Intel(R) Thread Profiler for Windows*

Getting Started Guide

Intel® Thread Profiler helps you improve the performance of applications threaded with Windows® API, OpenMP*, or POSIX* threads (Pthreads*). Use Thread Profiler to:

- Identify bottlenecks that limit the parallel performance of your multi-threaded application.
- Locate synchronization delays, stalled threads, excessive blocking time, and ineffective utilization of processors.
- Find the best sections of code to optimize for sequential performance and for threaded performance.
- Compare scalability across different numbers of processors or using different threading methods.

Overview

This guide presents a threaded code example and shows you how to use Thread Profiler to identify performance issues. After completing this guide, you will be ready to analyze and optimize your own code using Thread Profiler.

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Revision History

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1  **Build the Sample Code**

The Primes example is a prime number generator that uses the Windows* threading API. The code identifies and tallies the prime numbers from one to 100,000 by testing whether odd numbers are evenly divisible by smaller odd factors. The code generates four threads to do the work using Windows* API.

1. **Open the Primes.dsw Project Workspace file in Microsoft* Visual Studio. By default, this project is installed with Thread Profiler in:**
   C:\Program Files\Intel\VTune\tprofile\samples\Primes.

2. **Build the Primes.dsw project.**
   This project includes the following options: /Zi to include symbols, /Od to disable optimization, /fixed:no linker option to make code relocatable, and /MDd to build with thread-safe run-time libraries. These options are required to enable Thread Profiler to provide you with detailed information such as variable names and line numbers associated with performance problems.
   The project creates a debug image, Primes.exe.

**TIP:** To quickly start using Thread Profiler, print this short guide and walk through the example provided.

**TIP:** See Thread Profiler online Help for more hints on options and building applications.

**TIP:** Your applications do not need to be rebuilt with these options in order to benefit from Thread Profiler analysis. However, using the recommended options helps Thread Profiler give you the most detailed information about your code.

**NOTE:** Thread Profiler’s analysis of programs that use OpenMP* compiled using supported Intel compilers differs from the examples presented in this guide.
2 Collect Data

The Intel® Thread Profiler Wizard enables you to easily generate and collect performance data on your threaded code. To use the wizard:

1. Start the Intel(R) Thread Profiler from, for example, Start > All Programs > Intel(R) Software Development Tools > Intel(R) Thread Profiler > Intel(R) Thread Profiler.
   Or, double-click the Intel(R) Thread Profiler icon on your desktop.
2. In the Easy Start dialog box or from the main toolbar, click the New Project button, \[\ldots\] to open the New Project dialog box.
3. In the Category drop-down box, choose Threading Wizards and select Intel® Thread Profiler Wizard as shown:

4. Enter a Project Name, for example, PrimesProject.
5. Click OK. The Intel® Thread Profiler Wizard opens.
6. Under Threading Type, select Threaded (Windows* threads, POSIX* threads, and OpenMP* analysis).
7. Under Launch an application, click \[\ldots\] to navigate to the debug build of Primes.exe you built, located in …\Primes\Debug\Primes.exe.
8. Click Finish to complete the wizard.
   Thread Profiler instruments your application, executes it, collects and displays data results. The data results include instrumentation time.
9. Click \[\ldots\] to rerun your instrumented application. Thread Profiler now displays data that represent times for application execution only.

The exact results vary depending on your system configuration, but you should see two color charts, one with horizontal bars, one with vertical bars. Congratulations! You are now ready to identify and locate bottlenecks that are limiting the parallel performance of the sample software.

**TIP:** If you do not see results, open Help > Search and search “Troubleshooting Thread Profiler” for possible causes and solutions.
3 Analyze Results and Correct the Code

In this section, you will walk through Intel® Thread Profiler’s main views to identify performance issues related to threading. You will then consider ways to improve the performance of the sample code.

3.1 Profile View

By default, Thread Profiler displays Profile and Timeline views as shown in Figure 1:

![Figure 1 Profile and Timeline views are the default views for Intel(R) Thread Profiler Activity results.](image)

The Profile view (on top) displays a high-level summary of the time spent on the critical path, decomposed into time categories. The Timeline view (on bottom) illustrates the behavior of your program over time.

By default, Profile view initially shows results grouped by Concurrency Level, the number of active threads executing at the same time on the critical path. It includes...
threads which are currently running or are run queued and not waiting at a defined waiting or blocking API.

Double-click the tallest red bar in Profile view to drill down to group by Objects. Now the Objects button,  on the Profile view’s toolbar is selected and you can compare time due to different software objects as shown in Figure 2.

![Profile view grouped by Objects](image.png)

**Figure 2 Profile view grouped by Objects. In this case, the majority of time was spent in Under Utilized (red) time.**

Hover your mouse over a column to see more detailed data.

Thread Profiler shows columns corresponding to objects that cause contention on the critical path. You can see more detail about how time was spent on the Critical Path by checking **Behavior** in the **Legend** as shown in Figure 3:
Analyze Results and Correct the Code

Figure 3 Profile view's Legend enables you to select different levels of information to display by checking or unchecking options such as Concurrency and Behavior. Hover your mouse over the legend to show definition tooltips.

In this example, most of the time on the critical path is attributed to a Fork-Join object associated with thread 5: FindPrimes. The thread name is based on the function name of its entry point. The fork-join object implies that there could be imbalance between thread 2 and the thread waiting for thread 2.

In Profile view, you can also:

- Click any bar to display the detailed timing information in the Statistics table under the graph.
- Double-click any bar to "drill down" to the next logical level of grouping.
- Right-click any bar and select Filter Selection to filter by the current selection.
- Right-click a bar and select Filter and Group by > to filter and group by Concurrency Level, Thread, Object, Object Type, or Source Stack. You can also use the corresponding toolbar buttons to group data by the same categories.
- Apply second-level grouping using the secondary set of toolbar buttons:

- For certain types of data, you can right-click and select to Filter and Show Source Locations.
3.2 Timeline View

Timeline view shows the contribution of each thread to the total program, whether on the default critical path or not.

Figure 4 Timeline view shows the behavior of a program over time and across threads.

Notice in Figure 4 that the four created threads take increasingly longer to run. Thread 2, represented by the next-to top bar, works on a set of small numbers that take little time to check. Thread 3 checks a set of larger numbers, taking longer. Threads 4 and 5 check larger numbers, taking longer to complete. Though the program accomplishes its task, the loading is clearly unbalanced. In the next section, you will explore ways to improve the parallelism in this code example. Meanwhile, take a closer look at the Timeline view.

Thread Profiler tracks the flow of all threads in the application. The longest continuous path through the flows is defined as the default critical path. You can also set your own critical path targets to focus your analysis on a particular path or thread by right-clicking and selecting Change or Add Critical Path Target where you want the new target to appear. Use this feature to focus on a thread that is of particular interest to you, even if it is not on the default critical path.

In Timeline view, you can use the Legend to hide or show the corresponding time categories that appear in the Profile view. You can also chose to hide or show
Transitions, Forks and Joins, and User events that you defined. When you mouse over the different elements in the Timeline view’s Legend, the corresponding elements flash in the graph, helping you to locate or identify different elements in the graph.

In Timeline view you can also:

- Drag your mouse over a section of the Timeline view and release to zoom in on that section.
- Use the horizontal and vertical zoom buttons on the toolbar, to help you focus on a particular section of the graph. This feature is particularly useful when you have vast quantities of densely displayed data.
- Double-click a bar to drill-down to Source view to see where an event is happening in your code.

### 3.3 Time Categories

Thread Profiler breaks time into different Time Categories, represented in the graphs and Legends by different colors. In this example, the critical path is composed of the following time categories, with Behavior checked:

- **Serial & Impact** time (orange) indicates serial portions of the code.
- **Under Utilized & Impact** time (red) indicates that the code is not fully utilizing all processors.
- **Fully Utilized & Impact** time (green) indicates that portions of the code demonstrate good processor utilization.

Ideally, on a multi-processor system, your code should be characterized by a predominance of Fully Utilized time (the sum of all the greens). All other time categories indicate opportunities for improving performance. In this case, more efficient code would be characterized by more Fully parallel time than Under Utilized time, so there are opportunities to enhance performance.
To understand time categories:

1. In the **Profile** or **Timeline** view, press **F1** to open the online **Help**. A related help topic opens, as shown in Figure 5.
2. Click the link **Legend for Profile and Timeline Views** to open a topic that describes the elements of the legend.
3. Read the **Help** topic and follow links to related topics.

![Figure 5 Help topic for Profile and Timeline View. Press F1 to access help topics.](image)

In the **Help** you can also:

- Click entries in the **Contents** pane to jump to a topic.
- Click the **Search** tab to open the search window to find a topic on a particular subject.
- Find tips for improving your code such as **Dealing with Impact Time** for valuable tips on ways to reduce the delays on the critical path.
- Click the locate button on the **Help** toolbar, **Locate** to browse to related topics in the **Contents**.
To correct the imbalance and reduce the overhead identified during analysis, try the solutions presented in this section. Corrected versions of the sample code are provided for you to check your results and note the differences.

4.1 Solution: Increase Parallel Execution Time

The revised code in the sample PrimesBalanced.cpp interleaves the numbers each thread checks so that each thread works on both small and large values. To verify that the imbalance problem identified by Thread Profiler as a performance issue is indeed fixed, do the following:

1. Build the modified code which is in PrimesBalanced.cpp.
2. Right-click the project name to create a new Activity. Collect data using Intel® Thread Profiler. You can quickly create a new Activity result for the modified example, PrimesBalanced.exe by pressing the F5 key, or by clicking the Run Activity button.

4.2 Analyze Results

In Profile view, you should see improvements in the form of longer Fully Utilized (green) execution times. Note the little bit of Overhead (yellow) which indicates the delay of a transition of the critical path from one thread to the next.

In Timeline view, the threads now show improved workload balance over the original example.

4.3 Eliminate Overhead

You can further improve performance by eliminating overhead associated with entering and leaving the CRITICAL_SECTION. Since you really only need to control access to the incrementing of variable PrimeCount, you can use the InterlockedIncrement API to reduce overhead. See the PrimesLockfree.cpp sample for an implementation of this fix.
5 Next Steps

Before using Intel® Thread Profiler to improve performance, use the Intel® Thread Checker to verify that your code is free of conditions that could lead to inconsistent results. Find details about Thread Checker and other Intel software development products at: http://www.intel.com/software/products/.

To get the most out of Thread Profiler, explore the following resources:

- **Online Help** is the product’s complete user’s guide. Use Help to learn about features not mentioned in this Guide including remote data collection and other advanced options.
  Open Help by pressing the F1 key.

- **Samples** provide additional code examples for you to explore. Use them to learn to identify and resolve other types of threading errors.
  Open code samples in the tprofile\samples folder. Read the associated Guide to Sample Code, CodeExamplesGuide.pdf, available in the tprofile\Doc folder.

- **Release Notes** include key product details. See the Release Notes for updated information on requirements, technical support, and known limitations.
  Open Release Notes from, for example, Start > Programs > Intel(R) Software Development Tools > Intel(R) Thread Profiler > Intel(R) Thread Profiler Release Notes.