Download" is not active. It lists the number of complete profile sessions cached on each shared computer, and waiting for download to the controlling system.

5. **Refresh button**— Click this button to clear the table and search for shared computers and attached iOS devices again. Computers that you have added by hand will not be cleared from the list when you refresh.

6. **Add Computer button and Name field**— Pressing this button attempts to add the computer with the name or IP address entered into the computer name field to the list of shared computers. The specified computer must be attached to the network and running Shark in shared profiling mode, or this will fail.

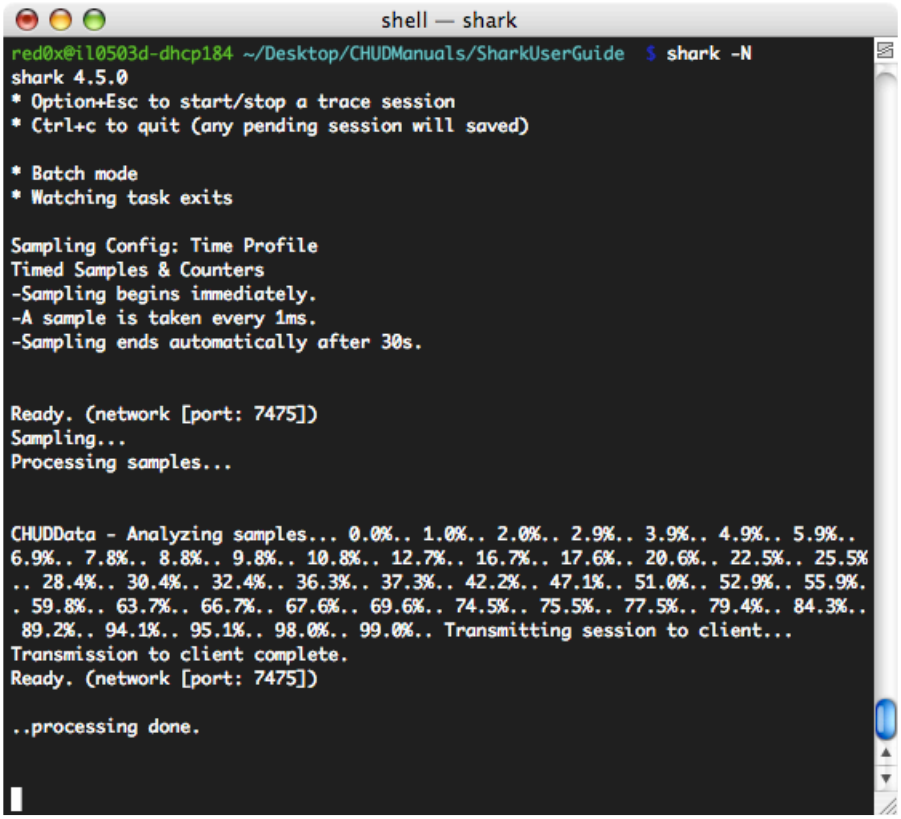
7. **Download One and Download All buttons**— If the *Auto Download* checkbox is not selected, then computers that are being controlled across the network will cache the session files they generate for later download rather than sending them immediately to the controlling Shark application. The number

of sessions available to download is listed in the Shared Computer table's *Cached Sessions* column. Clicking the *Download One* button will download a single session, while clicking the Download All button will download all available sessions. Sessions are always retrieved in the order that they were created.

Using Shared Profiling Mode

Although the graphical Shark application can be placed in "Share this computer" mode, it is more typical to use command line `shark` on any remote, shared computers. You can use `ssh(1)` to connect to a remote computer. Once connected, launch command line `shark` with the `-N` option. The remote run of `shark` will then respond to network requests to start and stop profiling. A sample transcript of a remote command line shark in "Network Sharing" mode is shown in Figure 5-10. For more information on the usage and configuration of command line `shark`, see "Timed Counters: The Performance Counter Spreadsheet" (page 104).

Figure 5-10 Command Line Shark in Network Profiling Mode



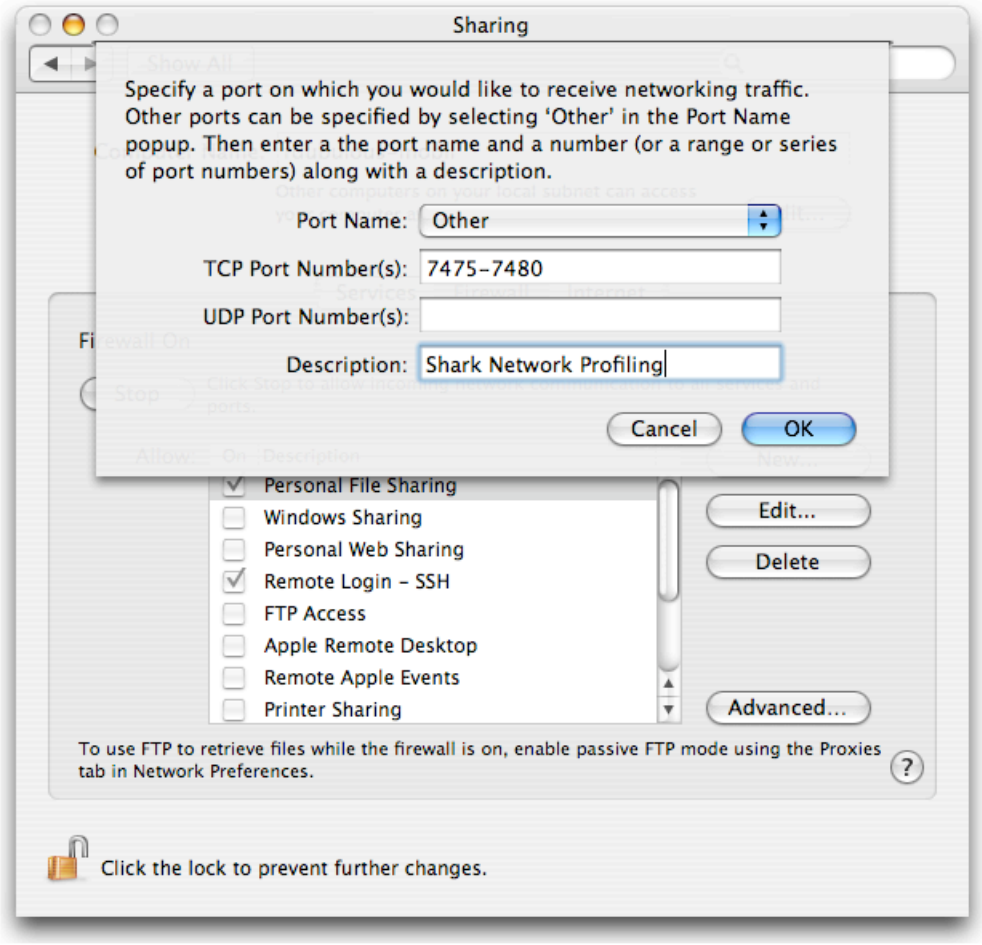
Mac OS X Firewall Considerations

The sharing firewall on Mac OS X can prevent Shark's network profiling from working in either sharing or control mode. When the Shark Network Manager successfully opens a network connection, the communication port number Shark is using is listed in brackets. This is normally port number 7475. Unfortunately, this port is not "open" through the firewall by default. If you attempt to enter "Shared Profiling" or "Network Control" mode while the firewall is enabled, you will be presented with a warning dialog, as illustrated in Figure 5-11

Figure 5-11 Sharing Firewall Warning Dialog

Click the *Sharing...* button in the warning dialog to bring up the *System Preferences* window *Sharing* tab. Otherwise click the *Ignore* button to dismiss the dialog, but note that doing so may result in the inability to use Shark over the network. Once in the *Sharing Preference* window of *System Preferences*, select the *Firewall* tab. If you have never before added settings for Shark, then click the *New…* button, and fill in the sheet as shown in Figure 5-12, and click the *OK* button.

Figure 5-12 Firewall Sharing Preferences, while adding a new port range for Shark



Advanced Session Management and Data Mining

Often, the profile analysis windows can provide you with a very helpful view of your application's behavior using the default settings. However, there are also many tools available in Shark that can help you sort through the large quantity of data that Shark can collect quite quickly. This chapter describes many of the techniques that you can use to adjust how data is presented if the profiles are providing you with too little or too much information.

Automatic Symbolication Troubleshooting

A common problem encountered by Shark users is a profile filled with instruction address ranges, instead of actual names, for all of the symbols (functions) in the program. Shark is very good at finding and using symbol information created by the compiler, but you do need to make sure that the compiler and linker actually record the correct symbol information, or you will be stuck deciphering cryptic address ranges instead of the names that you were expecting. This section explains how to solve some of the most common problems that can prevent Shark from finding and displaying the symbol names in your code.

Symbol Lookup

Shark records samples from the system in both user and supervisor code. In order to look up symbols for user space samples, the corresponding process is temporarily suspended while its memory is examined for symbols. Symbol lookup of user space samples will fail if the option to catch exiting processes (see "Shark Preferences" (page 23)) is disabled and the process is no longer running. In addition, if you need to profile a task which will exit before profiling is finished, then you should execute it with an absolute path (e.g. `/usr/local/bin/foo`) rather than a relative path (e.g. `../foo`). Otherwise you may not be able to examine program code in a Code Browser. Supervisor space symbol lookup is done by reconstructing the kernel and driver memory space from user accessible files: `/System/Library/Extensions` for drivers and other kernel extensions and `/mach_kernel` for kernel symbols. Samples from kernel extensions or drivers not in the locations specified on Shark's Search Paths Preference pane (see "Shark Preferences" (page 23)) will fail symbol lookup. Developers who download the KernelDebugKit SDK and mount the disk image are able to see source information for the kernel and base IOKit kernel extension classes (families).

If symbol lookup fails, Shark may present the missing "symbols" in two different ways. If the memory of the process is readable — for example, a binary that has had its symbols stripped — Shark tries to determine the range of the source function by looking for typical compiler-generated function prologue and epilogue sequences around the address of the sampled instruction. Symbol ranges gathered in this manner are listed as `address [length]`. If the memory of a process is completely unreadable, the sample will be listed with the placeholder symbol `address [unreadable]`.

Debugging Information

In order for Shark to look up symbol information, the sampled application must contain debugging information generated by a compiler or linker.

It is almost always more useful to profile a release build rather than a debug build because compiler optimizations can drastically alter the performance profile of an application. Debug-style code is most often compiled without any optimizations at all (`-O0`). This makes debugging simpler, but produces non-optimal code. A profile of unoptimized code is misleading because it will often have different performance bottlenecks than optimized code.

Xcode

To generate debugging information in Xcode, select *Project* > *Edit Active* Target and go to the *GNU C/C++ Compiler* panel. Make sure that the *Generate Debug Symbols* checkbox is enabled. If you want to have your *Release* style products left unstripped (with symbol information), select the *Unstripped Product* checkbox. Make sure that the `COPY_PHASE_STRIP` variable, if it is defined, is set to `NO`.

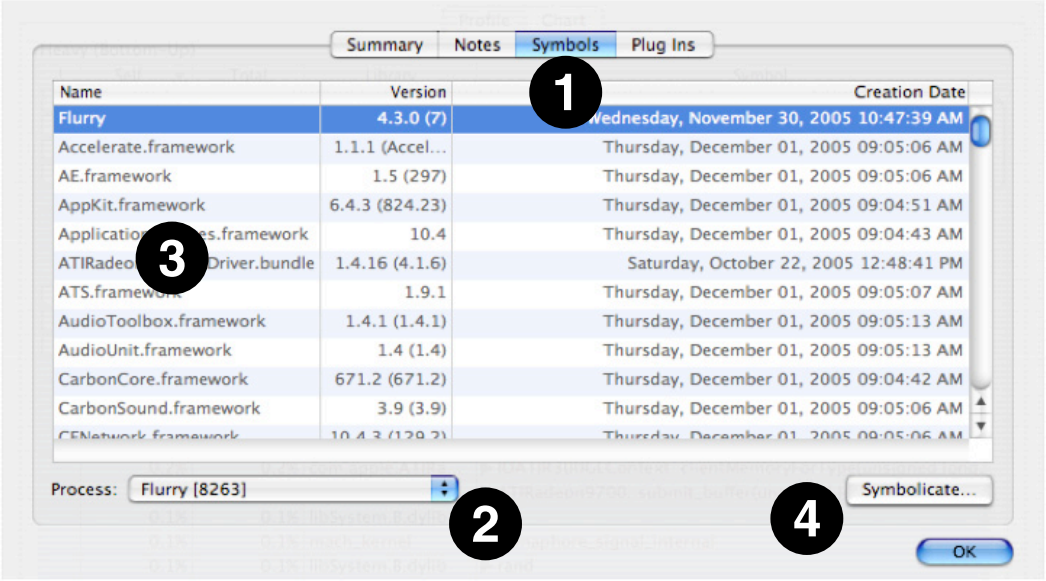
GCC/XLC/XLF

If you are using command-line compilers such as GCC, XLC/XLF, and/or makefiles, use the "-g" compiler flag to specify that debugging information is generated

Manual Session Symbolication

It's common practice for software built for public release to be stripped of debugging information (symbols and source locations). Although this reduces the overall size of the product and helps protect proprietary code against prying eyes, it makes it much more difficult to understand profiles taken with Shark. Shark doesn't require debugging information to work, but it can be much more helpful if it's available. In case you record a Shark session and discover that symbols have not been captured, then you can attempt to have Shark add them in afterwards.

Figure 6-1 Session Inspector: Symbols

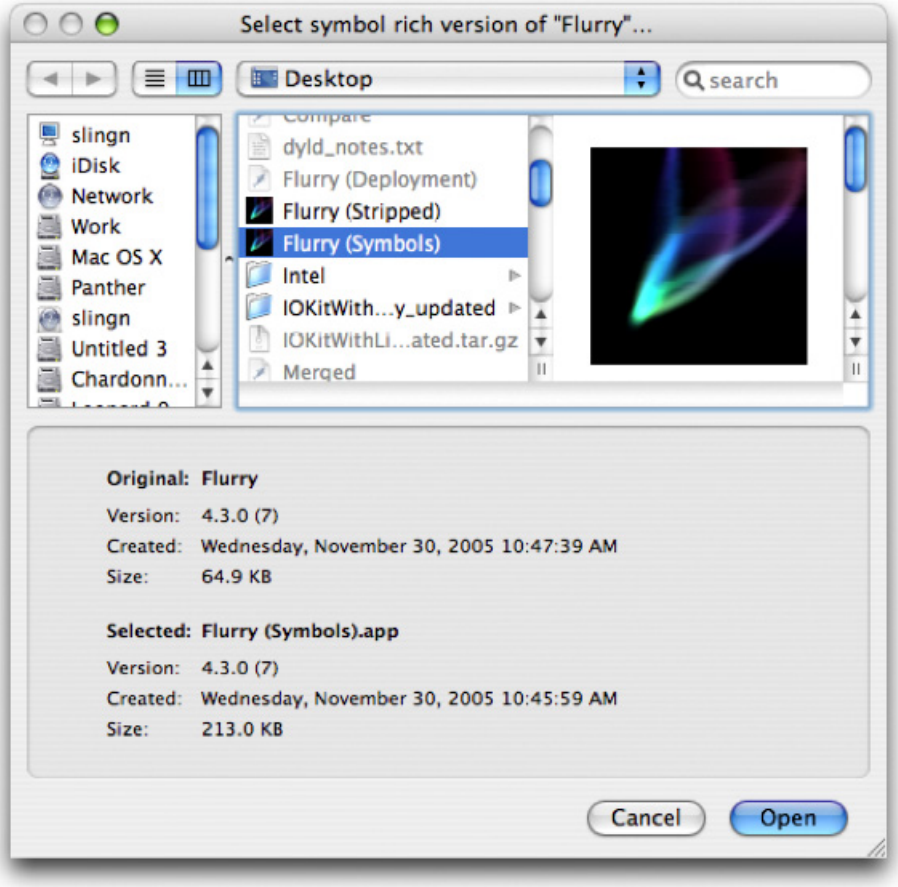


The most common way to "symbolicate" or add symbols (along with other debugging information) to your session is to simply use the *File*▷*Symbolicate...* command. With this command, you can quickly choose a symbol-rich application binary to attach to your Shark session, even if the original measurement was taken using a symbol-free binary.

Shark's *Session Inspector* window (see "Session Windows and Files" (page 20)) also allows you to add debugging information to a session. This technique requires more steps, but is recommended if you are adding symbols from a dynamic library used by your application, instead of the application itself, or if you need to selectively add symbols from many different application binary files. The *Symbols* tab (1) in the window shows you the list of all the profiled executables in the session, along with the libraries and frameworks they were linked with. The *Process* popup (2) allows you to select the application you're interested in inspecting or symbolicating. Each row of the table lists the name, version (if available) and creation date of each binary. The full path of each binary is displayed as a tooltip for each entry in the *Name* column (3). To symbolicate any particular binary, double-click on its entry in the table or select it and click the *Symbolicate* button (4).

No matter which way you choose to get here, you will be presented with a *Symbolication* dialog (Figure 2-20).

Figure 6-2 Symbolication Dialog



Use this dialog to select a symbol-rich (but otherwise identical) version of the binary you are symbolicating. The version, creation date and size is shown for both the original and selected binary. For maximum flexibility Shark does not restrict what you can select in any way. But it does indicate when something might be wrong with the selection you have made by highlighting potential problems. Ideally, this is the list of attributes that Shark expects for a good match:

- The name of the original and symbol-rich binaries should match (for bundles, this is the bundle name). Also, for bundles, the version strings should match.
- The creation date of the symbol-rich binary should be the same or earlier than the stripped version.
- The size of the symbol-rich binary should be larger than the stripped version.

Shark will warn you if you select a binary that is potentially problematic. If you do happen to select an executable that isn't a good match, the profile results will be incorrect. "Heavy View" and "Tree View" show an example session before and after symbolication.

Figure 6-3 Before Symbolication

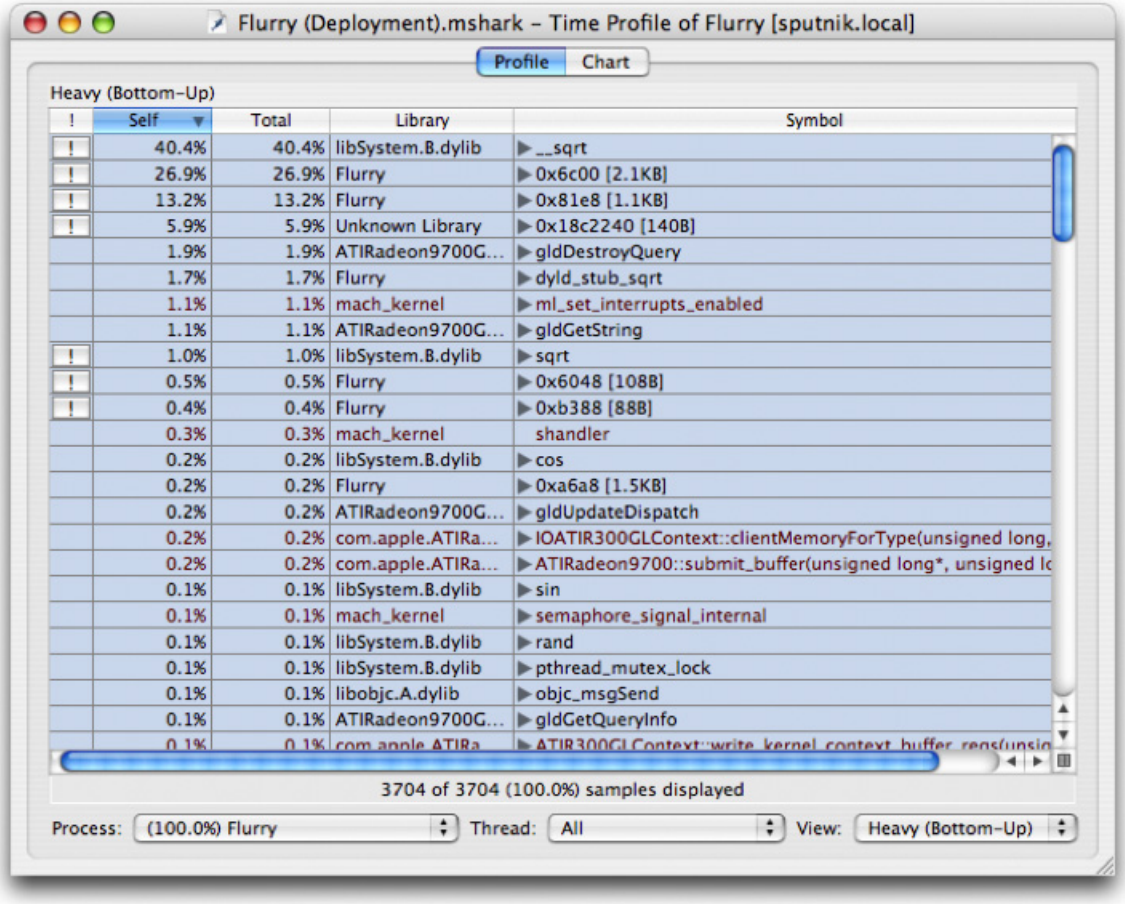
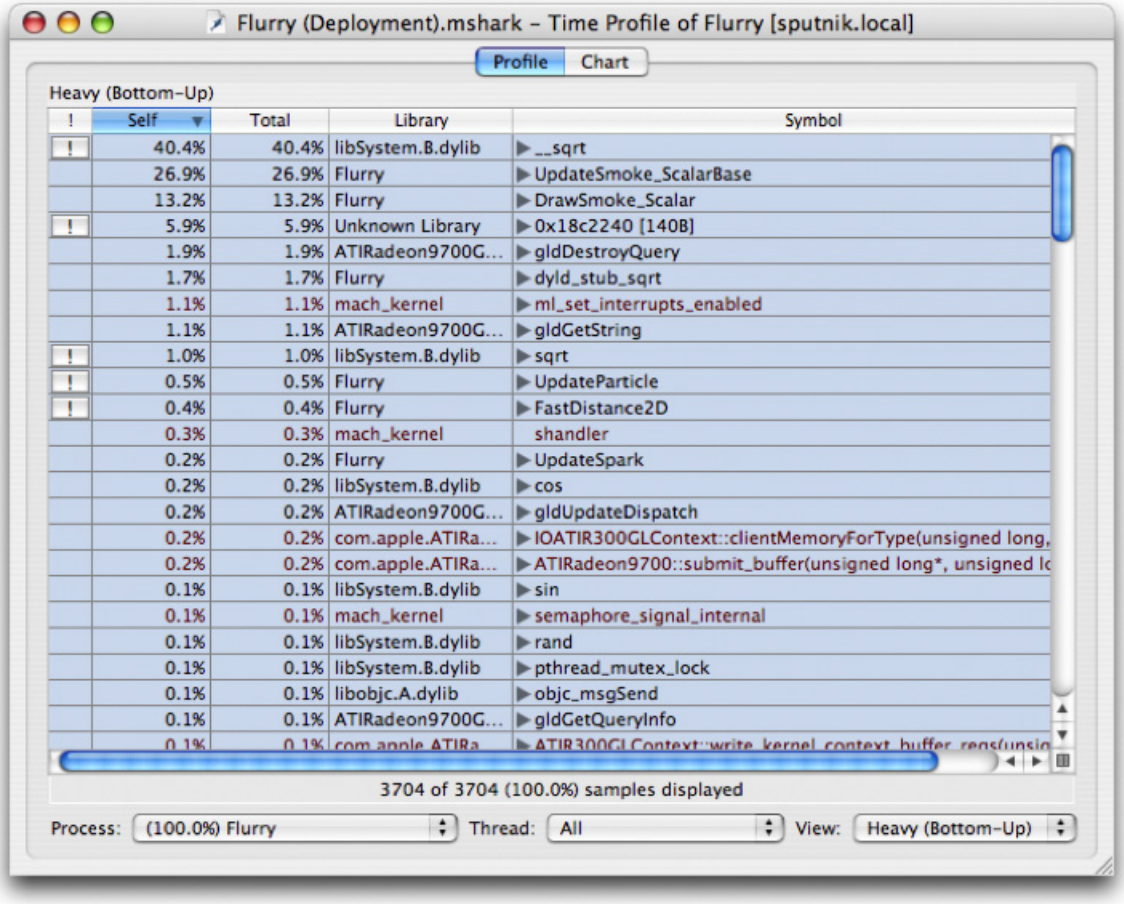


Figure 6-4 After Symbolication



Managing Sessions

If you have multiple sessions measuring the same application, it is possible to use Shark to compare or merge those sessions with each other.

Comparing Sessions

Shark can be used for tracking performance regressions. Shark allows you to compare the contents of two session files sampling the same process through the *File Compare...* menu item (*Command-Option-C*). Note that processes are identified by name rather than process ID (PID) by default when comparing sessions, so do not change the name of your program between sessions if you want to use this command.

When used, a new session is created from two existing ones: Session A and Session B. The first session (Session A) is given a negative scaling factor, and the second session (Session B) is given a positive scaling factor. The result of a compare operation is a new session with negative profile entries for more samples in the earlier session (Session A), and positive profile entries for more samples in the later session (Session B).

The magnitude of the scaling factor is adjusted according to the number of samples in each session so that both sessions are given equal total weight. In the case of comparing two sessions with an equal number of samples, the scaling factor for Session A is -1.0, and for Session B is +1.0.

Example

As an example of how the session comparison algorithm works, let's say that Session A has 400 samples in process `foo`, and Session B has 440 samples in process `foo`. The total weight for process `foo` in the combined session will be 840.

If in Session A there were 80 samples for function `bar()` in process `foo`, and in Session B there were 120 samples for function `bar()` in process `foo`, the value of `bar()` is 120 – 80 = +40. The value shown for `bar()` would be (+40 / 840) * 100 = +4.8%. Note that the meaning of percentage is consistent with the standard time profile display — the baseline is the total count for the currently selected scope (system, process or thread).

Merging Sessions

If you have profiled the individual components that make up a workload separately, you may want to merge the resulting sessions into a single file. Shark can merge two session files through a process similar to comparing them. The only difference is that each source session file is given a scaling factor of +1.0. Select the *File*▸*Merge*... menu item (*Command-Option-M*).

Data Mining

By default, Shark groups samples by symbol (although other groupings such as address, library and source line are also possible using the controls described previously in "Automatic Symbolication Troubleshooting" (page 133)). Although this is often sufficient, judiciously filtering out pieces of a profile can in some cases make it easier to analyze. Data mining allows you to hide samples that may obscure important behavioral or algorithmic characteristics in a profile.

Callstack Data Mining

In order to understand how to use data mining to better understand your application, it is necessary to first understand a few fundamental concepts about samples and callstacks. Each Shark session contains some number of samples. Each sample contains contextual information such as where and when it was taken (process and thread ID, timestamp) as well as the callstack information for how the sampled thread of execution arrived at the current program counter address. An example of several callstacks is shown in Figure 6-5.

Each callstack is made up of *N* stack frames (*N*=4 in the case of Sample 1). Note that when a sample is taken, the program's stack pointer points to the leaf entry at *N*-1 (`cos` in the first sample). When Shark builds up a call tree to analyze how routines call each other, "self" counts in the profile browser are simply the number of samples where this routine is the leaf entry function. Therefore, the "self" count represents the amount of time that code within the function was executing. In contrast, "total" counts are the number of samples where this function appears at *any* point in a callstack, and therefore represents the summation of a function's execution time *and* the time of all functions that it calls.

Shark can combine samples into call trees in two different ways. Figure 6-6 depicts the "Heavy" call tree assembled from the example samples, while Figure 6-7 shows the corresponding "Tree" view. As you can see, the "heavy" view starts from the leaf functions and builds towards the base of the callstack, while the "tree" view starts at the base of the callstack and works down to the leaves. The former view is usually better for finding out which parts of your program are executing most often, while the latter is often better for finding large routines farther down the callstack that call many other routines in the course of their execution. Once you have a clear picture of how callstacks are converted into call trees, it is easier to understand the application of the data mining operations.

Figure 6-5 Example Callstacks

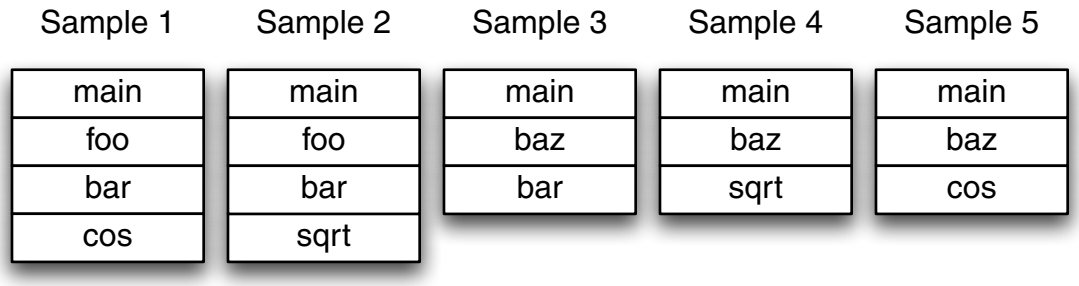


Figure 6-6 Heavy View

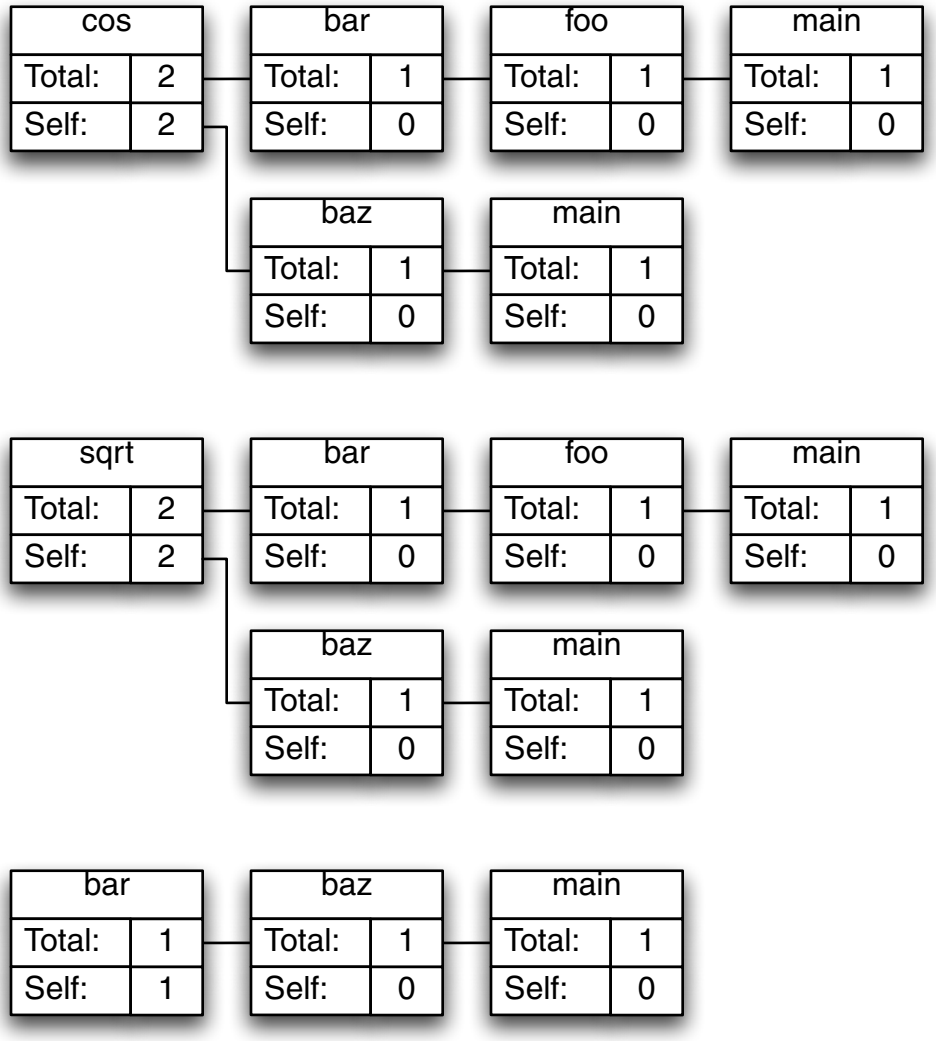
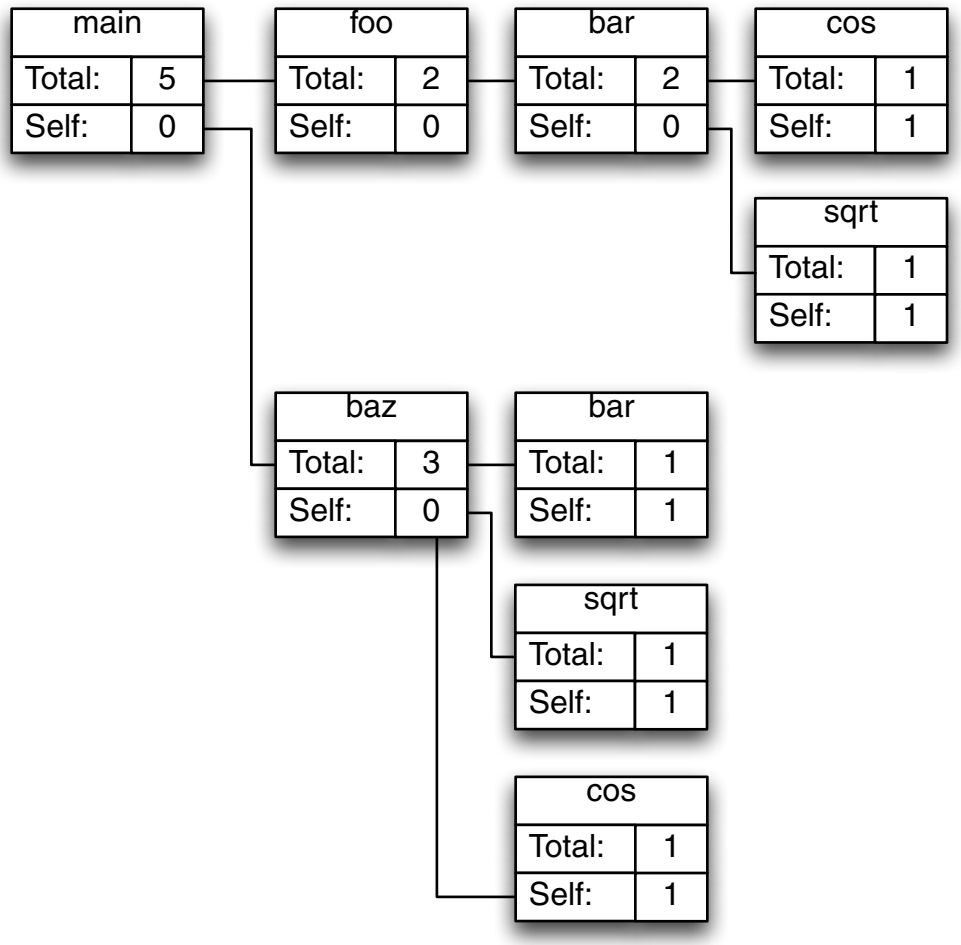
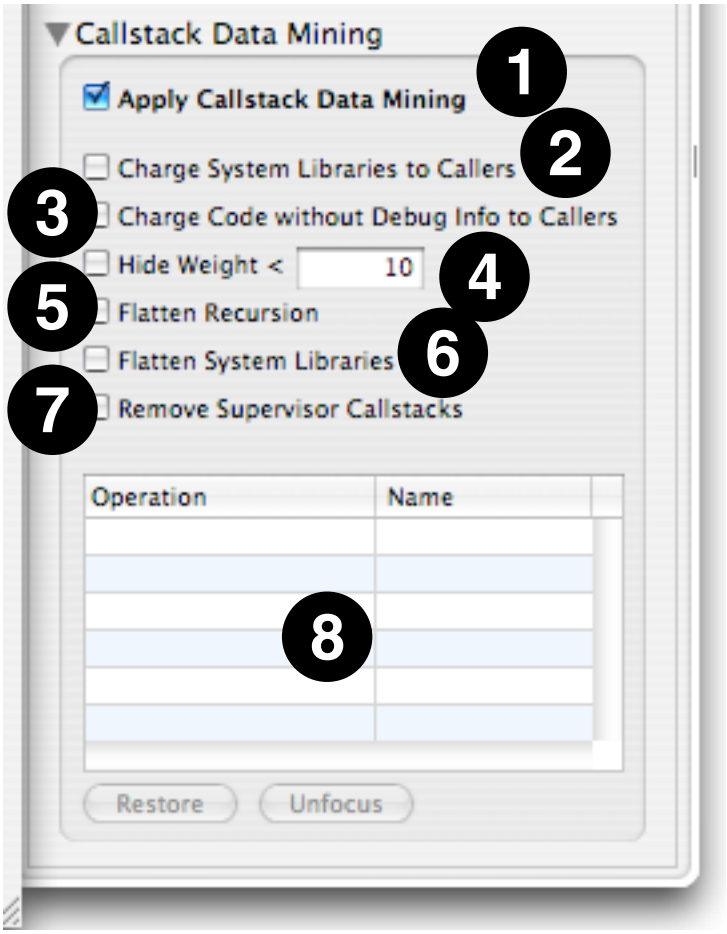


Figure 6-7 Tree View



Shark's Data Mining operations allow you to prune down call trees in order to make them easier to understand. While the small call trees in the preceding figures are fairly simple, in real applications with hundreds and thousands of symbols, the call trees can be huge. As a result, it is often useful to consolidate or prune off sections of the call trees that do not add useful information, in order to simplify the view that Shark provides in controlled ways. For example, you often won't care about the exact places that samples occur within MacOS X's extensive libraries — only which of *your* functions are calling them too much. Data Mining can help with simplifications like this. It is accessible in three different ways.

Figure 6-8 Data Mining Advanced Settings



The *Advanced Settings* drawer (Figure 6-8), in its lower half, contains the following controls that apply filtering to an entire session. This is a great way for making a few common quick trims to too-complex callstack trees.

1. **Apply Callstack Data Mining**— Global control that toggles the use of all data mining controls en masse, good for quickly comparing your results before and after data mining.

2. **Charge System Libraries to Callers**— Removes any callstack frames from system libraries and frameworks, effectively reassigning time spent in those functions to the callers. This is often quite useful, as you cannot usually modify the system libraries directly, but only your code that calls them. Samples from system libraries that aren't called from user code, such as the system idle loop, disappear entirely.

3. **Charge Code without Debug Info to Callers**— Removes any callstack frames from code without debugging information, effectively reassigning time spent in those functions to the callers. In a typical development environment, this will effectively show all samples only in source code that you own and compiled using a flag such as '–g' with GCC or XLC, and in the process eliminating a lot of user-level code that you probably do not have control over. Samples from code that isn't called from debug-friendly code are eliminated entirely.

4. **Hide Weight < N**— Hides any granules that have a total weight less than the specified limit. This macro helps reduce visual noise caused by granules (i.e. symbols) that only trigger a sample or two, making it easier to see the overall profile.

5. **Flatten Recursion**— For each branch in the call tree, this collapses functions that call themselves into a single entry, removing all of the recursive calls entirely from the trace.

6. **Flatten System Libraries**— Chops off the top of callstacks beyond the entry points into system libraries, so that any samples from the libraries are only identified by the entry points.

7. **Remove Supervisor Callstacks**— Completely removes (*without* charging to the callers) all samples in the profile from supervisor code (kernel and drivers).

8. **Granule List**— Displays a list of particular granules that you have identified for data mining, using the menu controls described next, along with the name of the operation applied to that granule. You can modify the operation used to mine them using the menu associated with this name.

A*Data Mining* menu appears in the menu bar whenever a Shark session is open. The menu contains the following items that allow you to selectively apply data mining to particular granules in your code:

1. **Charge Symbol *X* to Callers**— Removes any callstack frames containing the symbol *X*, and frames of functions called by *X*, effectively reassigning time spent in those functions to the callers.

2. **Charge Library to *X* Callers**— Removes any callstack frames containing the specified library, effectively reassigning samples to the callers of the library.

3. **Flatten Library *X***— Removes all but the first callstack frame for the specified library, attributing all samples in interior functions to the entry points of the library.

4. **Remove Callstacks with Symbol *X***— All callstacks that contain the specified symbol are removed from the profile; samples in matching callstacks are discarded.

5. **Retain Callstacks with Symbol *X***— Overrides all of the above operations for any callstack that contains the specified symbol.

6. **Restore All**— Undo all *Charge To*, *Flatten*, *Remove*, and *Retain* operations.

7. **Focus Symbol *X***— Makes the specified symbol the root of the call tree; removes symbols and samples above (callers to) this symbol in the call tree and remove callstacks that do not contain this symbol. This allows you to quickly eliminate all samples but those from an interesting part of a program.

8. **Focus Library *X***— Makes the specified library the root of the call tree; removes symbols and samples above (callers to) this library in the call tree and remove callstacks that do not contain this library.

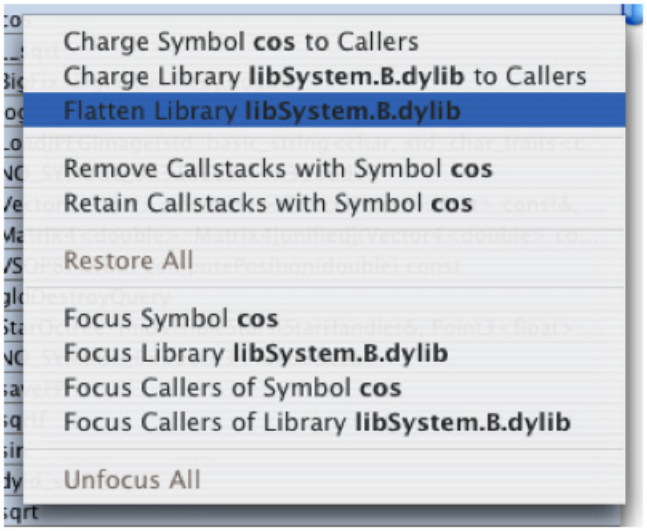
9. **Focus Callers of Symbol *X***— Removes functions called by the specified symbol and removes callstacks that do not contain the specified symbol.

10. **Focus Callers of Library *X***— Removes functions called by the specified library and removes callstacks that do not contain the specified library.

11. **Unfocus All**— Undo all *Focus* operations.

This same menu appears as a contextual menu on entries in the *Heavy*, *Tree* and *Callstack* results tables. While the mouse is held over a line in a table, you can control-click (or right-click) to bring up the menu, as is shown in (Figure 6-9).

Figure 6-9 Contextual Data Mining Menu



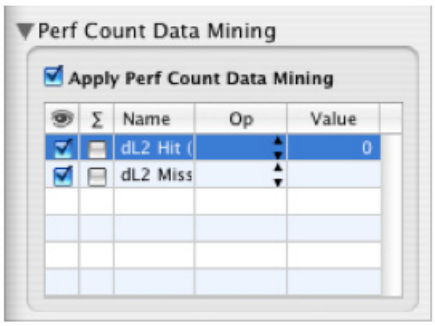
Perf Count Data Mining

In addition to data mining based on callstack symbol and library information, it is also possible to filter out samples based on associated performance count information (if available), using the *Perf Count Data Mining* palette (Figure 6-10). The available "perf count" data mining operations are:

- **Equal (==)**— Removes callstacks with perf counts equal to the specified value.
- **Not Equal (!=)**— Removes callstacks with perf counts not equal to the specified value.
- **Greater Than (>)**— Removes callstacks with perf counts greater than the specified value.
- **Less Than (<)**— Removes callstacks with a perf counts less than the specified value.

The *Perf Count Data Mining* palette also supplies a global enable/disable toggle, much like the one available with conventional data mining, and check boxes for toggling the visibility of perf count information (the eye column) and whether or not the perf count data is accumulated across processors (the Σ column), on a per-counter basis.

Figure 6-10 Perf Count Data Mining Palette



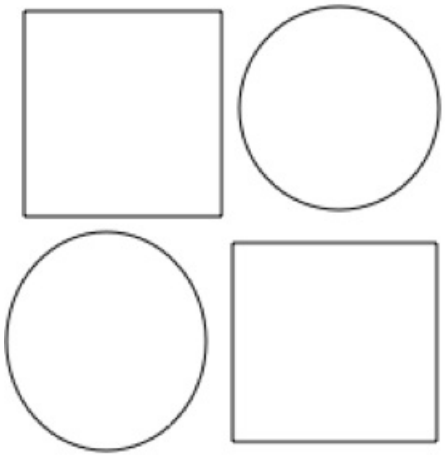
Example: Using Data Mining with a Time Profile

Our first example uses Shark's data mining tools to help isolate a performance problem from a time profile of the Sketch demo program. If you want to follow along with the demo, it is available in `/Developer/Applications/Examples/AppKit/Sketch`.

A Performance Problem...

1. Launch Sketch (located in `/Developer/Applications/Examples/AppKit/Sketch/build/` after you build the project with Xcode)
2. Make four shapes as shown in Figure 6-11

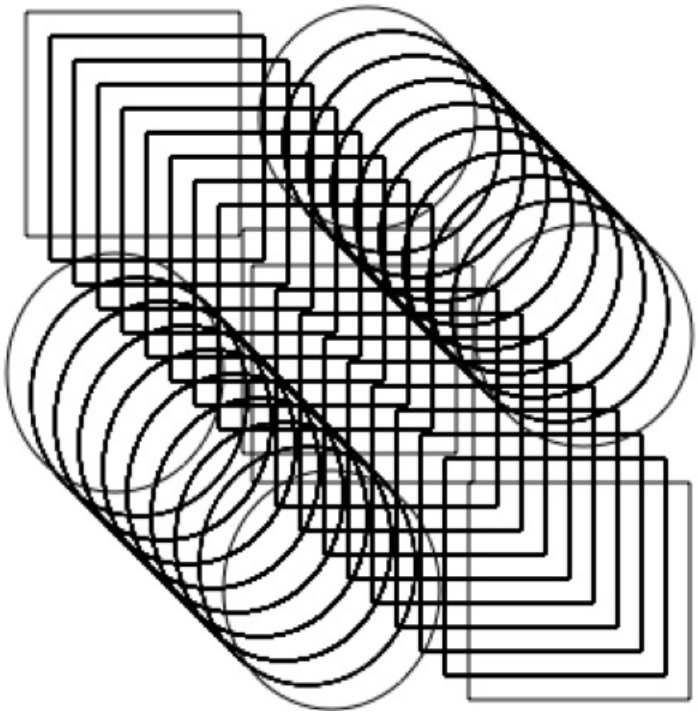
Figure 6-11 Example Shapes



3. Repeat the following steps until the app becomes sluggish (takes a half second or second to select all):
   - Select All (*Command-A*)
   - Copy (*Command-C*)
   - Paste (*Command-V*)

This should take 8-10 times (maybe more) depending on hardware. When you are done it should look something similar to Figure 6-12

Figure 6-12 Example Shapes, Replicated



4. Click in blank area of the window to deselect all the shapes.
5. Do select all and notice how long it takes for all of them to be selected. This is a performance problem.

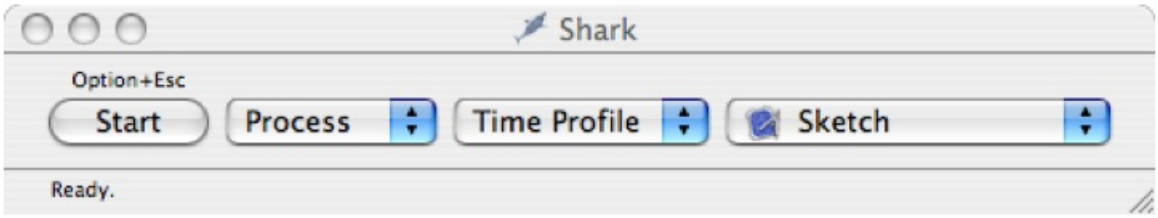
Taking Samples

1. Launch Shark (in `/Developer/Applications/Performance Tools/`)
2. Target your application by selecting the "Sketch" process, as shown in Figure 6-13.

   The start button will start and stop sampling. The Everything/Process pop-up will let you choose whether you wish to sample the entire system or just a single process. The Time Profile pop-up will let you choose different types of sampling that you can perform. In this case we will switch the System/Process pop-up to Process (to target a single process.)

This reveals a third pop-up button that you can use to target your application. Select Sketch from the list of running applications.

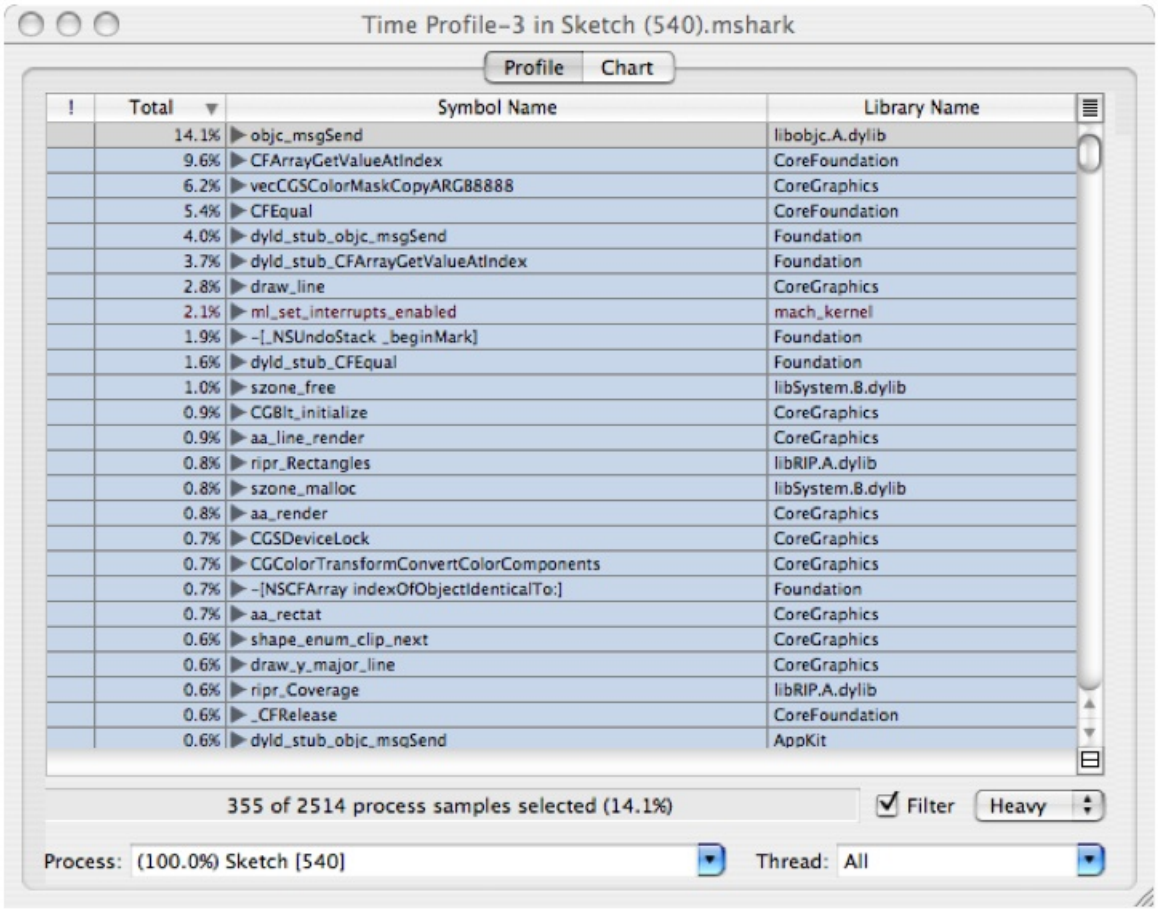
Figure 6-13 Sampling a Specific Process



3. Switch back to Sketch and make sure nothing is selected.
4. Move the Sketch window to expose the Shark window (optional but makes things easier).
5. Press *Option-Escape* to start sampling.
6. Press *Command-A* to select all and wait for the operation to complete.

7. Press *Option-Escape* to stop Sampling and you will get a window that looks like Figure 6-14.

Figure 6-14 Default Profile View



High Level Analysis

The session window gives you by default a summary of all the functions that the sampler found samples in and the percentage of the samples that were found there. So in the example, 14.1% of the samples were found in `objc_msgSend`. This view is very useful for doing analysis of performance when the bottlenecks occur in leaf functions. As you can see, the above window gives you a lot of detail about where your program is spending time, but unfortunately it is at too low a level to be of use to the developer of Sketch, or even the developers of the Frameworks that Sketch depends on.

To get at the parts of the program that are of most interest to the developer of Sketch, you can do the following:

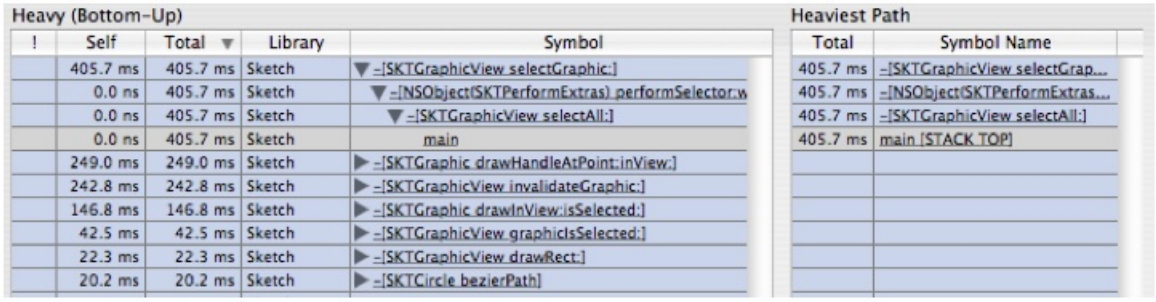
1. In the *Window* menu, choose *Show Advanced Settings...*. This will open a drawer with the data mining palette, among other things, as was shown in "Advanced Session Management and Data Mining" (page 133). We will go over each of these areas in more detail later. For now, let's turn on a couple of cool features. In the *Profile Analysis Palette*, do the following:

- Click on the *Stats Display* pop-up and select *Value*. This lets you the actual counts for the samples rather than percentage. This may be more intuitive for some users than weighting by %, especially while you are going through this tutorial. Use whichever you prefer.
- Click on the *Weight by:* pop-up and select *Time*. You will see the samples displayed as the time spent in that function rather than counts.
- Check the *Color by Library* checkbox. This will display the text of symbols and library names in different colors based on the library they came from. This is handy for visually identifying groups of related functions.

2. In the *Data Mining Palette* box, check *Charge System Libraries to Callers*. This will eliminate system libraries and frameworks, and charge the cost of their calls to the application level functions or methods that are calling them.

3. Click on the callstack  button on the lower right corner of the table to reveal the callstack pane, as shown in Figure 6-15. As you click on symbols on the left, the callstack pane will show you the stack leading up to the selected symbol. Since system libraries and frameworks were filtered out in the previous step, you will only see your application's symbols. Note that if you click on a symbol in the callstack pane, the outline on the left will automatically expand the outline to show that symbol.

Figure 6-15 Navigation Via the Call-Stack Pane



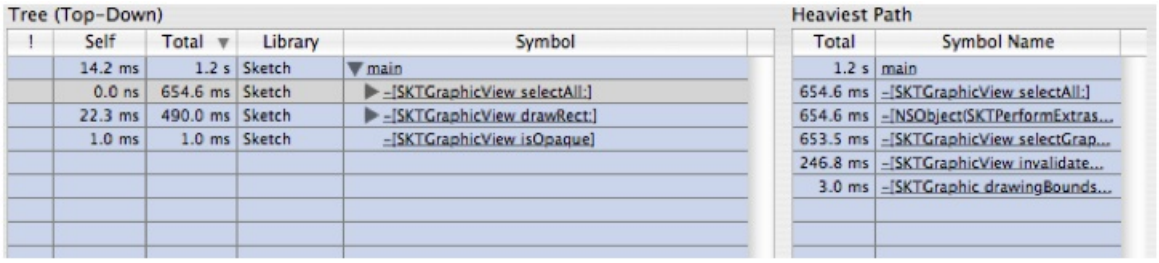
4. Click on the 

pop-up menu on the lower right corner of the window and select 

to split it in half. The top half will continue to show the Heavy View ("Bottom-Up View") of the samples and the bottom will show the Tree View ("Top-Down View").

If you click on the symbol main in the bottom pane, you will see that the callstack view on the right will show the stack, as shown in Figure 6-16. This view will control navigation for whichever outline that was last selected

Figure 6-16 Navigation Via the Call-Stack Pane with Tree View



5. Looking at this outline, we see there are two areas where a lot of time is being spent: `-[SKTGraphicView drawRect:]` and `-[SKTGraphicView selectAll:]`. Let's look at the `selectAll` method first.

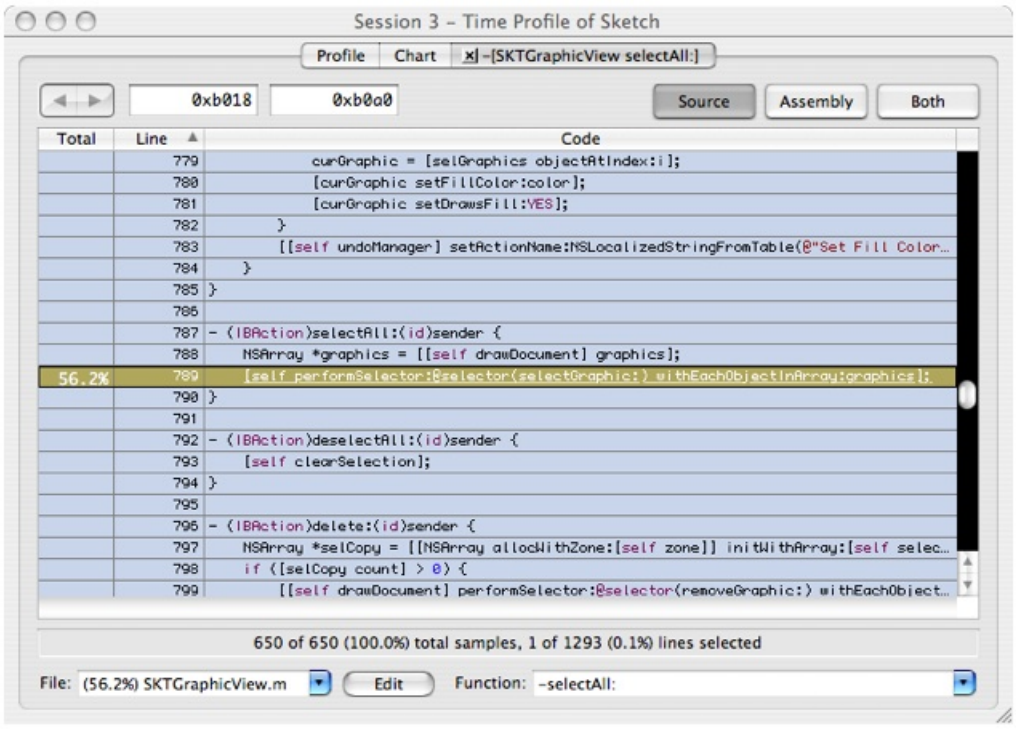
Analysis Via Source Navigation

The following is an example of doing interior analysis across a few levels of function calls.

1. Open up the tree view as shown in Figure 6-16.

2. Double click on the symbol `-[SKTGraphicView selectAll:]` in the tree view above. You will see a source window that looks like Figure 6-17

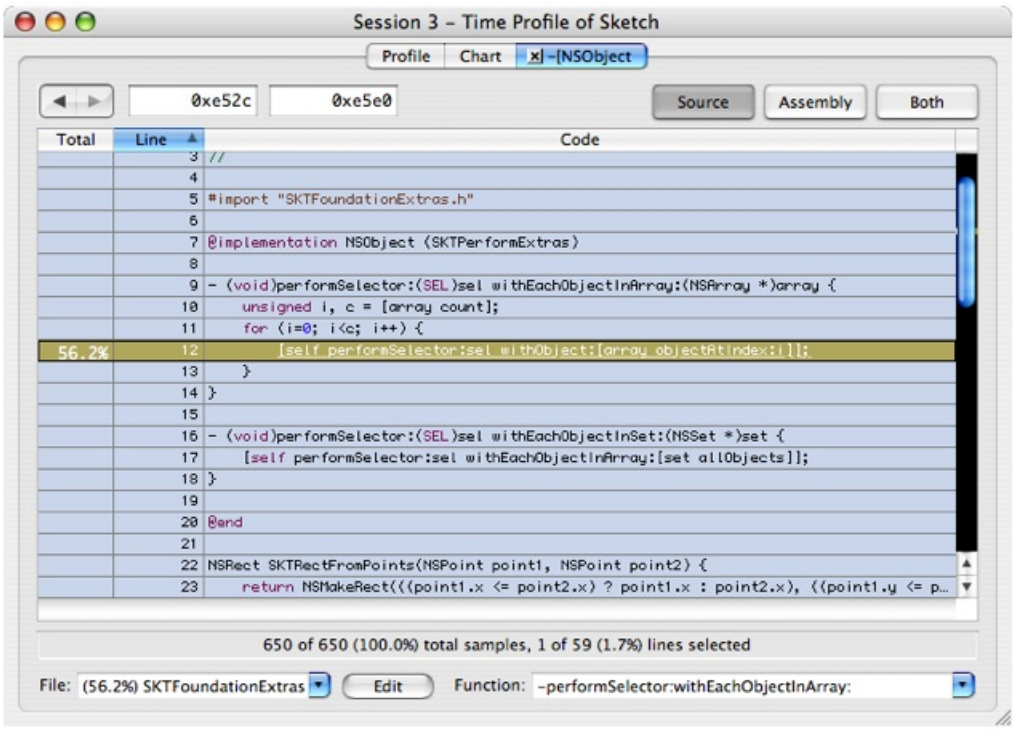
Figure 6-17 Source View: SKTGraphicView selectAll



The code browser uses yellow to indicate sample counts that occur in this function or functions called by that function.

3. Double-click on the yellow colored line to navigate to the function (performSelector) called here. When the new source window comes up, double-click in the yellow area marked with 2.7 s. This will display the counts for this code, which should look like Figure 6-18:

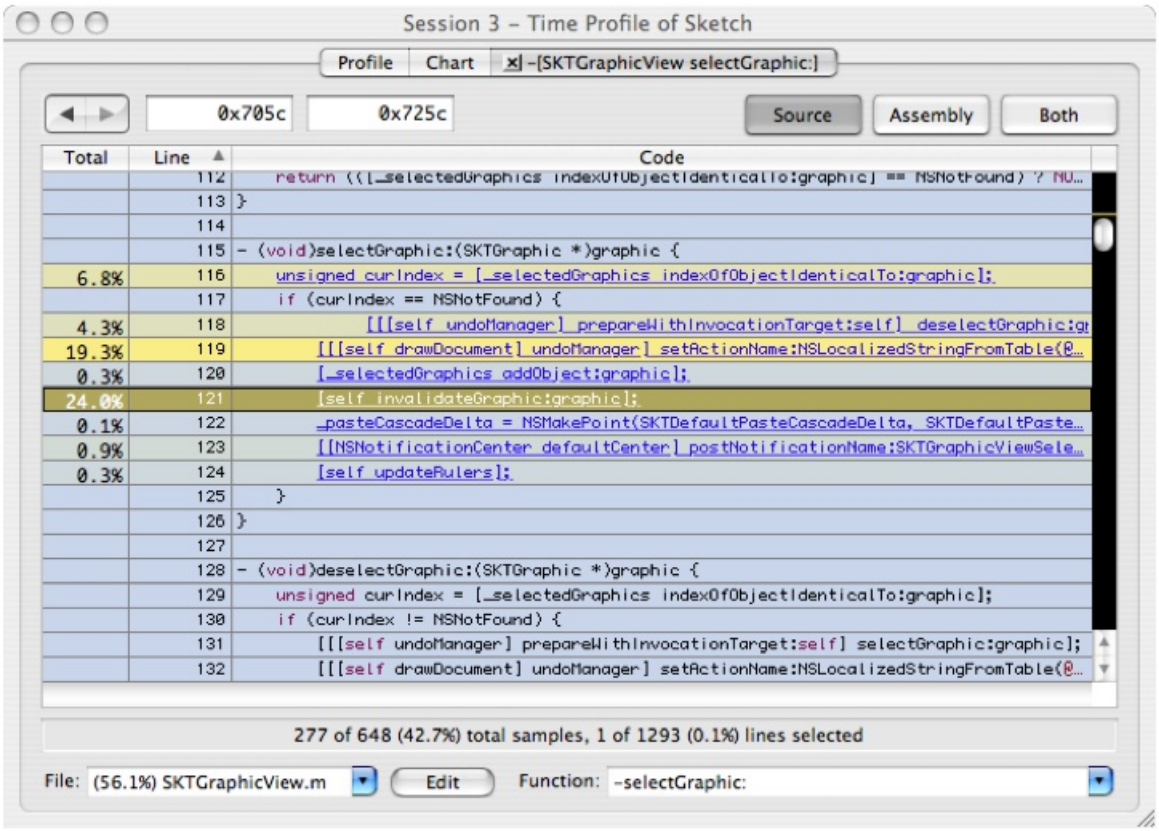
Figure 6-18 Source View: NSObject



Before we go on, please notice that this is a `for` loop that iterates over all the items in the array, which in this case is the array of all the graphic objects stored in Sketch's model.

4. Double-click on the yellow colored line `[self performSelector: sel withObject:[array ObjectAtIndex:i]];` and you'll get Figure 6-19:

Figure 6-19 Source View: SKTGraphicView selectGraphic



There are several hotspots here:

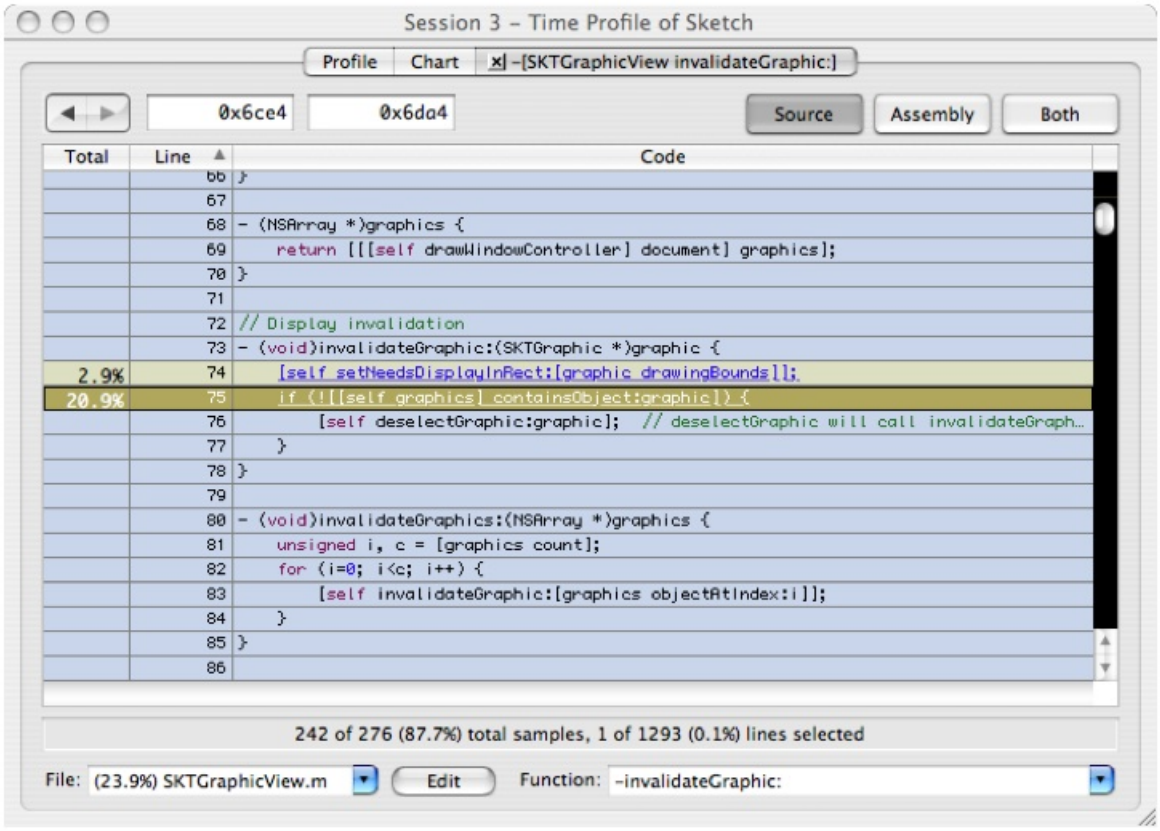
At line 116, there is a call to `indexOfObjectIdenticalTo:graphic`. This is a linear search of the selected graphics. Since we are doing a "select all" operation, this is a linear search inside of a linear search. You have just found a fundamentally $O(N^2)$ operation. Interestingly, this is not where most of the time is being spent.

The operation in lines 118 and 119 appears to be an expensive framework call. This should be hoisted out of the `performSelector: OnEachObjectInArray` loop and done once, if possible. If we were the framework developers, it might also be interesting to investigate why these calls are so costly.

Line 121 shows a call out to `-[SKTGraphicView invalidateGraphic]`. Let's dig deeper into this since this is in Sketch's code.

5. Double-click on `[self invalidateGraphic:graphic];` and you'll get Figure 6-20. This contains one line of expensive code that tests for nested objects.

Figure 6-20 Source View: SKTGraphicView invalidateGraphic



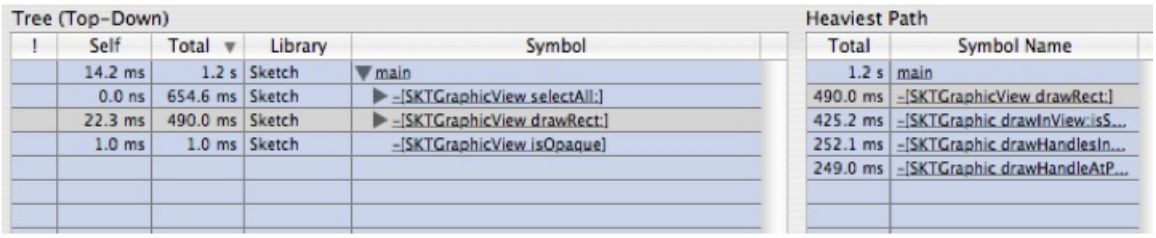
It is interesting to note that even with this fairly quick analysis we have already identified several glaring problems. The first problem we found was $O(N^2)$ behavior introduced by our code implementation hiding within functions and the use of abstraction. In general it is good to create and use abstraction in your coding. However, doing so can unintentionally introduce unnecessary performance pitfalls. Each of these functions is well conceived locally, but when they are used together they combine to have poor scalability. Second, we used expensive framework calls (in this case, to the undo manager) inside of a loop. Since undoing each step of a "select all" operation really isn't necessary, the expensive call can be moved up to a higher level, in order to just undo all of the selects at once. This is an example of hoisting functionality to a higher level in the execution tree. Finally, the `invalidateGraphic` routine was doing some heavyweight testing, and it would clearly be worthwhile to see if we can move this testing outside of the inner loops, if possible.

Introduction To Focusing

This example will take us through analyzing the behavior of drawing the selected rectangles. Here, we will develop ideas for analyzing larger and more complex programs (or frameworks) that involve multiple libraries. In doing so, we will introduce the Analysis menu/context menu and the ideas of focusing and filtering. This example will use system frameworks to demonstrate the ideas but the principles apply just as well to any large-scale application built as a collection of modules.

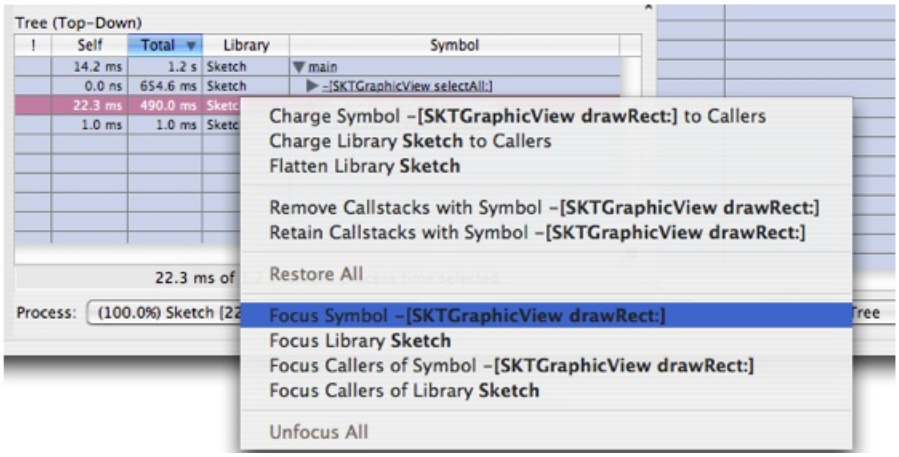
1. Close all the source windows from the analysis of `-[SKTGraphicView selectAll:]` by clicking on the close buttons in the tabs of the tab view.
2. Switch to the profile tab and do option click on the top most disclosure triangle to close all of the triangles.
3. Open the first two levels so it looks like Figure 6-21:

Figure 6-21 Tree view before focusing



4. Select `-[SKTGraphicView drawRect:]` and control-click to bring up a contextual menu which contains the focus and exclusion operations available in Shark (the operations in this menu are also available via the *Data Mining* Menu in the menu bar). It looks like Figure 6-22.

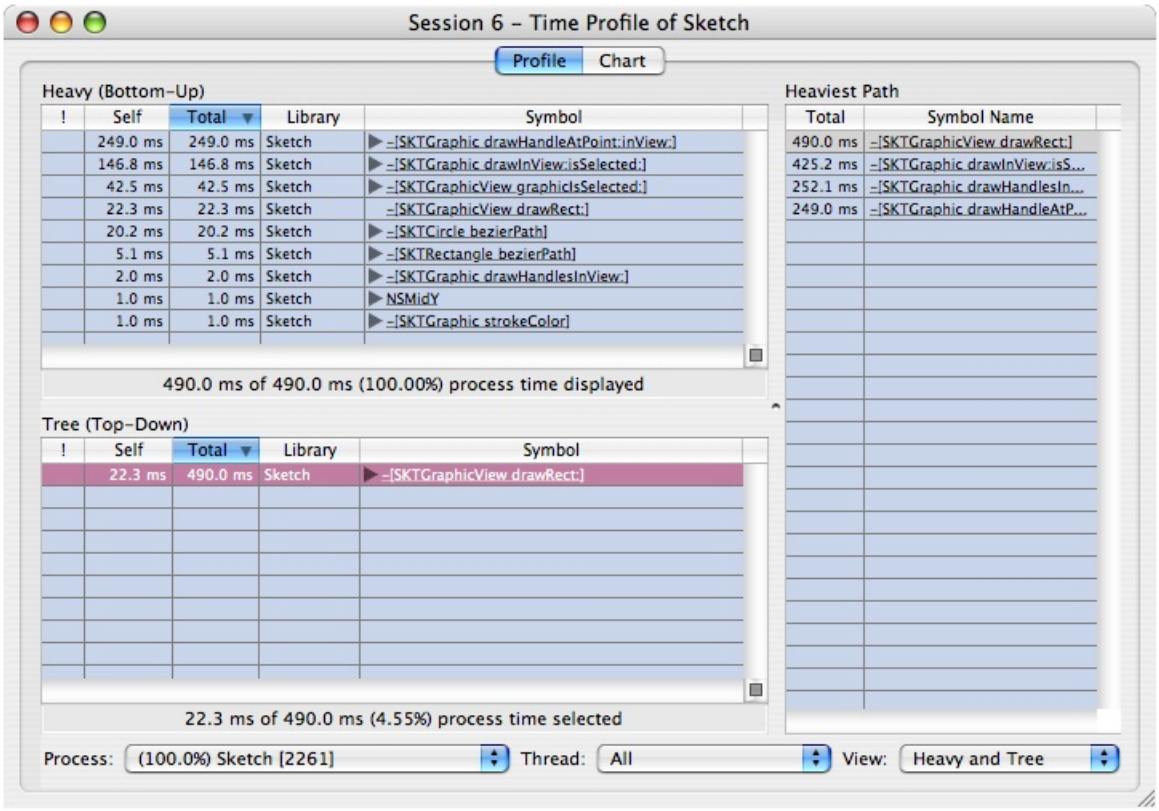
Figure 6-22 Data Mining Contextual Menu



In this tutorial we'll describe and demonstrate a few of them as well. A full description of these operations is given in "Callstack Data Mining" (page 139).

5. Choose "Focus Symbol `-[SKTGraphicView drawRect:]`" and you will get something that looks like Figure 6-23

Figure 6-23 After Focus Symbol -[SKTGraphicView drawRect:]

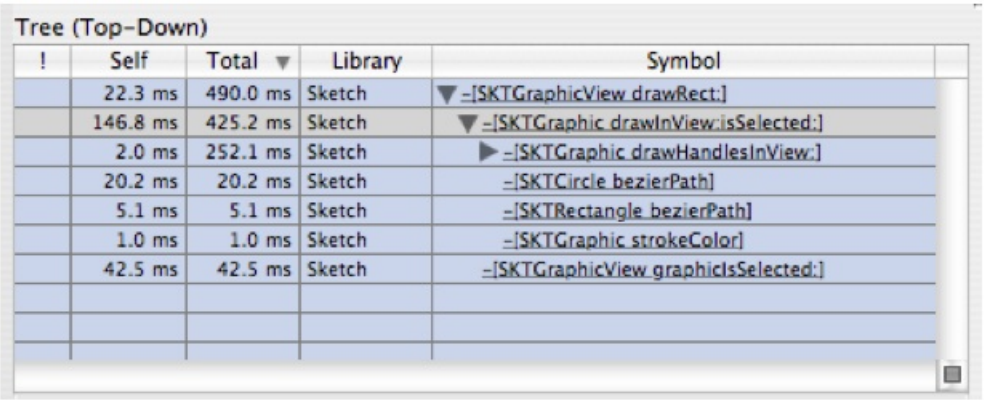


The bottom pane (Tree view) is now rooted on the symbol that we focused on and the items in the top pane (Heavy view) have changed to reflect only the leaf times relative to the execution tree under this new root. In the Heavy view, we see that the most time is spent in `-[SKTGraphic drawHandleAtPoint:inView]`. We'll come back to this in a bit.

It is also worth noting that if you look in the *Advanced Settings* drawer at the bottom of the data mining controls (you may need to scroll down the drawer if your document window is small), you will see an entry for the symbol you just focused in the list of symbols. You can change the focus behavior here at any time by clicking in the pop-up next to the symbol name.

6. Expand `-[SKTGraphicView drawRect:]` in the bottom outline a few times until it looks likes likeFigure 6-24:

Figure 6-24 After focus and expansion



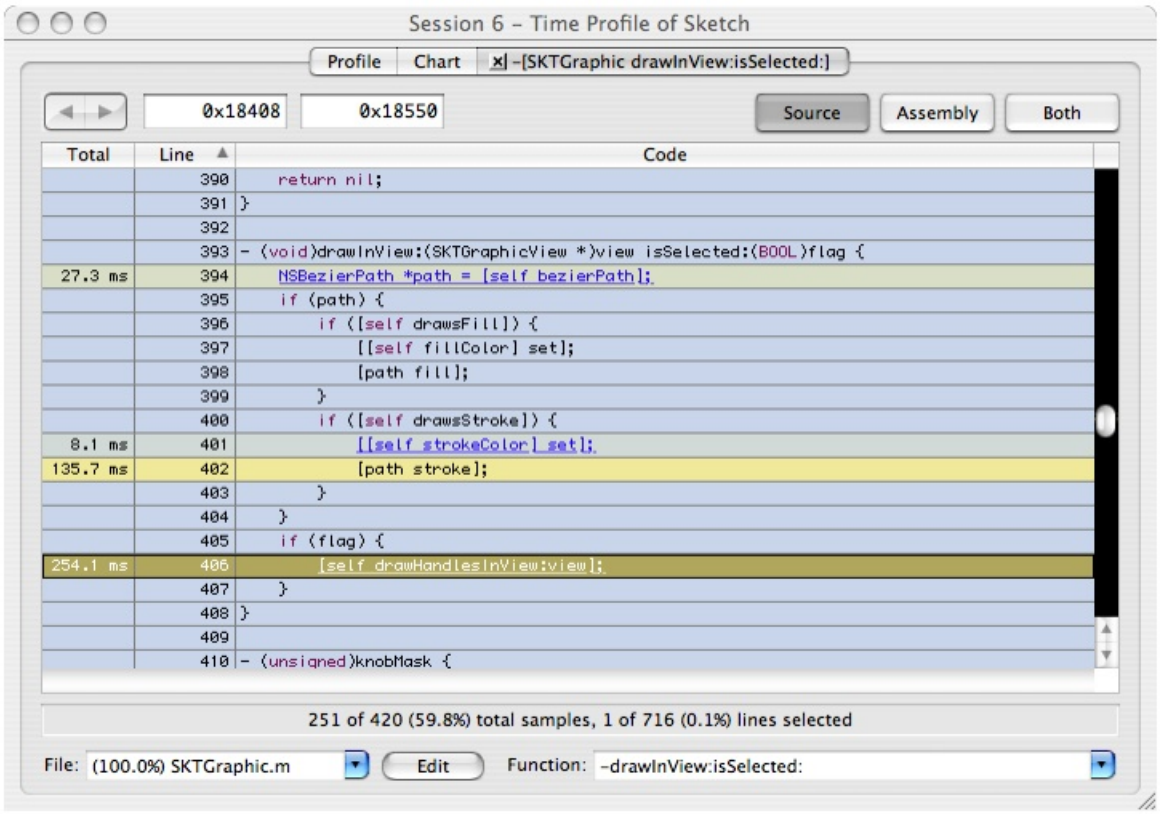
There are two interesting things here:

- The self time is pretty large in this function
- A lot of time is spent in `-[SKTGraphic drawHandleAtPoint: inView]`

Let's look at the self time first.

7. Double click on `-[SKTGraphic drawInView:isSelected]` to see the source, as shown in Figure 6-25:

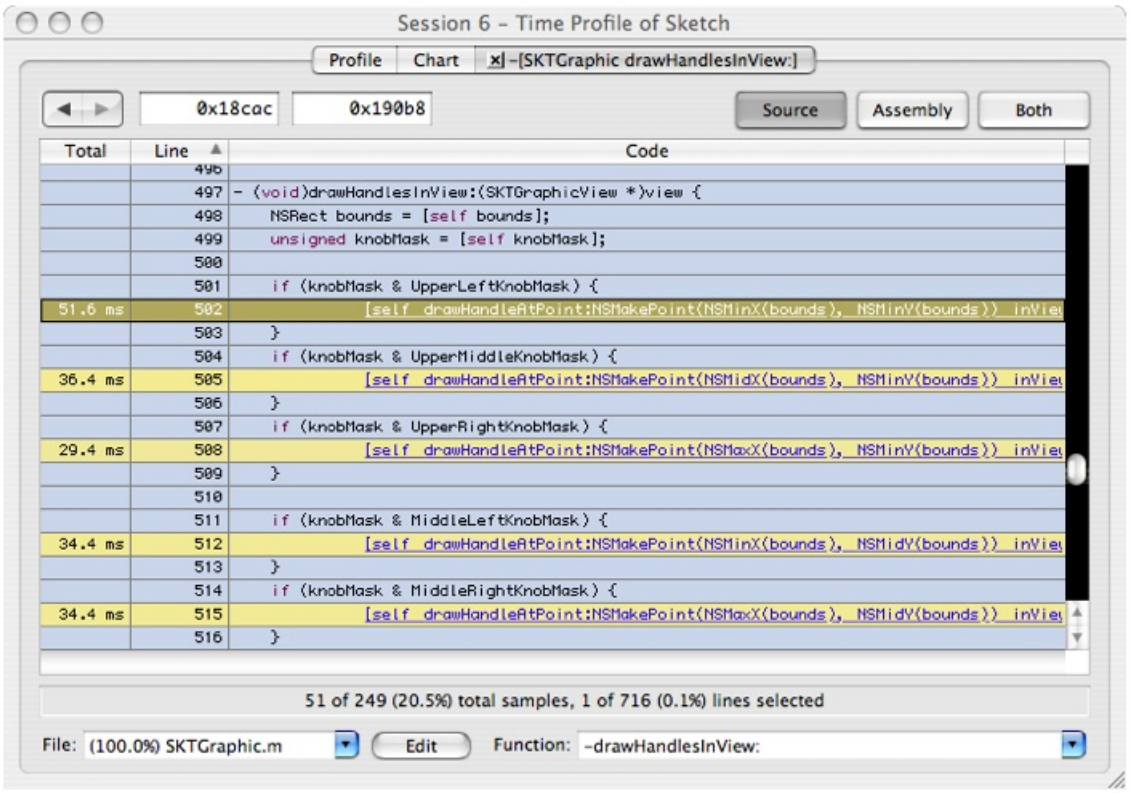
Figure 6-25 Source View: SKTGraphic drawInView:isSelected:



Here we see that time is split pretty evenly between the AppKit graphics primitive `[path stroke]` and the call to `-[SKTGraphic drawHandleAtPoint: inView]`. The only option for a developer to deal with the AppKit graphics primitive is to consider using raw Quartz calls, an option that we'll look into using NSBezierPath a bit later. For now, let's take a look at `-[SKTGraphic drawHandleAtPoint:inView]`.

8. Double click on line 406 on the text `-[self drawHandlesInView: view]` and you'll get Figure 6-26:

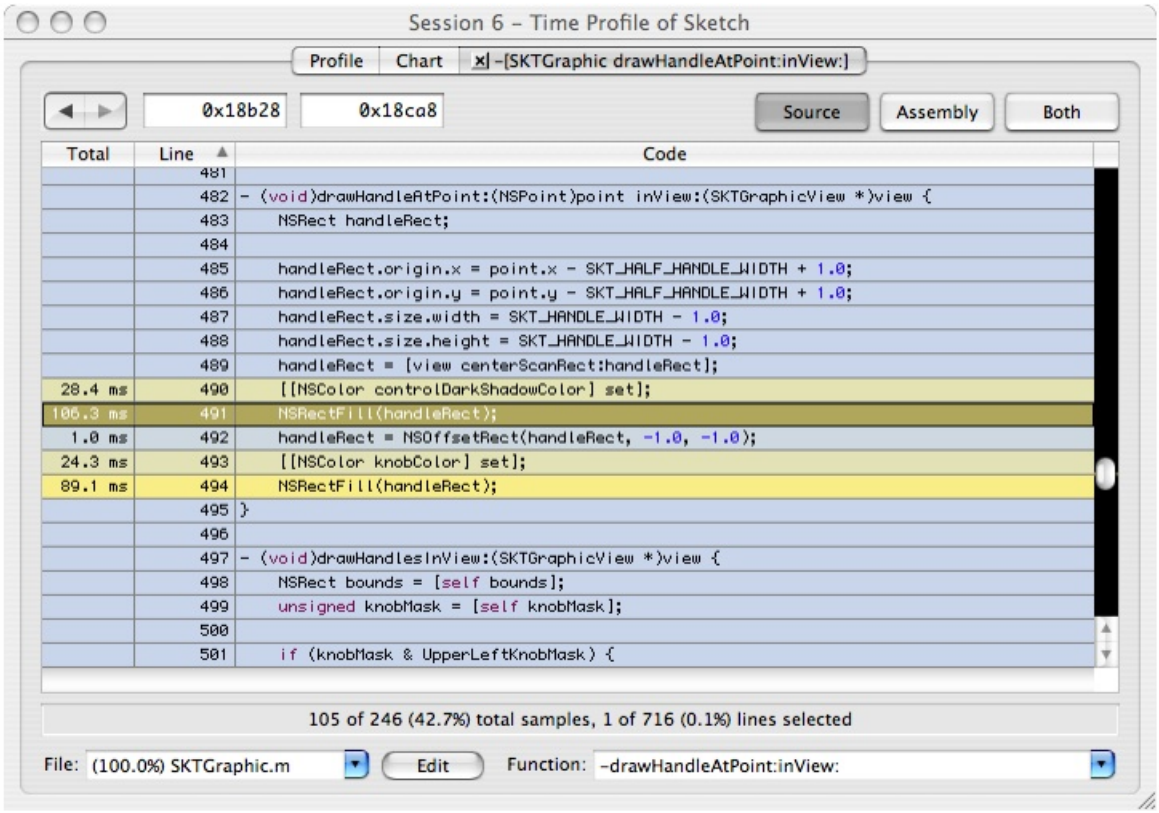
Figure 6-26 Source View: SKGraphic drawHandlesInView:



This continues on with other calls to `[self drawHandleAtPoint: inView]`, so it's been elided for brevity.

9. Double click on line 502 in the text `[self drawHandleAtPoint: ...]` and it will take you to the code for `[SKTGraphicview drawHandleAtPoint: ...]` which is shown in Figure 6-27

Figure 6-27 Source View: SKGraphic drawHandleAtPoint:inView:



Here we see another call into an NS drawing primitive. At this point, if you are a developer, your only option is to investigate using other graphics primitives such as direct calls to Quartz. In this example we'll do some further analysis to show some techniques useful for analyzing larger apps and frameworks.

Dig Deeper by Charging Costs

To dig deeper we will turn off “Charge System Libraries to Callers” and go through a more step-by-step analysis of what is involved in drawing the shapes for Sketch. This will be focus more on demonstrating various data mining operations and less on particular issues in the frameworks.

1. Go to the filter box in the advanced drawer and un-check the "Charge System Libraries to Callers" checkbox. Since we are still focused on `-[SKTGraphicView drawRect:]` we avoid seeing all the framework code that went brought us to that draw routine, and thereby avoid being overwhelmed with symbols. In the heavy view you will now find all sorts of system symbols, so we may need some help to make sense of these. A powerful tool for pruning useless symbols is “Filter Library.”

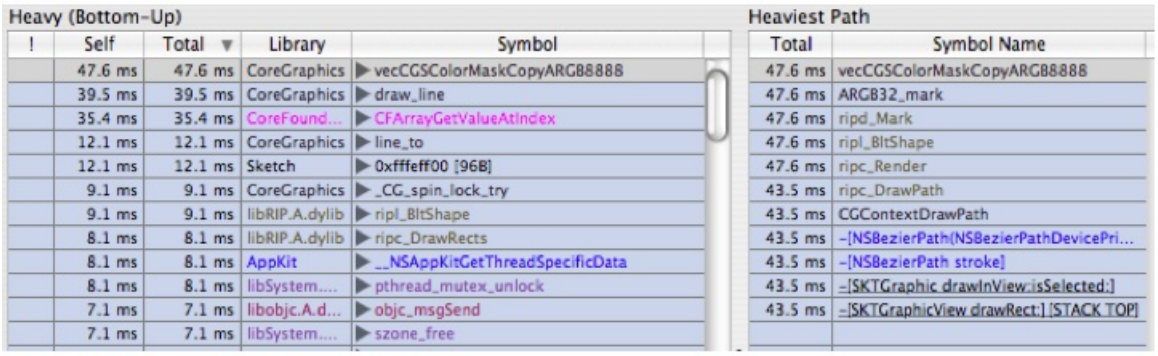
2. We're going to work with the “Heavy View” (the upper profile) for a bit. So click the 

and set it back to 

.

3. Select the first symbol in the upper profile, as shown in Figure 6-28.

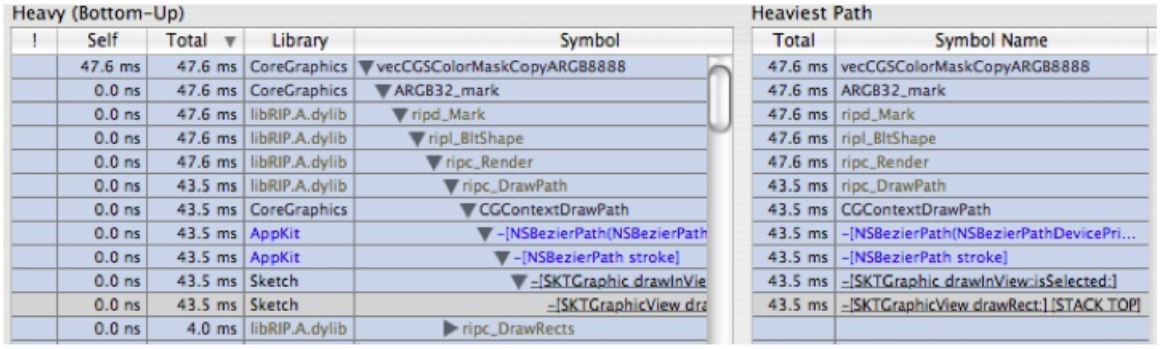
Figure 6-28 Heavy View of Focused Sketch



Notice that the stack view on the right shows a backtrace leading up to our old friend `-[SKTGraphicView drawRect:]`.

4. In the callstack view on the right click on `-[SKTGraphicView drawRect:]` and you'll get Figure 6-29:

Figure 6-29 Expanded Heavy View of Focused Sketch

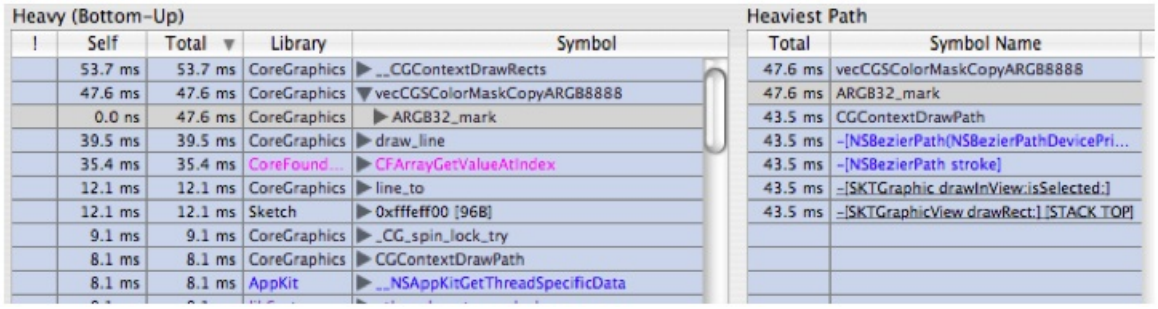


Suppose we are interested in understanding the calls made into CoreGraphics. This is challenging because AppKit calls CoreGraphics, which calls libRIP.A.dylib, which then calls back into CoreGraphics. This is a lot of interdependency to sort out.

Fortunately there is a way to hide this complexity and see just what we are interested in. We use what are called the exclusion commands. One of the most powerful ones is “Charge Library.” This command tells Shark to hide all functions in a particular library and charge the costs of those functions to the functions calling into that library. We'll show this in action in our example:

5. In the left hand outline select the symbol `ripd_mark` and control+click on it to bring up the data mining contextual menu. Choose "Charge Library **libRIP.A.dylib**" and you get Figure 6-30:

Figure 6-30 After Charge Library libRIP.A.dylib

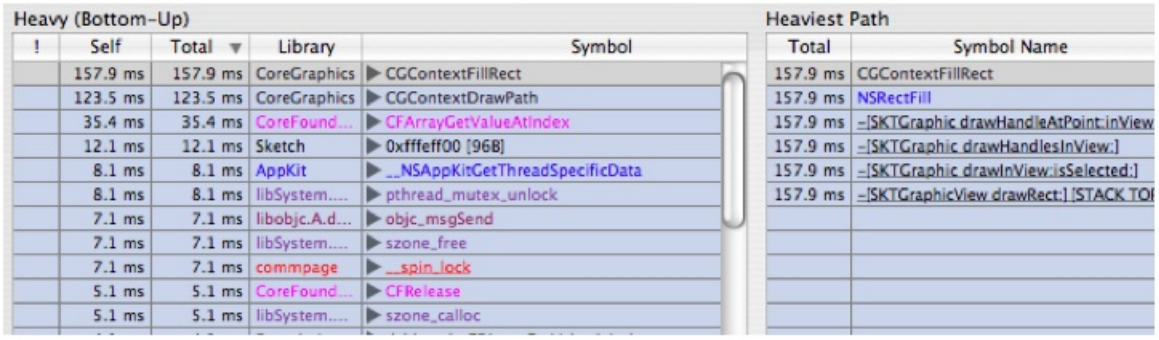


Notice that the symbols for **libRIP.A.dylib** are gone from the samples. Now this is a bit cleaner, but there are still multiple layers in CoreGraphics. Notice that we have `CGContextDrawPath` both in the caller chain to `vecCGSColorMaskCopyARGB8888` and as a leaf function. What we really want to see is how much time we're spending in `CGContextDrawPath`.

This is most easily accomplished with “Flatten Library.” “Flatten Library” is similar to “Charge Library,” except that it leaves the first function (entry point) into the library intact. It in effect collapses the library down to just its entry points. There is a quick click button in the *Advanced Settings* Drawer’s Data Mining Palette that lets you flatten all system libraries. This is a good quick shortcut for flattening all the system libraries, which greatly simplifies your trace in one shot.

6. Do a control+click on `vecCGSColorMaskCopyARGB8888` and choose "Flatten Library **CoreGraphics**" and you'll get Figure 6-31

Figure 6-31 After Flatten Library



Now this is getting interesting. Time spent has converged into `CGContextFillRect` and `CGContextDrawPath`. These two call trees represent the two different places we saw hot spots in our top down analysis. But now we have exposed more detail. The CoreGraphics team could now choose to use the “Focus on Symbol” commands to study either piece of the execution tree in detail.

This example is a bit simplistic, but it shows the power of the exclusion operations to strip out unnecessary information and identify where the real choke points are in the middle part of the execution tree. Please note that using the data mining operations does not change the underlying sample data that you've recorded. It just changes how the data is displayed, and so you can always remove all data mining choosing "Restore All" and "Unfocus All" from the Data Mining Menu at any time. As you master the use of these operations, you will learn how to identify the dynamic behavior of complex programs and frameworks faster than you ever thought possible.

Example: Graphical Analysis using Chart View with a Malloc Trace

The previous example demonstrated how to use various filtering/focusing data mining techniques to identify hot spots in your program. All of these also apply to sampling by malloc events (heap tracing), in addition to samples obtained by time profiling.

However, *graphical analysis* is also a useful technique for examining the results Shark provides, when used in conjunction with the time based analysis described previously. This technique involves looking at the actual execution pattern using Shark's *Chart* view tab (see "Chart View " (page 39)). While time analysis helps us prioritize which areas of complexity we wish to attack first, graphical analysis helps us identify the patterns of complexity within these regions in a way that just doesn't come through when looking at the "average" summaries seen in the profile browsers. While this concept applies to all configurations, it is particularly critical with the *Malloc Trace* configuration (see "Malloc Trace" (page 94)), because analyzing the precise memory allocation/deallocation patterns, and determining which calls are causing these allocations and deallocations, is often more important than just looking at the averages seen with the browsers.

Please note an important distinction between malloc tracing and time profiling. With time profiling, you generally want choose a data set that will take an interestingly long amount of time so that you can get a good set of samples. In contrast, with exact tracing you generally want to scale back your operation size so that you do one operation on just a few items, in order to keep the number of trace elements manageable.

This example uses the same Sketch demo build environment as the previous one. Complete that one up to the end of "A Performance Problem... " (page 146) if you have not already gone through it in order to follow along.

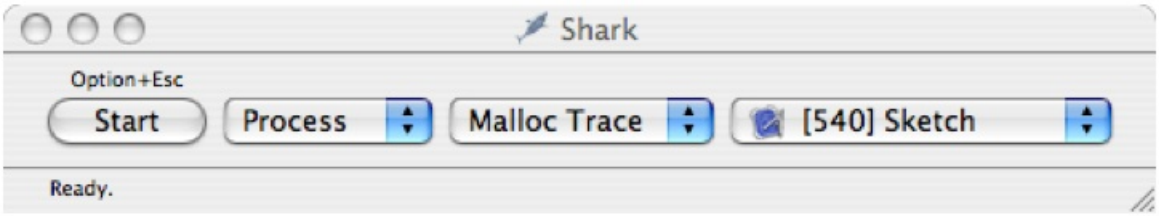
Taking Samples

1. Switch to "Sketch" with your array of replicated shapes from "A Performance Problem... " (page 146). Do a "Select All" to select all of the shapes before continuing.

2. Launch Shark (in `/Developer/Applications/Performance Tools/`).

3. Target your application and choose "Malloc Trace" instead of "Time Profile," as with Figure 6-32.

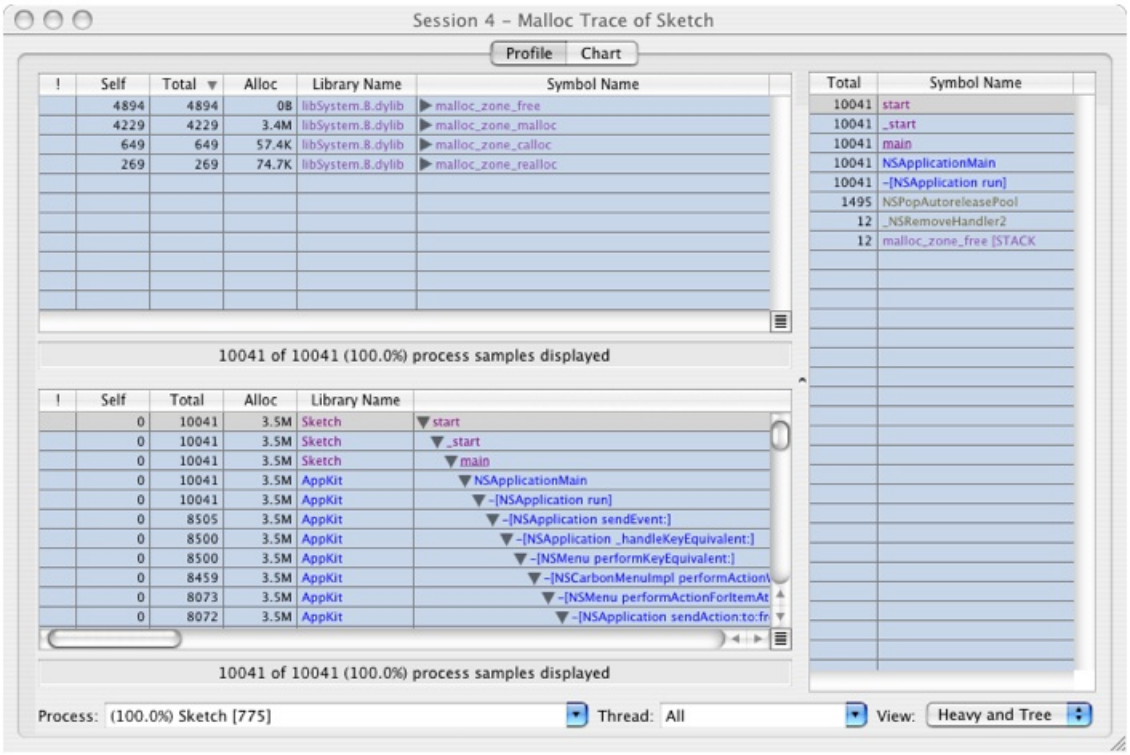
Figure 6-32 Malloc Trace Main Window



4. Switch back to Sketch.
5. Move the Sketch window to expose the Shark window (optional but makes things easier).
6. Make sure everything is selected.
7. Press *Option+Escape* to start sampling.
8. Choose *Edit Copy* and wait for the menu bar highlight to go away.
9. Press *Option+Escape* to stop Sampling.
10. Hit *Command-1* to switch the weighting to by count (or do it via the Weighting popup in the *Advanced Settings* drawer).

The window should look like Figure 6-33, if you have gone through Tutorial 1 first. Otherwise, it will look similar but not exactly the same.

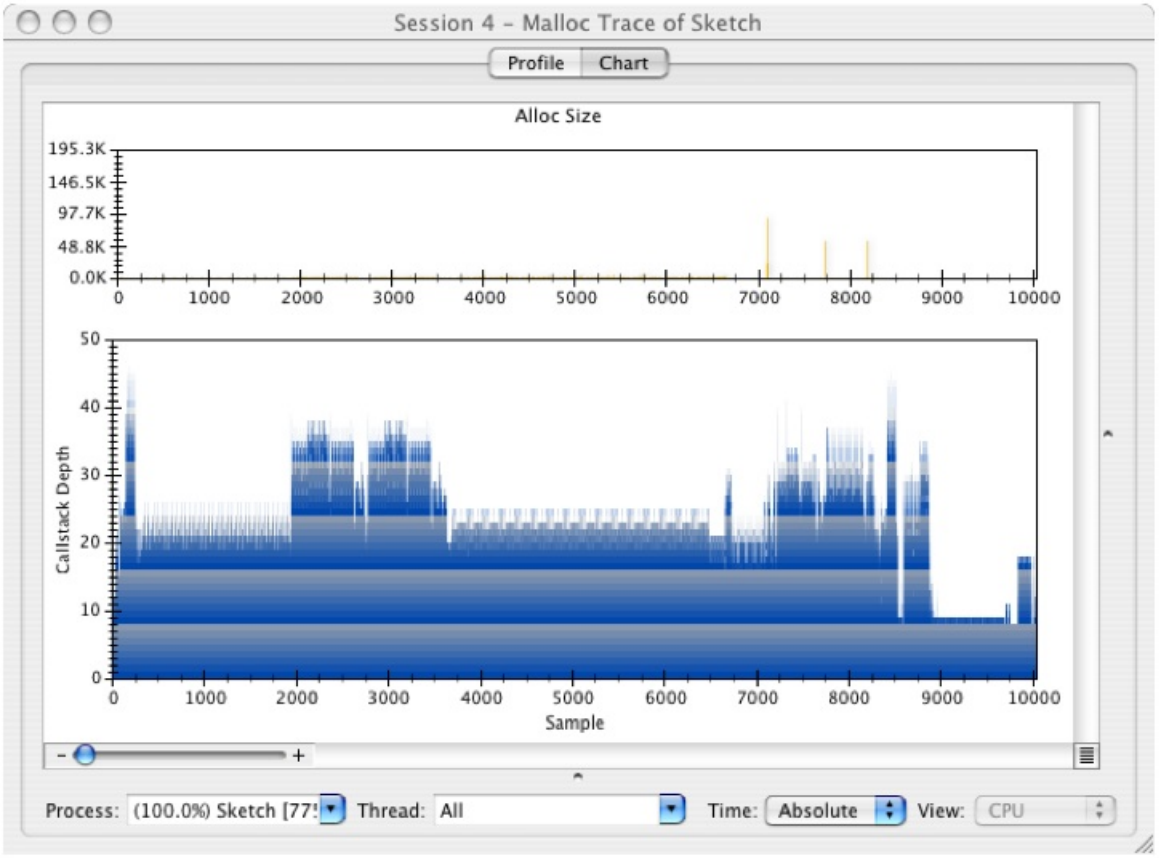
Figure 6-33 Result of Malloc Sampling



Graphical Analysis of a Malloc Trace

1. Click on the *Chart* Tab and you'll get a window that looks like Figure 6-34.

Figure 6-34 Chart View



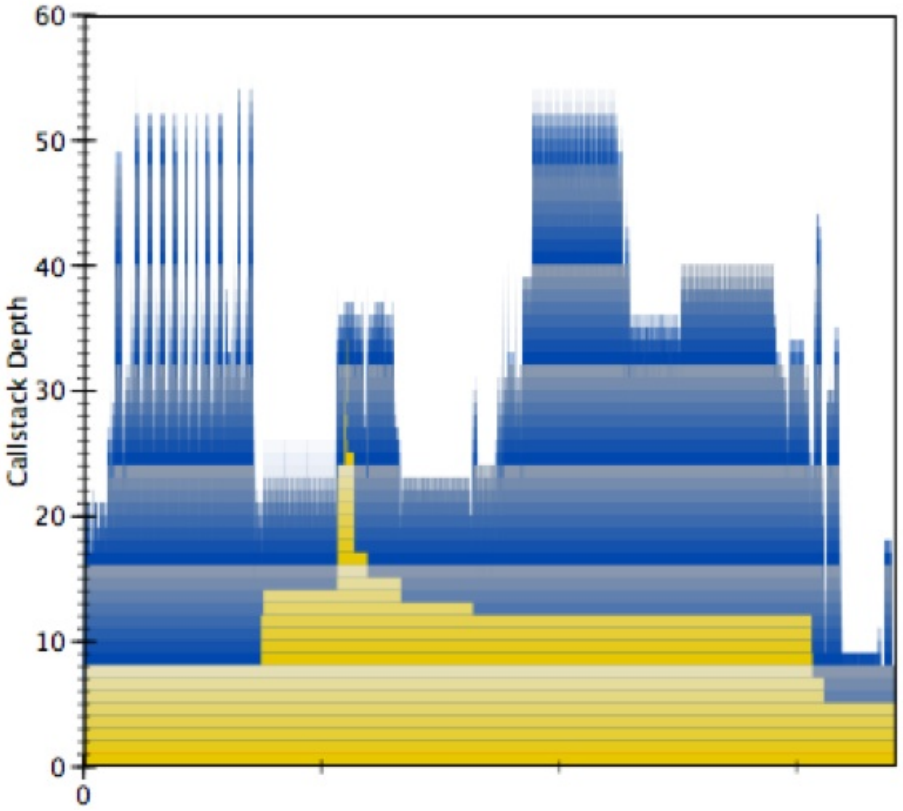
The lower graph a standard plot of the callstacks, with sample number on the X axis and stack depth on the Y axis, while the upper graph is a plot of the size of each allocated block plotted against the sample number.

This plot is useful for identifying repeated execution paths in your code due to the fact that execution trees leave a form of “fingerprint” that is often quite readily visible. Basically, if you see similar patterns in the graph, it is a strong indication that you are going through the same code path. It may be acting on different data each time, but these repeated patterns often represent good opportunities for improving performance. Often, you can hoist some computation outside of the innermost loop in each nesting and make the actual work done in the loop smaller while performing the same actual work. This kind of change would show up in the graph by reducing the size and the complexity of the repeated structure.

Let's show an example of a repeated structure.

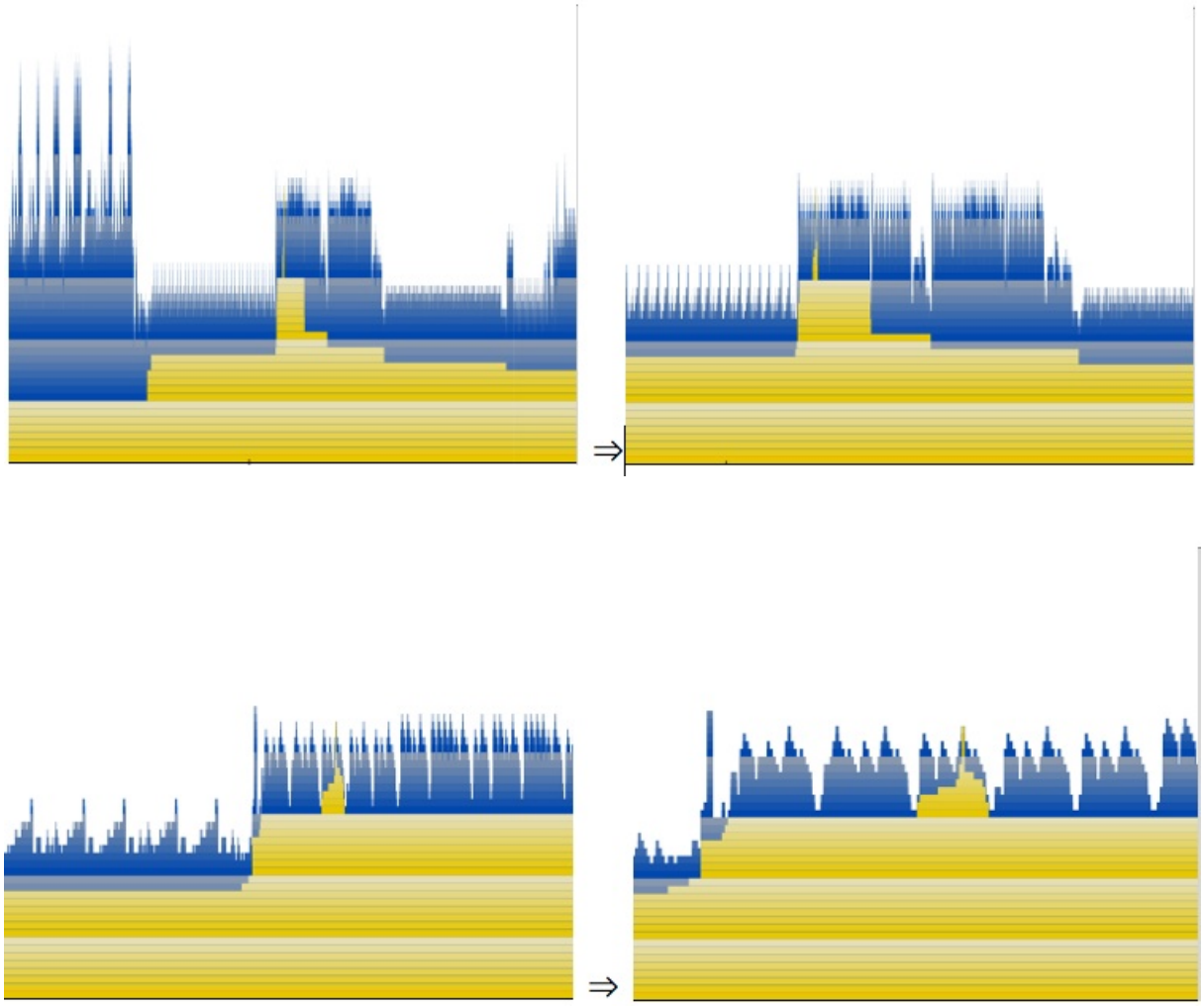
2. Select the first hump just before sample 6,000 and enlarge it, as shown in Figure 6-35:

Figure 6-35 Place to Select



The yellow indicates the tenure of different stack frames. Stack frame 0 is main and it is active the entire time. As you get deeper into the stack the tenures get narrower and narrower. Tall skinny spikes of yellow indicate deep chains of calls that do little work and this should be avoided.

3. Now use the slider on the bottom left of the window to adjust zoom. Play with this a bit. As you zoom in and out you'll see that there are multiple levels of unfolding complexity — much like a fractal. Here is a sequence of zooms that show complexity at different levels:



It is a good idea to explore around your execution trace and identify every range of repeated structure and understand what it is doing in each case. The reason this has a fractal like quality is that Mac OS X's library calls have many layers of libraries that encapsulate one another. Each of these layers can introduce levels of iteration that is nested inside of other layers. This is like the problem with the nested iteration that we showed in "Analysis Via Source Navigation" (page 151), but on a system wide scale. In order to drastically improve performance you must attack this problem of complexity creep and eliminate it as much as possible. Application developers obviously can't fix framework issues, but they can strive to eliminate similar complexity issues in their libraries.

4.

We'll finish up with another good application of this graphical analysis. Click on the call stack button to reveal the call stack for this sample, as shown in Figure 6-36:

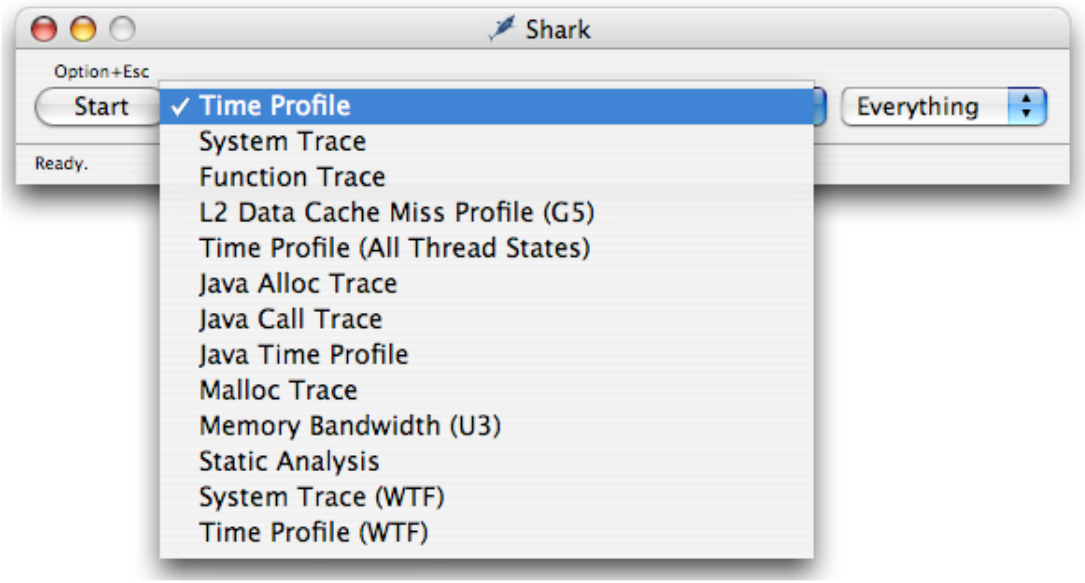
Figure 6-36 Graph View with Call-Stack Pane

Using the callstack view, notice that a bunch of XML parsing to build up some kind of *NSPrintInfo* is occurring. This is surprising since all we did was a clipboard copy. In fact, all of the malloc events from about 5,000 to 15,000 are involved with manipulating printer stuff. It turns out that this is due to Sketch actually exporting a full PDF onto the clipboard rather than using a "promise" that it has material to put there if the user actually switches applications and then performs a "paste" operation — the uncommon case, generally. This is a great example of how doing something fairly innocuous at the application level can cause the system libraries to do a lot of extra work. It is also a great example of a cross-library problem that needs to be optimized on multiple levels, ranging from the application to the printing framework to the XML parsing code.)

Custom Configurations

Up until now, you have been using the configuration menu in Shark's main window (in Figure 7-1) to select from various built-in sampling methods. Each of these sampling methods is called a *configuration* (abbreviated as "configs"), and Shark saves each configuration as a separate configuration file (which is also often called a "config"). Each config file describes a variety of settings for Shark which enable it to sample or profile your application in a particular way, plus a summary of any hardware requirements that are necessary to use it.

Figure 7-1 Main Configuration Menu



Once you have gained some experience with Shark, you might want to change some of the settings or adjust some of the types of data Shark collects when a particular config is active. For example, you might adjust the default sample rate of the Time Profiling config to sample more often, if your examinations routinely need higher sampling resolution. This chapter gives an overview as to how this can be accomplished using Shark's sophisticated *Configuration Editor*.

The Config Editor

The *Configuration Editor* lets you individually modify settings for any of Shark's modules, which are called *PlugIns*. The properties available in each PlugIn differ depending on the nature of the work that particular PlugIn is designed to do. Shark uses three types of PlugIns:

- **Data Source** – These are responsible for collecting and/or generating session data. Many user-modifiable parameters are typically available to control the sampling or profiling performed by these modules.

- **Analysis** – These process raw data and produce intermediate results that are typically shared by more than one viewer. Only a few settings are available for these modules.
- **Viewer** – These display analysis results and performance data. Because users typically want immediate feedback to viewer adjustments, options for these are set by interacting directly with the visible display or through the *Advanced Settings Drawer* (see "Advanced Settings Drawer" (page 22)) attached to each analysis window, instead of here in the Configuration Editor.

Once you have decided that the built-in configs are not sufficient for the work that you are doing, the first step to creating or editing your own configurations is to start the *Configuration Editor* using one of two techniques:

- Select the *Config➤New...* (*Command-N*) command to start a new config from scratch.
- Select *Config➤Edit...* (*Command-Option-Shift-C*) to modify the current config.

Either technique will bring up the *Configuration Editor* dialog box, which allows you to examine and modify any part of a configuration. "Adding Shortcut Equations" points out the four main major parts of this editor:

1. **The Config Listing** — This contains an entry for every configuration Shark knows about. This includes documents stored in `/System/Library/Application Support/Shark/Configs` folder, and any custom config documents stored in `$USER/Library/Application Support/Shark/Configs` in your home folder. Some config file names may be dimmed in the list. This means they are not compatible with the system Shark is currently running on, and therefore cannot be enabled for sampling or profiling, but you can still select and modify them here in the Configuration Editor. The rest of the Configuration Editor controls always modify the selected entry in this list.

   Next to the main listing, various controls support basic file operations to manage these config files:

   - You can *Duplicate* any config in the list. This is usually the best way to begin making a custom config. In fact, selecting "New..." from the Config Menu just makes a duplicate of the current config in order to provide a starting baseline.
   - You can *Delete* any custom config in the list, but not built-in config files. A verification message will appear when you click the Delete button. A deleted config will be erased from the appropriate Configs folder when you finally press the OK button.
   - You can *Rename* any custom config in the list, but not built-in config files. A renamed config will be changed in the appropriate Configs folder immediately.
   - You can *Import* any config that you may have saved on your system or a mounted fileserver. Imported configs are copied to your home `$USER/Library/Application Support/Shark/Configs` folder. You can also perform this function without invoking the Configuration Editor by using the *Config➤Import...* menu command.
   - You can *Export* any listed config to an arbitrary file on your system or a fileserver. This is a great way to share configs between computers or user accounts. You can also perform this function without invoking the Configuration Editor by using the *Config➤Export...* menu command.

2. **The Summary** — Explains the details of the selected config and all the PlugIn settings that will be used to collect data.

3. **The PlugIn List** — Each PlugIn type in the configuration may optionally provide an editor for its properties in the configuration. You can select the PlugIn to edit by clicking on the desired PlugIn name here. You can also enable or disable PlugIns using the checkboxes.

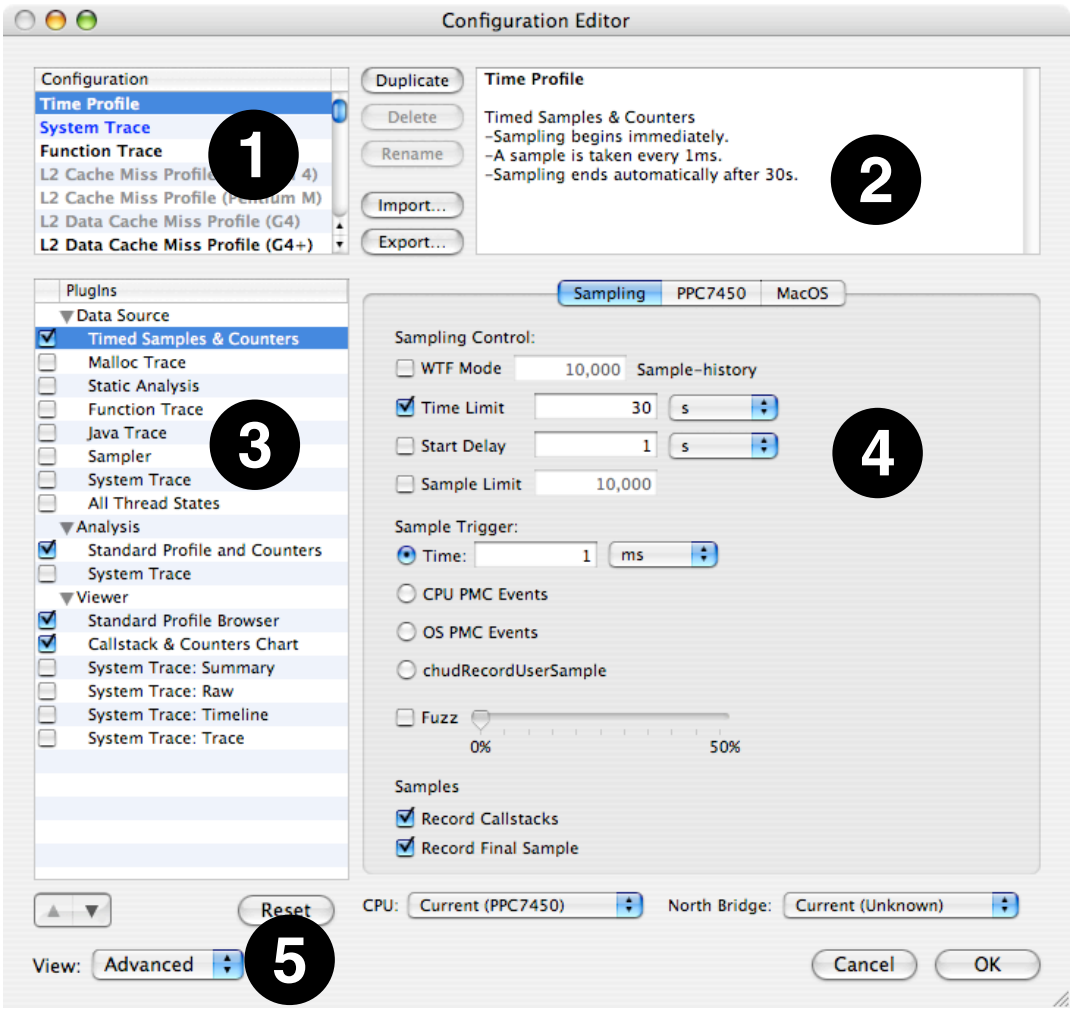
The order of the plugins has a different meaning depending upon on the type of plugin. For data source plugins, the vertical order of the enabled plugins indicates the order in which data sources will be started and stopped. Analysis plugin order indicates the order of their creation, and viewer plugin order determines the order of viewer tabs in the resulting Shark session window. The position of a plugin can be changed using the *Up* and *Down* arrow buttons to the lower left of the *PlugIn List*.

4. **The PlugIn Property Editor** — This displays user-tunable options, if any, for the PlugIn currently selected in the *PlugIn List*. Some PlugIns have no or only a few controls, while other PlugIns (such as the "Timed Samples & Counters" Data Source plugin) have many properties, and require multiple tabbed window panes to organize all the various settings available.

5. **The Property View Pop-up**: Each plugin's property editor can optionally support two modes of operation: *Simple* (the default) and *Advanced*. This menu allows you to select between them, if they are both present. In addition, this control modifies the *PlugIn List* as follows:

    - In *Simple* mode, only plugins enabled by the currently selected config that have property editors are listed.
    - In *Advanced* mode, all of the available plugins are listed with a checkbox next to each indicating whether or not it is enabled in the current config.

Figure 7-2 Config Editor



The remainder of this chapter describes Shark's wide variety of PlugIn editors that are controllable through the *Configuration Editor*. In addition, because it is very complex, the "Advanced" mode of the "Timed Samples and Counters" config editor is described in "Hardware Counter Configuration" (page 189).

Simple Timed Samples and Counters Config Editor

The Timed Samples and Counters data source is used for collecting system-wide time and performance count profiles. This is used for several default configurations, including the Time Profiling one described in "Time Profiling" (page 29). In *Simple* mode, there are two types of settings that can be modified in the editor:

- **Sampling Tab** – The controls on this tab (see Figure 7-3) determine when to start and stop recording samples.

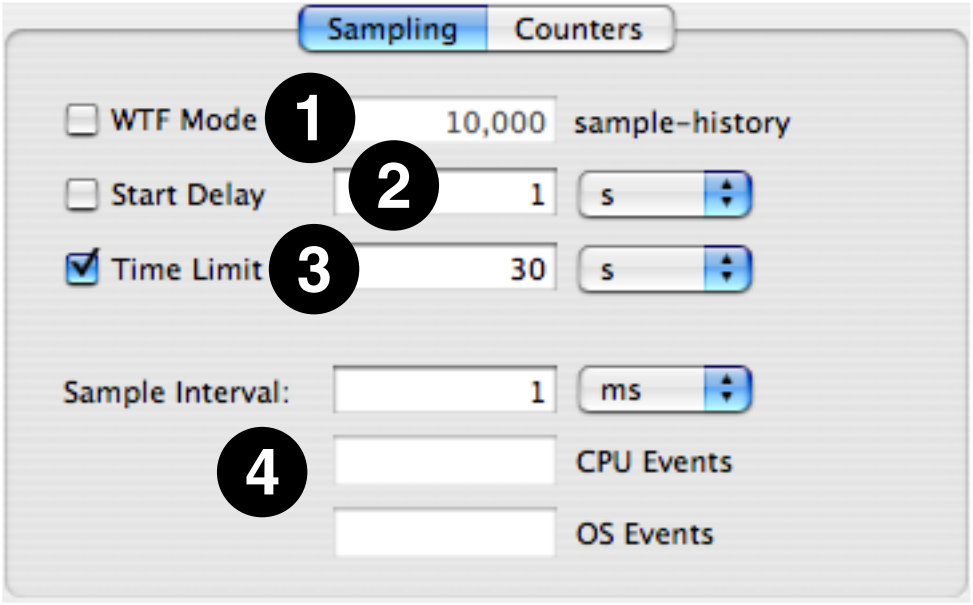
  1. **Windowed Time Facility**— If enabled, Shark will collect samples until you explicitly stop it. However, it will only store the last N samples, where N is the number entered into the sample history field (10,000 by default). This mode is also described in "Windowed Time Facility (WTF)" (page 118).

2. **Start Delay**— Amount of time to wait after the user selects "Start" before data collection actually begins. This helps prevent Shark from sampling itself.

3. **Time Limit**— The maximum amount of time to record samples. This is ignored if WTF mode is enabled.

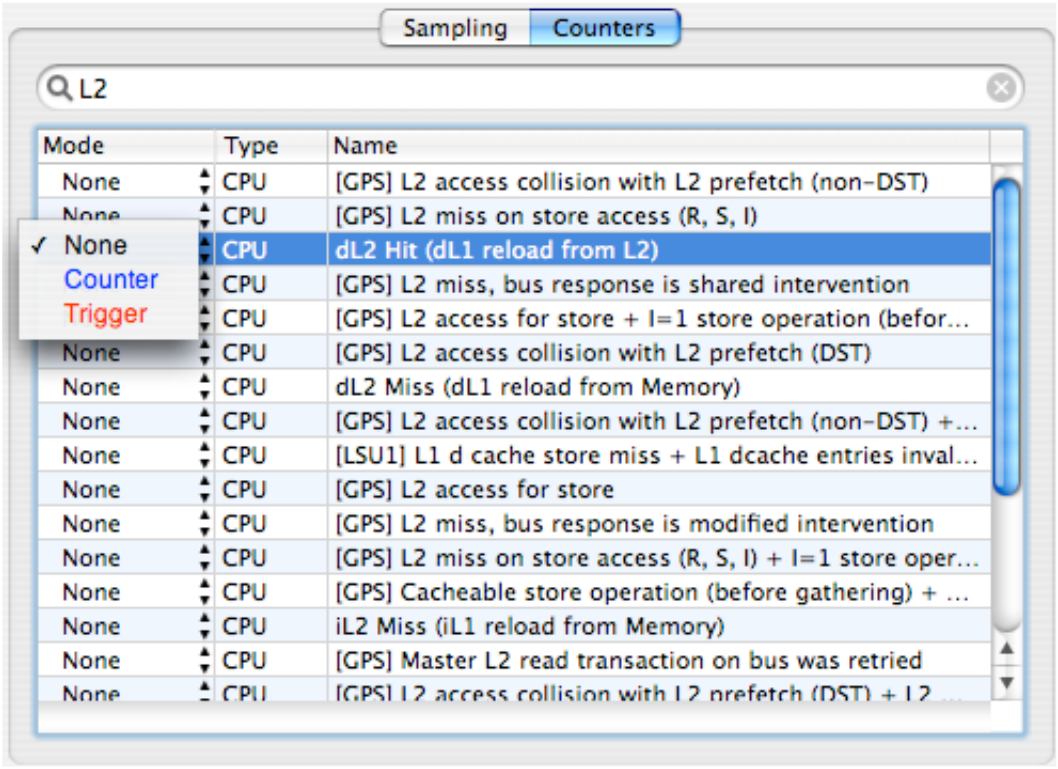
4. **Sample Interval**— Determines the sampling rate. The interval can be a time period (1 ms default), CPU performance event count, or OS performance event count . If no performance counters (CPU or OS) are configured as triggers, the sample interval is assumed to be a time interval, and hence only the time entry field is enabled.

Figure 7-3 Simple Timed Samples and Counters Data Source - Sampling Tab



- **Counters Tab**— This tab (see Figure 7-4) presents a fast and simple way to search and configure the *Processor* (CPU), *Operating System* (OS), and *Northbridge* (MEM) performance counters. Enter an event keyword or partial description in the search field to see a list of matching counter events. Use the *Mode* column to select the performance counter mode (**None**, **Counter**, or **Trigger**). Only a small subset of possible counter options are available here. For more, you will have to use the Advanced settings, described in "Hardware Counter Configuration" (page 189).

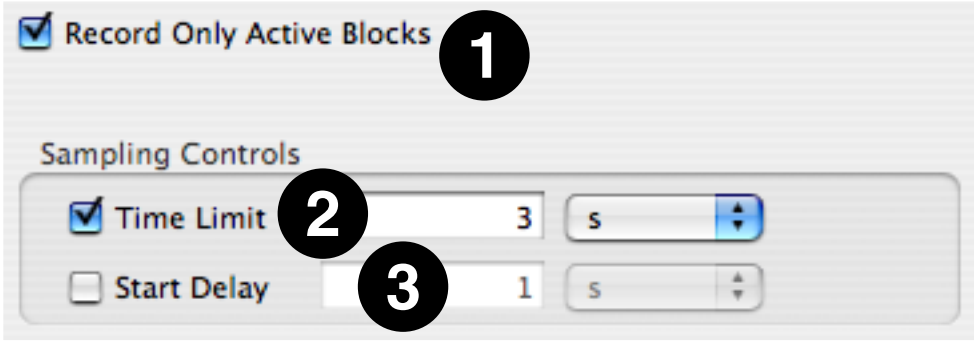
Figure 7-4 Simple Timed Samples and Counters Data Source - Counter Settings



Malloc Data Source PlugIn Editor

The Malloc data source is used for the Malloc Trace config described in "Malloc Trace" (page 94). It is used for collecting a memory allocation profile from a particular executable. All of its configurable controls are contained in a single tab (see Figure 7-5), which modifies the timing of starting and stopping of memory allocation recording behavior:

Figure 7-5 Malloc Data Source - Sampling Settings



1. **Record Only Active Blocks**— If enabled, Shark will collect samples only in memory regions that were allocated during a profile and not released. Otherwise, any allocation or deallocation that takes place is recorded.

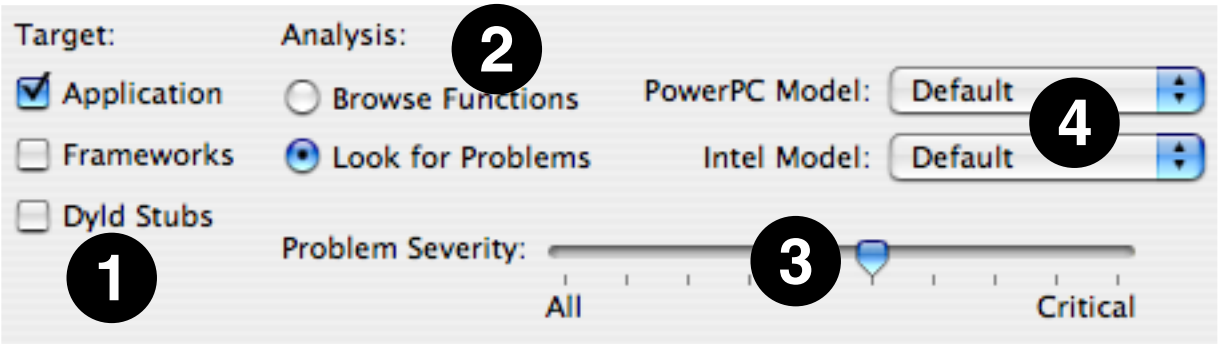
2. **Time Limit**— The maximum amount of time to record samples.

3. **Start Delay**— Amount of time to wait after the user selects "Start" before data collection actually begins.

Static Analysis Data Source PlugIn Editor

The Static Analysis data source is used by the Static Analysis default configuration, described in "Static Analysis" (page 99). It is used to search for potential performance issues by looking for problems that might crop up through some other (as yet untested) code path. All of its configurable controls are contained in a single tab (see Figure 7-6), which modifies the type and severity of potential problems that can be identified using the mechanism:

Figure 7-6 Static Analysis Data Source - Settings



1. **Target Selection**— These options allow you to narrow down the area of memory examined by Shark.

   - *Application*— Looks for potential performance issues in the main text segment of the target process
   - *Frameworks*— Looks for potential performance issues in the frameworks that are dynamically loaded by the target process.
   - *Dyld Stubs*— Looks for any potential performance or behavior anomalies in the glue code inserted into the binary by the link phase of application building.

2. **Analysis Options**— These allow you to enable or disable analysis.

   - *Browse Functions*— Gives each function in the text image of a process a reference count of one. This allows you to browse all of the functions of a given process with Shark's code browser. No analysis (or problem weighting) is performed.
   - *Look For Problems* — search all functions in the text image of a process for problems of at least the level of severity specified by the Problem Severity slider. Any address with a problem instruction or code is given a reference count equivalent to its severity.

3. **Problem Severity Slider**— This slider acts as a filter, adjusting the minimum "importance" of problems to report using a predefined problem weighting built into Shark. The further to the right the slider, the less output is generated, as more and more potential problems are ignored because their "importance" is not high enough.

4. **Processor Settings**— Shark needs to know which model of processor is your target before it can examine code and find potential problems. Separate menus are provided for PowerPC and Intel processors because it can analyze for one model of each processor family simultaneously.

    - *PowerPC Model*— Selects the PowerPC model to use when searching for and assigning problem severities .
    - *Intel Model*— Selects the Intel model to use when searching for and assigning problem severities .

Java Trace Data Source PlugIn Editor

The Java Trace data source supports three types of Java tracing: *Time*, *Alloc*, and *Method*. All of these have default configurations described in "Java Tracing Techniques" (page 102). These types of tracing only work on a single Java process at a time, as there is no systemwide Java tracing. The controls on the tab (see Figure 7-7) determine what type of Java Tracing to perform, and the time between samples for a Java Time Trace.

Figure 7-7 Java Trace Data Source - Sampling Settings

1. **Trace Type PopUp Menu**— Chooses one of the four types of Java tracing available:

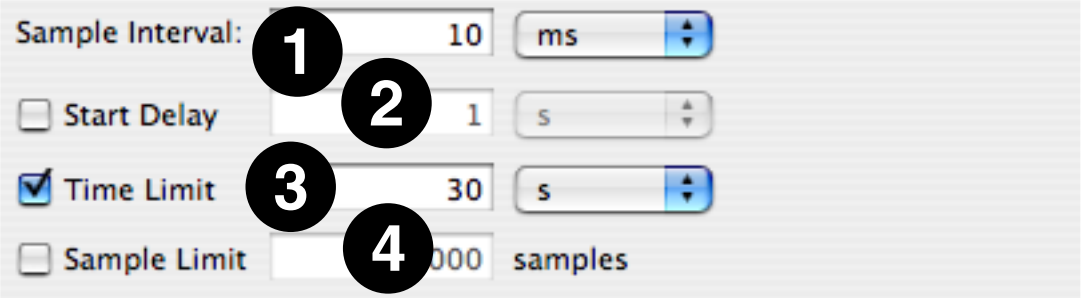
    - *Timed Samples*— Selects the Java *Time Trace* mode. This is similar to a regular Time Profile. It periodically stops the Java process and takes samples of the running threads.
    - *Memory Allocations*— Selects the Java *Alloc Trace* mode. Memory allocations and the sizes of the objects allocated are recorded.
    - *Method Trace*— This type of Java tracing is still under development, and should not be used yet.
    - *Call Trace*— Selects the Java *Call Trace* mode. This records each entry into every method during the execution of your program. Hence, this is an exact trace of the methods called (within the limitations of the Java VM).

2. **Interval field**— Enter the time between samples here, for the *Timed Samples* mode.

Sampler Data Source PlugIn Editor

The Sampler data source provides the same functionality as the separate *Sampler* application and command-line tool. It is not used for any of the default configurations provided with Shark, as most of its functionality has been superseded by features of the much more sophisticated "Timed Samples and Counters" PlugIn. All configurable features can be modified on a single tab (see Figure 7-8), which adjusts basic timing parameters:

Figure 7-8 Sampler Data Source - Settings

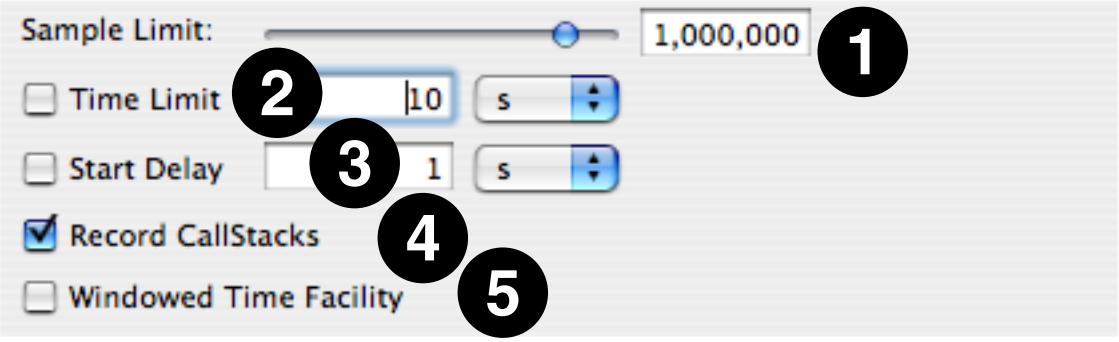


1. **Sample Interval**— Determines the sampling rate. The interval is a time period (10 ms default).
2. **Start Delay**— Amount of time to wait after the user selects "Start" before data collection actually begins.
3. **Time Limit**— The maximum amount of time to record samples.
4. **Sample Limit** — The maximum number of samples to record. Specifying a maximum of *N* samples will result in at most *N* samples being taken, even on a multi-processor system, so this should be scaled up as larger systems are sampled.

System Trace Data Source PlugIn Editor

This data source collects data for the *System Trace* default configuration, described in "System Tracing" (page 59). All configurable features can be modified on a single tab (see Figure 7-9), which adjusts basic timing parameters:

Figure 7-9 System Trace Data Source - Settings



1. **Sample Limit** — The maximum number of samples to record. Specifying a maximum of *N* samples will result in at most *N* samples being taken, even on a multi-processor system, so this should be scaled up as larger systems are sampled. On the other hand, you may need to reduce the sample limit if Shark runs out of memory when you attempt to start a system trace, because it must be able to allocate a buffer in RAM large enough to hold this number of samples. When the sample limit is reached, data collection automatically stops, unless the *Windowed Time Facility* is enabled (see below). The Sample Limit is always enforced, and cannot be disabled.

2. **Time Limit**— The maximum amount of time to record samples. This is ignored if *Windowed Time Facility* is enabled, or if Sample Limit is reached before the time limit expires.

3. **Start Delay**— Amount of time to wait after the user selects "Start" before data collection actually begins.

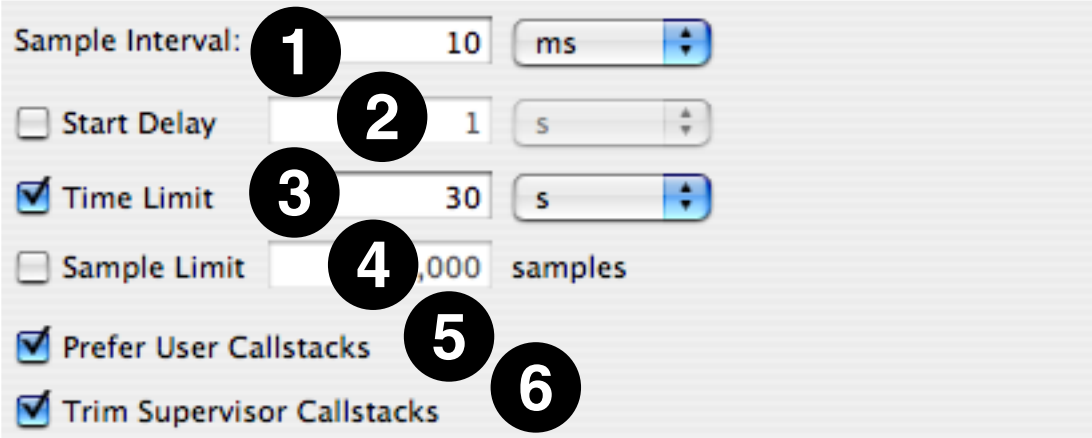
4. **Record Callstacks**— When enabled, Shark will collect the function backtrace along with the program counter value for each sample. This should normally be enabled, but can be disabled if you need to record longer traces with a limited amount of memory or if the performance impact of recording the callstacks is too high.

5. **Windowed Time Facility**— If enabled, Shark will collect samples until you explicitly stop it. However, it will only store the last N samples, where N is the number entered into the Sample Limit field. This mode is also described in "Windowed Time Facility (WTF)" (page 118).

All Thread States Data Source PlugIn Editor

This data source collects data for the *Time Profile (All Thread States)* default configuration, described in "Time Profile (All Thread States)" (page 91), which samples the callstacks of all threads on the system simultaneously, whether they are running or blocked. All configurable features can be modified on a single tab (see Figure 7-10), which adjusts basic timing parameters:

Figure 7-10 All Thread States Data Source - Settings



1. **Sample Interval**— Determine the trigger for taking a sample. The interval is a time period (10 ms default).
2. **Start Delay**— Amount of time to wait after the user selects "Start" before data collection actually begins.
3. **Time Limit**— The maximum amount of time to record samples. This is ignored if Sample Limit is enabled and reached before the time limit expires.
4. **Sample Limit** — The maximum number of samples to record. Specifying a maximum of *N* samples will result in at most *N* samples being taken, even on a multi-processor system, so this should be scaled up as larger systems are sampled. When the sample limit is reached, data collection automatically stops. This is ignored if the *Time Limit* is enabled and expires first.
5. **Prefer User Callstacks**— When enabled, Shark will ignore and discard any samples from threads running exclusively in the kernel. This can eliminate spurious samples from places such as idle threads and interrupt handlers, if your program is not affected by these.
6. **Trim Supervisor Callstacks**— When enabled, Shark will automatically trim the recorded callstacks for threads calling into the kernel down to the kernel entry points, and discarding the parts of the stack from within the kernel itself. These shortened stacks are usually sufficient, since most performance problems in your programs can be debugged without knowing about how the kernel is running internally. You just need to know how and when your code is blocking, and not how Mac OS X is actually processing the blocking operation itself.

Analysis and Viewer PlugIn Summary

All Data Source PlugIns include configuration editors. However, most of the analysis and viewer editors do not. While you generally will not need to spend much time worrying about these plugins during the configuration process, you will still need to enable or disable the correct PlugIns in your configuration in order to be able to see your results in the way you expect. The lists in this section give you an overview of when to enable or disable various PlugIns.

There are only a few analysis PlugIns. They just need to be matched to the data source and viewer PlugIns used before and after them, since they connect these PlugIns together:

- **Standard Profile and Counters**— This should be enabled for all configurations except ones that use "System Trace" or "Timed Samples and Counters" configurations that only use the "Counter Spreadsheet" viewer.
- **Counter Spreadsheet**— This can only be used with the "Timed Samples and Counters" data source and the matching "Counter Spreadsheet" viewer. Unlike the rest of the analysis and viewer PlugIns, it actually has an editor for configuring a preset list of "shortcut equations." See "Counter Spreadsheet Analysis PlugIn Editor" (page 182), below, for details.
- **System Trace**— This can only be used with the "System Trace" data source and any of the four "System Trace" viewers.

There are several viewer PlugIns. When these are enabled, the matching tabs will appear across the top of any session windows made with these configurations, in the order that the configurations are listed in the *Configuration Editor*. Like the analysis PlugIns, you can only enable these usefully when other PlugIns are also enabled, as we note below.

- **Standard Profile Browser**— This is the standard tabular browser view of symbols and sample counts used by most configurations, as is described in "Profile Browser" (page 32). To use it, you need to enable the "Standard Profile and Counters" analysis PlugIn.
- **Callstack & Counters Chart**— This is the the *Chart View* used by many configurations to graphically display the callstacks of samples over time, as is described in "Chart View " (page 39). To use it, you need to enable the "Standard Profile and Counters" analysis PlugIn.
- **Counter Spreadsheet**— This presents the counter spreadsheet view described in "Timed Counters: The Performance Counter Spreadsheet" (page 104). To use it, you must have the "Timed Samples and Counters" data source enabled and the "Counter Spreadsheet" analysis PlugIn enabled.
- **System Trace: Summary**— This can only be used with the "System Trace" data source and analysis PlugIns. It displays the Summary tab used by System Trace and described in "Summary View In-depth" (page 62).
- **System Trace: Trace**— This can only be used with the "System Trace" data source and analysis PlugIns. It displays the Trace tab used by System Trace and described in "Trace View In-depth" (page 68).
- **System Trace: Timeline**— This can only be used with the "System Trace" data source and analysis PlugIns. It displays the Timeline tab used by System Trace and described in "Timeline View In-depth" (page 72).
- **System Trace: Raw**— This can only be used with the "System Trace" data source and analysis PlugIns. It displays raw and unprocessed samples recorded by System Trace, and is normally not used by end users.

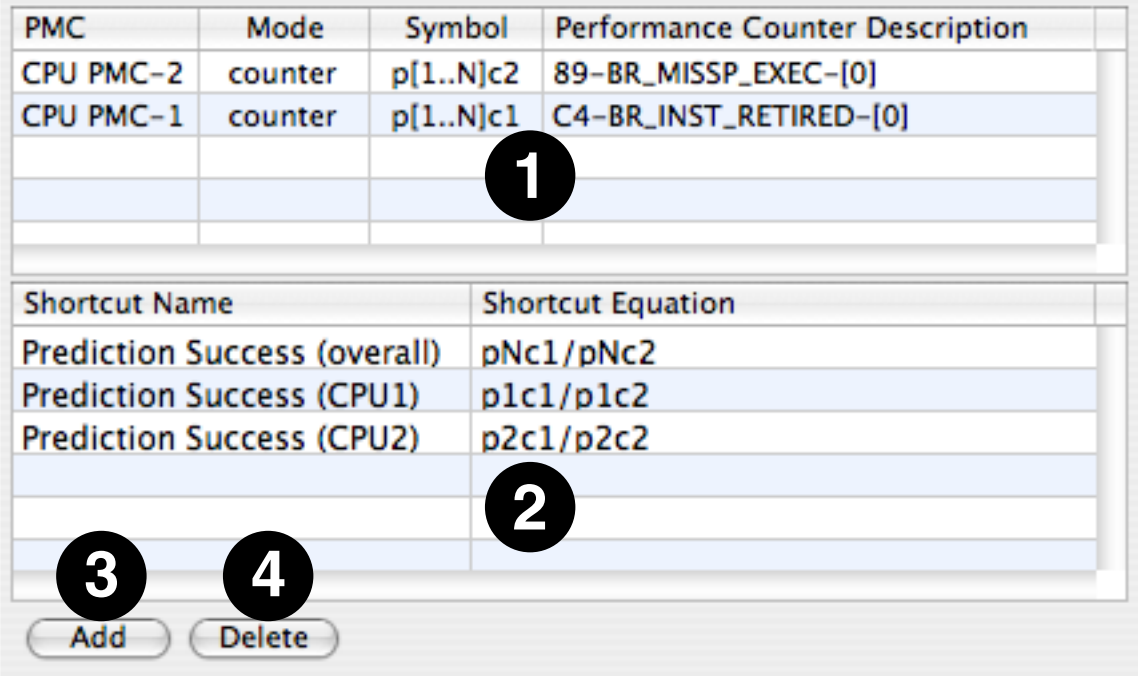
Counter Spreadsheet Analysis PlugIn Editor

When PMCs are active during sampling, this analysis plugin can be enabled. The controls on this editor allow you to create new results equations called *shortcuts*. The shortcuts will show up in the counter spreadsheet as extra columns of data that you can plot in the counter spreadsheet's chart view. With these shortcuts, you can effectively create new types of results data that use the event counts from the sampling to derive new information about the way the event counts may relate to each other, without forcing you to first export the data into another application, such as a spreadsheet. These derivative results can then be viewed just as if they were any other bit of "raw" counter data sampled by Shark.

Using the Editor

When using the editor, you will first be presented with the view shown in Figure 7-11:

Figure 7-11 Counter Spreadsheet Analysis



This view contains the following constituent parts:

1. **PMC Sumary Table** – This table summarizes all the performance counters (PMCs) that are currently selected and enabled in the Timed Samples and Counters data source.
    - *PMC column*— This is a short description of the counter and the device in which this performance monitor counter is found.
    - *Mode column*— The counter's current mode. This is typically *counter*, because *unused* and *trigger* PMCs are filtered out and not listed in this table.
    - *Symbol column*— This display's the counter's *term*. This is the algebraic symbol that represents the counter in the shortcut equations .
    - *PMC Description column*— The name of the event type currently being counted by the selected PMC, which is also used as the header for the results column for this PMC in the Counter Spreadsheet.
2. **Shortcut Equation Table** – This table will list any equations that you have defined to generate extra results in the counter spreadsheet viewer. You can edit the names of the shortcut equations in the left column, and their formulas in the right.
3. **Add Button** – Creates a new shortcut equation.
4. **Delete Button**– Erases the existing shortcut equation that you are currently editing.

If you decide that you would like to combine the existing counter results into a new, derivative result, then simply click the *Add* button. A new line will be added to the *Shortcut Equation Table*, where you can type a name in the left column and the equation itself in the right. The name can be whatever you like, but the equation must follow a proscribed format consisting of input terms (using the notation in the table below) combined together using basic four-function math symbols (+ for addition, - for subtraction, * for multiplication, and / for division) and using parenthesis to order the operations, if necessary. You may also include numeric constants at any point in an equation. These are most often used when you need to convert between different types of units.

Once created, each shortcut equation is applied to each row of results (i.e. on a per-sample basis). Shark adds a new column titled with the shortcut name to its "spreadsheet" of counter results in order to hold the newly calculated values.

Shortcut Equation Terms	Description
pXcY	Represents **p**rocessor-*X*, **c**ounter-*Y*. For example: `p2c1` is the term that represents counter #1 on processor #2. *X* = CPU number, numbered 1, 2, 3, ... *Y* = PMC number, numbered 1, 2, 3, ...
pNcY	Represents a summation of results from all processors on **c**ounter-*Y*. For example: `pNc1` is the term that represents event count samples for every active processor's counter #1, all added together. You could get the same effect with an equation of your own like `(p1c1+p2c1+p3c1+p4c1)`, but this would only work correctly on a four processor system. On a two processor system, it would fail, since processors 3 and 4 do not exist, while on an eight processor system it would get incorrect results because it would miss results from processors 5–8. *Y* = PMC number, numbered 1, 2, 3, ...
mXcY	Represents **m**emory Controller-*X*, **c**ounter-*Y*. For example: `m1c1` is the term that represents counter #1 on memory controller #1. *X* = Memory controller number, numbered 1, 2, 3, ... (At present, there are no Macs with more than one memory controller.) *Y* = PMC number, numbered 1, 2, 3, ...
oXcY	Represents **o**perating System-*X*, **c**ounter-Y. For example: `o1c1` is the term that represents counter #1 in operating system image #1. *X* = OS image number, numbered 1, 2, 3, ... (At present, there are no Macs with multiple operating system images.) *Y* = PMC number, numbered 1, 2, 3, ...
aXcY	Represents **a**pple Processor Interface-*X*, **c**ounter-Y. For example: `a1c1` is the term that represents counter #1 in API #1. *X* = Apple Processor Interface (API) number, numbered 1, 2, 3, ... (At present, there are no Macs with multiple APIs.) *Y* = PMC number, numbered 1, 2, 3, ...

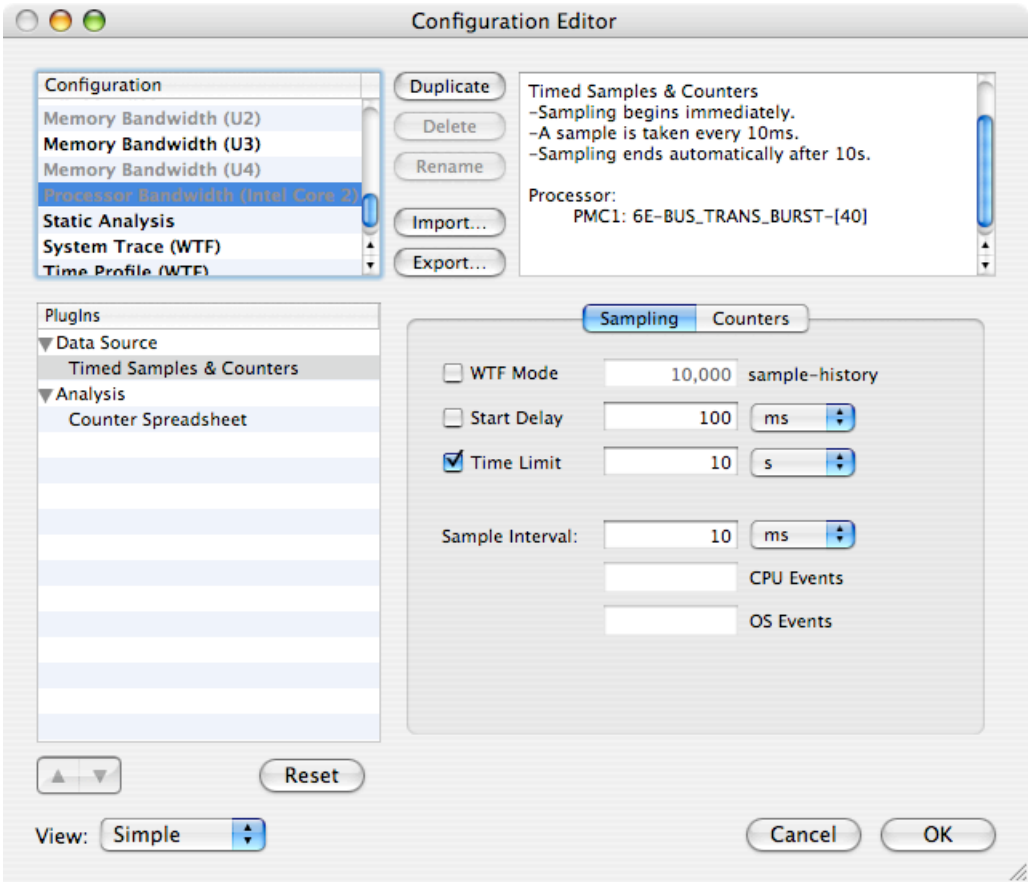
Shortcut Equation Terms	Description
tbX	Represents **t**imebase Register in core *X*. For example: `tb1` is the term that represents the timebase register in core #1. *X* = Core to take the timebase from, numbered 1, 2, 3, ...
eqX	Represents **e**quation-*X* . For example: `eq01` is the term that represents the result already calculated by the first shortcut equation in the results table. In this way, new equations can be built using results already calculated.

Spreadsheet Configuration Example

Because this editor is very flexible and powerful, an example can be helpful to illustrate how it might be used. Starting with a predefined config, we will add some performance counter events, and activate the *Performance Counter Spreadsheet* plugins. Last, we will add some shortcut equations to the analysis.

Select the configuration named "Processor Bandwidth (Intel Core 2)" (Figure 7-12).

Figure 7-12 Choosing a counter-based starting configuration



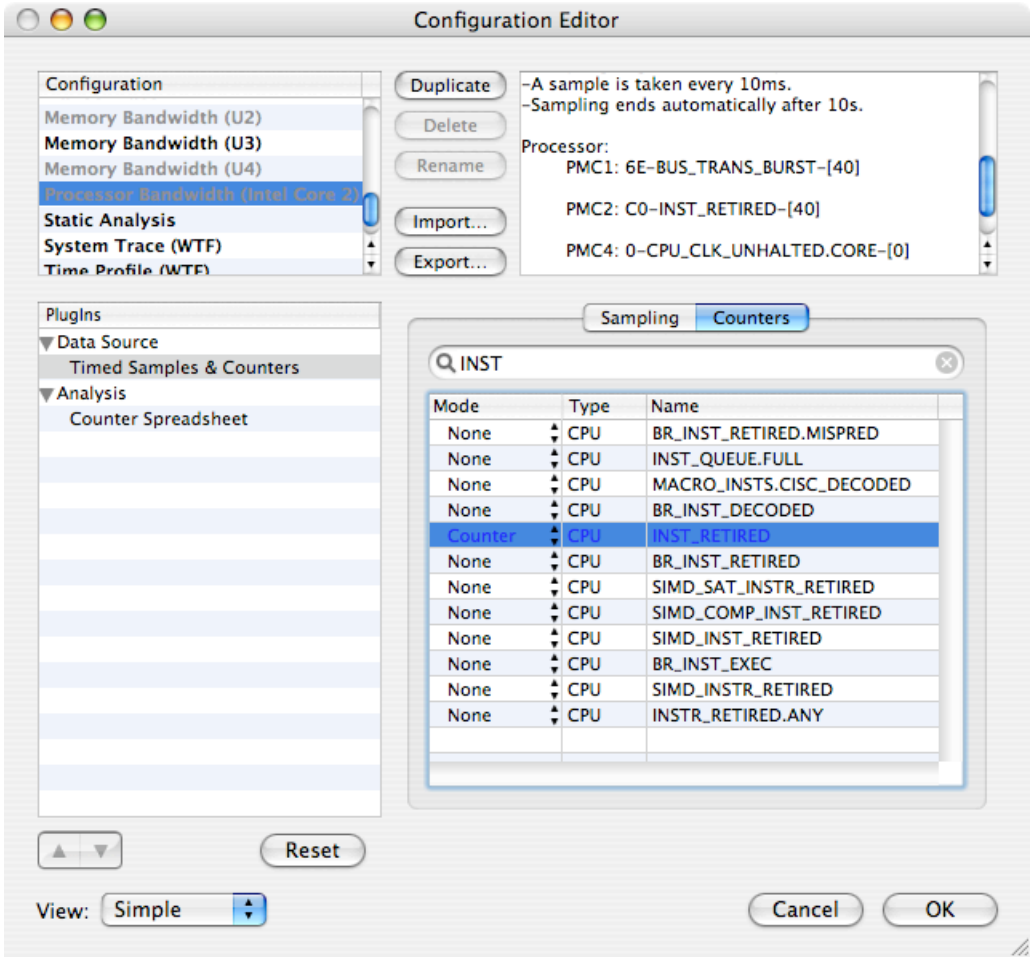
Click the *Duplicate button*. Change the name of the new configuration to be "Core CPI (Intel Core 2)."

Make sure that "Simple" is selected in the *View popup*. Now click the *Counters* tab in the *Config Editor* window. Add the following two performance counter events to the profile config:

1. Find the entry in the performance counter event list that reads "CPU_CLK_UNHALTED.CORE." Select "Counter" in the *Mode column*. The event name will change color (blue) to indicate that the selected event is to be used as a counter.

2. Next search the list by typing "INST" into the search field, as is shown in Figure 7-13. Select the "INST_RETIRED" entry and change the mode to "Counter" as with the first event.

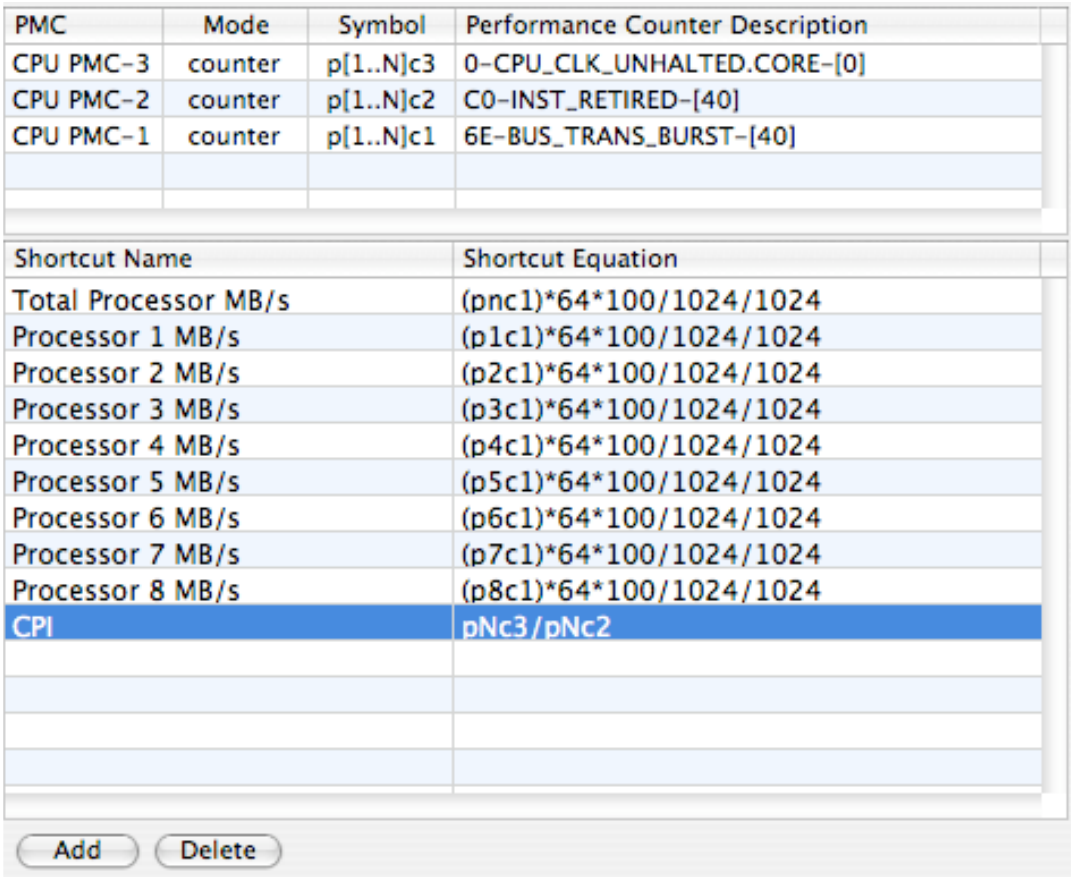
Figure 7-13 Enabling two performance counters



Click on the *Counter Spreadsheet* line in the list of PlugIns to see the *Performance Counter Spreadsheet*. You will see the editor described previously in "Using the Editor" (page 183). To add a new equation to the Shortcut Equation table click the *Add button*. Enter a shortcut name (e.g. "CPI" – this equation will compute the average number of CPU cycles per instruction for each sample).

Next, enter the equation `pNc3/pNc2`, as is shown in Figure 7-14. This will automatically calculate the number of cycles per completed instruction, or CPI, and allow you to display it alongside the "raw" counts of CPU cycles, instructions completed, and the bus bandwidths already calculated by the original "Processor Bandwidth" configuration.

Figure 7-14 Performance Spreadsheet: Shortcut Equation



Hardware Counter Configuration

The different CPUs and North bridge chipsets available in Macintosh systems have widely varying performance monitoring capabilities. Because there are such a wide variety of counters and ways in which they can be combined to get useful information, the default configurations supplied with each version of Shark can only scratch the surface of the immense variety of possible configurations. As a result, this is one of the main areas where building custom Shark configurations can be helpful — but for the same reason it is also one of the most complex aspects of Shark configuration.

Above and beyond its basic, system-wide sampling functionality, Shark's main "Timed Samples and Counters" data source offers access to this rich selection of performance counters. Its basic sampling configuration options were already covered briefly in "Simple Timed Samples and Counters Config Editor" (page 174). However, there are many more options available in *Advanced* mode of the configuration editor (see "The Config Editor" (page 171) for how to get here), where multiple separate tabs provide access to *all* of the settings that the PlugIn has. Depending upon factors such as the underlying hardware capabilities, the number of tabs can vary. In general, Shark will present the advanced **Sampling** tab, one to four processor and/or North bridge tab(s), and the **MacOS** performance counter tab. The "processor" tab(s) allow configuration of processor performance counters, and are titled with the make and model of the processor. For most processors, all counter configuration fits in a single tab, but in the case of the PowerPC 970 CPU there are so many settings that a second **IMC** tab is also added. Finally, if the North bridge chipset in the system has hardware performance counters, then there will be one or two tab(s) titled with the model of the chipset.

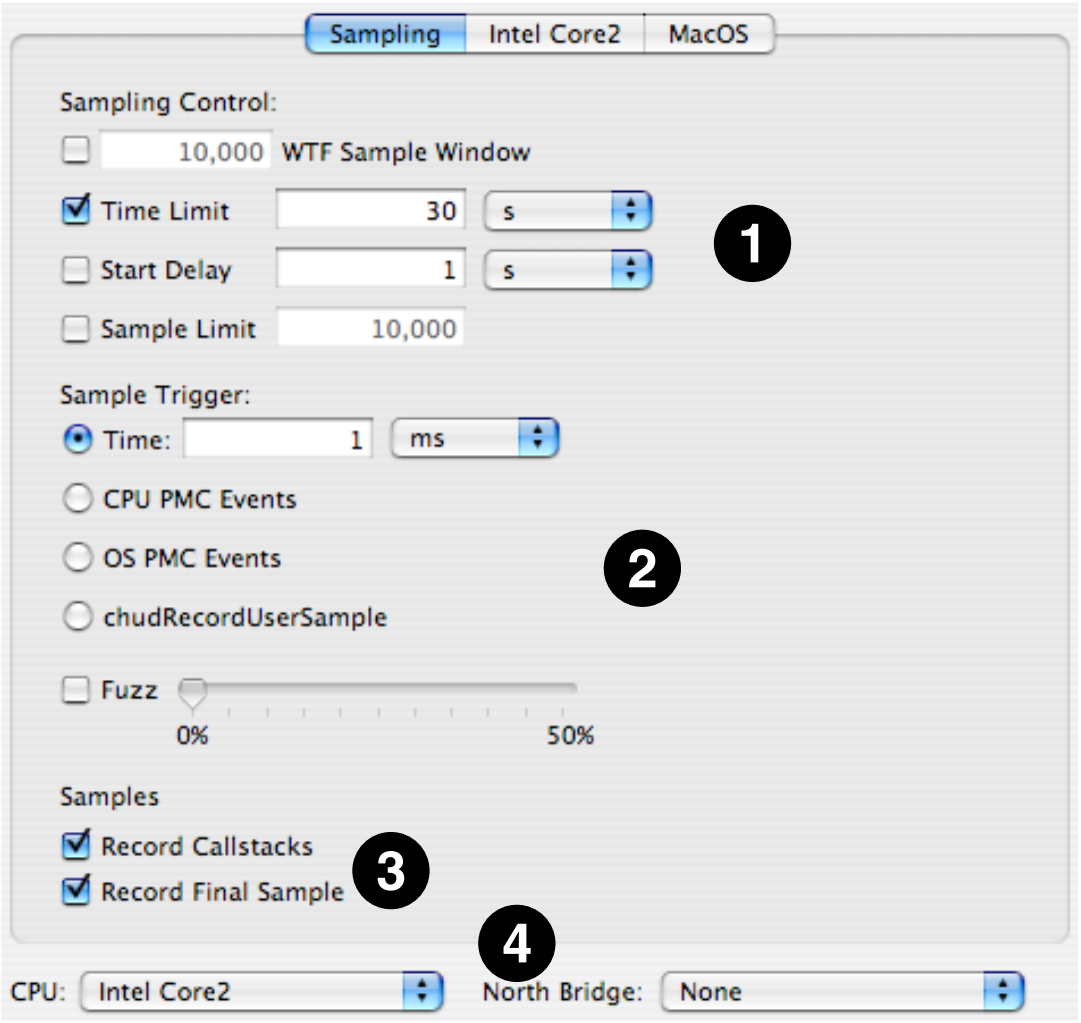
This chapter describes how you can configure the wide variety of hardware counters using the customized controls available in these configuration editor panes. It will start by describing the advanced data source PlugIn settings available on the most modern Macs and work through describing the PlugIn tabs supporting the older systems' CPUs and North bridge performance monitor counters (PMCs), in detail.

Configuring the Sampling Technique: The Sampling Tab

The *Sampling* tab is always the **first** tab presented when one chooses to edit the "Timed Samples and Counters" data source in "Advanced" mode. This tab controls how to start and stop sampling, and when samples are taken. The remainder of this section discusses the various features of the tab.

Once you have decided which counters you want to measure, and thought a bit about how you might want to control sampling, there are several configuration steps that must be performed using the controls on the *Sampling* tab, illustrated in Figure 8-1.

Figure 8-1 Timed Samples & Counters Data Source - Advanced Sampling Tab



1. **Sampling Control**— First, you must choose ways to start and stop sampling using the options at the top of the configuration controls. These options are essentially identical to the basic options used to control "Timed Samples and Counters."

    - *WTF Mode*— If enabled, Shark will collect samples until you explicitly stop it. However, it will only store the last N samples, where N is the number entered into the sample history field (10,000 by default). This mode is also described in "Windowed Time Facility (WTF)" (page 118).
    - *Time Limit*— The maximum amount of time to record samples. This is ignored if WTF mode is enabled.
    - *Start Delay*— Amount of time to wait after the user selects "Start" before data collection actually begins. This helps prevent Shark from sampling itself.
    - *Sample Limit*— Sets the maximum number of samples to record. Specifying a maximum of *N* samples will result in at most *N* samples being taken on a uniprocessor machine or *C***N* samples taken on a multiprocessor system with *C* processors. This prevents the sample buffers from growing too large in case you happen to choose a combination of a large time limit and high sampling rate.

2. **Sample Trigger**— Next, choose when you want samples to be taken between the "start" and "stop" events using the options in the middle of the configuration controls. There are a variety of ways, one of which is unique to performance monitor work.

   - *Timed Sampling*— The most common way to use counters is to record the values of all counters periodically, when a timer fires. This produces a distribution of events over time, much like a Time Profile. Because the events are counted for the entire time between sample points, and not just *at* the sample points, they are only approximately correlated with the program counter information sampled by Shark.
   - *Event-Triggered Sampling*— An alternative is to let performance events trigger sampling themselves. As a result, this is only possible when performance monitoring counters are used. One counter at a time can be set to a special *Trigger* mode which initiates sampling when the event count reaches a preset *Sample Interval*. If the event occurs frequently, many samples will be taken, while if it occurs infrequently then only a few samples will be taken. There are pros and cons to this mode. First, you can only trigger on one event type at a time. However, each sample point will be taken *immediately* after the event occurs, so you can accurately determine which lines of code from your program are causing the events. Hence, this mode is most helpful when you are trying to determine which code is triggering a particular event.
   - *Programmatic Sampling*— A third alternative is to let your program determine when to take a sample. Your program can link to the CHUD framework and call chudRecordUserSample, which will force a performance counter sample to be taken. In this way, you will be able to see events at a rate that is precisely controlled by you. This is useful when you want to examine issues such as how your program's behavior varies over time, from one loop iteration to another.

   Once you have chosen a technique for controlling the sampling, just check the appropriate box in this section of the tab and fill out any necessary parameters.

   - *Time*— A sample is taken every *T* time units (1 millisecond, by default). This is the same control used ot vary the sampling frequency of a standard time profile.
   - *CPU PMC Events*— A sample is taken every *N* CPU PMC events from the selected CPU PMC. Only one trigger PMC can be selected at a time. In a multi-processor system, any CPU can trigger the collection for all CPUs.
   - *OS PMC Events*— A sample is taken every *N* OS performance monitor counter (PMC) events from a selected OS PMC. Only one trigger PMC can be selected at a time.
   - *chudRecordUserSample*— A sample is recorded for every call to the `CHUD.frameworkchudRecordUserSample()` function. This is analogous to using signposts ("Sign Posts " (page 80)) with system trace.

   Finally, once you have chosen a sampling mode, there is one additional variation that can be applied to the nominal sampling rate. The **Fuzz** feature, when enabled, randomizes the sampling interval by ±N% around the specified nominal value. For example, if timer sampling is selected, the sampling period is 1ms and *Fuzz* is set to 5%, the actual sampling period will vary randomly between 0.95ms and 1.05ms. *Fuzz* helps prevent harmonic relationships between the sampling interval and execution behavior. You should use this if your code performs the same work repeatedly, with very little variation in its patterns.

3. **Samples**—Down at the bottom of the tab are a couple of "miscellaneous" options.

   - *Record Callstacks*— When enabled, Shark will collect the function backtrace along with the program counter value for each sample. This is used by default, but can be disabled if you need to record an extremely large number of samples into Shark's kernel buffers or if the callstack recording is impacting performance (a possibility if sample rates are very high).

- *Record Final Sample*— By default, when sampling is stopped all collection is terminated *immediately*. In a multiprocessor system, this can cause the last sample from some processors to be dropped if they are a little bit behind the "main" processor and therefore have not quite completed a time interval or reached an interrupt state when Shark is stopped. This setting will force collection of the last sample from all processors, even if it is not a "full" sample.

4. **Device Selection**— Finally, below the tab itself are menus that let you choose a device to target. While this will often simply be the processor and/or North bridge on your own machine, Shark also allows you to choose other processors that aren't even installed on your machine. This latter option is quite useful if you are making measurements of a different machine over a network "Network/iPhone Profiling" (page 128).

   - *CPU PopUp Menu*— This selects the processor type to configure. By default, the CPU in the running system is selected. If *any* CPU performance counters are enabled (in either Counter or Trigger mode, as described in "Counter Control" (page 192)), then the configuration will only be compatible with machines that have the specified CPU.
   - *North Bridge PopUp Menu*— This selects the memory controller type to configure. By default, the North bridge in the running system is selected, or "none" if no North bridge counters are available in the system. If *any* memory controller performance counters are enabled (in Counter mode, as described in "Counter Control" (page 192)), then the configuration will only be compatible with machines that have the specified memory controller. Please note that currently there are no supported North bridge performance counters in Intel-based Macs.

   Changing either of these settings will not have a visible effect on the "Sampling" tab. However, both will change the contents of the relevant hardware tab(s), the name of those tab(s) will update immediately, and the controls for setting up events will change if one of the hardware tabs is visible.

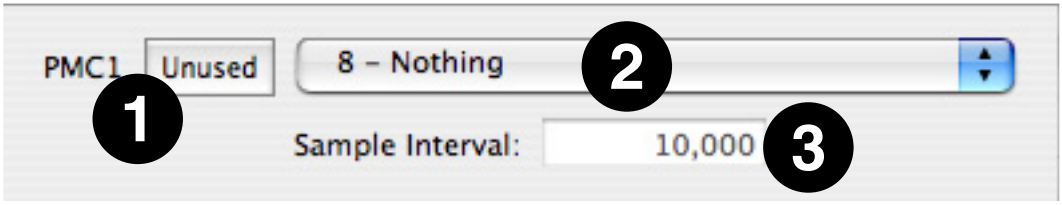
Common Elements in Performance Counter Configuration Tabs

All of the various performance counter configuration tabs have many unique elements, as the various processors and North bridges supported by MacOS X are significantly different from each other in many ways. However, Shark uses several common interfaces throughout these various tabs in order to make it reasonably easy for you to work with more than one variety of Macintosh. To avoid repeating these descriptions for every tab, they are discussed here.

Counter Control

Every performance counter is controlled with a consistent set of three controls, like those illustrated below in Figure 8-2. This section describes how they work, for any variety of hardware.

Figure 8-2 A typical set of performance counter controls



There are three controls associated with every performance counter

1. **Enable Button**— This button turns the counter on and off. If it is on, then it further controls whether the counter is used as the event trigger source or not. As a result, every time it is pressed it will toggle among three different states:
   - *Unused*— The counter will not count, and is ignored by Shark.
   - *Counter*— The counter counts the event selected using the *Event List* menu. Its contents will be recorded every time that Shark takes a sample.
   - *Trigger*— The counter is enabled as the sampling trigger. Whenever it has counted the number of events listed in the *Sample Interval* box, it will cause Shark to record another sample. Only one counter at a time can be in this mode; you must switch any previous counter to use one of the other two modes before it is possible to select this mode with a second counter. Also, note that this mode is not available on the counters in all types of Macintosh hardware (particularly older processors and North bridges).

2. **Event List**— This list displays the names of all events that can be counted by this counter. It may also include some "reserved" event types that can be chosen, but are not actually implemented on the hardware in any useful way. For most types of hardware, these lists are constant. However, in the case of the PowerPC 970, the event lists can change depending upon the settings of the other controls in the tab. See "PPC 970 (G5) Performance Counter Event List" (page 263) for more details.

3. **Sample Interval**— This is the number of events that must occur before this PMC will trigger sampling. It is ignored unless this particular counter has been set to *Trigger* mode using the *Enable Button*. If a counter cannot support *Trigger* mode, then this box will not be present.

Privilege Level Filtering

With the various performance counters, it is often possible to filter events such that only events from user-level code or only events from privileged (supervisor mode) are counted. Shark disables this option if it is not applicable to the currently selected sampling trigger.

- **Any** — Record all performance counter events of this type.
- **User**— Record performance counter events of this type only when running user-level code.
- **Supervisor**— Record performance counter events of this type only when running supervisor-level code in the OS kernel.

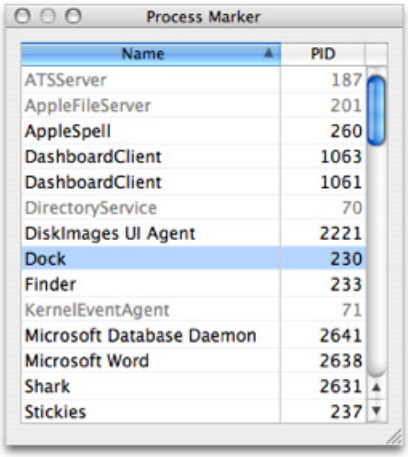
Process Marking

With the various performance counters, Shark can filter events such that only events from a user-defined selection of "marked" processes are actually counted. In this way, you could limit counting to events from your own application's process, for example, while ignoring all others. Alternatively, a user may choose to record events from all "unmarked" processes. This is a good choice when you want to tell Shark to ignore a few processes — probably background ones like daemons or the Finder — while recording events from everything else.

- **Any**— Record all events, no matter when they occur
- **Marked**— Record only events that occur in "marked" processes or threads that you have selected.
- **Unmarked**— Record only events that occur in "unmarked" processes or threads.

You can mark processes with Shark's *Process Marker* (Figure 8-3). The *Process Marker* can be opened via the *Sampling*▯*Mark Process* menu item. Shark disables this menu item for timer sampling, because the marked bit is ignored in that case.

Figure 8-3 Process Marker



It is also possible to enable thread marking programmatically, using the `chudMarkPID(pid_t pid, int markflag)` call (in the CHUD framework) to set the marked flag to a value of TRUE (`markflag` = 1) or FALSE (`markflag` = 0) for any arbitrary process.

While this mechanism is powerful, it does have some limitations imposed on it by how the OS internally tracks the "marked" state of each thread. New threads created by a process *after* you have marked it will not be marked; you will need to mark the process again to make sure all of the newly created threads are marked. In addition, the marked bit is not copied to supervisor space during system calls or other supervisor state code done on behalf of the marked process, so if you choose to record "marked" events only you will only see events triggered by your user-level code.

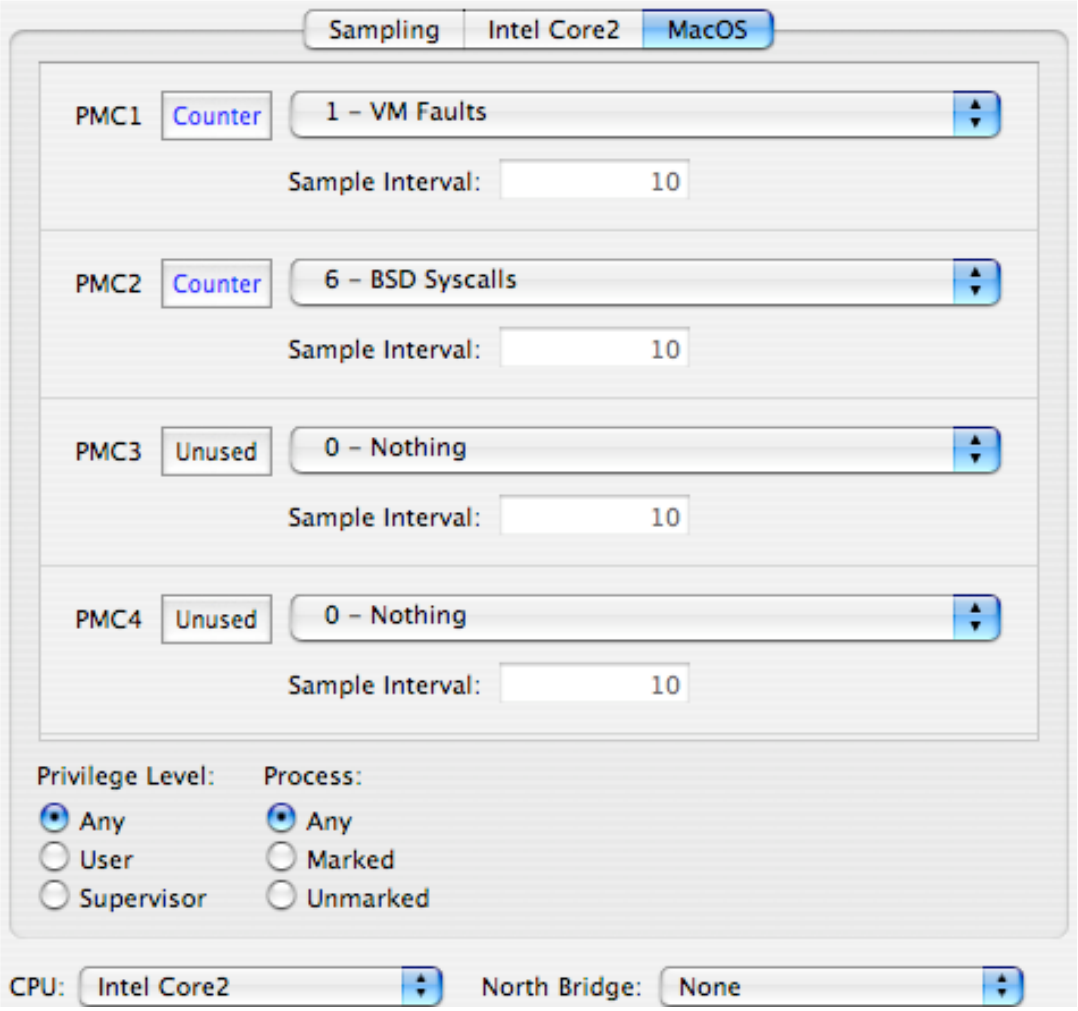
MacOS X OS-Level Counters Configuration

This tab, illustrated in Figure 8-4, is always the rightmost tab in the editor. It provides access to a variety of counters for operating system events, such as page faults. These OS counters support trigger mode, privilege level filtering, and marked thread filtering on all Macintosh platforms. However, all OS performance counters must share the same settings for privilege level and marked thread filtering. The events counted by the operating system's counters can be divided into the following categories:

- **Virtual Memory:** Events such as page faults, zero fill faults, copy-on-write faults, and page cache hits
- **System Calls:** Transfers into the kernel requested by user code, divided up into BSD and Mach syscalls
- **Scheduler Events:** Events such as context switches, "thread ready" events, and stack handoffs
- **Disk I/O Events:** Disk reads and writes, with optional breakdown by type (data, disk control metadata, VM page-in, and VM page-out) and timing (synchronous and asynchronous)

No unique controls are needed to control these counters; for information on all of the controls, see "Counter Control" (page 192).

Figure 8-4 MacOS X Performance Counters Configuration



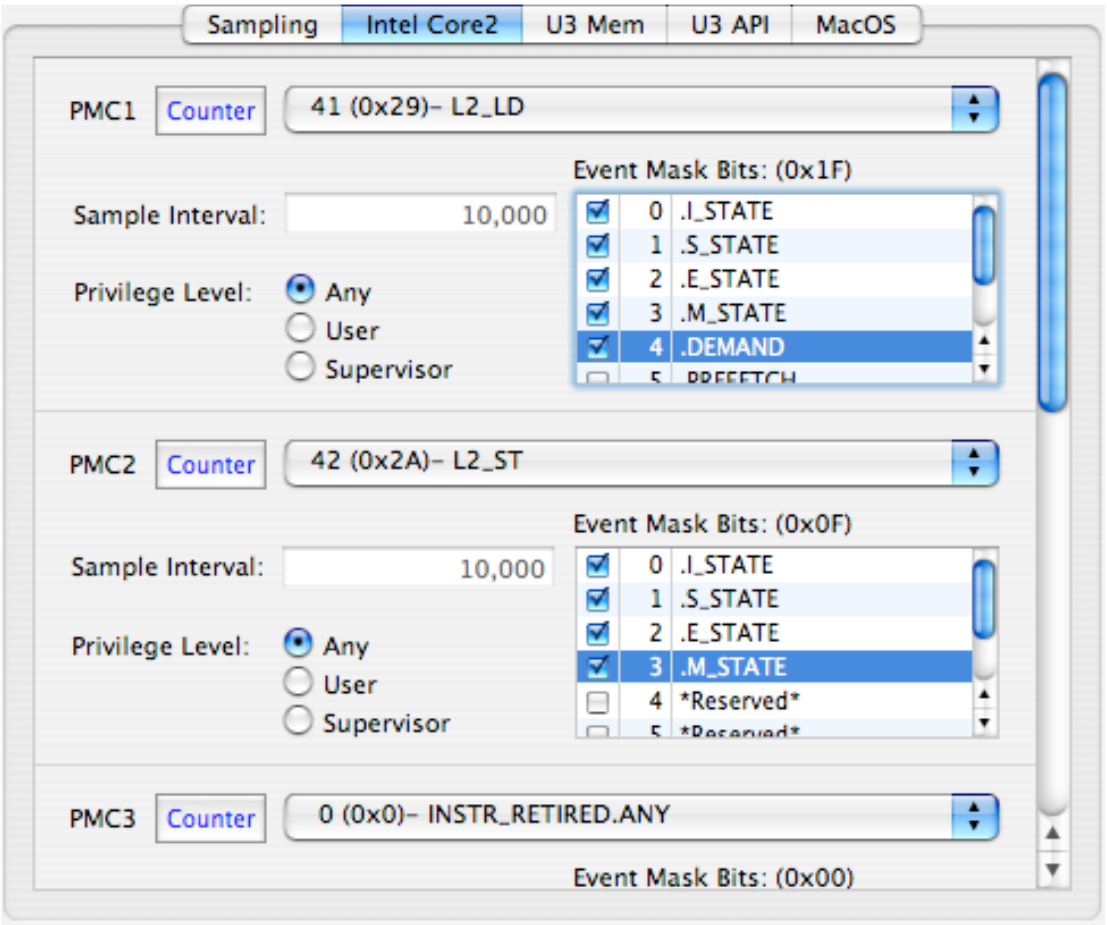
Intel CPU Performance Counter Configuration

This section describes how you can make custom configurations for Macs equipped with Intel processors. Macs equipped with Intel Core processors have access to two fully programmable performance counters, and Macs equipped with Intel Core 2 processors have an additional three fixed-purpose counters. The two families can both count a similar but not identical list of events on the programmable processors. Full event listings are provided in "Intel Core Performance Counter Event List" (page 229) and "Intel Core 2 Performance Counter Event List" (page 235) for the Core and Core 2, respectively.

Figure 8-5 shows the single configuration tab for the Intel Core 2 processor (the one for the Core is virtually identical, but lacks PMCs 3–5). For the most part, it uses the standard controls from "Counter Control" (page 192). A nice feature of these cores is that control over user/supervisor event counting selection is provided *independently* for each counter on these cores. On the other hand, "marked" threads and processes cannot be used.

One unique control is necessary with these cores: the **Event Mask Bits** control. This control, which is used more extensively in the Core 2 than in the Core processor, acts to fine-tune the type of events counted. For example, instead of just counting all line fetches from the L2 cache, you can use these bits to only count line fetches of lines in particular states (such as "exclusive," or only in this L2 cache). The selection of bits available and their behavior varies depending upon the type of event being counted. The description of the effect that mask bits will have on the event counting is described in a tooltip both on the event name, as you are choosing among the various event types, and also in a tooltip that appears if you wave your mouse cursor over each of the bit-names in the mask list. Any bit in the list labeled *Reserved* should not be enabled. A brief summary of which bits are active for any particular event is included in the event lists in "Intel Core Performance Counter Event List" (page 229) and "Intel Core 2 Performance Counter Event List" (page 235).

Figure 8-5 Intel Core 2 Configuration Tab



PowerPC G3/G4/G4+ CPU Performance Counter Configuration

This section describes how you can make custom configurations for Macs equipped with PowerPC G3, G4, and G4+ processors. Macs equipped with these processors have access to four (G3, G4) or six (G4+) fully programmable performance counters. The list of available events varies significantly from processor to processor, since many new event types were added with each generation of PowerPC chips. Full event listings

are provided in "PPC 750 (G3) Performance Counter Event List" (page 245), "PPC 7400 (G4) Performance Counter Event List" (page 247), and "PPC 7450 (G4+) Performance Counter Event List" (page 253) for the G3, G4, and G4+ processor cores, respectively.

Figure 8-6 shows the single configuration tab for the G4+ processor (the one for the G3 and G4 is virtually identical, but lacks PMCs 5–6). For the most part, it uses the standard controls from "Counter Control" (page 192). Both user/supervisor event counting selection and "marked" threads and processes can be used, but all counters must use the same settings at once.

Three relatively minor additional controls are provided with all of these cores, to adjust features specific to these processors. The three controls are numbered on Figure 8-6, and are:

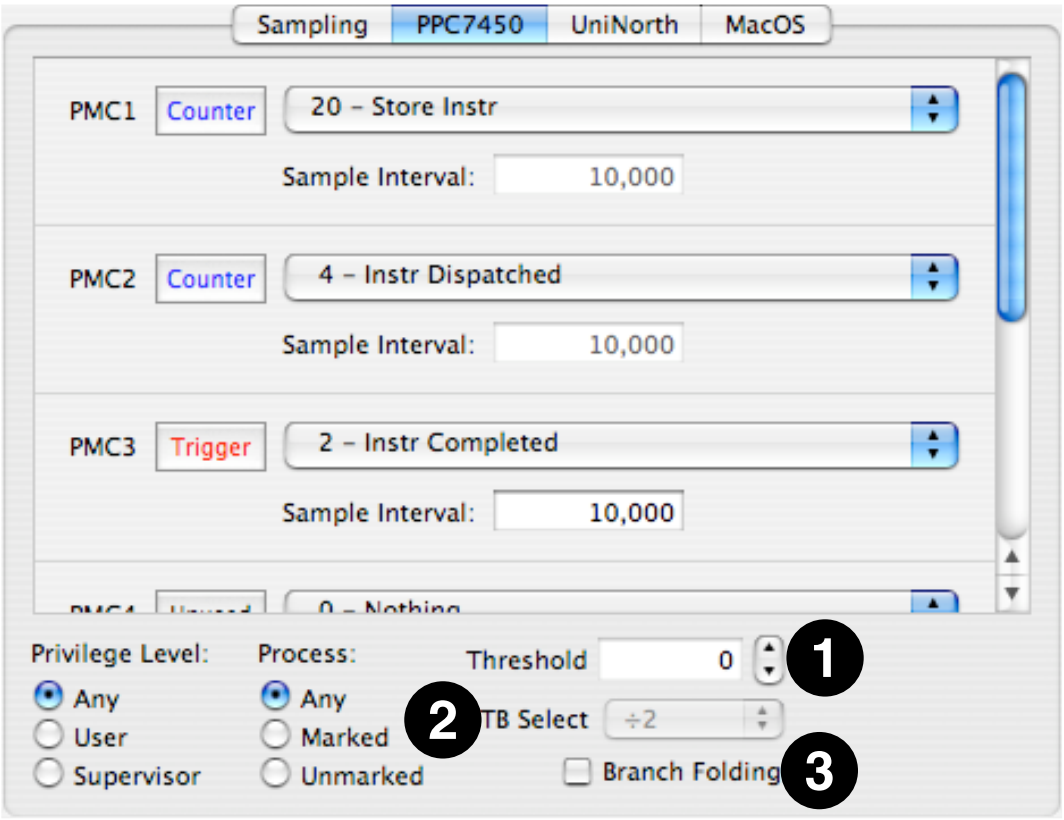
1. **Threshold:** This sets a lower limit on the number of processor cycles that a wide variety of stall events must take before they are actually recorded, in case you want to filter out short stalls and thereby focus in only on the most lengthy and problematic stalls.

2. **TB Select:** This is the divider used for timebase events that cause processor exceptions, and selects from four different division ratios.

3. **Branch Folding:** PowerPC G3 and G4 CPUs have a feature that allows them to coalesce multiple branch instructions into one instruction, instead of issuing multiple branch instructions. When this feature is enabled (the default) performance events counting branch instructions and predictions can be inaccurate. Hence, for best results when counting performance events dealing with branch instructions, you should usually disable this feature. See your processor's User Manual for more details.

   *Warning:*If you leave branch folding disabled and exit Shark, branch folding will *remain* disabled. While this will not cause any correctness problems or crashes, it can adversely affect performance.

Figure 8-6 PowerPC G4+ Configuration Tab (G3 and G4 are similar)



PowerPC G5 (970) Performance Counter Configuration

This section describes how you can make custom configurations for Macs equipped with PowerPC G5 (970) processors. Macs equipped with these processors have access to eight fully programmable performance counters that can count an incredible number of different performance events, as listed in "PPC 970 (G5) Performance Counter Event List" (page 263). Because there are so many different types of events, the G5 uses a unique system of multiplexers to pre-filter many types of events before they reach the event counters. Depending upon the settings supplied for these various multiplexers, it is possible to enable vastly different selections of events in the performance counter event menus.

Figure 8-7 shows the first of two configuration tabs used by the G5 processor's configuration control. The top half and lower left corner just use standard controls from "Counter Control" (page 192). Both user/supervisor event counting selection and "marked" threads and processes can be used, but all counters must use the same settings at once.

In addition, several additional controls are provided. Most are multiplexer controls to switch the various event pre-filtering multiplexers, but the last two adjust features specific to these processors. These controls are numbered on Figure 8-7, and are:

1. **TTM0 Event Selector:** This first-stage mux selects collections of events from different processor functional units for all four second-stage muxes (FPU = floating point unit, ISU = instruction sequencer unit, IFU = instruction fetch unit, and VMX = Altivec processing unit).

2. **TTM1 Event Selector:** This first-stage mux selects collections of events from different processor functional units for all four second-stage muxes (IDU = instruction dispatch unit, ISU = instruction sequencer unit, and GPS = storage subsystem).

3. **TTM3 Event Selector:** This stage 1 mux selects collections of events from load/store unit #1 (LSU1), in four different patterns for second-stage muxes 2 and 3 only (2/3 = lane 2 & 3 both "upper" LSU1 events, 2/7 = lane 2 "upper" & 3 "lower" LSU1 events, 6/3 = lane 2 "lower" & 3 "upper" LSU1 events, 6/7 = lane 2 & 3 both "lower" LSU1 events).

4. **Even Lane Event Selectors:** These two second-stage muxes select inputs for performance counters 1, 2, 5, and 6 from among the different first-stage muxes or directly from the load/store units (LSU0/LSU1).

5. **Odd Lane Event Selectors:** These two second-stage muxes select inputs for performance counters 3, 4, 7, and 8 from among the different first-stage muxes or directly from the load/store units (LSU0/LSU1).

6. **Speculative Event Selector:** This enables speculative event recording and performance counters 5 and/or 7. A full discussion of these counts is beyond the scope of this document. See the PowerPC 970 Documentation for more information.

7. **Threshold:** This sets a lower limit on the number of processor cycles that a wide variety of stall events must take before they are actually recorded, in case you want to filter out short stalls and thereby focus in only on the most lengthy and problematic stalls.

8. **TB Select:** This is the divider used for timebase events that cause processor exceptions, and selects from four different division ratios. More information is available in the PowerPC 970 Documentation.

Figure 8-7 PowerPC 970 Processor Performance Counters Configuration

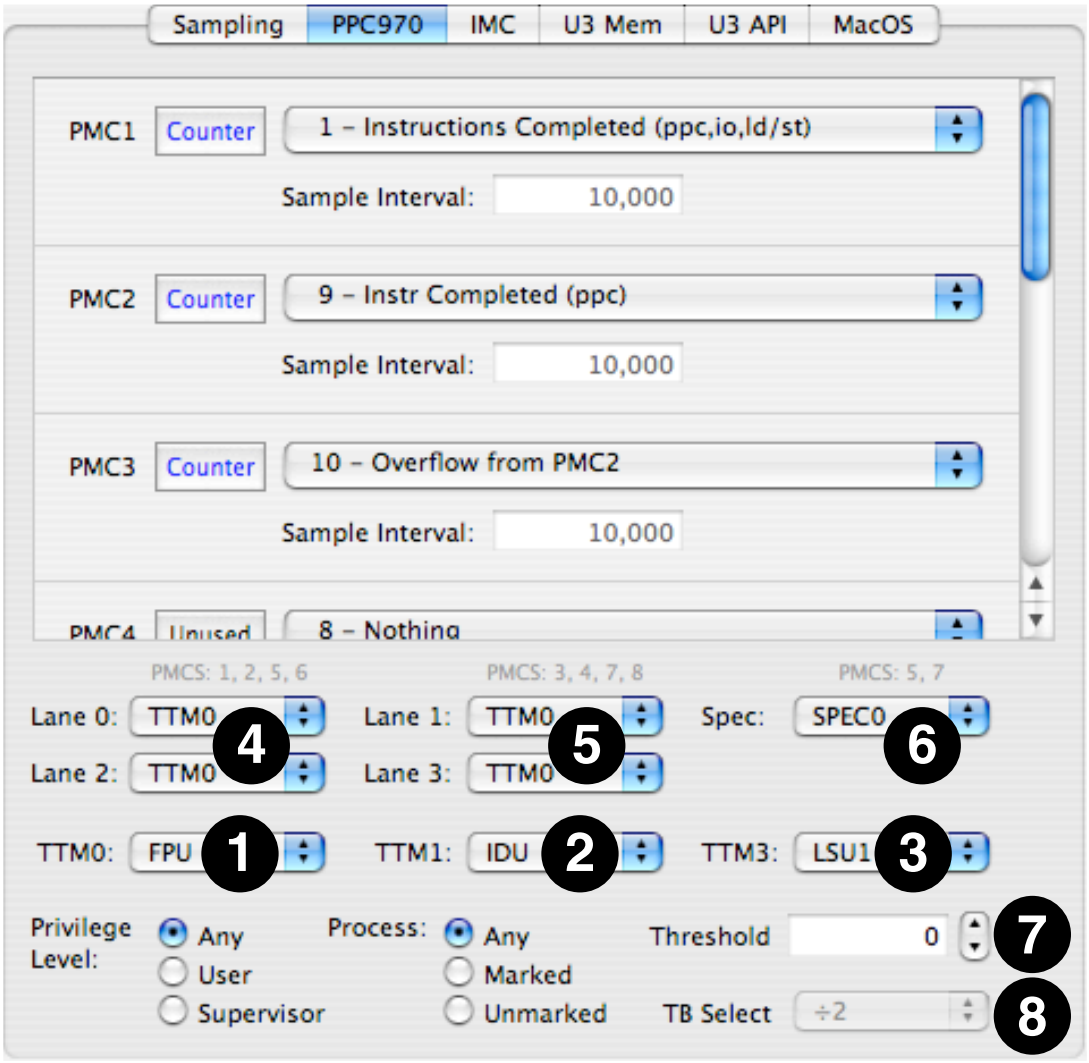


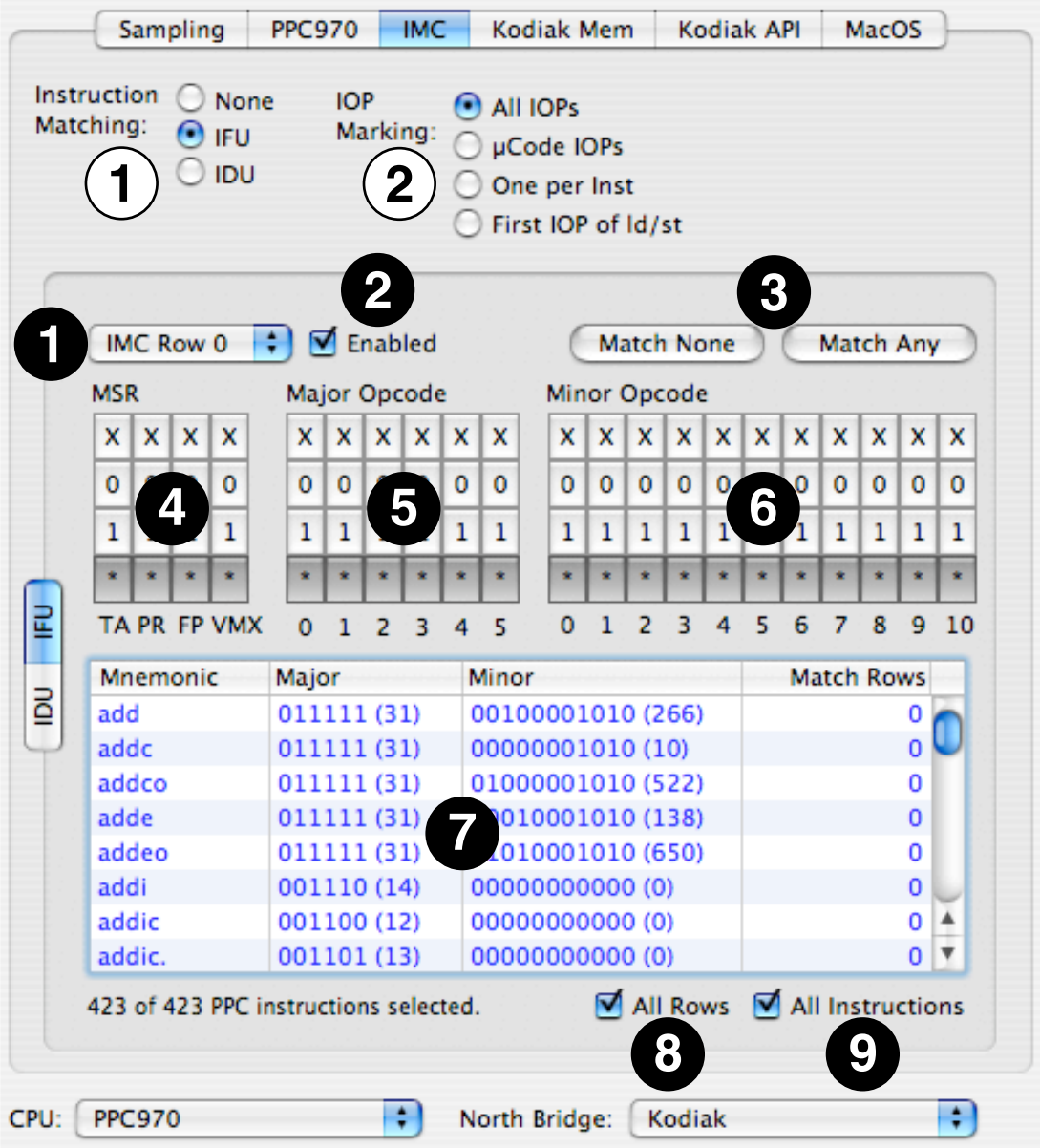
Figure 8-8 shows the second tab used to configure the PowerPC 970 performance counters, the **IMC** tab. This tab provides access to the Instruction Fetch Unit's instruction marking and the Instruction Dispatch Unit's instruction sampling feature, a pair of mechanisms that allow you to count individual instruction types as they are executed on the PowerPC 970.

The IFU instruction matching facility provides a CAM array to match PowerPC instructions by opcode or extended opcode as they are fetched. When a PowerPC instruction is fetched from memory, the IFU instruction matching facility compares the instruction with the opcode/extended opcode mask values in each of its CAM array rows. If a PowerPC instruction matches one or more IMC array row masks, you may have it "mark" the instruction in the L1 instruction cache. Thereafter, every time it is executed special performance counter events may occur to count it. Please note that as long as an instruction resides in the L1 instruction cache, its match bit will remain unchanged. Hence, if the match condition for an instruction changes, then the L1 instruction cache should be flushed to force the lines to be reloaded and the "match" bits to be recalculated.

Another level of instruction matching — performed in the IDU — allows you to mark instructions (or their constituent microinstructions, for the more complex PowerPC instructions) on the basis of some categories related to how they interact with the PowerPC 970 pipeline, such as whether or not they are internally broken up into microcode. Because this comes later in the processor's pipeline, it is possible that it can override previous IFU marking.

Due to the very flexible and complex nature of these mechanisms, it is highly recommended that you read the pertinent sections of the PowerPC 970 Documentation, Sections 10.9 and 10.10 in the main user's manual.

Figure 8-8 PowerPC 970 IMC (IFU) Configuration Tab



In the top part of the IMC pane are some general controls (black numbers on white):

1. **Instruction Matching**— This selects the type of instruction matching to setup and use.

- *None* – (default) No instruction matching will take place
- *IFU* – Use the Instruction Fetch Unit's IMC capability.
- *IDU* – Use the Instruction Dispatch Unit's sampling capability.

2. **IOP Marking** – This pre-filter will limit the type of internal PowerPC microinstructions (IOPs) that are matched or sampled.

    - *All IOPs* – (default) Any IOP will pass
    - *µCode IOPs* –Only IOPs resulting from microcode expansion will pass.
    - *One Per Inst* – Only pass one IOP per PowerPC instruction.
    - *1st IOP of ld/st* – Only pass the first IOP to go to an LSU for every PowerPC load/store instruction, a less restrictive form of the previous filter.

Below that, a variety of controls (white numbers on black) operate on either the IFU's instruction matching or IDU's sampling. In Figure 8-8, the IFU instruction matching pane is shown:

1. **IMC Row PopUp**— There are six CAM rows that can be configured to match instructions in the IFU. Use this to select one of the six rows to manage.
2. **IMC Row Enable**— Enable and disable the IMC rows with this check box.
3. **IMC Match None/All Buttons**— Flips the configuration bits to match no PowerPC or all PowerPC instructions with a single button press. If you only want to match a small number of instructions, start with "none" and enable the instructions you want, while if you want to match many then start with "all" and knock off ones you don't need.
4. **MSR Configuration Bits**— Selects instructions to match on the basis of a few large and coarse categorizations about when they may execute (matching specific bits in the machine status register, or MSR). In general, you will want to leave these set to "any" (asterisk), but you may optionally narrow down the possible list by setting these to 0 or 1.

    - *TA* — (Target) Leave this set to "any" (asterisk), since it is ignored in all cases.
    - *PR*— (Privilege) Matches instructions on the basis of their privilege requirements.
        - *0* — Matches only instructions executable in both user and supervisor mode.
        - *1*— Matches only privileged instructions executable in supervisor mode only.
    - *FP*— (Floating Point Unit Availablity) This matches instructions on the basis of whether or not they need and FPU to be present.
        - *0* — Matches only non-FPU instructions.
        - *1*— Matches only FPU instructions..
    - *VMX*— (Vector Unit Availability) This matches instructions on the basis of whether or not they need an Altivec vector unit to be present.
        - *0* — Matches only non-Altivec unit instructions..
        - *1*— Matches only Altivec unit instructions.

5. **Major Opcode Bits**— This allows you to select marked instructions on the basis of their six major opcode bits (bits 0–5 of each PowerPC instruction). There is a column for each bit, and you can individually control matching on the basis of each bit.
   - *X*— (default) Ignore the bit
   - *0*— Only match if this bit is a zero
   - *1*— Only match if this bit is a one
   - ** (any)*— Match any state.

6. **Minor Opcode Bits**— This allows you to select marked instructions on the basis of their eleven minor opcode bits (bits 21–30 of each PowerPC instruction). There is a column for each bit, and you can individually control matching on the basis of each bit. Note that you should only use these for major opcodes 4 (Altivec instructions), 19 (branch unit operations), 31 (integer instructions), 59 (FP instructions), and 63 (FP instructions); these bits are not used as part of the opcode by other types of instructions.
   - *X*— (default) Ignore the bit
   - *0*— Only match if this bit is a zero
   - *1*— Only match if this bit is a one
   - ** (any)*— Match any state.

7. **Instruction Table**— This allows you to see which instructions are actually being matched on the basis of your various settings.
   - *Mnemonic column*— This lists the assembly language mnemonic for an instruction.
   - *Major opcode column*— This shows the actual major opcode for the instruction.
   - *Minor opcode column*— This shows the actual minor opcode for the instruction, or zero for instructions that do not use the minor opcode.
   - *Match Rows column*— This shows which row(s) in the IMC are the cause of any match(es), so you can see which ones need to be turned on or off as a result.

8. **All Rows**— If checked, the *Instruction Table* shows instructions that are matched by any of the IMC rows, all combined together. This is usually the most useful view since it shows all instructions that will be marked. Otherwise, only instructions that match the row currently selected in the *IMC Row PopUp* are displayed.

9. **All Instructions**— If checked, the *Instruction Table* shows non-selected instructions in a grayed-out form. Otherwise, they are completely omitted from the table.

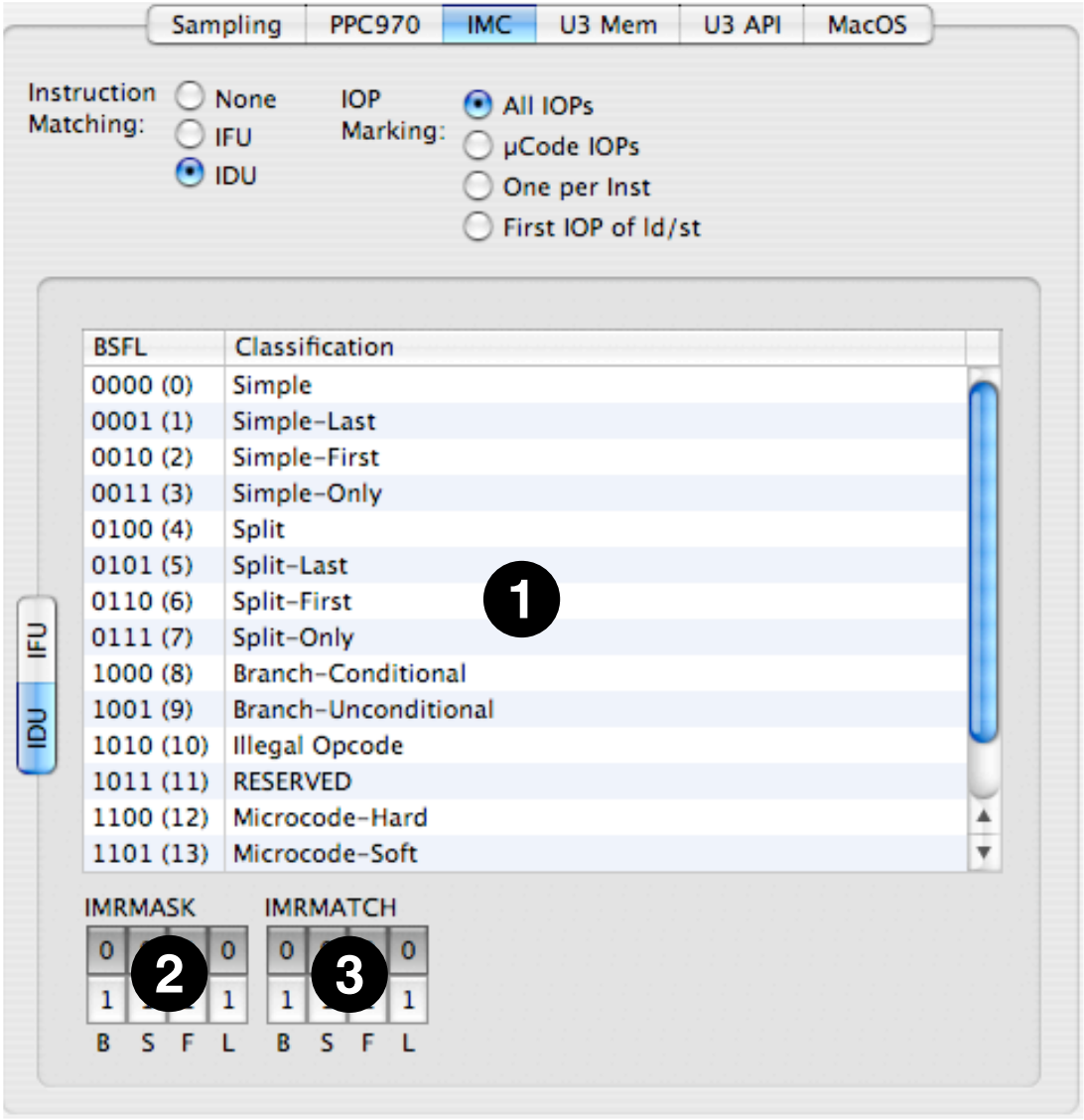
Finally, in Figure 8-9, the IDU instruction filtering pane is shown:

1. **Microinstruction Table**— This allows you to see which classes of instructions are actually being matched on the basis of your various settings.
   - *BSFL column*— This lists the **BSFL** (**B**ranch instruction, instruction that will be **S**plit, **F**irst instruction in a dispatch group, and **L**ast instruction in a dispatch group) bits associated with every instruction in the L1 cache.
   - *Classification column*— This gives the name of every microinstruction class.

2. **IMRMASK bits**— These bits mask off an instruction's *BSFL* bits before matching.
   - *0*— AND this bit position with 0, requiring an IMRMATCH of 0 here.
   - *1*— AND this bit position with 1, enabling full matching with the IMRMATCH bits here.

3. **IMRMATCH bits**— These bits select the value to match for any corresponding IMRMASK bits set to 1.
   - *0*— Match this bit position with 0. Note that this *must* be 0 for any IMRMASK bit positions that equal 0, or no matches will ever occur.
   - *1*— Match this bit position with 1. Normally only desired if the corresponding IMRMASK bit is 1, or if you want to intentionally match nothing.

Figure 8-9 PowerPC 970 IMC (IDU) Configuration Tab



PowerPC North Bridge Counter Configuration

This section describes how you can make custom configurations to examine counters in some of the North Bridge (memory interface) chips of Macs equipped with PowerPC processors, using the "Advanced" configuration interface. Because some of the "useful" options for these counters require fairly complex combinations of settings, we strongly suggest that you start using the "Simple" settings at first, as described in "Simple Timed Samples and Counters Config Editor" (page 174), at least until you learn which combinations of settings are best at producing useful information.

Memory controller counters are available on PowerPC machines with UniNorth v1.5 and later memory controllers. Unfortunately, no equivalent exists for Intel processors. These counters do not support event-triggered interrupts (PMI, or "trigger" mode), privilege level filtering, or marked thread/process filtering. However, on most of the chips they do support filtering on the basis of which interface generated the performance event (see the description of each chipset for details).

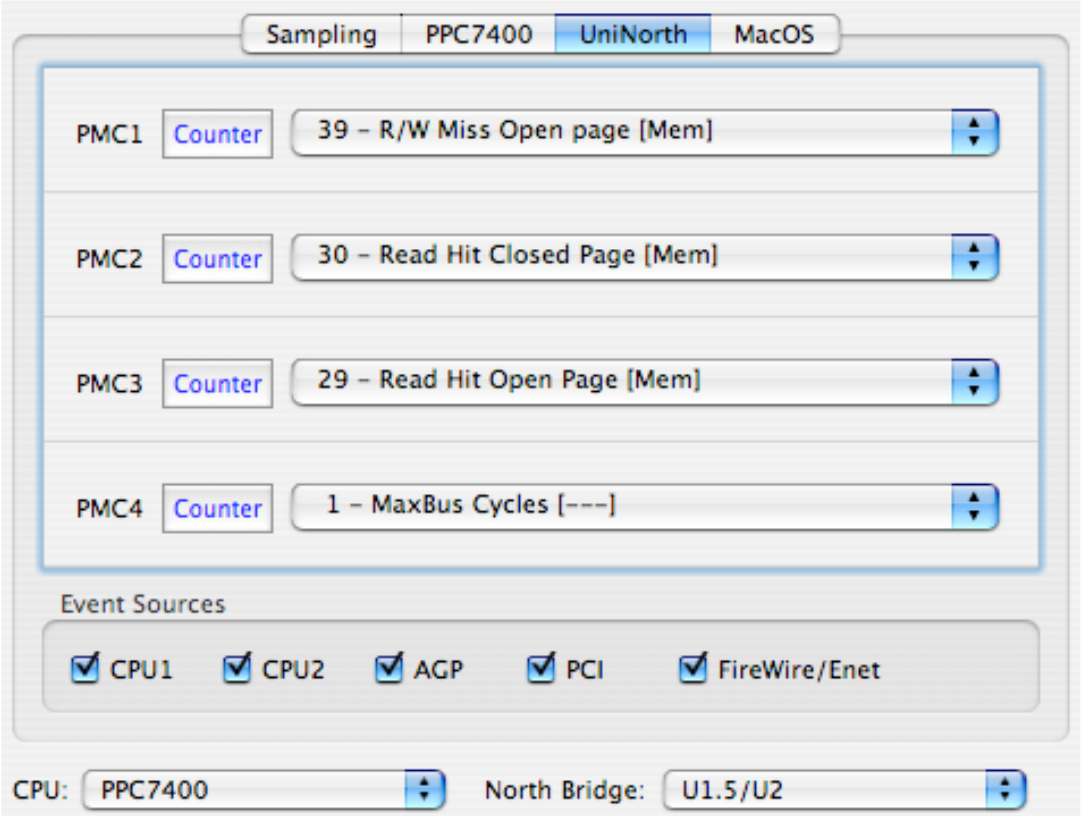
U1.5/U2 North Bridges

This section describes how you can make custom configurations for Macs equipped with the U1.5/U2 North bridge chipset used in some PowerPC G4 Macs. Macs equipped with these North bridge chipsets have access to four fully programmable performance counters that can record various memory system event types, as listed in "UniNorth-2 (U1.5/2) Performance Counter Event List" (page 291).

Figure 8-10 shows the configuration tab for the U1.5/2's configuration control. All controls for each of the PMC are just standard controls from "Counter Control" (page 192), except for the *Event Sources* checkboxes along the bottom. These allow filtering of events based on which North bridge interface is involved. These sources are chosen via checkbox, so you can selectively look at events from all sources or only a specific subset of sources that you choose. You may choose to enable or disable events from any of the following interfaces:

1. *CPU1*—*CPU2*— Processor interface(s)
2. *AGP*— The AGP interface
3. *PCI*— The PCI interface
4. *FireWire/Enet*— The dedicated FireWire and Ethernet I/O ports

Figure 8-10 U1.5/U2 Configuration Tab



U3 North Bridge

This section describes how you can make custom configurations for Macs equipped with the U3 North bridge chipset used in some PowerPC G5 Macs. Macs equipped with these North bridge chipsets have access to two sets of six fully programmable performance counters, on both the memory interface controller and the Apple processor interface (API) controller. These can count a wide variety of different event types, as listed in "UniNorth-3 (U3) Performance Counter Event List" (page 295), and also filter events on the basis of their source interface and type of access.

Figure 8-11 shows the first of two configuration tabs used by the U3's configuration control, the memory interface configuration panel. The first line of each PMC's controls are just standard controls from "Counter Control" (page 192). Below this are four custom controls that may be set independently for each of the different PMCs:

1. **Access PopUp**— This popup menu lets you restrict the event counting to only certain types of memory accesses, either reads or writes.
    a. *None*— Disables the counter.
    b. *Write*— Only store requests to memory can increment the counter.
    c. *Read*— Only load requests from memory can increment the counter.
    d. *Any* — All memory requests cause a counter increment, read or write.

2. **Divider PopUp**— Because U3 PMCs are 32-bit, you may overflow a counter if you are counting high-frequency events or are counting continuously for a long time. You can use this popup to set up a division factor that will slow the rate of incoming events by a fixed power of 2 in order to make it more difficult to overflow the main counter. Choices of every even power of 2 from 1 (no division) to 128 (effectively adds 7 bits to the counter) are available using this menu.

3. **Page State**— U3's events involving DRAM access can be filtered on the basis of the current SDRAM page state for the accessed DIMM. This allows you to monitor the effectiveness of different memory paging policies, such as how long to keep a page open before closing it.

    a. *Open Hit*— DRAM access events are counted if they hit on an open page in the addressed DIMM. This is the most desirable case, and will generate the minimum latency because the data can be returned immediately from the DRAM's page cache.

    b. *Open Miss*— DRAM access events are counted if they miss on a currently open page in the addressed DIMM. This is the least desirable case, because it will generate the maximum latency when the old DRAM page is closed and then the new one is opened before data can be returned.

    c. *Closed*— DRAM access events are counted if the addressed DIMM does not have an open page. This is an intermediate case, because while a new page must be opened before data can be returned, at least we do not have to wait for a previously-accessed page to be closed first.

4. **Source Filter**— Events can be filtered before they reach U3's PMCs on the basis of the interface where they originate. These sources are chosen via checkbox, so you can selectively look at events from all sources or only a specific subset of sources that you choose. You may choose to enable or disable events from any of the following interfaces:

    a. *CPU1—CPU4*— Processor interface(s)

    b. *HT*— The Hypertransport interface

    c. *CV*, *NCV*— Obsolete interfaces, do not use

    d. *PCI*— The PCI interface

    e. *AGP*— The AGP interface

Figure 8-11 U3 Memory Configuration Tab

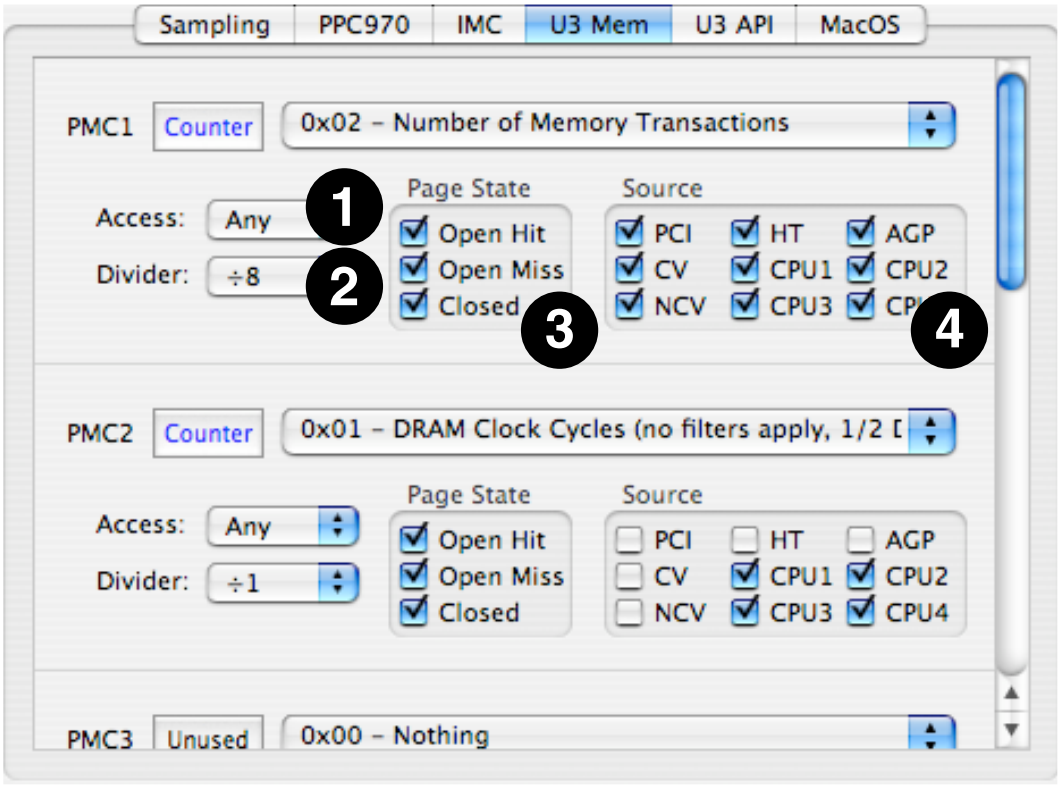
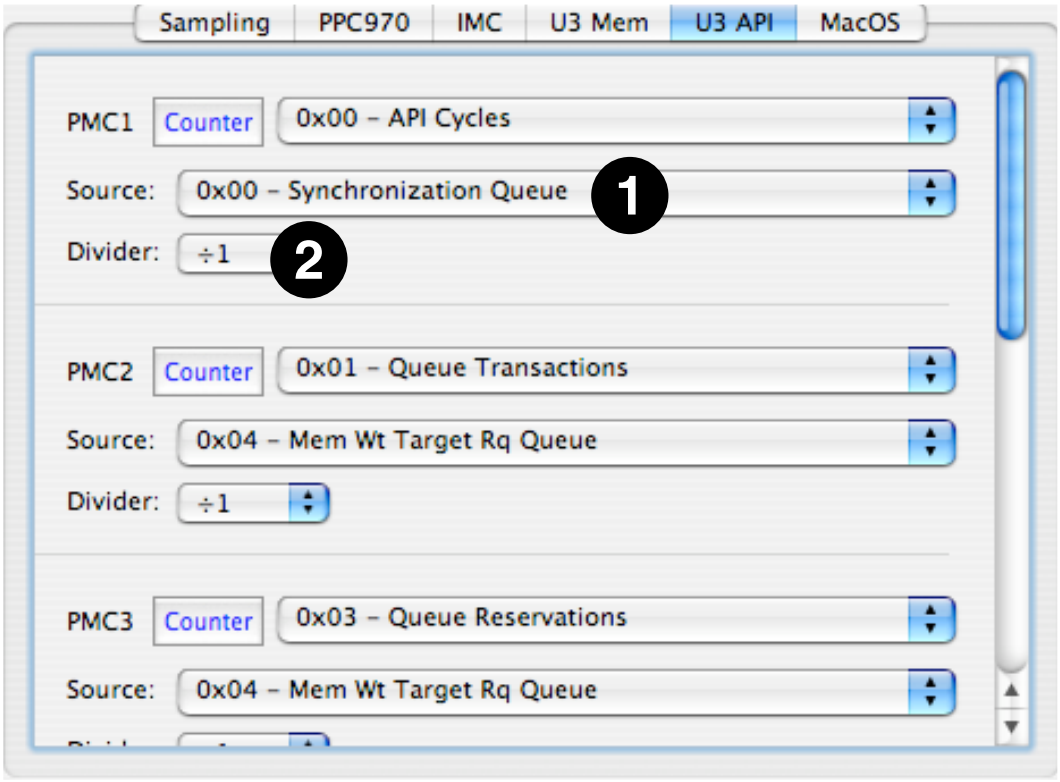


Figure 8-12 shows the second of U3's two configuration tabs, the API configuration panel. As with the memory tab, the first line of each PMC's controls are just standard controls from "Counter Control" (page 192). Below this is a pair of custom controls that may be set independently for each of the different PMCs:

1. **Source PopUp**— The API controller chip has 51 different selectable event sources, mostly different types of request queues within the chip. You must select one of these sources in order to count its events. To count events from multiple sources simultaneously, you will have to use different PMCs for each source. A full list of these sources is listed in "UniNorth-3 (U3) Performance Counter Event List" (page 295).

2. **Divider PopUp**— This is the same as the Divider PopUp on the memory tab.

Figure 8-12 U3 API Configuration Tab



U4 (Kodiak) North Bridge

This section describes how you can make custom configurations for Macs equipped with the U4 (Kodiak) North bridge chipset used in some PowerPC G5 Macs. Macs equipped with these North bridge chipsets have access to two sets of six fully programmable performance counters, on both the memory interface controller and the Apple processor interface (API) controller. These can count a wide variety of different event types, as listed in "Kodiak (U4) Performance Counter Event List" (page 299), and also filter events on the basis of their source interface and type of access.

Figure 8-13 shows the first of two configuration tabs used by the U4's configuration control, the memory interface configuration panel. The first line of each PMC's controls are just standard controls from "Counter Control" (page 192). Below this are three custom controls that may be set independently for each of the different PMCs:

1. **Access PopUp**— This popup menu lets you restrict the event counting to only certain types of memory accesses, either reads or writes.

    a. *None*— Disables the counter.

    b. *Write*— Only store requests to memory can increment the counter.

    c. *Read*— Only load requests from memory can increment the counter.

    d. *Any* — All memory requests cause a counter increment, read or write.

2. **Divider PopUp**— Because Kodiak PMCs are 32-bit, you may overflow a counter if you are counting high-frequency events or are counting continuously for a long time. You can use this popup to set up a division factor that will slow the rate of incoming events by a fixed power of 2 in order to make it more difficult to overflow the main counter. Choices of every even power of 2 from 1 (no division) to 128 (effectively adds 7 bits to the counter) are available using this menu.

3. **Source Filter**— Events can be filtered before they reach Kodiak's PMCs on the basis of the interface where they originate. These sources are chosen via checkbox, so you can selectively look at events from all sources or only a specific subset of sources that you choose. You may choose to enable or disable events from any of the following interfaces:

    a. *CPU1—CPU4*— Processor interface(s)

    b. *HT*— The Hypertransport interface

    c. *CPCIE*— The PCIE interface (for coherent requests)

    d. *NCPCIE*— The PCIE interface (for non-coherent requests)

Figure 8-13 U4 (Kodiak) Memory Configuration Tab

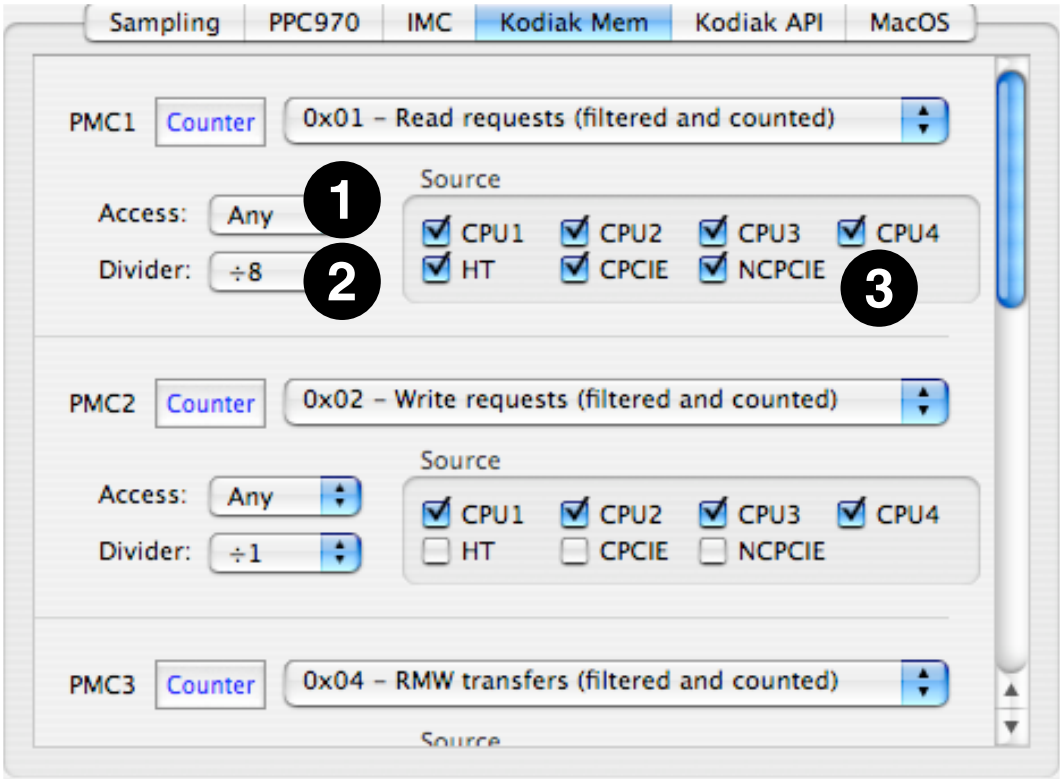
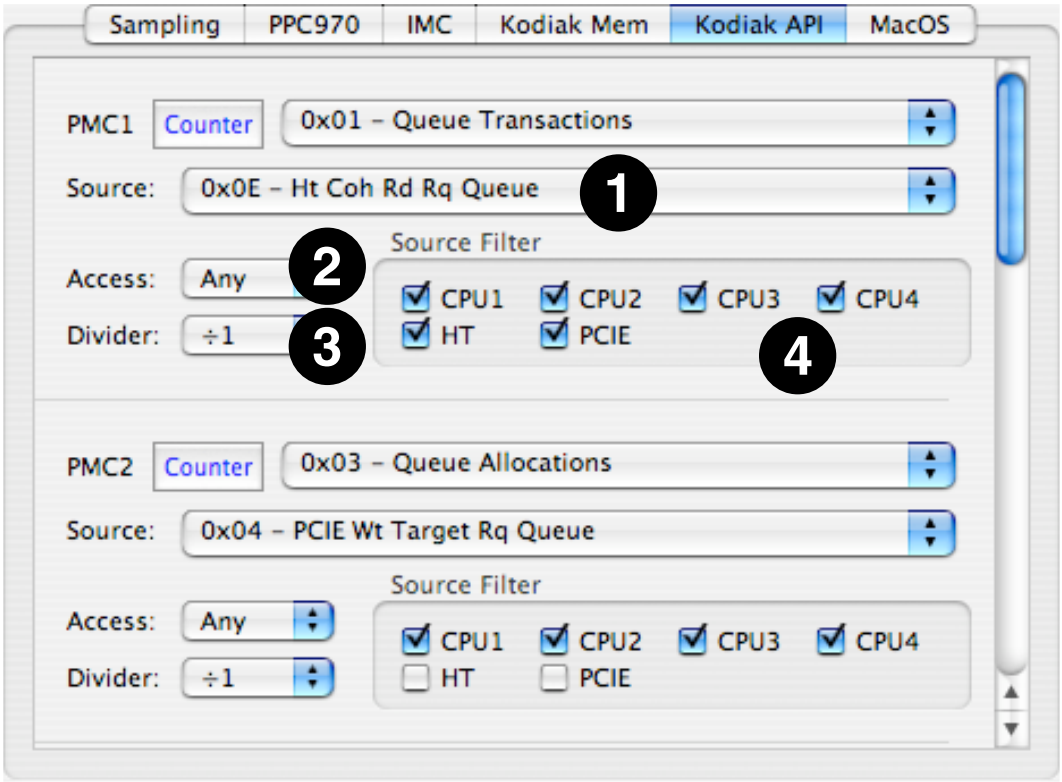


Figure 8-14 shows the second of U4's two configuration tabs, the API configuration panel. As with the memory tab, the first line of each PMC's controls are just standard controls from "Counter Control" (page 192). Below this are four custom controls that may be set independently for each of the different PMCs:

1. **Source PopUp**— The API controller chip has 33 different selectable event sources, mostly different types of request queues within the chip. You must select one of these sources in order to count its events. To count events from multiple sources simultaneously, you will have to use different PMCs for each source. A full list of these sources is listed in "Kodiak (U4) Performance Counter Event List" (page 299).
2. **Access PopUp**— This is the same as the Access PopUp on the memory tab.
3. **Divider PopUp**— This is the same as the Divider PopUp on the memory tab.
4. **Source Filter**— This is the same as the filter on the memory tab, except that all PCIE events are grouped together into a single source, whether or not they are coherent.

Figure 8-14 U4 (Kodiak) API Configuration Tab



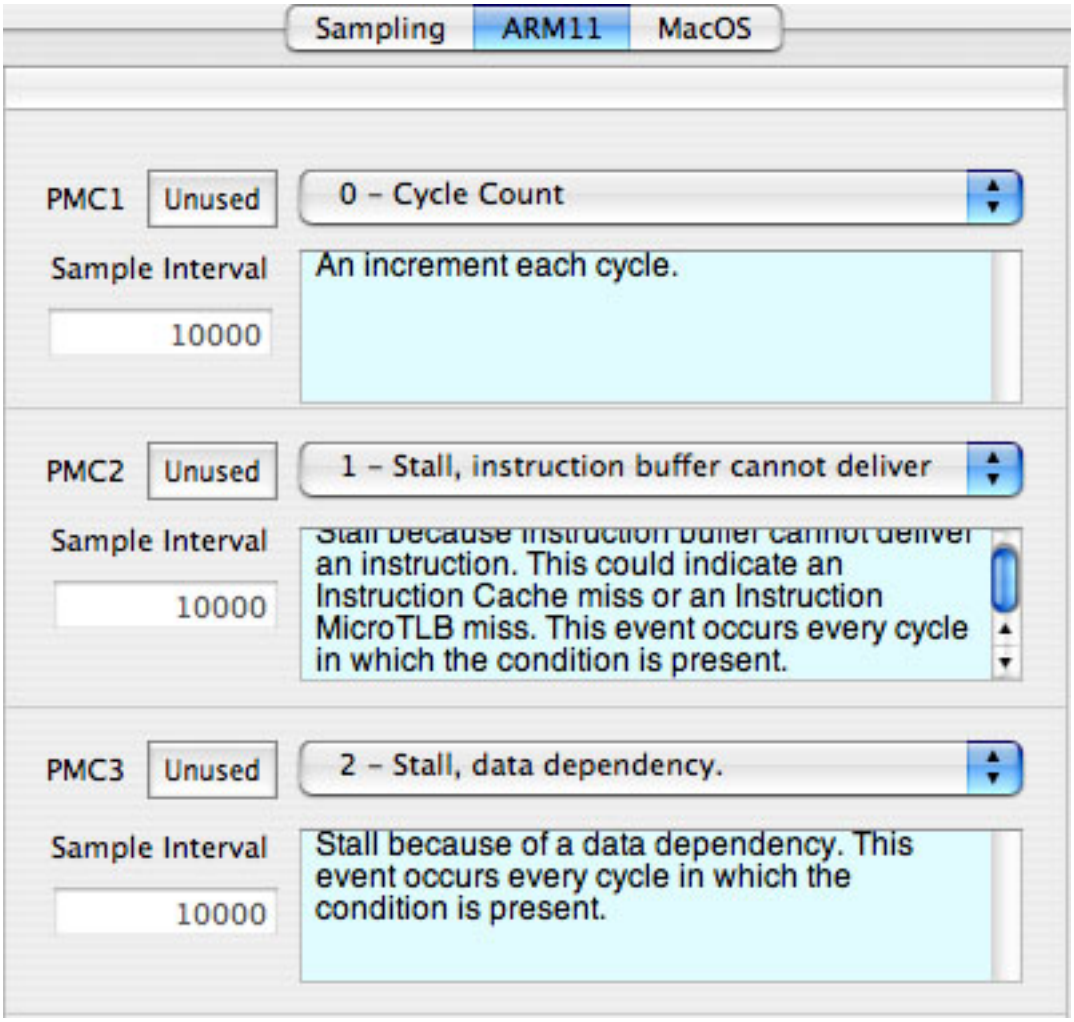
ARM11 CPU Performance Counter Configuration

This section describes how you can make custom configurations for iOS devices with ARM11 processors. These devices have two identical, fully programmable performance counters plus one counter (#1) that can record cycle counts only. Full event listings are provided in "ARM11 Performance Counter Event List" (page 303).

Figure 8-15 shows the configuration tab for the ARM11 processor. It just uses three sets of the standard PMC controls from "Counter Control" (page 192), although each PMC also includes a "help" field that describes what the currently-selected counter actually counts with some additional text.

Important: Currently, while you can make custom ARM counter configurations with Shark, there is no way to load customized configuration files onto your iOS device using the iOS SDK. This restriction may be relaxed in future versions of the SDK. In the meantime, send suggestions for useful configurations to perftools-feedback@group.apple.com and we may include them in future iOS SDK releases.

Figure 8-15 ARM11 Counter Configuration Tab



Command Reference

Menu Reference

This section summarizes Shark's commands, arranged by menu.

Shark

This menu contains the usual application-menu commands.

Command	Shortcut	Description	Where Described
About Shark...		See revision information for Shark.	
Preferences...	Cmd-,	Edit some global Shark parameters.	"Shark Preferences" (page 23)
Hide Shark	Cmd-H	Hides Shark's window(s) and switches to the next-frontmost application.	
Hide Others	Opt-Cmd-H	Hides all other applications' windows.	
Show All		Restores all windows hidden with the previous two commands.	
Quit Shark	Cmd-Q	Quits Shark.	

File

This menu contains commands that control the processing of Shark's session files. Most are fairly standard File operations, but there are a few commands here that are unique to Shark and described further in the sections noted below.

Command	Shortcut	Description	Where Described
Open	Cmd-O	Open a saved session.	
Open Recent		Contains a list of recently used saved sessions — choose one to open it.	

Command	Shortcut	Description	Where Described
Close	Cmd-W	Close the frontmost window. If the frontmost window is the main control window, this will quit Shark.	
Close All	Opt-Cmd-W	Close all session windows.	
Save	Cmd-S	Save the frontmost session.	"Session Files" (page 20)
Save As...	Shift-Cmd-S	Save the frontmost session to a new location.	"Session Files" (page 20)
Mail This Session		Attach a copy of the frontmost session to a new email in your default email program.	"Session Files" (page 20)
Compare...	Opt-Cmd-C	Compare two saved sessions.	"Comparing Sessions" (page 138)
Merge...	Opt-Cmd-M	Merge two saved sessions.	"Merging Sessions" (page 139)
Get Info	Cmd-I	Opens the Info sheet for the frontmost session.	"Session Information Sheet" (page 21)
Symbolicate...	Opt-Cmd-S	Add symbols to the frontmost session from a symbol-rich copy of the target application on disk.	"Manual Session Symbolication" (page 134)
Generate Report...	Cmd-J	Create a plain text summary of highlights from the frontmost session.	"Session Report" (page 22)
Page Setup...	Shift-Cmd-P	Configure printers and print settings.	
Print...	Cmd-P	Print the frontmost window.	

Edit

All items in this menu are standard text editing items. They work generally as expected when you are editing or examining text in Shark, and the cut/copy/paste commands will also work with some higher-level objects.

Command	Shortcut	Description
Undo	Cmd-Z	Undo the previous action.
Redo	Shift-Cmd-Z	Redo the next action.
Cut	Cmd-X	Cut the selected text, placing it on the clipboard.
Copy	Cmd-C	Copy the selected text to the clipboard.
Paste	Cmd-V	Paste the contents of the clipboard.

Command	Shortcut	Description
Paste and Match Style	Opt-Shift-Cmd-V	Paste the contents of the clipboard using the same style as existing text.
Select All	Cmd-A	Select all of whatever was most recently selected (samples, text, etc.).
Find		
Find...	Cmd-F	Open the Find text window.
Find Next	Cmd-G	Find the next occurrence of the text search pattern.
Find Previous	Shift-Cmd-G	Find the previous occurrence of the text search pattern.
Spelling		
Show Spelling and Grammar	Cmd-:	Open the Spelling and Grammar palette.
Check Spelling	Cmd-;	Check the spelling within the current text field, opening the Spelling and Grammar palette to highlight suspected errors.
Check Spelling while Typing		If ticked, spelling is checked as it is typed. Suspected errors are underlined.
Speech		
Start Speaking		Start speaking the selected text, if any, or else the contents of the current text field.
Stop Speaking		Stop speaking.
Special Characters...	Opt-Cmd-T	Open the character palette, to access special characters and symbols.

Format

All items in this menu are standard text processing commands. Since it is generally not possible to apply custom formats to most text within Shark, this menu is seldom used.

Command	Shortcut	Description
Font		
Show Fonts	Cmd-T	Show the Font palette.
Bold	Cmd-B	Toggle the bold attribute of the selected text.
Italic		Toggle the italic attribute of the selected text.
Underline	Cmd-U	Toggle the underline attribute of the selected text.

Command	Shortcut	Description
Bigger	Cmd-+	Increase the font size of the selected text.
Smaller	Cmd--	Decrease the font size of the selected text.
Show Colors		Show the color picker palette.
Copy Style		Copy the style of the selected text to the clipboard.
Paste Style	Opt-Cmd-V	Apply the style information on the clipboard to the selected text.
Text		
Align Left	Cmd-{	Align the current line or selected text to the left margin.
Center	Cmd-|	Center the current line or selected text.
Justify		Align the current line or selected text justified across the page.
Align Right	Cmd-}	Align the current line or selected text to the right margin.
Show Ruler		Show the ruler and text editing tools for the current text view.
Copy Ruler	Ctrl-Cmd-C	Copy the current ruler configuration to the clipboard.
Paste Ruler	Ctrl-Cmd-V	Paste the current ruler configuration from the clipboard.

Config

This menu contains commands that allow you to adjust Shark's built-in configurations to match your needs. These are described further in "Custom Configurations" (page 171) and "Hardware Counter Configuration" (page 189), in the sections noted below.

Command	Shortcut	Description	Where Described
Show/Hide Mini Config Editor	Shift-Cmd-C	Show/Hide the mini config editor attached to the main control window.	"Mini Configuration Editors" (page 18)
Edit...	Opt-Shift-Cmd-C	Edit the current configuration.	"The Config Editor" (page 171)
New...	Cmd-N	Create a new configuration.	"The Config Editor" (page 171)
Export...		Export the current configuration to a file.	"The Config Editor" (page 171)
Import...		Import a configuration from a file.	"The Config Editor" (page 171)

Sampling

This menu contains commands that modify when Shark starts and stops profiling and tracing operations. These are described further in "Advanced Profiling Control" (page 115), in the sections noted below.

Command	Shortcut	Description	Where Described
Programmatic (Remote)	Shift-Cmd-R	Causes Shark to listen for programmatic start/stop commands. It will then take sessions using the currently selected configuration.	"Interprocess Remote Control" (page 125)
Unresponsive Applications	Shift-Cmd-A	Using the currently selected configuration, Shark automatically profiles all applications which become unresponsive. Automatically activates Batch Mode when used.	"Unresponsive Application Measurements" (page 121)
Batch Mode	Shift-Cmd-B	Toggles Batch mode, allowing the recording of multiple sessions before analysis begins. Automatically enabled when Unresponsive Applications is ticked.	"Batch Mode" (page 117)
Network/iPhone Profiling...	Shift-Cmd-N	Enable Network Profiling of other computers or iPhones, instead of local profiling, or share this computer for others to profile.	"Network/iPhone Profiling" (page 128)

Data Mining

This menu, which disappears when data mining is not possible, provides access to Shark's powerful symbol-level data mining capabilities. These are described in more detail in "Data Mining" (page 139).

Command	Shortcut	Description
Charge Symbol to Callers	Cmd-E	Add the cost of the selected symbol(s) to their caller(s), and hide the selected symbol(s).
Charge Library to Callers	Shift-Cmd-E	Add the cost of all calls to the selected library(ies) to their caller(s), and hide the selected library(ies).
Flatten Library	Shift-Cmd-F	Just hide the selected library(ies), without adding time to the callers.
Remove Callstacks with Symbol	Cmd-K	Hide all callstacks which contain the selected symbol(s).
Retain Callstacks with Symbol	Shift-Cmd-K	Keep visible all callstacks which contain the selected symbol(s). Callstacks retained in this way will not be hidden even if they contain symbols that are used with "Remove Callstacks with Symbol".

Command	Shortcut	Description
Restore All	Cmd-R	Show all symbols and libraries previously hidden by "Charge Symbol to Callers", "Charge Library to Callers" or "Remove Callstacks with Symbol", and restore original costs for all symbols.
Focus Symbol	Cmd-Y	Hide all except the selected symbol(s).
Focus Library	Shift-Cmd-Y	Hide all except the selected library(ies).
Focus Callers of Symbol	Opt-Cmd-Y	Hide all except the caller(s) of the selected symbol(s).
Focus Callers of Library	Opt-Shift-Cmd-Y	Hide all except the caller(s) of the selected library(ies).
Unfocus All		Show all symbols and libraries previously hidden by any of the Focus commands.

Window

Along with standard window control functionality, this contains the command to show or hide the *Advanced Settings* drawer on the right side of each session window, as described in "Advanced Settings Drawer" (page 22).

Command	Shortcut	Description
Minimize	Cmd-M	Minimise the frontmost window.
Minimize All		Minimise all Shark windows.
Zoom		Zoom the frontmost window.
Show Advanced Settings	Shift-Cmd-M	Toggle visibility of the advanced settings drawer of the frontmost session.
Bring All to Front		Bring all Shark windows to the front.

Help

This menu provides access to Shark's online documentation, which is what you are reading! It also provides access to instruction reference manuals for PowerPC, 32-bit x86, and 64-bit x86 instructions, through the viewer described in "ISA Reference Window" (page 51).

Command	Shortcut	Description
Shark Help	Cmd-?	Show the Shark User Guide (PDF).
PowerPC ISA Reference		Show the PowerPC Instruction Set Architecture Reference.
IA32 ISA Reference		Show the IA32 Instruction Set Architecture Reference.

Command	Shortcut	Description
EM64T ISA Reference		Show the EM64T Instruction Set Architecture Reference.
Acknowledgements		Show acknowledgements for open-source materials used in Shark.

Alphabetical Reference

This section summarizes Shark's unique commands, arranged alphabetically. Common text editing commands have been omitted from this table.

Command	Shortcut	Description	Where Described	Menu
Batch Mode	Shift-Cmd-B	Toggles Batch mode, allowing the recording of multiple sessions before analysis begins. Automatically enabled when Unresponsive Applications is ticked.	"Batch Mode" (page 117)	Sampling
Charge Library to Callers	Shift-Cmd-E	Add the cost of all calls to the selected library(ies) to their caller(s), and hide the selected library(ies).	"Data Mining" (page 139)	Data Mining
Charge Symbol to Callers	Cmd-E	Add the cost of the selected symbol(s) to their caller(s), and hide the selected symbol(s).	"Data Mining" (page 139)	Data Mining
Compare...	Opt-Cmd-C	Compare two saved sessions.	"Comparing Sessions" (page 138)	File
Edit...	Opt-Shift-Cmd-C	Edit the current configuration.	"The Config Editor" (page 171)	Config
EM64T ISA Reference		Show the EM64T Instruction Set Architecture Reference.	"ISA Reference Window" (page 51)	Help
Export...		Export the current configuration to a file.	"The Config Editor" (page 171)	Config
Flatten Library	Shift-Cmd-F	Just hide the selected library(ies), without adding time to the callers.	"Data Mining" (page 139)	Data Mining
Focus Callers of Library	Opt-Shift-Cmd-Y	Hide all except the caller(s) of the selected library(ies).	"Data Mining" (page 139)	Data Mining
Focus Callers of Symbol	Opt-Cmd-Y	Hide all except the caller(s) of the selected symbol(s).	"Data Mining" (page 139)	Data Mining

Command	Shortcut	Description	Where Described	Menu
Focus Library	Shift-Cmd-Y	Hide all except the selected library(ies).	"Data Mining" (page 139)	Data Mining
Focus Symbol	Cmd-Y	Hide all except the selected symbol(s).	"Data Mining" (page 139)	Data Mining
Generate Report...	Cmd-J	Create a plain text summary of highlights from the frontmost session.	"Session Report" (page 22)	File
Get Info	Cmd-I	Opens the Info sheet for the frontmost session.	"Session Information Sheet" (page 21)	File
IA32 ISA Reference		Show the IA32 Instruction Set Architecture Reference.	"ISA Reference Window" (page 51)	Help
Import...		Import a configuration from a file.	"The Config Editor" (page 171)	Config
Mail This Session		Attach a copy of the frontmost session to a new email in your default email program.	"Session Files" (page 20)	File
Merge...	Opt-Cmd-M	Merge two saved sessions.	"Merging Sessions" (page 139)	File
Network/iPhone Profiling...	Shift-Cmd-N	Enable Network Profiling of other computers or iPhones, instead of local profiling, or share this computer for others to profile.	"Network/iPhone Profiling" (page 128)	Sampling
New...	Cmd-N	Create a new configuration.	"The Config Editor" (page 171)	Config
PowerPC ISA Reference		Show the PowerPC Instruction Set Architecture Reference.	"ISA Reference Window" (page 51)	Help
Preferences...	Cmd-,	Edit some global Shark parameters.	"Shark Preferences" (page 23)	Shark
Programmatic (Remote)	Shift-Cmd-R	Causes Shark to listen for programmatic start/stop commands. It will then take sessions using the currently selected configuration.	"Interprocess Remote Control" (page 125)	Sampling
Remove Callstacks with Symbol	Cmd-K	Hide all callstacks which contain the selected symbol(s).	"Data Mining" (page 139)	Data Mining

Command	Shortcut	Description	Where Described	Menu
Restore All	Cmd-R	Show all symbols and libraries previously hidden by "Charge Symbol to Callers", "Charge Library to Callers" or "Remove Callstacks with Symbol", and restore original costs for all symbols.	"Data Mining" (page 139)	Data Mining
Retain Callstacks with Symbol	Shift-Cmd-K	Keep visible all callstacks which contain the selected symbol(s). Callstacks retained in this way will not be hidden even if they contain symbols that are used with "Remove Callstacks with Symbol".	"Data Mining" (page 139)	Data Mining
Shark Help	Cmd-?	Show the Shark User Guide (PDF).		Help
Show Advanced Settings	Shift-Cmd-M	Toggle visibility of the advanced settings drawer of the frontmost session.	"Advanced Settings Drawer" (page 22)	Window
Show/Hide Mini Config Editor	Shift-Cmd-C	Show/Hide the mini config editor attached to the main control window.	"Mini Configuration Editors" (page 18)	Config
Symbolicate...	Opt-Cmd-S	Add symbols to the frontmost session from a symbol-rich copy of the target application on disk.	"Manual Session Symbolication" (page 134)	File
Unfocus All		Show all symbols and libraries previously hidden by any of the Focus commands.	"Data Mining" (page 139)	Data Mining

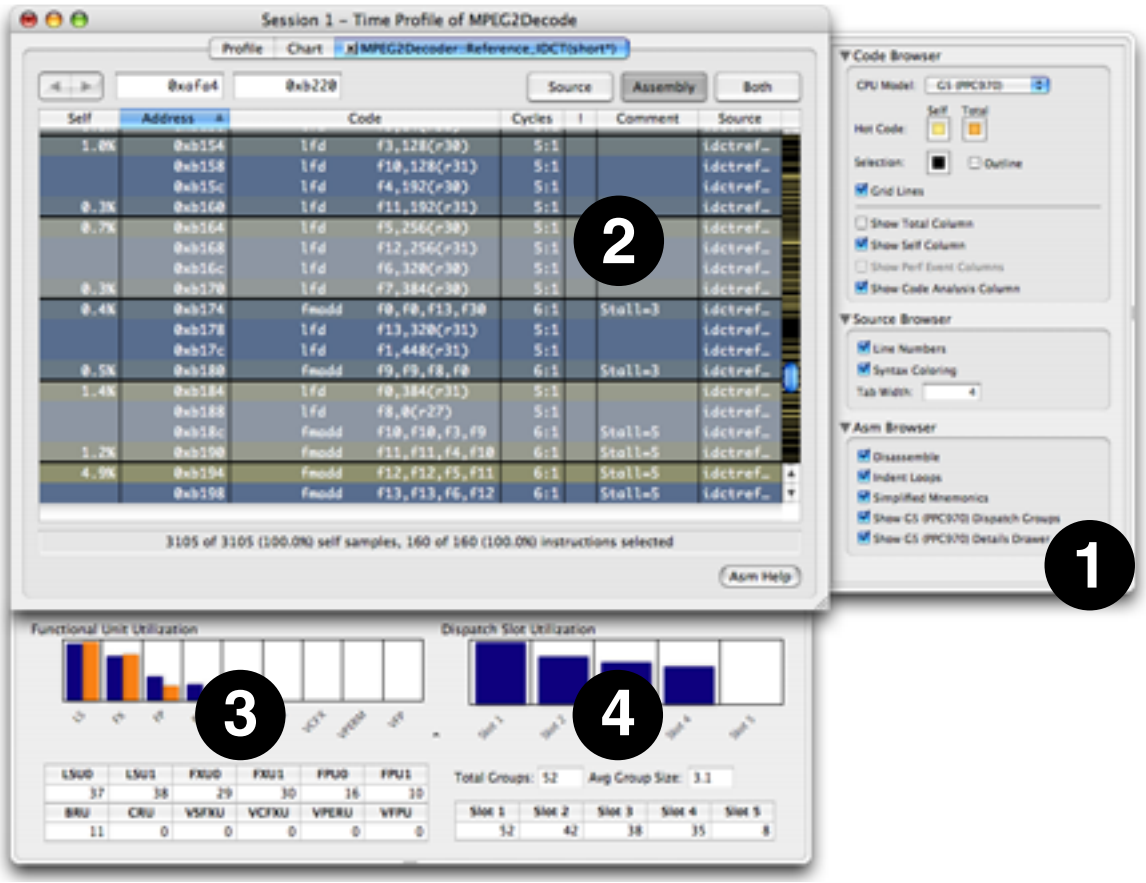
Miscellaneous Topics

Code Analysis with the G5 (PPC970) Model

Shark offers several features designed to help the programmer understand instruction execution behavior on the G5 (PPC970). From the *Advanced Settings* drawer's *Assembly Browser* tab, you can set the *Assembly Browser* to display an estimate of G5 dispatch group formations, using the check box near item #1 in Figure B-1. After this is checked, the assembly display around item #2 has dark lines added to indicate breaks between instruction dispatch groups. If you look closely, you will see that all of Shark's samples generally fall on the first or last instructions of dispatch groups, due to the way program counters are captured by Shark on the G5 processor. A key factor in optimizing performance on the G5 is maximizing dispatch group sizes. A detailed explanation of G5 dispatch group formation rules is beyond the scope of this document, but Shark accurately models the CPU behavior as much as possible using static analysis. See the PowerPC970 User Manual (see the PowerPC 970 documentation) for a complete description of dispatch groups.

Functional unit utilization and dispatch slot utilization are two more features that Shark offers to visualize G5 execution behavior. When the user selects Show G5 (PPC970) *Details Drawer* in the *Advanced Settings* drawer (at #1 in Figure B-1), the user will see the *G5 Resource Utilization* drawer. The *Functional Unit Utilization* chart and table (item #3) provide visual feedback to the programmer about how effectively instructions are spread among the various functional units within the G5. Similarly, the number of dispatch groups and instructions flowing into each G5 dispatch slot are shown in the *Dispatch Slot Utilization* chart and table (item #4). Please note that the data in the *G5 Resource Utilization* drawer is based on the currently selected instructions in the Code Table, or on the entire code sequence if nothing is selected. The user can specify a subset of instructions within the current *Code Table*, and the *G5 Resource Utilization* charts and tables will update dynamically.

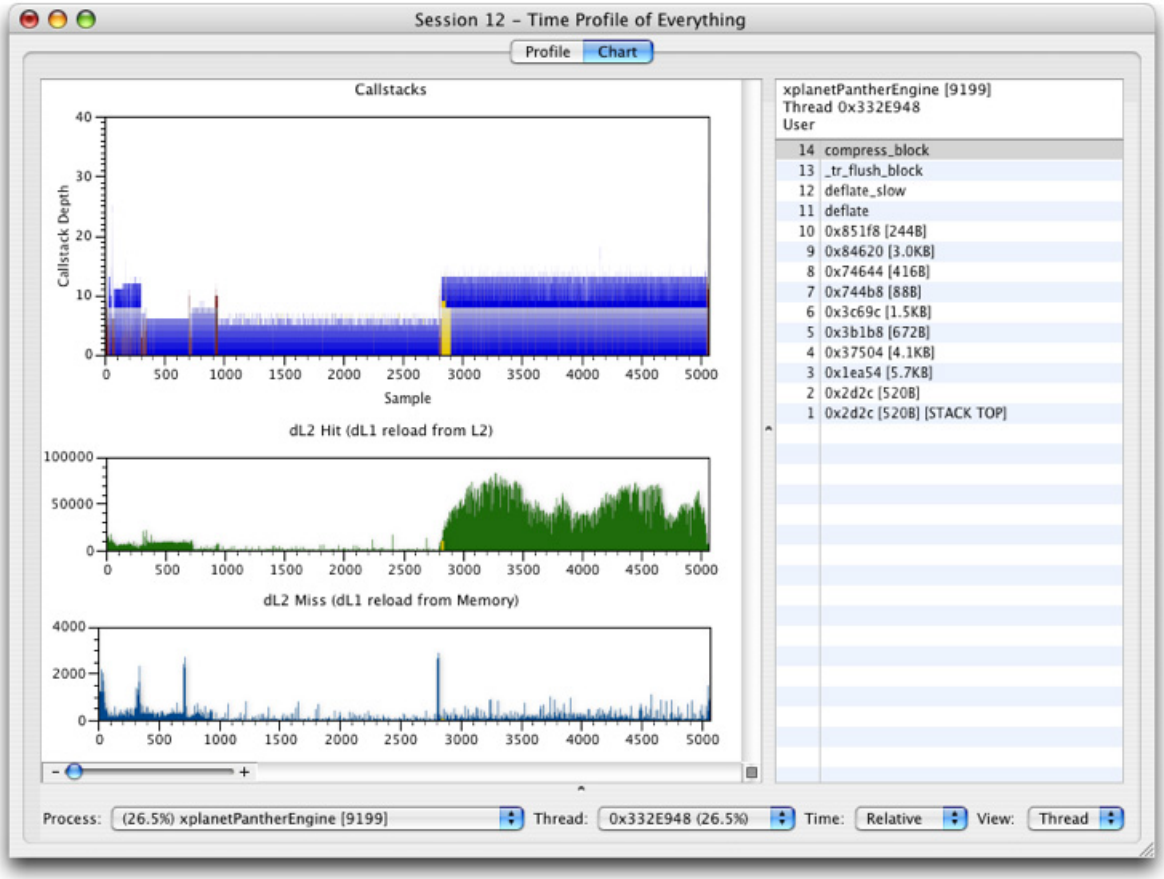
Figure B-1 PPC970 Resource Modeling



Supervisor Space Sampling Guidelines

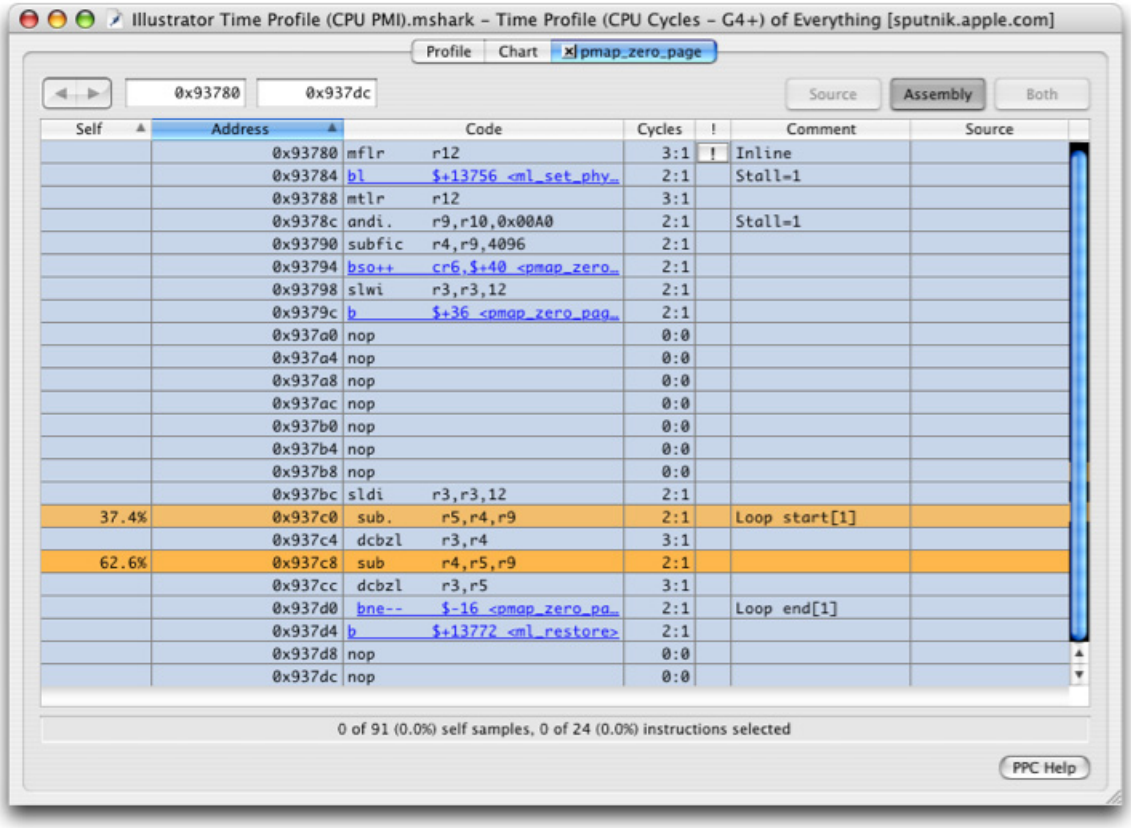
Supervisor space samples come from either the Mach kernel or kernel extensions. If you are a driver writer or simply interested in the workings of the Mac OS X kernel, you may encounter inconsistent results between timer sampling and event sampling when profiling code that executes with interrupts disabled. For example, consider the PowerPC-specific virtual memory (VM) page-zeroing code in the kernel. When profiled with timer sampling, Shark displays the output shown in Figure B-2. Because `pmap_zero_page()` disables interrupts, any timer interrupts that occur in it are not serviced until interrupts are reenabled in `ml_restore()`. It is for this reason that all of the timer samples appear to come from the isync instruction at `0x96da8` (see Figure B-2).

Figure B-2 Timer Sampling in the Kernel



A more accurate picture of the kernel behavior can be seen with event sampling (Figure B-3). This is because CPU event sampling reads the SIAR (sampled instruction address register) rather than the originating PC when the performance monitor interrupt is serviced. Whenever a CPU performance monitor interrupt (PMI) occurs, the SIAR register is set to the currently executing PC (program counter) . As in the timer sampling case, the PMI is not actually serviced until interrupts are reenabled.

Figure B-3 CPU PMI Sampling in the Kernel



Intel Core Performance Counter Event List

Intel's Core processors have 2 performance counters per core. Both are programmable, and can count 111 (#1) or 112 (#2) different types of events.

Most of the events are reserved, and not listed here. The available events can be modified by enabling *Event-Mask* bits, in the PMC control registers. There are eight such bits in each programmable PMC.

In addition, the available events can be modified by enabling any of the eight *Event-Mask* bits associated with each programmable counter. The event-mask bits are critical to determining exactly which events will be counted. Most of the events can be selected without enabling any event-mask bits at all. The mask bits just modify the type of event slightly or the way the counter gets incremented when the event occurs. In particular, the mask settings often act as an event filter, limiting or expanding the selection of related events that can be counted simultaneously. In contrast, for some types of events you*must* set event-mask bits properly, in order to count anything at all. These bits are labeled 'Required' in the event-mask bit list.

The table below lists each Event Name, the counter (PMC) number(s) for counters which can count the event, the event's number, and the valid mask bits that can be enabled, for every useful event type. This last column lists mask bits using numbers between 0 and 7. Missing numbers indicate bits that are reserved and should not be enabled. If no mask bits are valid for that type of event, then "none" is listed.

In Shark, more complete documentation as to what the event names mean and how each mask bit modifies the count are provided as "tool-tips" when you hover the mouse over an event name in the popup menu, or over a specific bit name in the event-mask list. The event-mask bit controls are only accessible from the *Advanced View* controls shown in the ""The Counters Menu" (page 106).

For more information on how to configure these counters, see "Intel CPU Performance Counter Configuration" (page 196).

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
BACLEARS	230	1,2	none
BR_BAC_MISSP_EXEC	138	1,2	none
BR_BOGUS	228	1,2	none
BR_CALL_EXEC	146	1,2	none
BR_CALL_MISSP_EXEC	147	1,2	none
BR_CND_EXEC	139	1,2	none
BR_CND_MISSP_EXEC	140	1,2	none
BR_IND_CALL_EXEC	148	1,2	none
BR_IND_EXEC	141	1,2	none

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
BR_IND_MISSP_EXEC	142	1,2	none
BR_INST_DECODED	224	1,2	none
BR_INST_EXEC	136	1,2	none
BR_INST_RETIRED	196	1,2	none
BR_MISS_PRED_RETIRED	197	1,2	none
BR_MISS_PRED_TAKEN_RET	202	1,2	none
BR_MISSP_EXEC	137	1,2	none
BR_RET_BAC_MISSP_EXEC	145	1,2	none
BR_RET_EXEC	143	1,2	none
BR_RET_MISSP_EXEC	144	1,2	none
BR_TAKEN_RETIRED	201	1,2	none
BTB_MISSES	226	1,2	none
BUS_BNR_DRV	97	1,2	none
BUS_DATA_RCV	100	1,2	6
BUS_DRDY_CLOCKS	98	1,2	5
BUS_LOCK_CLOCKS	99	1,2	6
BUS_REQ_OUTSTANDING	96	1,2	4 5 6 7
BUS_SNOOP_STALL	126	1,2	none
BUS_TRAN_ANY	112	1,2	5 6 7
BUS_TRAN_BRD	101	1,2	6
BUS_TRAN_BURST	110	1,2	5 6 7
BUS_TRAN_DEF	109	1,2	5 6 7
BUS_TRAN_IFETCH	104	1,2	6
BUS_TRAN_INVAL	105	1,2	6
BUS_TRAN_MEM	111	1,2	5 6 7
BUS_TRAN_PWR	106	1,2	6
BUS_TRAN_RFO	102	1,2	6

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
BUS_TRANS_IO	108	1,2	6
BUS_TRANS_P	107	1,2	6
BUS_TRANS_WB	103	1,2	5 6 7
CPU_CLK_UNHALTED	60	1,2	0 1
CYCLES_DIV_BUSY	20	1	none
CYCLES_INT_MASKED	198	1,2	none
CYCLES_INT_PENDING_AND_MASKED	199	1,2	none
DATA_MEM_REFS	67	1,2	none
DCU_LINES_IN	69	1,2	none
DCU_M_LINES_IN	70	1,2	none
DCU_M_LINES_OUT	71	1,2	none
DCU_MISS_OUTSTANDING	72	1,2	none
DCU_SNOOPS	120	1,2	0 1 6
DIV	19	2	0 1 6
DTLB Misses	73	1,2	none
EMON_ESP_UOPS	215	1,2	none
EMON_FUSED_UOPS_RET	218	1,2	0 1
EMON_KNI_PREF_DISPATCHED	7	1,2	0 1
EMON_KNI_PREF_MISS	75	1,2	0 1
EMON_PREF_RQSTS_DN	248	1,2	none
EMON_PREF_RQSTS_UP	240	1,2	none
EMON_SIMD_INSTR_RETIRED	206	1,2	none
EMON_SSE_SSE2_COMP_INST_RETIRED	217	1,2	0 1
EMON_SSE_SSE2_INST_RETIRED	216	1,2	0 1 2
EMON_SYNCH_UOPS	211	1,2	none
EMON_UNFUSION	219	1,2	none
EST_TRANS	58	1,2	0 1

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
EXTERNAL_BUS_CYCLES	119	1,2	0 1 2 4
EXTERNAL_BUS_QUEUE	125	1,2	6
FLOPS	193	1,2	none
FP_ASSIST	17	2	none
FP_COMP_OPS_EXE	16	1	none
FP_MMX_TRANS	204	1,2	0
HW_INT_RX	200	1,2	none
IFU_IFETCH	128	1,2	none
IFU_IFETCH_MISS	129	1,2	none
IFU_MEM_STALL	134	1,2	none
ILD_STALL	135	1,2	none
INST_DECODED	208	1,2	none
INST_RETIRED	192	1,2	none
ITLB_MISS	133	1,2	none
L1_CACHEABLE_DATA_READS	64	1,2	0 1 2 3
L1_CACHEABLE_DATA_READS_AND_WRITES	68	1,2	0 1 2 3
L1_CACHEABLE_DATA_WRITES	65	1,2	0 1 2 3
L1_CACHEABLE_LOCK_READS	66	1,2	0 1 2 3
L1_PREFETCH_REQUEST_MISSES	79	1,2	none
L2_ADS	33	1,2	6
L2_DBUS_BUSY	34	1,2	none
L2_DBUS_BUSY_RD	35	1,2	6
L2_IFETCH	40	1,2	0 1 2 3 4 5 6
L2_LD	41	1,2	0 1 2 3 4 5 6
L2_LINES_IN	36	1,2	0 1 2 3 4 5 6
L2_LINES_OUT	38	1,2	0 1 2 3 4 5 6
L2_M_LINES_INM	37	1,2	6

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
L2_M_LINES_OUT	39	1,2	0 1 2 3 4 5 6
L2_NO_REQUEST_CYCLES	50	1,2	6
L2_REJECT_CYCLES	48	1,2	6
L2_RQSTS	46	1,2	0 1 2 3 4 5 6
L2_ST	42	1,2	0 1 2 3 4 5 6
LD_BLOCKS	3	1,2	none
MISALIGN_MEM_REF	5	1,2	none
MMX_ASSIST	205	1,2	none
MMX_INSTR_EXEC	176	1,2	none
MMX_INSTR_TYPE_EXEC	179	1,2	0 1 2 3 4 5
MMX_SAT_INSTR_EXEC	177	1,2	none
MMX_SAT_INSTR_RET	207	1,2	none
MMX_UOPS_EXEC	178	1,2	none
MUL	18	2	none
PARTIAL_RAT_STALLS	210	1,2	none
RESOURCE_STALLS	162	1,2	none
RET_SEG_RENAMES	214	1,2	none
SB_DRAINS	4	1,2	none
SEG_REG_RENAMES	213	1,2	0 1 2 3
SEG_RENAME_STALLS	212	1,2	0 1 2 3
SEGMENT_REG_LOADS	6	1,2	none
SELF_MODIFYING_CODE	195	1,2	none
THERMAL_TRIP	59	1,2	6 7
UOPS_RETIRED	194	1,2	none

Intel Core Performance Counter Event List

Intel Core 2 Performance Counter Event List

Intel's Core 2 processors have 5 performance counters per core. Two of these are fully programmable, and can count 116 (#1) or 115 (#2) different types of events. The other three counters are fixed, and can only count one type of event (for counter 3: INSTR_RETIRED.ANY, 4: CPU_CLK_UNHALTED.CORE, and 5: CPU_CLK_UNHALTED.REF).

In addition, the available events can be modified by enabling any of the eight *Event-Mask* bits associated with each programmable counter. The event-mask bits are critical to determining exactly which events will be counted. Most of the events can be selected without enabling any event-mask bits at all. The mask bits just modify the type of event slightly or the way the counter gets incremented when the event occurs. In particular, the mask settings often act as an event filter, limiting or expanding the selection of related events that can be counted simultaneously. In contrast, for some types of events you*must* set event-mask bits properly, in order to count anything at all. These bits are labeled 'Required' in the event-mask bit list.

The table below lists each Event Name, the counter (PMC) number(s) for counters which can count the event, the event's number, and the valid mask bits that can be enabled, for every useful event type. This last column lists mask bits using numbers between 0 and 7. Missing numbers indicate bits that are reserved and should not be enabled. If no mask bits are valid for that type of event, then "none" is listed.

In Shark, more complete documentation as to what the event names mean and how each mask bit modifies the count are provided as "tool-tips" when you hover the mouse over an event name in the popup menu, or over a specific bit name in the event-mask list. The event-mask bit controls are only accessible from the *Advanced View* controls shown in the "Timed Counters: The Performance Counter Spreadsheet" (page 104).

For more information on how to configure these counters, see "Intel CPU Performance Counter Configuration" (page 196).

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
BACLEARS	230	1	none
		2	0
BR_BAC_MISSP_EXEC	138	1	none
		2	0
BR_BOGUS	228	1	none
		2	0
BR_CALL_EXEC	146	1	none
		2	0
BR_CALL_MISSP_EXEC	147	1	none
		2	0

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
BR_CND_EXEC	139	1	none
		2	0
BR_CND_MISSP_EXEC	140	1	none
		2	0
BR_IND_CALL_EXEC	148	1	none
		2	0
BR_IND_EXEC	141	1	none
		2	0
BR_IND_MISSP_EXEC	142	1	none
		2	0
BR_INST_DECODED	224	1	none
		2	0
BR_INST_EXEC	136	1	none
		2	0
BR_INST_RETIRED	196	1	0 1 2 3 6 7
		2	0 2 3 4 5 6 7
BR_INST_RETIRED.MISPRED	197	1	none
		2	0 2 3 4 5
BR_MISSP_EXEC	137	1	none
		2	0
BR_RET_BAC_MISSP_EXEC	145	1	none
		2	0
BR_RET_EXEC	143	1	none
		2	0
BR_RET_MISSP_EXEC	144	1	none
		2	0
BR_TKN_BUBBLE_1	151	1	none

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
		2	0
BR_TKN_BUBBLE_2	152	1	none
		2	0
BUS_BNR_DRV	97	1	5
		2	0
BUS_DATA_RCV	100	1	6 7
		2	0 7
BUS_DRDY_CLOCKS	98	1	5
		2	0
BUS_HIT_DRV	122	1	5
		2	0 2 3 5 7
BUS_HITM_DRV	123	1	5
		2	0 2 3
BUS_IO_WAIT	127	1	6 7
		2	0
BUS_LOCK_CLOCKS (Core and Bus Agents masks apply)	99	1	5 6 7
		2	0 6 7
BUS_REQ_OUTSTANDING	96	1	4 5 6 7
		2	0
BUS_TRAN_RFO	102	1	5 6 7
		2	0 7
BUS_TRANS_ANY	112	1	5 6 7
		2	0 7
BUS_TRANS_BRD	101	1	5 6 7
		2	0 7
BUS_TRANS_BURST	110	1	5 6 7
		2	0 7

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
BUS_TRANS_DEF	109	1	5 6 7
		2	0 7
BUS_TRANS_IFETCH	104	1	5 6 7
		2	0 7
BUS_TRANS_INVAL	105	1	5 6 7
		2	0 7
BUS_TRANS_IO	108	1	5 6 7
		2	0 7
BUS_TRANS_MEM	111	1	5 6 7
		2	0 7
BUS_TRANS_P	107	1	5 6 7
		2	0 7
BUS_TRANS_PWR	106	1	5 6 7
		2	0 7
BUS_TRANS_WB	103	1	5 6 7
		2	0
BUSQ_EMPTY	125	1	6 7
		2	0 7
CMP_SNOOP	120	1	0 1 6 7
		2	0
CPU_CLK_UNHALTED	60	1	0 1
		2	0
CPU_CLK_UNHALTED.CORE	0	4	none
CPU_CLK_UNHALTED.REF	0	5	none
CYCLES_DIV_BUSY	20	1	none
CYCLES_INT	198	1	0 1
		2	0 2 4

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
CYCLES_L1I_MEM_STALLED	134	1	none
		2	0 3
DELAYED_BYPASS	25	2	0
DIVIDES	19	2	0
DTLB_MISSES	8	1	0 1 2 3
		2	0
EIST_TRANS	58	1	none
		2	0
ESP Register	171	1	0 1
		2	0
EXT_SNOOP	119	1	0 1 3 5
		2	0
FP_ASSIST	17	2	0
FP_COMP_OPS_EXE	16	1	none
FP_MMX_TRANS	204	1	0 1
		2	0
HW_INT_RCV	200	1	none
		2	0
IDLE_DURING_DIV	24	1	none
ILD_STALL	135	1	none
		2	0
INST_QUEUE.FULL	131	1	1
		2	0
INST_RETIRED	192	1	0 1 2
		2	0
INSTR_RETIRED.ANY	0	3	none
ITLB	130	1	1 4 6

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
		2	0
ITLB_MISS_RETIRED	201	1	none
		2	0 2 3
L1D_ALL_REF	67	1	0 1
		2	0 2 3 4 5
L1D_CACHE_LD	64	1	0 1 2 3
		2	0
L1D_CACHE_LOCK	66	1	0 1 2 3 4
		2	0
L1D_CACHE_ST	65	1	0 1 2 3
		2	0
L1D_M_EVICT	71	1	none
		2	0
L1D_M_REPL	70	1	none
		2	0 2 3
L1D_PEND_MISS	72	1	none
		2	0 2 3 4 5
L1D_PREFETCH.REQUESTS	78	1	4
		2	0 2 3
L1D_REPL	69	1	0 1 2 3
		2	0 2 3 4 5 6
L1D_SPLIT	73	1	0 1
		2	0
L1I_MISSES	129	1	none
		2	0 6 7
L1I_READS	128	1	none
		2	0

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
L2_ADS	33	1	6 7
		2	0
L2_DBUS_BUSY_RD	35	1	6 7
		2	0
L2_IFETCH	40	1	0 1 2 3 6 7
		2	0
L2_LD	41	1	0 1 2 3 4 5 6 7
		2	0 6 7
L2_LINES_IN	36	1	4 5 6 7
		2	0
L2_LINES_OUT	38	1	4 5 6 7
		2	0
L2_LOCK	43	1	0 1 2 3 4 5 6 7
		2	0 2 3 4 5
L2_M_LINES_IN	37	1	6 7
		2	0
L2_M_LINES_OUT	39	1	4 5 6 7
		2	0 6 7
L2_NO_REQ	50	1	6 7
		2	0
L2_REJECT_BUSQ	48	1	0 1 2 3 4 5 6 7
		2	0
L2_RQSTS	46	1	0 1 2 3 4 5 6 7
		2	0 2 3 4 5 6 7
L2_ST	42	1	0 1 2 3 6 7
		2	0 6 7
LOAD_BLOCK	3	1	1 2 3 4 5

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
		2	0
LOAD_HIT_PRE	76	1	none
		2	0 2 3
MACHINE_NUKES	195	1	0 2
		2	0 2 3 4
MACRO_INSTS.CISC_DECODED	170	1	3
		2	0
MEM_LOAD_RETIRED	203	1	none
MEMORY_DISAMBIGUATION	9	1	0 1
		2	0
MISALIGN_MEM_REF	5	1	none
		2	0
MULTIPLIES	18	2	0
PAGE_WALKS	12	1	0 1
		2	0 2 3
PREF_RQSTS_DN	248	1	none
		2	0
PREF_RQSTS_UP	240	1	none
		2	0
RAT_STALLS	210	1	0 1 2 3
		2	0
RESOURCE_STALLS	220	1	0 1 2 3 4
		2	0
RS_UOPS_DISPATCHED	160	1	none
		2	0
SEG_REG_RENAMES	213	1	0 1 2 3
		2	0 2 3 4 5

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
SEG_RENAME_STALLS	212	1	0 1 2 3
		2	0
SEGMENT_REG_LOADS	6	1	none
		2	0 3 4 5 6 7
SIMD_ASSIST	205	1	none
		2	0 2 3 4 5
SIMD_COMP_INST_RETIRED	202	1	0 1 2 3
		2	0 2 3 4 5 6
SIMD_INST_RETIRED	199	1	0 1 2 3 4
		2	0 2 3 4 5
SIMD_INSTR_RETIRED	206	1	none
		2	0 2 3 4 5 6
SIMD_SAT_INSTR_RETIRED	207	1	none
		2	0 2 3
SIMD_SAT_UOP_EXEC	177	1	none
		2	0
SIMD_UOP_TYPE_EXEC	179	1	0 1 2 3 4 5
		2	0
SIMD_UOPS_EXEC	176	1	none
		2	0
SNOOP_STALL_DRV	126	1	4 5 6 7
		2	0 7
SSE_PRE_EXEC	7	1	0 1
		2	0 2 3 5
SSE_PRE_MISS	75	1	0 1
		2	0
STORES BLOCKED	4	1	0 1 3

Performance Counter Event Name	Event Number	PMC Number	Valid Event-Mask Bits
		2	0
THERMAL_TRIP	59	1	6 7
		2	0
UOPS_RETIRED	194	1	0 1 2 3
		2	0
X87_OPS_RETIRED	193	1	0 1 2 3 4 5 6
		2	0

PPC 750 (G3) Performance Counter Event List

The PowerPC 750 (G3) cores contain four independent performance counters, each of which can count 12–17 different types of events. Four commonly measured types of events (CPU cycles, instructions completed, timebase clock transitions, and instructions dispatched) can be counted on any counter, while other types of events can only be counted on a limited subset of the counters.

The table below lists each Event Name, the counter (PMC) number(s) for counters which can count the event, and each event's number.

For more information on how to configure these counters, see "PowerPC G3/G4/G4+ CPU Performance Counter Configuration" (page 197).

Performance Counter Event Name	PMC Number(s)	Event Number
2nd Spec Branch Buffer Correct	3	16
Branch Unit LR/CTR Stall Cycles	3	17
Branch Unit Speculative Stall Cycles	1, 2	12
	4	14
CacheOp L2 Hits	3	13
CPU Cycles	1, 2, 3, 4	1
dL1 Load Miss Cycles	3	15
dL1 Miss Cycles > Threshold	1, 2	10
dL1 Misses	3	5
dL2 Misses	3	7
DTLB Misses	3	6
DTLB Search Cycles	4	6
EIEIO Instr	1, 2	5
Floating Point Instr	3	11
Instr Bkpt Matches	1, 2	9
Instr Completed	1, 2, 3, 4	2
Instr Dispatched	1, 2, 3, 4	4
Instr Fetches	1, 2	8

Performance Counter Event Name	PMC Number(s)	Event Number
Integer Instr	4	13
ITLB Search Cycles	1, 2	6
L2 Castouts	4	5
L2 Hits	1, 2	7
L2 Snoop Castouts	3	12
Marked/Unmarked Supervisor Transitions	4	9
Marked/Unmarked User Transitions	3	9
Mispredicted Branches	4	8
Nothing	1, 2, 3, 4	0
Snoop Retries	4	12
STWCX Instr	3	10
Successful STWCX Instr	4	10
SYNC Instr	4	11
Taken Branches	3	8
TimeBase (Lower) 0->1 bit transitions	3, 4	3
TimeBase (Upper) 0->1 bit transitions	1, 2	3
Unresolved Branches	1, 2	11

PPC 7400 (G4) Performance Counter Event List

The PowerPC 7400 (G4) cores contain four independent performance counters, each of which can count 27–48 different types of events. Four commonly measured types of events (CPU cycles, instructions completed, timebase clock transitions, and instructions dispatched) can be counted on any counter, while other types of events can only be counted on a limited subset of the counters.

The table below lists each Event Name, the counter (PMC) number(s) for counters which can count the event, and each event's number.

For more information on how to configure these counters, see "PowerPC G3/G4/G4+ CPU Performance Counter Configuration" (page 197).

Performance Counter Event Name	PMC Number(s)	Event Number
1st Spec Branch Buffer Correct	2	38
2nd Spec Branch Buffer Correct	3	14
AltiVec Load Instr	1	48
AltiVec MFVSCR Instr Sync Cycles	1	14
AltiVec MTVRSAVE Instr	1	16
AltiVec MTVSCR Instr	1	15
AltiVec VCIU Instr	3	7
AltiVec VFPU Instr	4	7
AltiVec VFPU Stall Cycles	3	8
AltiVec VFPU Traps	2	34
AltiVec VPU Instr	1	7
AltiVec VPU Stall Cycles	4	8
AltiVec VSCR[SAT] 0->1	1	17
AltiVec VSIU Stall Cycles	1	8
Branch Unit LR/CTR Stall Cycles	3	15
Branch Unit Speculative Load Stall Cycles	1	37
Branch Unit Speculative Stall Cycles	1	13
	4	14

Performance Counter Event Name	PMC Number(s)	Event Number
Branches Taken	3	5
Bus Kill Transactions (Non-Retried)	4	12
Bus Multi Beat Write TAs	4	25
Bus Multi-Beat Read TAs	2	21
Bus Read TAs	2	42
Bus Retries	2	20
Bus Single Beat Read TAs	1	28
Bus Single Beat Write TAs	3	29
Bus Transactions (Non-Retried)	1	27
Cache Inhibited Stores	2	24
Clean L1 Castouts to L2	1	18
Conditional Store Instr	3	12
CPU Cycles	1, 2, 3, 4	1
Data Bkpt match	1	10
Data Reload Table Snoop Hits	2	35
Data Reload Table Store Miss Merges	2	22
Dirty L1 Castouts to L2	2	13
dL1 CacheOp Cycles	3	17
dL1 Castout to L2 Misses	2	28
dL1 Castouts to L2	4	19
dL1 Cycles	3	18
dL1 Hits	1	24
dL1 Load Hits	1	22
dL1 Load Misses	2	15
dL1 Miss Cycles > Threshold	1	11
dL1 Misses	2	17
dL1 Reloads	3	30

Performance Counter Event Name	PMC Number(s)	Event Number
dL1 Snoop Hits	4	23
dL1 Snoop Interventions	4	16
	4	26
dL1 Store Hits	1	23
dL1 Store Misses	2	16
dL1 Touch Hits	3	16
dL1 Touch Misses	4	15
dL1 Writes Hit Shared	1	30
dL2 Hits	1	33
dL2 Misses	2	26
DSS Instr	3	24
DSSALL Instr	4	22
DST DTLB Table Successful Searches	4	27
DST Instr Dispatched	1	38
DTLB Misses	3	6
DTLB Search Cycles	4	6
DTLB Search Cycles > Threshold	1	20
EIEIO Instr	1	5
External Snoop Requests	1	42
Fall through Branches	2	5
Floating Point Instr	3	11
Full Cache Line Store Miss Merge	3	21
Hit Exclusive Interventions	3	28
Hit Interventions	1	45
Hit Modified Interventions	2	36
Hit Shared Interventions	4	24
iL1 Misses	1	32

Performance Counter Event Name	PMC Number(s)	Event Number
iL1 Reloads	2	25
iL2 Hits	2	27
iL2 Misses	1	34
Instr Bkpt match	1	9
Instr Completed	1, 2, 3, 4	2
Instr Dispatched	1, 2, 3, 4	4
Integer Instr	4	13
ITLB Misses	2	6
ITLB Search Cycles	1	6
ITLB Search Cycles > Threshold	1	19
L1 Castout to L2 Hits	1	35
L1 Load Fold Queue Reload Hits	1	29
L1 Load Fold Queue Touch Hits	1	46
L1 Operations Queue Snoop Hits	1	47
L2 Allocations	1	36
L2 Castout Snoop Hits	1	44
L2 Sectors Castout	2	29
L2 Snoop Hits	3	27
L2 Snoop Interventions	3	13
L2 Tag Accesses	1	26
L2 Tag Lookup	1	25
L2 Tag Snoop Writes	4	17
L2 Tag Snoops	3	19
L2 Tag Writes	2	18
L2 Write Hit on Shared	2	23
L2SRAM Cycles	4	18
L2SRAM Read Cycles	2	19

Performance Counter Event Name	PMC Number(s)	Event Number
L2SRAM Write Cycles	3	20
Load Instr	2	11
Mispredicted Branches	4	5
Nothing	1, 2, 3, 4	0
Reserved Loads	2	10
Snoop Hits	2	37
Snoop Retries	3	26
Snooped TLB Invalidations	2	41
Snoops Serviced	2	12
Store Instr	1	21
Successful STWCX Instr	4	10
SYNC Instr	4	11
System Register Unit Instr	2	14
TimeBase (Lower) 0->1 bit transitions	1, 2, 3, 4	3
TLBI Instr	2	40
TLBSYNC Instr	3	10
Unresolved Branches	1	12
User/Supervisor Switches	2	9
VCIU Wait Cycles	2	8
VSIU Instr	2	7
VTE Data Reload Table Hits	3	22
VTE dL1 Hits	4	20
VTE L1 Cache Misses	2	30
VTE Line Fetches	2	32
VTE Premature Cancels	2	33
VTE Refresh	1	40
VTE Resume on Context Switch	2	39

Performance Counter Event Name	PMC Number(s)	Event Number
VTE Suspend Context Switch	1	41
VTE0 Fetches	1	39
VTE1 Line Fetches	2	31
VTE2 Line Fetches	3	23
VTE3 Line Fetches	4	21
Window of Opportunity Push Address Tenures	1	43
Write Through Stores	1	31

PPC 7450 (G4+) Performance Counter Event List

The PowerPC 7450 (G4+) cores contain six independent performance counters, each of which can count 20–94 different types of events. CPU cycles can be measured on any counter, five other commonly measured types of events (instructions completed, timebase clock transitions, instructions dispatched, performance monitor interrupts, and external performance monitor events) can also be counted on any of the first four counters, while other types of events can only be counted on a limited subset of the counters.

The table below lists each Event Name, the counter (PMC) number(s) for counters which can count the event, and each event's number.

For more information on how to configure these counters, see "PowerPC G3/G4/G4+ CPU Performance Counter Configuration" (page 197).

Performance Counter Event Name	PMC Number(s)	Event Number
1st Spec Buffer Active Cycles	1	24
2nd Spec Branch Buffer Active	2	56
2nd Spec Branch Buffer Correct	3	27
3rd Spec Branch Buffer Active	3	28
3rd Spec Branch Buffer Correct	4	27
Aligned FP Store Instr	1	65
AltiVec CFX Instr	1, 2, 4	11
AltiVec CFX Stall Cycles	1, 2	17
AltiVec Float Instr	1, 2, 4	9
AltiVec Float Stall Cycles	1, 2	15
AltiVec Issue Queue > Threshold	1	31
AltiVec Issue Stalls	3	11
AltiVec Loads	1	64
AltiVec MFVSCR Instr Sync Cycles	1, 2	18
AltiVec MTVRSAVE Instr	1, 2, 4	13
AltiVec MTVSCR Instr	1, 2, 4	12
AltiVec Permute Instr	1, 2, 4	8

Performance Counter Event Name	PMC Number(s)	Event Number
AltiVec Permute Stall Cycles	1, 2	14
AltiVec SFX Instr	1, 2, 4	10
AltiVec SFX Stall Cycles	1, 2	16
AltiVec VSCR[SAT] 0->1	1, 2	19
Branch Flushes	3	26
Branch Instr	1	34
Branch Link Stack Correct	2	59
Branch Link Stack Mispredicts	3	31
Branch Link Stack Prediction Used	1	27
Branch Unit CTR Stall Cycles	3	29
Branch Unit Stall Cycles	1	25
	2	57
BTIC Hits	1	26
BTIC Misses	2	58
Bus Outstanding Read Queue Full Cycles	6	28
Bus Read/Writes not Retried	6	46
Bus Reads not Retried	6	44
Bus Retries	6	26
Bus Retry from Collision	6	49
Bus Retry from Intervention	6	50
Bus Retry from L1 Retry	6	47
Bus Retry from Prev-Adjacent	6	48
Bus TA's for Reads	6	42
Bus TA's for Writes	6	43
Bus Writes not Retried	6	45
Cache-Inhibited Stores	1	52
Canceled iL1 Misses	3	19

Performance Counter Event Name	PMC Number(s)	Event Number
Completed 0 Instr	1	32
Completed 1 Instr	2	33
Completed 2 Instr	3	8
Completed 3 Instr	4	14
Completion Queue > Threshold	2	32
Complex Integer Instr	1	33
CPU Cycles	1, 2, 3, 4, 5, 6	1
Data Bkpt Matches	2	53
DCBF/DCBST Instr dL1 Hits	3	20
Dispatched 0 Instr	4	15
Dispatched 1 Instr	3	9
Dispatched 2 Instr	2	34
Dispatched 3 Instructions	1	29
Dispatched AltiVec Instr	3	10
dL1 Castouts	2	50
dL1 Cycles	2	41
dL1 Hits	1	56
dL1 Load Hits	1	53
dL1 Load Miss Cycles	3	21
dL1 Load Misses	2	37
dL1 Load-Miss Cycles > Threshold	1	43
dL1 Misses	2, 3	23
dL1 Pushes	3	22
dL1 Reloads	2	49
dL1 Snoop Hit in COQ	1	48
dL1 Snoop Hit in COQ Retry	1	49
dL1 Snoop Hit Modified	1	44

Performance Counter Event Name	PMC Number(s)	Event Number
dL1 Snoop Hits	1	50
dL1 Snoops	1, 2	22
dL1 Store Hits	1	55
dL1 Store Misses	2	39
dL1 Touch Hits	1	54
dL1 Touch Miss Cycles	2	40
dL1 Touch Misses	2	38
dL2 Misses	5, 6	6
dL3 Misses	5, 6	7
	6	34
DSS Instr	1	60
DSSALL Instr	4	19
dst-Instr Dispatched	1	57
DSTx Search Success	1	59
DTLB Misses	3	18
DTLB Search Cycles	4	23
DTLB Search Cycles > Threshold	1	40
DTQ Full	6	25
EIEIO Instr	1	35
Extern Perf Monitor	1, 2, 3, 4	7
External Interventions	6	22
External Pushes	6	23
External Snoop Retries	6	24
Fall Thru Branches	2	54
Fast BTIC Hits	3	30
Folded Branches	4	29
FP Denorm Result	1	94

Performance Counter Event Name	PMC Number(s)	Event Number
FP Denormalize	1	67
FP Instr Dispatched to FPR Queue	2	24
FP Issue Queue > Threshold	3	13
FP Issue Stalls	2	60
FP Load Instr	1	79
FP Load-Double Instr	1	81
FP Load-Single Instr	1	80
FP Renormalize	1	66
FP Store Double Instr	4	30
FP Store Single Instr	2	62
FP Store Stall Cycles	1	68
FPSCR Renames 1/2 Busy	1	91
FPSCR Renames 1/4 Busy	1	90
FPSCR Renames 3/4 Busy	1	92
FPSCR Renames All Busy	1	93
FPU Instr	3	14
GPR Issue Queue > Threshold Cycles	4	16
GPR Issue Queue Stall Cycles	4	17
GPR Rename Buffer > Threshold	3	12
iL1 Accesses	1	41
iL1 Miss Cycles	2	36
iL1 Misses	1, 2	21
iL1 Reloads	2	48
iL2 Misses	5, 6	4
iL3 Misses	5, 6	5
	6	33
Instr Bkpt Matches	1	42

Performance Counter Event Name	PMC Number(s)	Event Number
Instr Completed	1, 2, 3, 4	2
Instr Dispatched	1, 2, 3, 4	4
Instr Dispatched to GPR Queue	1	28
Instr Queue > Threshold	1	30
Interventions	5, 6	18
ITLB Misses	2	35
ITLB Search Cycles	1	39
ITLB Search Cycles > Threshold	3	17
L1 External Interventions	6	19
L2 Castout Queue Full Cycles	6	10
L2 Castouts	6	8
L2 External Interventions	6	20
L2 Hits	5, 6	2
L2 Load Hits	5	8
L2 Misses	5	19
	6	29
L2 Store Hits	5	9
L2 Touch Hits	5, 6	13
L2 Valid Requests	6	27
L3 Castout Queue Full Cycles	6	11
L3 Castouts	6	9
L3 External Interventions	6	21
L3 Hits	5, 6	3
	6	31
L3 Load Hits	5	10
	6	35
L3 Misses	5	20

Performance Counter Event Name	PMC Number(s)	Event Number
	6	30
	6	32
L3 Read Queue Full Cycles	6	16
L3 Store Hits	5	11
	6	36
L3 Touch Hits	5, 6	14
	6	37
L3 Write Queue Full Cycles	6	17
LD/ST Alias vs. CSQ	1	73
LD/ST Alias vs. FSQ/WB0/WB1	1	72
LD/ST CSQ Forwards	1	86
LD/ST Indexed Alias Stalls	1	71
1st Spec Branch Buffer Correct	2	55
LD/ST LMQ Full Stalls	1	78
LD/ST LMQ Index Alias Stalls	1	84
LD/ST Load vs. STQ Alias Stalls	1	83
LD/ST Load-Hit Line vs. CSQ0	1	74
LD/ST Load-Miss Line vs. CSQ0	1	75
LD/ST RA Latch Stall	1	82
LD/ST STQ Index Alias Stalls	1	85
LD/ST Touch Alias vs. CSQ	1	77
LD/ST Touch Alias vs. FSQ/WB0/WB1	1	76
LD/ST True Alias Stalls	1	70
Load Instr	2	26
Load String/Multi Instr Pieces	3	16
Load-Miss Alias	1	45
Load-Miss Alias on Touch	1	46

Performance Counter Event Name	PMC Number(s)	Event Number
Load/Store Instr	2	25
LSWI/LSWX/LMW Instr	1	38
LWARX Instr	2	29
MFSPR Instr	2	30
Mispredicted Branches	4	28
MTSPR Instr	1	36
Nothing	1, 2, 3, 4, 5, 6	0
Perf Monitor Interrupts	1, 2, 3, 4	5
Prefetch Engine Full	6	57
Prefetch Engine Requests	6	52
Prefetch Instr Fetch Collisions	6	55
Prefetch Load Collisions	6	53
Prefetch Load/Store/Instr Fetch Collisions	6	56
Prefetch Store Collisions	6	54
Refetch Serializations	2	31
Refreshed DSTs	1	58
SC Instr	1	37
Simple Integer Instr	4	18
Snoop Modified	5	16
Snoop Requests	6	51
Snoop Retries	4	24
	5, 6	15
Snoop Valid	5	17
Store Instr	1, 2	20
Store Merge to 32 Bytes	2	52
Store Merge/Gathers	2	51
Store String/Multi Pieces	4	22

Performance Counter Event Name	PMC Number(s)	Event Number
STSWI/STSWX/STMW Instr	2	27
STWCX Instr	3	15
Successful STWCX Instr	4	25
SYNC Instr	4	21
Taken Branches	3	25
TimeBase (Lower) 0->1 bit transitions	1, 2, 3, 4	3
TLBIE Instr	2	28
TLBIE Snoops	2	47
TLBSYNC Instr	4	20
Touch Alias	1	47
Unaligned Load Instr	1	87
Unaligned Load/Store Instr	1	89
Unaligned Store Instr	1	88
Unresolved Branches	1	23
User/Supervisor Switches	2	61
VTE Branch Speculation Cancel	2	43
VTE Line Fetch dL1 Hits	1	63
VTE Line Fetch dL1 Miss	2	45
VTE Line Fetches	2	46
VTE Resume on Context Switch	2	44
VTE Suspended on Context Switch	1	62
VTE0 Line Fetches	1	61
VTE1 Line Fetches	2	42
VTE2 Line Fetches	3	24
VTE3 Line Fetches	4	26
Write-Through Stores	1	51

PPC 970 (G5) Performance Counter Event List

The PowerPC 970 (G5) cores contain an extremely sophisticated and complex set of performance counters. Unlike the other processors used in Macintoshes, one cannot simply choose a counter and type of performance counter event for it to count. There are simply too many different possible events in these processors that can be counted. Instead, one must first select various options on the "TTM" and "Byte Lane" muxes in order to narrow down the possible field of events that can be counted, before actually selecting one particular event to count.

The table below lists each Event Name followed by the various selections of event number(s), counter (PMC) number(s), TTM mux settings, and Byte Lane settings that can be used to count that type of event. Where lists of both event and PMC numbers are given in a single row of the table, the corresponding event and PMC numbers (first with first, second with second, etc.) should be used together.

For more information on how to configure these counters, see "PowerPC G5 (970) Performance Counter Configuration" (page 199).

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
1 or more Instrs Completed	3	5		
[FPU] fp0 add, mult, sub, compare, fsel	19	1, 2, 5, 6	0: FPU	0: TTM0
[FPU] fp0 add, mult, sub, compare, fsel + fp1 add, mult, sub, compare, fsel	0	5	0: FPU	0: TTM0
[FPU] fp0 denorm operand	24	1, 2, 5, 6	0: FPU	2: TTM0
[FPU] fp0 denorm operand + fp1 denorm operand	32	1	0: FPU	2: TTM0
[FPU] fp0 divide	16	1, 2, 5, 6	0: FPU	0: TTM0
[FPU] fp0 divide + fp1 divide	0	1	0: FPU	0: TTM0
[FPU] fp0 estimate	18	3, 4, 7, 8	0: FPU	1: TTM0
[FPU] fp0 estimate + fp1 estimate	0	3	0: FPU	1: TTM0
[FPU] fp0 finished and produced a result	19	3, 4, 7, 8	0: FPU	1: TTM0
[FPU] fp0 finished and produced a result + fp1 finished and produced a result	0	4	0: FPU	1: TTM0
[FPU] fp0 fpscr	24	3, 4, 7, 8	0: FPU	3: TTM0

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[FPU] fp0 fpscr + nothing	32	8	0: FPU	3: TTM0
[FPU] fp0 move, estimate	16	3, 4, 7, 8	0: FPU	1: TTM0
[FPU] fp0 move, estimate + fp1 move, estimate	0	8	0: FPU	1: TTM0
[FPU] fp0 mult-add	17	1, 2, 5, 6	0: FPU	0: TTM0
[FPU] fp0 mult-add + fp1 mult-add	0	2	0: FPU	0: TTM0
[FPU] fp0 round, convert	17	3, 4, 7, 8	0: FPU	1: TTM0
[FPU] fp0 round, convert + fp1 round, convert	0	7	0: FPU	1: TTM0
[FPU] fp0 single precision	27	1, 2, 5, 6	0: FPU	2: TTM0
[FPU] fp0 single precision + fp1 single precision	32	5	0: FPU	2: TTM0
[FPU] fp0 square root	18	1, 2, 5, 6	0: FPU	0: TTM0
[FPU] fp0 square root + fp1 square root	0	6	0: FPU	0: TTM0
[FPU] fp0 stall 3	25	1, 2, 5, 6	0: FPU	2: TTM0
[FPU] fp0 stall 3 + fp1 stall 3	32	2	0: FPU	2: TTM0
[FPU] fp0 store	26	1, 2, 5, 6	0: FPU	2: TTM0
[FPU] fp0 store + fp1 store	32	6	0: FPU	2: TTM0
[FPU] fp1 add, mult, sub, compare, fsel	23	1, 2, 5, 6	0: FPU	0: TTM0
[FPU] fp1 denorm operand	28	1, 2, 5, 6	0: FPU	2: TTM0
[FPU] fp1 divide	20	1, 2, 5, 6	0: FPU	0: TTM0
[FPU] fp1 estimate	22	3, 4, 7, 8	0: FPU	1: TTM0
[FPU] fp1 finished and produced a result	23	3, 4, 7, 8	0: FPU	1: TTM0
[FPU] fp1 move, estimate	20	3, 4, 7, 8	0: FPU	1: TTM0
[FPU] fp1 mult-add	21	1, 2, 5, 6	0: FPU	0: TTM0
[FPU] fp1 round, convert	21	3, 4, 7, 8	0: FPU	1: TTM0
[FPU] fp1 single precision	31	1, 2, 5, 6	0: FPU	2: TTM0

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[FPU] fp1 square root	22	1, 2, 5, 6	0: FPU	0: TTM0
[FPU] fp1 stall 3	29	1, 2, 6	0: FPU	2: TTM0
[FPU] fp1 store	30	1, 2, 5, 6	0: FPU	2: TTM0
[GPS] All CO state machines busy	28	1, 2, 5, 6	1: GPS	2: TTM1
[GPS] All read/claim state machines busy	27	1, 2, 5, 6	1: GPS	2: TTM1
[GPS] All read/claim state machines busy + l=1 store queue full	32	5	1: GPS	2: TTM1
[GPS] All snoop state machines busy	29	1, 2, 6	1: GPS	2: TTM1
[GPS] Cacheable store operation (before gathering)	17	3, 4, 7, 8	1: GPS	1: TTM1
[GPS] Cacheable store operation (before gathering) + Master L2 read transaction on bus was retried	0	7	1: GPS	1: TTM1
[GPS] Cacheable store queue full	30	1, 2, 5, 6	1: GPS	2: TTM1
[GPS] l=1 load operation completed on bus	16	3, 4, 7, 8	1: GPS	1: TTM1
[GPS] l=1 load operation completed on bus + Master L2 store transaction on bus was retried	0	8	1: GPS	1: TTM1
[GPS] l=1 store operation (before gathering)	22	1, 2, 5, 6	1: GPS	0: TTM1
[GPS] l=1 store operation completed on bus	23	1, 2, 5, 6	1: GPS	0: TTM1
[GPS] l=1 store queue full	31	1, 2, 5, 6	1: GPS	2: TTM1
[GPS] L2 access collision with L2 prefetch (DST)	16	1, 2, 5, 6	1: GPS	0: TTM1
[GPS] L2 access collision with L2 prefetch (DST) + L2 miss, bus response is modified intervention	0	1	1: GPS	0: TTM1
[GPS] L2 access collision with L2 prefetch (non-DST)	17	1, 2, 5, 6	1: GPS	0: TTM1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[GPS] L2 access collision with L2 prefetch (non-DST) + L2 miss, bus response is shared intervention	0	2	1: GPS	0: TTM1
[GPS] L2 access for store	18	1, 2, 5, 6	1: GPS	0: TTM1
[GPS] L2 access for store + I=1 store operation (before gathering)	0	6	1: GPS	0: TTM1
[GPS] L2 miss on store access (R, S, I)	19	1, 2, 5, 6	1: GPS	0: TTM1
[GPS] L2 miss on store access (R, S, I) + I=1 store operation completed on bus	0	5	1: GPS	0: TTM1
[GPS] L2 miss, bus response is modified intervention	20	1, 2, 5, 6	1: GPS	0: TTM1
[GPS] L2 miss, bus response is shared intervention	21	1, 2, 5, 6	1: GPS	0: TTM1
[GPS] Load or store dispatch retries	26	1, 2, 5, 6	1: GPS	2: TTM1
[GPS] Load or store dispatch retries + Cacheable store queue full	32	6	1: GPS	2: TTM1
[GPS] Load or store dispatch retries due to CO conflicts	24	1, 2, 5, 6	1: GPS	2: TTM1
[GPS] Load or store dispatch retries due to CO conflicts + All CO state machines busy	32	1	1: GPS	2: TTM1
[GPS] Load or store dispatch retries due to Snoop conflicts	25	1, 2, 5, 6	1: GPS	2: TTM1
[GPS] Load or store dispatch retries due to Snoop conflicts + All snoop state machines busy	32	2	1: GPS	2: TTM1
[GPS] Master bus transactions completed	18	3, 4, 7, 8	1: GPS	1: TTM1
[GPS] Master bus transactions completed + Master SYNC operation competed	0	3	1: GPS	1: TTM1
[GPS] Master bus transactions retried	19	3, 4, 7, 8	1: GPS	1: TTM1
[GPS] Master bus transactions retried + Master SYNC operation retried	0	4	1: GPS	1: TTM1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[GPS] Master L2 read transaction on bus was retried	21	3, 4, 7, 8	1: GPS	1: TTM1
[GPS] Master L2 store transaction on bus was retried	20	3, 4, 7, 8	1: GPS	1: TTM1
[GPS] Master SYNC operation competed	22	3, 4, 7, 8	1: GPS	1: TTM1
[GPS] Master SYNC operation retried	23	3, 4, 7, 8	1: GPS	1: TTM1
[GPS] Snoop (external)	24	3, 4, 7, 8	1: GPS	3: TTM1
[GPS] Snoop (external) + Snoop caused cache transition from M to E or S	32	8	1: GPS	3: TTM1
[GPS] Snoop caused cache transition from E or S to R or I	30	3, 4, 7, 8	1: GPS	3: TTM1
[GPS] Snoop caused cache transition from E to S	29	3, 4, 7, 8	1: GPS	3: TTM1
[GPS] Snoop caused cache transition from M to E or S	28	3, 4, 7, 8	1: GPS	3: TTM1
[GPS] Snoop caused cache transition from M to I	31	3, 4, 7, 8	1: GPS	3: TTM1
[GPS] Snoop retried due to all snoop state machines busy	27	3, 4, 7, 8	1: GPS	3: TTM1
[GPS] Snoop retried due to all snoop state machines busy + Snoop caused cache transition from M to I	32	4	1: GPS	3: TTM1
[GPS] Snoop retried due to any conflict	26	3, 4, 7, 8	1: GPS	3: TTM1
[GPS] Snoop retried due to any conflict + Snoop caused cache transition from E or S to R or I	32	3	1: GPS	3: TTM1
[GPS] Snoop state machine dispatched	25	3, 4, 7, 8	1: GPS	3: TTM1
[GPS] Snoop state machine dispatched + Snoop caused cache transition from E to S	32	7	1: GPS	3: TTM1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[IDU] instruction queue fullness	16, 17, 18, 19, 20, 21, 22, 23, 16, 17, 18, 19, 20, 21, 22, 23, 16, 17, 18, 19, 20, 21, 22, 23, 16, 17, 18, 19, 20, 21, 22, 23	3, 4, 4, 4, 4, 4, 4, 4, 4, 7, 7, 7, 7, 7, 7, 7, 8, 8, 8, 8, 8, 8, 8, 8	1: IDU	1: TTM1
[IDU] instruction queue fullness + instruction queue fullness	0	3, 4, 7, 8	1: IDU	1: TTM1
[IFU] branch execution issue valid	25	3, 4, 7, 8	0: IFU	3: TTM0
[IFU] branch execution issue valid + nothing	32	7	0: IFU	3: TTM0
[IFU] branch mispredict due to CR value	26	3, 4, 7, 8	0: IFU	3: TTM0
[IFU] branch mispredict due to CR value + nothing	32	3	0: IFU	3: TTM0
[IFU] branch mispredict due to target address predict	24	3, 4, 7, 8	0: IFU	3: TTM0
[IFU] branch mispredict due to target address predict + valid instructions available, but ifu held by BIQ or IDU	32	8	0: IFU	3: TTM0
[IFU] cycles i L1 write active	27	3, 4, 7, 8	0: IFU	3: TTM0
[IFU] cycles i L1 write active + nothing	32	4	0: IFU	3: TTM0
[IFU] i cache data source	24, 25, 26, 27, 24, 25, 26, 27, 24, 25, 26, 27, 24, 25, 26, 27	1, 2, 2, 2, 2, 5, 5, 5, 5, 6, 6, 6, 6	0: IFU	2: TTM0
[IFU] i cache data source + instr prefetch installed in prefetch buffer	32	6	0: IFU	2: TTM0
[IFU] i cache data source + instruction prefetch request	32	2	0: IFU	2: TTM0

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[IFU] i cache data source + translation written to i erat	32	5	0: IFU	2: TTM0
[IFU] i cache data source + valid instruction available	32	1	0: IFU	2: TTM0
[IFU] instr prefetch installed in prefetch buffer	30	1, 2, 5, 6	0: IFU	2: TTM0
[IFU] instruction prefetch request	29	1, 2, 6	0: IFU	2: TTM0
[IFU] translation written to i erat	31	1, 2, 5, 6	0: IFU	2: TTM0
[IFU] valid instruction available	28	1, 2, 5, 6	0: IFU	2: TTM0
[IFU] valid instructions available, but ifu held by BIQ or IDU	28	3, 4, 7, 8	0: IFU	3: TTM0
[ISU] br issue queue full	21	1, 2, 5, 6	0: ISU	0: TTM0
			1: ISU	0: TTM1
[ISU] completion table full	16	1, 2, 5, 6	0: ISU	0: TTM0
			1: ISU	0: TTM1
[ISU] completion table full + cr mapper full	0	1	0: ISU	0: TTM0
			1: ISU	0: TTM1
[ISU] cr issue queue full	17	3, 4, 7, 8	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] cr issue queue full + flush originated by LSU	0	7	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] cr mapper full	20	1, 2, 5, 6	0: ISU	0: TTM0
			1: ISU	0: TTM1
[ISU] dispatch blocked by scoreboard	25	3, 4, 7, 8	0: ISU	3: TTM0
			1: ISU	3: TTM1
[ISU] dispatch blocked by scoreboard + gpr mapper full	32	7	0: ISU	3: TTM0
			1: ISU	3: TTM1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[ISU] dispatch reject	28	1, 2, 5, 6	0: ISU	2: TTM0
			1: ISU	2: TTM1
[ISU] dispatch valid	27	1, 2, 5, 6	0: ISU	2: TTM0
			1: ISU	2: TTM1
[ISU] dispatch valid + group experienced a branch mispredict	32	5	0: ISU	2: TTM0
			1: ISU	2: TTM1
[ISU] duration MSR(EE) = 0	27	3, 4, 7, 8	0: ISU	3: TTM0
			1: ISU	3: TTM1
[ISU] duration MSR(EE) = 0 + MSR(EE)=0 and interrupt pending	32	4	0: ISU	3: TTM0
			1: ISU	3: TTM1
[ISU] flush (includes LSU, branch mispredict)	23	3, 4, 7, 8	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] flush originated by branch mispredict	22	3, 4, 7, 8	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] flush originated by LSU	21	3, 4, 7, 8	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] fp0 issue queue full	19	1, 2, 5, 6	0: ISU	0: TTM0
			1: ISU	0: TTM1
[ISU] fp0 issue queue full + fp1 issue queue full	0	5	0: ISU	0: TTM0
			1: ISU	0: TTM1
[ISU] fp1 issue queue full	23	1, 2, 5, 6	0: ISU	0: TTM0
			1: ISU	0: TTM1
[ISU] fpr mapper full	17	1, 2, 5, 6	0: ISU	0: TTM0
			1: ISU	0: TTM1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[ISU] fpr mapper full + br issue queue full	0	2	0: ISU	0: TTM0
			1: ISU	0: TTM1
[ISU] fx0 produced a result	26	3, 4, 7, 8	0: ISU	3: TTM0
			1: ISU	3: TTM1
[ISU] fx0 produced a result + fx1 produced a result	32	3	0: ISU	3: TTM0
			1: ISU	3: TTM1
[ISU] fx0/ls0 issue queue full	16	3, 4, 7, 8	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] fx0/ls0 issue queue full + fx1/ls1 issue queue full	0	8	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] fx1 produced a result	30	3, 4, 7, 8	0: ISU	3: TTM0
			1: ISU	3: TTM1
[ISU] fx1/ls1 issue queue full	20	3, 4, 7, 8	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] gpr mapper full	29	3, 4, 7, 8	0: ISU	3: TTM0
			1: ISU	3: TTM1
[ISU] group experienced a branch mispredict	31	1, 2, 5, 6	0: ISU	2: TTM0
			1: ISU	2: TTM1
[ISU] group experienced a branch redirect	30	1, 2, 5, 6	0: ISU	2: TTM0
			1: ISU	2: TTM1
[ISU] instructions dispatched count	24, 25, 26, 24, 25, 26, 24, 25, 26, 24, 25, 26	1, 2, 2, 2, 5, 5, 5, 6, 6, 6	0: ISU	2: TTM0
			1: ISU	2: TTM1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[ISU] instructions dispatched count + dispatch reject	32	1	0: ISU	2: TTM0
			1: ISU	2: TTM1
[ISU] instructions dispatched count + group experienced a branch redirect	32	6	0: ISU	2: TTM0
			1: ISU	2: TTM1
[ISU] instructions dispatched count + nothing	32	2	0: ISU	2: TTM0
			1: ISU	2: TTM1
[ISU] lr/ctr mapper full	22	1, 2, 5, 6	0: ISU	0: TTM0
			1: ISU	0: TTM1
[ISU] LRQ full	18	3, 4, 7, 8	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] LRQ full + flush originated by branch mispredict	0	3	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] MSR(EE)=0 and interrupt pending	31	3, 4, 7, 8	0: ISU	3: TTM0
			1: ISU	3: TTM1
[ISU] SRQ full	19	3, 4, 7, 8	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] SRQ full + flush (includes LSU, branch mispredict)	0	4	0: ISU	1: TTM0
			1: ISU	1: TTM1
[ISU] xer mapper full	18	1, 2, 5, 6	0: ISU	0: TTM0
			1: ISU	0: TTM1
[ISU] xer mapper full + lr/ctr mapper full	0	6	0: ISU	0: TTM0
			1: ISU	0: TTM1
[LSU0] d erat miss side 0	18	1, 2, 5, 6		0: LSU0

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[LSU0] d erat miss side 0 + d erat miss side 1	0	6		0: LSU0
[LSU0] d erat miss side 1	22	1, 2, 5, 6		0: LSU0
[LSU0] d slb miss	21	1, 2, 5, 6		0: LSU0
[LSU0] d tlb miss	20	1, 2, 5, 6		0: LSU0
[LSU0] fl pt load side 0	24	3, 4, 7, 8		3: LSU0
[LSU0] fl pt load side 0 + fl pt load side 1	32	8		3: LSU0
[LSU0] fl pt load side 1	28	3, 4, 7, 8		3: LSU0
[LSU0] i slb miss	17	1, 2, 5, 6		0: LSU0
[LSU0] i slb miss + d slb miss	0	2		0: LSU0
[LSU0] i tlb miss	16	1, 2, 5, 6		0: LSU0
[LSU0] i tlb miss + d tlb miss	0	1		0: LSU0
[LSU0] L1 Prefetch	25	3, 4, 7, 8		3: LSU0
[LSU0] L1 Prefetch + SRQ sync duration	32	7		3: LSU0
[LSU0] L2 Prefetch	27	3, 4, 7, 8		3: LSU0
[LSU0] L2 Prefetch + new stream allocated	32	4		3: LSU0
[LSU0] larx executed 0	31	1, 2, 5, 6		2: LSU0
[LSU0] marked flush from LRQ shl, lhl side 0	18	3, 4, 7, 8		1: LSU0
[LSU0] marked flush from LRQ shl, lhl side 0 + marked flush from LRQ shl, lhl side 1	0	3		1: LSU0
[LSU0] marked flush from LRQ shl, lhl side 1	22	3, 4, 7, 8		1: LSU0
[LSU0] marked flush SRQ lhs side 0	19	3, 4, 7, 8		1: LSU0
[LSU0] marked flush SRQ lhs side 0 + marked flush SRQ lhs side 1	0	4		1: LSU0
[LSU0] marked flush SRQ lhs side 1	23	3, 4, 7, 8		1: LSU0

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[LSU0] marked flush unaligned load side 0	16	3, 4, 7, 8		1: LSU0
[LSU0] marked flush unaligned load side 0 + marked flush unaligned load side 1	0	8		1: LSU0
[LSU0] marked flush unaligned load side 1	20	3, 4, 7, 8		1: LSU0
[LSU0] marked flush unaligned store side 0	17	3, 4, 7, 8		1: LSU0
[LSU0] marked flush unaligned store side 0 + marked flush unaligned store side 1	0	7		1: LSU0
[LSU0] marked flush unaligned store side 1	21	3, 4, 7, 8		1: LSU0
[LSU0] marked imr reload	26	1, 2, 5, 6		2: LSU0
[LSU0] marked imr reload + marked stcx fail	32	6		2: LSU0
[LSU0] marked L1 d cache store miss	27	1, 2, 5, 6		2: LSU0
[LSU0] marked L1 d cache store miss + larx executed 0	32	5		2: LSU0
[LSU0] marked L1 dcache load miss side 0	24	1, 2, 5, 6		2: LSU0
[LSU0] marked L1 dcache load miss side 0 + marked L1 dcache load miss side 1	32	1		2: LSU0
[LSU0] marked L1 dcache load miss side 1	28	1, 2, 5, 6		2: LSU0
[LSU0] marked stcx fail	30	1, 2, 5, 6		2: LSU0
[LSU0] new stream allocated	31	3, 4, 7, 8		3: LSU0
[LSU0] out of streams	26	3, 4, 7, 8		3: LSU0
[LSU0] out of streams + reserved	32	3		3: LSU0
[LSU0] reserved	30	3, 4, 7, 8		3: LSU0
[LSU0] snoop tlbie	19	1, 2, 5, 6		0: LSU0

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[LSU0] snoop tlbie + tablewalk duration	0	5		0: LSU0
[LSU0] SRQ sync duration	29	3, 4, 7, 8		3: LSU0
[LSU0] stcx failed	25	1, 2, 5, 6		2: LSU0
[LSU0] stcx failed + stcx passed	32	2		2: LSU0
[LSU0] stcx passed	29	1, 2, 6		2: LSU0
[LSU0] tablewalk duration	23	1, 2, 5, 6		0: LSU0
[LSU1] flush from LRQ shl,lhl side 0	18	1, 2, 5, 6	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] flush from LRQ shl,lhl side 0 + flush from LRQ shl,lhl side 1	0	6	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] flush from LRQ shl,lhl side 1	22	1, 2, 5, 6	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] flush SRQ lhs side 0	19	1, 2, 5, 6	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] flush SRQ lhs side 0 + flush SRQ lhs side 1	0	5	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
			3: LSU1 6|7	
[LSU1] flush SRQ lhs side 1	23	1, 2, 5, 6	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] flush unaligned load side 0	16	1, 2, 5, 6	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] flush unaligned load side 0 + flush unaligned load side 1	0	1	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] flush unaligned load side 1	20	1, 2, 5, 6	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] flush unaligned store side 0	17	1, 2, 5, 6	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] flush unaligned store side 0 + flush unaligned store side 1	0	2	3: LSU1 2|3	0: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] flush unaligned store side 1	21	1, 2, 5, 6	3: LSU1 2|3	0: LSU1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
	29	5	0: FPU	2: TTM0
			0: ISU	
			0: IFU	
			0: VMX	
			1: IDU	2: TTM1
			1: ISU	
			1: GPS	
				2: LSU0
			3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 d cache store miss	19	3, 4, 7, 8	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
	27	1, 2, 5, 6	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
[LSU1] L1 d cache store miss + L1 dcache entries invalidated from L2	0	4	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 d cache store miss + LSU ls1 reject	32	5	3: LSU1 2|3	2: LSU1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
			3: LSU1 2|7	
[LSU1] L1 dcache entries invalidated from L2	23	3, 4, 7, 8	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 dcache load miss side 0	18	3, 4, 7, 8	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 dcache load miss side 0 + L1 dcache load miss side 1	0	3	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 dcache load miss side 1	22	3, 4, 7, 8	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 dcache load side 0	16	3, 4, 7, 8	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 dcache load side 0 + L1 dcache load side 1	0	8	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[LSU1] L1 dcache load side 1	20	3, 4, 7, 8	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 dcache store side 0	17	3, 4, 7, 8	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 dcache store side 0 + L1 dcache store side 1	0	7	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 dcache store side 1	21	3, 4, 7, 8	3: LSU1 2|3	1: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 reload data source	24, 25, 26, 27, 24, 25, 26, 27, 24, 25, 26, 27, 24, 25, 26, 27	3, 4, 4, 4, 4, 7, 7, 7, 7, 8, 8, 8, 8	3: LSU1 2|3	3: LSU1
			3: LSU1 2|7	
			3: LSU1 6|3	
			3: LSU1 6|7	
[LSU1] L1 reload data source + L1 reload data valid	32	8	3: LSU1 2|3	3: LSU1
			3: LSU1 6|3	
[LSU1] L1 reload data source + LMQ full	32	4	3: LSU1 2|3	3: LSU1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
			3: LSU1 6|3	
[LSU1] L1 reload data source + LMQ load hit reload merge	32	7	3: LSU1 2|7	3: LSU1
			3: LSU1 6|7	
[LSU1] L1 reload data source + LMQ slot 0 allocated	32	3	3: LSU1 2|3	3: LSU1
			3: LSU1 6|3	
[LSU1] L1 reload data source + LMQ slot 0 valid	32	7	3: LSU1 2|3	3: LSU1
			3: LSU1 6|3	
[LSU1] L1 reload data source + Marked L1 reload data source valid	32	8	3: LSU1 2|7	3: LSU1
			3: LSU1 6|7	
[LSU1] L1 reload data source + Marked SRQ valid	32	3	3: LSU1 2|7	3: LSU1
			3: LSU1 6|7	
[LSU1] L1 reload data source + nothing	32	4	3: LSU1 2|7	3: LSU1
			3: LSU1 6|7	
[LSU1] L1 reload data valid	28	3, 4, 7, 8	3: LSU1 2|3	3: LSU1
			3: LSU1 6|3	
[LSU1] LMQ full	31	3, 4, 7, 8	3: LSU1 2|3	3: LSU1
			3: LSU1 6|3	
[LSU1] LMQ load hit reload merge	29	3, 4, 7, 8	3: LSU1 2|7	3: LSU1
			3: LSU1 6|7	
[LSU1] LMQ reject 0 - LMQ full or missed data coming	25	1, 2, 5, 6	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	
[LSU1] LMQ reject 0 - LMQ full or missed data coming + LMQ reject 1- LMQ full or missed data coming	32	2	3: LSU1 6|3	2: LSU1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
			3: LSU1 6|7	
[LSU1] LMQ reject 1- LMQ full or missed data coming	29	1, 2, 6	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	
[LSU1] LMQ slot 0 allocated	30	3, 4, 7, 8	3: LSU1 2|3	3: LSU1
			3: LSU1 6|3	
[LSU1] LMQ slot 0 valid	29	3, 4, 7, 8	3: LSU1 2|3	3: LSU1
			3: LSU1 6|3	
[LSU1] LRQ slot 0 allocated	30	1, 2, 5, 6	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
[LSU1] LRQ slot 0 valid	26	1, 2, 5, 6	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
[LSU1] LRQ slot 0 valid + LRQ slot 0 allocated	32	6	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
[LSU1] LS0 reject - erat miss.	27	1, 2, 5, 6	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	
[LSU1] LS0 reject - erat miss. + LS1 reject - erat miss	32	5	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	
[LSU1] LS0 reject - reload cdf or tag updata collision	26	1, 2, 5, 6	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	
[LSU1] LS0 reject - reload cdf or tag updata collision + LS1 reject - reload cdf or tag updata collision	32	6	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	
[LSU1] LS1 reject - erat miss	31	1, 2, 5, 6	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[LSU1] LS1 reject - reload cdf or tag updata collision	30	1, 2, 5, 6	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	
[LSU1] LSU ls1 reject	31	1, 2, 5, 6	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
[LSU1] Marked L1 reload data source valid	28	3, 4, 7, 8	3: LSU1 2|7	3: LSU1
			3: LSU1 6|7	
[LSU1] Marked SRQ valid	30	3, 4, 7, 8	3: LSU1 2|7	3: LSU1
			3: LSU1 6|7	
[LSU1] SRQ reject 0 - load hit store	24	1, 2, 5, 6	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	
[LSU1] SRQ reject 0 - load hit store + SRQ reject 1- load hit store	32	1	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	
[LSU1] SRQ reject 1- load hit store	28	1, 2, 5, 6	3: LSU1 6|3	2: LSU1
			3: LSU1 6|7	
[LSU1] SRQ slot 0 allocated	29	1, 2, 6	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
[LSU1] SRQ slot 0 valid	25	1, 2, 5, 6	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
[LSU1] SRQ slot 0 valid + SRQ slot 0 allocated	32	2	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
[LSU1] SRQ store forwarding side 0	24	1, 2, 5, 6	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
[LSU1] SRQ store forwarding side 0 + SRQ store forwarding side 1	32	1	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[LSU1] SRQ store forwarding side 1	28	1, 2, 5, 6	3: LSU1 2|3	2: LSU1
			3: LSU1 2|7	
[SPECA] reserved	11	5		
[SPECB] reserved	11	7		
[SPECC] reserved	12	5		
[SPECD] reserved	12	7		
[VMX] ALU issue marked inst	18	1, 2, 5, 6	0: VMX	0: TTM0
[VMX] ALU issue marked inst + Store issue marked inst	0	6	0: VMX	0: TTM0
[VMX] ALU issue queue full	16	1, 2, 5, 6	0: VMX	0: TTM0
[VMX] ALU issue queue full + Sat zero to one	0	1	0: VMX	0: TTM0
[VMX] Denorm traps	19	3, 4, 7, 8	0: VMX	1: TTM0
[VMX] Denorm traps + nothing	0	4	0: VMX	1: TTM0
[VMX] finish contention cycle	21	3, 4, 7, 8	0: VMX	1: TTM0
[VMX] Finish with IMR	16	3, 4, 7, 8	0: VMX	1: TTM0
[VMX] Finish with IMR + Sat bit set	0	8	0: VMX	1: TTM0
[VMX] forwarding occurred from perm or alu or load	29	1, 2, 6	0: VMX	2: TTM0
[VMX] Generic forward	17	3, 4, 7, 8	0: VMX	1: TTM0
[VMX] Generic forward + finish contention cycle	0	7	0: VMX	1: TTM0
[VMX] instruction finish with IMR	28	1, 2, 5, 6	0: VMX	2: TTM0
[VMX] issue valid	30	1, 2, 5, 6	0: VMX	2: TTM0
[VMX] Perm issue marked inst	19	1, 2, 5, 6	0: VMX	0: TTM0
[VMX] Perm issue marked inst + nothing	0	5	0: VMX	0: TTM0
[VMX] Perm issue queue full	17	1, 2, 5, 6	0: VMX	0: TTM0
[VMX] Perm issue queue full + VMX mapper full	0	2	0: VMX	0: TTM0

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
[VMX] Sat bit set	20	3, 4, 7, 8	0: VMX	1: TTM0
[VMX] Sat zero to one	20	1, 2, 5, 6	0: VMX	0: TTM0
[VMX] saturation count for valid instruction	31	1, 2, 5, 6	0: VMX	2: TTM0
[VMX] Store issue marked inst	22	1, 2, 5, 6	0: VMX	0: TTM0
[VMX] VMA issue count	18	3, 4, 7, 8	0: VMX	1: TTM0
[VMX] VMA issue count + nothing	0	3	0: VMX	1: TTM0
[VMX] VMX mapper full	21	1, 2, 5, 6	0: VMX	0: TTM0
BRU marked instr finish	5	2		
Completion Stall by other reason	11	1		
CPU Cycles	15	1, 2, 3, 4, 5, 6, 7, 8		
CPU Cycles (hypervisor)	4	3		
CPU Marked Instruction finish	5	4		
Dispatch Successes	1	5		
dL2 Hit (dL1 reload from L2)	7	1		3: LSU1
dL2 Miss (dL1 reload from Memory)	7	3		3: LSU1
External Interrupt	2	8		
FPU marked instruction finish	4	7		
FXU Marked Instr finish	4	6		
FXU0 busy and FXU1 busy	2	6		
FXU0 busy and FXU1 idle	2	7		
FXU0 Idle and FXU1 Busy	2	4		
FXU0 idle and FXU1 idle	2	5		
GCT Empty	4	1		
GCT empty by SRQ full	11	2		
Group Completed	3	7		
Group Dispatch	4	2		

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
Group Dispatch Reject	3	8		
Group Marked in IDU	4	5		
iL2 Hit (iL1 reload from L2)	6	1	0: IFU	2: TTM0
iL2 Miss (iL1 reload from Memory)	6	3	0: IFU	2: TTM0
Instr Completed (ppc)	9	1, 2, 3, 4, 5, 6, 7, 8		
Instr Completed (ppc,io,ld/st)	1	4, 6, 7, 8		
Instr Src Encode 0 (Lane 2 not set to IFU)	6	1	0: FPU	2: TTM0
			0: ISU	
			0: VMX	
			0: FPU	2: TTM1
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU0
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU1
			0: ISU	
			0: IFU	
			0: VMX	
Instr Src Encode 1 (Lane 2 not set to IFU)	6	2	0: FPU	2: TTM0
			0: ISU	
			0: VMX	
			0: FPU	2: TTM1

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU0
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU1
			0: ISU	
			0: IFU	
			0: VMX	
Instr Src Encode 2 (Lane 2 not set to IFU)	6	3	0: FPU	2: TTM0
			0: ISU	
			0: VMX	
			0: FPU	2: TTM1
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU0
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU1
			0: ISU	
			0: IFU	
			0: VMX	

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
Instr Src Encode 3 (Lane 2 not set to IFU)	6	4	0: FPU	2: TTM0
			0: ISU	
			0: VMX	
			0: FPU	2: TTM1
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU0
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU1
			0: ISU	
			0: IFU	
			0: VMX	
Instr Src Encode 4 (Lane 2 not set to IFU)	6	5	0: FPU	2: TTM0
			0: ISU	
			0: VMX	
			0: FPU	2: TTM1
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU0
			0: ISU	
			0: IFU	
			0: VMX	

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
			0: FPU	2: LSU1
			0: ISU	
			0: IFU	
			0: VMX	
Instr Src Encode 5 (Lane 2 not set to IFU)	6	6	0: FPU	2: TTM0
			0: ISU	
			0: VMX	
			0: FPU	2: TTM1
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU0
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU1
			0: ISU	
			0: IFU	
			0: VMX	
Instr Src Encode 6 (Lane 2 not set to IFU)	6	7	0: FPU	2: TTM0
			0: ISU	
			0: VMX	
			0: FPU	2: TTM1
			0: ISU	
			0: IFU	
			0: VMX	

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
			0: FPU	2: LSU0
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU1
			0: ISU	
			0: IFU	
			0: VMX	
Instr Src Encode 7 (Lane 2 not set to IFU)	6	8	0: FPU	2: TTM0
			0: ISU	
			0: VMX	
			0: FPU	2: TTM1
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU0
			0: ISU	
			0: IFU	
			0: VMX	
			0: FPU	2: LSU1
			0: ISU	
			0: IFU	
			0: VMX	
Instructions Completed (ppc,io,ld/st)	1	1		
LSU empty (LMQ and SRQ empty)	2	2, 3		
LSU Marked Instr finish	4	8		

Performance Counter Event Name	Event Number(s)	PMC Number(s)	TTM Mux Number	Byte Lane Number
Marked Group complete	4	4		
Marked Group Complete Timeout	5	5		
Marked group dispatch	2	1		
Marked Group issued	5	6		
Marked Instr finish in any unit	5	7		
Marked store complete	3	1		
Marked Store Complete w/int.	3	3		
Marked Store sent to GPS	3	6		
Nothing	8	1, 2, 3, 4, 5, 6, 7, 8		
Overflow from PMC1	10	2		
Overflow from PMC2	10	3		
Overflow from PMC3	10	4		
Overflow from PMC4	10	5		
Overflow from PMC5	10	6		
Overflow from PMC6	10	7		
Overflow from PMC7	10	8		
Overflow from PMC8	10	1		
Run Cycles	5	1		
SRQ empty	3	4		
Stop Completion	1	3		
Threshold Timeout	3	2		
Timebase Event	5	8		
VMX Marked Instruction finish	5	3		
Work Held	1	2		

UniNorth-2 (U1.5/2) Performance Counter Event List

The U1.5 and U2 North bridge chipsets contain four independent counters, each of which can count any one of 55 different types of events.

The table lists the events alphabetically by name, followed by the Event Number that must be selected to activate counting of a particular event. Some of the events are suffixed with a term in braces at the end of the event name. for example: If the term is [AGP], then the event can only occur if the AGP event source is active. If an event has no suffix, it can be generated by any active event source. The events suffixed with [Bus] are never generated by any of the sources, only by the front-side bus activities.

For more information, see "U1.5/U2 North Bridges" (page 206).

Performance Counter Event Name	Event Number
Addr-only Xacts Not Retried [Bus]	93
AGP R/W Hit Closed Page [AGP]	49
AGP R/W Hit Open Page [AGP]	48
AGP R/W Miss Open Page [AGP]	50, 100
AGP Read Hit Closed Page [AGP]	52
AGP Read Hit Open Page [AGP]	51
AGP Read Miss Open Page [AGP]	53, 101
All Xacts [Bus]	90
Burst Mem Reads [Bus]	88
Burst Mem Reqs [Bus]	77
Burst Mem Writes [Bus]	89
Burst PCI Reads [Bus]	84
Burst PCI Reqs [Bus]	76
Burst PCI Writes [Bus]	85
Burst Read Reqs [Bus]	72
Burst Write Reqs [Bus]	73
Burst Xacts [Bus]	65
Cache Inhib. Xacts [Bus]	91

Performance Counter Event Name	Event Number
Cycles Addr Bus Busy [Bus]	94
Cycles Data Bus Busy [Bus]	95
MaxBus Cycles [---]	1
Mem Read Reqs [Bus]	80
Mem Requests [Bus]	67
Mem Write Reqs [Bus]	81
PCI Read Reqs [Bus]	78
PCI Requests [Bus]	66
PCI Write Reqs [Bus]	79
R/W Hit Closed Page [Mem]	17
R/W Hit Open Page [Mem]	16
R/W Miss Open Page [Mem]	18
R/W Miss Open page [Mem]	39
R/W Page Hit (LRU) [Mem]	28
R/W Page Hit (MRU) [Mem]	27
Read Hit Closed Page [Mem]	30
Read Hit Open Page [Mem]	29
Read Miss Open page [Mem]	40
Read Miss Open Page [Mem]	31
Read Prefetch Buff Hits [Mem]	99
Read Prefetch Ops [Mem]	98
Read Xacts [Bus]	69
Retries on Maxbus [Bus]	97
Single Beat Mem Reads [Bus]	86
Single Beat Mem Reqs [Bus]	75
Single Beat Mem Writes [Bus]	87
Single Beat PCI Reads [Bus]	82

Performance Counter Event Name	Event Number
Single Beat PCI Reqs [Bus]	74
Single Beat PCI Writes [Bus]	83
Single Beat Read Reqs [Bus]	70
Single Beat Write Reqs [Bus]	71
Single Beat Xacts [Bus]	64
Sync/Eieio Not Retried [Bus]	92
UniN Retries on Maxbus [Bus]	96
Write Xacts [Bus]	68

UniNorth-2 (U1.5/2) Performance Counter Event List

UniNorth-3 (U3) Performance Counter Event List

The U3 North bridge chipsets contain two distinct sets of counters.

The first set of counters counts memory events, in a manner similar to the counters for the other North bridge chips. Six independent memory counters are present, each of which can count any one of five different general types of events. Each of these types may be focused further by filtering events on the basis of their source I/O interface (any combination of the nine independently selectable interfaces may be counted) and three memory page states (for events involving DRAM interaction).

The second set of counters ("API counters") count queueing and buffering events internal to the chip, allowing a more detailed look at its inner workings. Six independent API counters are present, each of which can count any one of six different general types of events. Each of these types may be focused further by filtering events on the basis of their source queue/buffer (any one from among 51 possible sources).

The first of the three tables in this appendix lists the memory events alphabetically by name, followed by the Event Number that needs to be selected to activate counting of a particular event. The second table does the same for the API performance counters. Finally, the third table provides a list of the sources for API events and their corresponding numbers.

For more information, see "U3 North Bridge" (page 207).

Memory Performance Counter Event Name	Event Number
Cycles 1 or more queues have 0 entries	8
Cycles 1 or more queues have 2 entries	16
DRAM Clock Cycles (no filters apply, 1/2 DDR freq.)	1
Nothing	0
Number of Memory Transactions	2
Read/write request beats (bytes=beats*16)	4

API Performance Counter Event Name	Event Number
Accumulate Queue Requests	0x02
API Cycles	0x00
Nothing	0xFF
Queue Reservations	0x03
Queue Transactions	0x01

API Performance Counter Event Name	Event Number
Retries	0x05
Transaction Size (bytes)	0x04

API Event Source Name	Source Number
API0 Mem MI Target Rq Queue	0x1A
API0 Mem Rd Target Rq Queue	0x16
API0 Mem Wt Target Rq Queue	0x18
API1 Mem MI Target Rq Queue	0x1B
API1 Mem Rd Target Rq Queue	0x17
API1 Mem Wt Target Rq Queue	0x19
Command Slot	0x01
Ht Coh Rd Rq Queue	0x13
Ht Coh Wt Rq Queue	0x14
Ht Rd Data Queue	0x90
Ht Rd Target Rq Queue	0x09
Ht Response Queue	0x0E
Ht Wt Data Queue	0x40
Ht Wt Target Rq Queue	0x08
Intervention Queue	0x03
Master Tag: All	0xE00
Master Tag: API0	0x200
Master Tag: API0 and API1	0x400
Master Tag: API1	0x300
Master Tag: HT	0xA00
Master Tag: PCI	0x900
Master Tag: VSP	0x800
Master Tag: VSP, PCI, and HT	0xC00
Mem Rd Data Queue	0x70

API Event Source Name	Source Number
Mem Rd Target Rq Queue	0x05
Mem Response Queue	0x0C
Mem Wt Data Queue	0x20
Mem Wt Target Rq Queue	0x04
Pci Coh Rd Rq Queue	0x11
Pci Coh Wt Rq Queue	0x12
Pci Rd Data Queue	0x80
Pci Rd Target Rq Queue	0x07
Pci Response Queue	0x0D
Pci Wt Data Queue	0x30
Pci Wt Target Rq Queue	0x06
Reg Rd Data Queue	0xB0
Reg Response Queue	0x10
Reg Target Rq Queue	0x0B
Reg Wt Data Queue	0x60
Snoop Slots	0x02
Synchronization Queue	0x00
Vsp Coh Rd Rq Queue	0x15
Vsp Rd Data Queue	0xA0
Vsp Response Queue	0x0F
Vsp Target Rq Queue	0x0A
Vsp Wt Data Queue	0x50
Write Data Buffer	0x100
Write Data Buffer API0 MI	0x130
Write Data Buffer API0 Wr	0x110
Write Data Buffer API1 MI	0x140
Write Data Buffer API1 Wr	0x120

UniNorth-3 (U3) Performance Counter Event List

Kodiak (U4) Performance Counter Event List

The U4/Kodiak North bridge chipsets contain two distinct sets of counters.

The first set of counters counts memory events, in a manner similar to the counters for the other North bridge chips. Six independent memory counters are present, each of which can count any one of 22 different general types of events. Each of these types may be focused further by filtering events on the basis of their source interface (any combination of the seven independently selectable sources may be counted).

The second set of counters ("API counters") count queueing and buffering events internal to the chip, allowing a more detailed look at its inner workings. Six independent API counters are present, each of which can count any one of six different general types of events. Each of these types may be focused further by filtering events on the basis of their source queue/buffer (any one from among 33 possible sources) and source I/O interface (any combination of the six independently selectable interfaces may be counted simultaneously).

The first of the three tables in this appendix lists the memory events alphabetically by name, followed by the Event Number that needs to be selected to activate counting of a particular event. The second table does the same for the API performance counters. Finally, the third table provides a list of the sources for API events and their corresponding numbers.

For more information, see "U4 (Kodiak) North Bridge" (page 210).

Memory Performance Counter Event Name	Event Number
Activate commands -- open page (filtered and counted)	7
Bottom entry aged (count events, no filters)	64
Cache line sized transfers -- 128 bytes (filtered and counted)	3
Commands with auto-precharge enabled (filtered and counted)	5
Conflict detected in oldest read reorder queue (count events, no filters)	32
DRAM Cycle Count (1/2 DDR frequency, no filters)	255
Entries in non-coherent request queue (accumulate events, no filters)	113
Entries in read reorder queue (accumulate events, no filters)	81
Entries in write reorder queue (accumulate events, no filters)	80
Issued transfer size (accumulate events, no filters)	83
Non-coherent read request [RT #24253] (count events, no filters)	97
Non-coherent request [RT #24252] (count events, no filters)	96
Nothing	0

Memory Performance Counter Event Name	Event Number
Precharge commands -- close page (filtered and counted)	6
Read reorder queue empty (count events, no filters)	17
Read requests (filtered and counted)	1
Request queue empty [RT #23441] (count events, no filters)	16
Requested transfer size (accumulate events, no filters)	82
Requested transfer size from non-coherent queue (accumulate events, no filters)	112
RMW transfers (filtered and counted)	4
Write high watermark reached (count events, no filters)	48
Write reorder queue empty (count events, no filters)	18
Write requests (filtered and counted)	2

API Performance Counter Event Name	Event Number
Accumulate Queue Requests	0x02
API Cycles	0x00
Nothing	0xFF
Queue Reservations	0x03
Queue Transactions	0x01
Retries	0x05
Transaction Size (bytes)	0x04

API Event Source Name	Source Number
API Wt Data Buffer	0x28
Bypass Queue	0x10
Command Slot	0x01
GCR Rd Data Queue	0x27
GCR Response Queue	0x0B
GCR Target Rq Queue	0x08
GCR Wt Data Queue	0x23

API Event Source Name	Source Number
Ht Coh Rd Pending Queue	0x14
Ht Coh Rd Rq Queue	0x0E
Ht Coh Wt Pending Queue	0x15
Ht Coh Wt Rq Queue	0x0F
Ht Rd Data Queue	0x26
Ht Rd Target Rq Queue	0x07
Ht Response Queue	0x0A
Ht Wt Data Queue	0x22
Ht Wt Target Rq Queue	0x06
Intervention Buffer	0x29
Memory Rd Buffer (NI)	0x2A
Memory Request Queue	0x11
Memory Response Buffer	0x20
Memory Wt Data Buffer	0x24
PCIE Coh Rd Pending Queue	0x12
PCIE Coh Rd Rq Queue	0x0C
PCIE Coh Wt Pending Queue	0x13
PCIE Coh Wt Rq Queue	0x0D
PCIE Rd Data Queue	0x25
PCIE Rd Target Rq Queue	0x05
PCIE Response Queue	0x09
PCIE Wt Data Queue	0x21
PCIE Wt Target Rq Queue	0x04
Power Management	0x3F
Snoop Slots	0x02
Synchronization Queue	0x00

ARM11 Performance Counter Event List

The ARM11 cores used in iOS devices contain three independent performance counters. The first counter can count only cycle counts, while the other two (which are identical) can count 25 different types of events.

The table below lists each Event Name, the counter (PMC) number(s) for counters which can count the event, and each event's number.

For more information on how to configure these counters, see "ARM11 CPU Performance Counter Configuration" (page 212).

Performance Counter Event Name	PMC Number(s)	Event Number
Branch instruction executed	2-3	5
Branch mispredicted	2-3	6
Cycle Count	1,2-3	0,255
Data cache access, no cache operations (cacheable accesses only)	2-3	9
Data cache access, no cache operations	2-3	10
Data cache miss, no cache operations	2-3	11
Data cache writeback per 4 words	2-3	12
Data MicroTLB miss	2-3	4
ETMEXTOUT[0,1] asserts	2-3	34
ETMEXTOUT[0] asserts	2-3	32
ETMEXTOUT[1] asserts	2-3	33
Explicit external data access	2-3	16
Instruction cache miss requires fetch	2-3	0
Instruction executed	2-3	7
Instruction MicroTLB miss	2-3	3
Main TLB miss	2-3	15
Procedure call instruction executed	2-3	35
Procedure return instruction executed, return address predicted incorrectly	2-3	38

Performance Counter Event Name	PMC Number(s)	Event Number
Procedure return instruction executed, return address predicted	2-3	37
Procedure return instruction executed	2-3	36
Software changed the PC	2-3	13
Stall, data dependency	2-3	2
Stall, instruction buffer cannot deliver	2-3	1
Stall, LSU request queue full	2-3	17
Write buffer drained count	2-3	18

Document Revision History

This table describes the changes to *Shark User Guide*.

Date	Notes
2008-04-14	TBD
2007-10-31	New document that explains how to analyze code performance by profiling the system.

Document Revision History