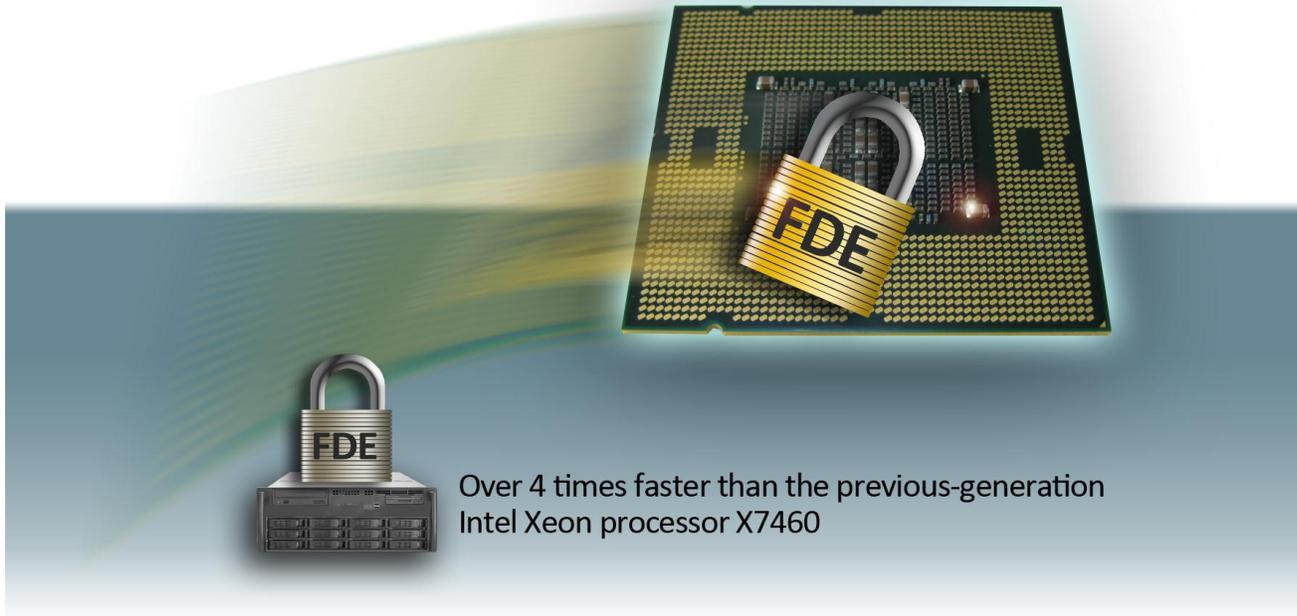


## Intel® Xeon® processor E7-4870: All the safety of full disk encryption At almost no performance cost



Over 4 times faster than the previous-generation Intel Xeon processor X7460

### Executive summary

Because your company's servers store sensitive information, you understand the importance of guarding against data theft. You also strive to minimize the power demands of your servers. While full disk encryption (FDE) is very powerful—the gold standard for data protection—it has traditionally carried a significant performance price and required power-hungry servers. Many businesses have considered the trade-offs involved and elected to forego the security FDE offers so they can avoid the crippling database performance hit and increased power usage that would accompany it.

Happily, this trade-off is no longer necessary. In our hands-on testing of the new Intel Xeon processor E7-4870, featuring Intel Advanced Encryption Standard New Instructions (AES-NI), we were able to invoke the protection of full disk encryption with minimal performance and power impact. We showed that enabling FDE reduced database performance by only 3.85 percent, a dramatic improvement over the unacceptable 21.89 percent performance decrease FDE caused when we enabled it on a similarly configured legacy server with the previous-generation Intel Xeon processor X7460. In addition, the Intel Xeon processor E7-4870-based server delivered more than four times the performance and approximately four times the performance per watt of the Intel Xeon processor X7460-based server when both ran using FDE.



# INTEL REMOVES THE FDE PERFORMANCE HIT

## Mea culpa

On March 14, 2011, executives from the managed care organization Health Net, Inc. announced that nine server drives from its California data center were currently “unaccounted for.” These hard drives hold the names, Social Security numbers, addresses, and health and financial information of approximately 1.9 million current and former policyholders and employees.<sup>1</sup>

As these situations become increasingly common, the need for full disk encryption becomes more urgent than ever.

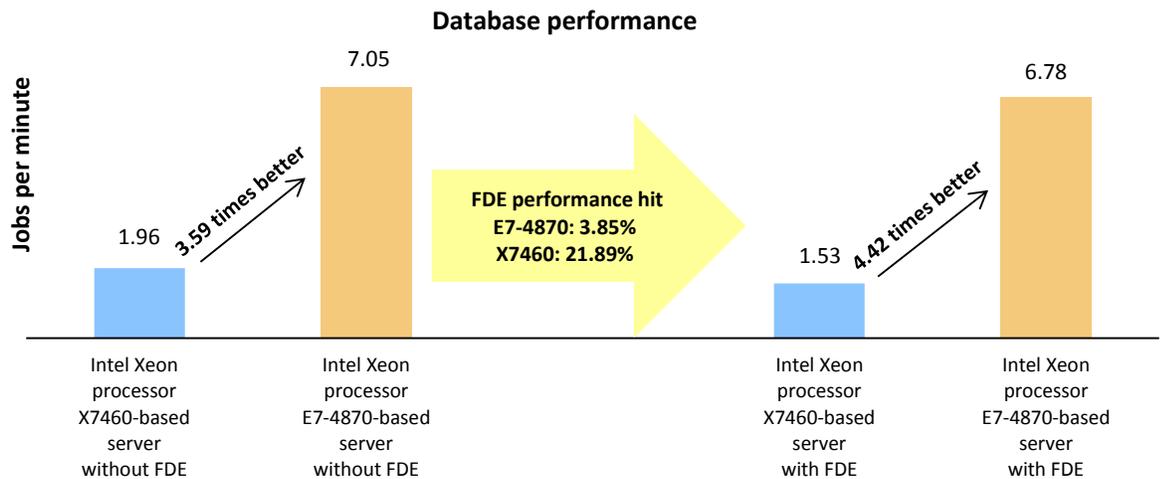
Picture this: Despite your best efforts at security, an entire server hard drive full of sensitive company data is in the wrong hands. The root cause could be as malicious as a criminal removing a server from the building or as innocuous as an employee failing to wipe the hard drives on a server sent out for repair.<sup>2</sup> Once the device is at large, your only hope is that whoever now possesses it cannot access the data it holds. That’s where Intel AES-NI, and FDE come in. But can you run FDE and still achieve acceptable performance?

Based on our findings, the answer is an emphatic “yes.” We measured the database performance of the two servers, both with and without FDE, and present our findings in jobs per minute (JPM). The performance boost of the new Intel Xeon processor E7-4870 using AES-NI was significant enough to allow our server to use FDE and still run database applications quickly.

## Performance boost

The new Intel Xeon processor E7-4870-based server achieved 4.42 times the performance of the previous-generation Intel Xeon processor X7460-based legacy server when both ran FDE, and 3.59 times the performance when neither ran FDE. We show specific JPM results below. Note the minimal performance impact, only 3.85 percent, from enabling FDE on the Intel Xeon processor E7-4870-based server.

Figure 1: The Intel Xeon processor E7-4870-based server demonstrated superb database performance, even with FDE enabled, making fast performance with robust encryption a reality.



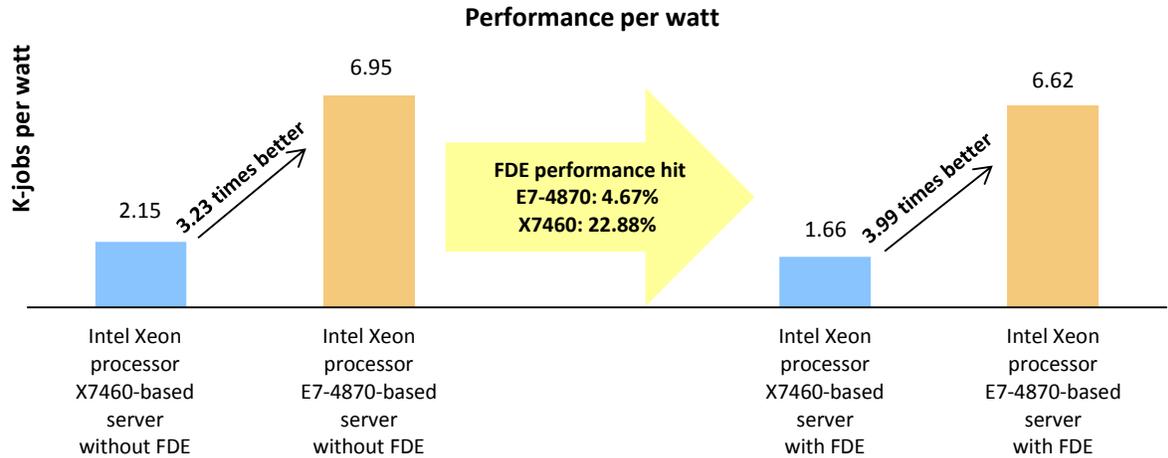
<sup>1</sup> <http://www.californiahealthline.org/articles/2011/3/15/health-net-reports-data-breach-affecting-19m-current-past-enrollees.aspx>

<sup>2</sup> In 2009, at the National Archive and Records Administration, this actually happened, resulting in the breach of over 70 million personnel records of US military veterans. <http://www.scmagazineuk.com/lost-hard-drive-could-affect-70-million-us-military-veterans/article/151478/>

## Performance-per-watt improvement

The Intel Xeon processor E7-4870-based server delivered 3.99 times better performance per watt than the Intel Xeon processor X7460-based server when each ran FDE, and 3.23 times better performance per watt when neither ran FDE. We show specific K-jobs-per-watt results below. The performance-per-watt impact of enabling FDE on the Intel Xeon processor E7-4870-based server was minimal, only 4.67 percent.

Figure 2: The Intel Xeon processor E7-4870-based server achieved impressive performance-per-watt results, even with FDE enabled.



## Faster full disk encryption

We also measured the time each server took to encrypt the data store volume (an eight-disk RAID 5). The Intel Xeon processor E7-4870-based server did so 36.90 percent faster: 53 minutes vs. 84 minutes on the Intel Xeon processor X7460-based server.

## INTEL AES-NI AND FDE: PART OF YOUR INSURANCE POLICY AGAINST DATA THEFT

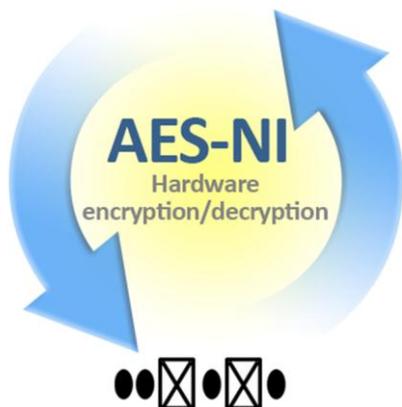
(Note: If you're already familiar with cryptography, AES-NI, and FDE, you might want to skip to the [detailed test results](#).)

### From pottery recipes to national security

Cryptography, or the hiding of sensitive information, has existed for as long as people have had something to hide. From its humble origins circa 1500 BC as an encrypted Mesopotamian pottery glaze recipe, the practice of cryptography has evolved, becoming increasingly complex. In 2001, the US Government adopted the Advanced Encryption Standard for protection of classified data.

The AES algorithm uses a symmetric block cipher method to convert data to an unreadable ciphertext; AES then decrypts this ciphertext and converts it into readable plaintext. AES offers a variety of key lengths, the highest of which (192 and 256) are sufficiently strong that the National Security Agency uses

John Doe DOB 02/15/1975



**Intel AES-NI speeds up AES encryption.**

#### Getting serious about data loss

These US government and industry regulations now enforce strict encryption rules and impose severe penalties on companies who fail to comply:

- Health Insurance Portability and Accountability Act of 1996 requires health data to be encrypted. Penalties: 10-year prison sentence and \$25,000 maximum yearly fine.
- Health Information Technology for Economic and Clinical Health Act of 2009 requires companies to notify media and government after unencrypted data is breached, sets encryption standards for data.
- Sarbanes-Oxley Act requires strict security guidelines, and defines best practices. Penalties: 10-year prison sentence and \$15,000,000 maximum fine.
- Payment Card Industry Data Security Standard requires encryption of card and account numbers. Penalty: Fines up to \$500,000.

them to protect top-secret data. AES was specifically designed to make effective use of computing resources, offering high speed with minimal RAM usage.

### New Intel instructions optimize AES

With AES-NI, Intel has created a set of seven new instructions for its new Xeon processor series. Each instruction accelerates the encryption and decryption process by using processor hardware to speed up portions of the AES algorithms. Four improve encryption and decryption, two improve matrix manipulation and key generation, and one improves carry-less multiplication (which improves error-correcting codes, data deduplication, and general-purpose cyclic redundancy checks).

Additionally, the fact that Intel AES-NI is hardware based means that server drives are less vulnerable to attacks that exploit certain types of data held in the memory of software-based AES. For example, a cache-based software-side channel attack can detect changes in the memory cache, allowing it to identify parts of the cryptographic key value. A server using an AES-NI encrypted hard drive isn't vulnerable to such attacks because it executes its instructions in hardware.

The end result? Servers powered by the Intel Xeon processor E7-4870 offer faster and more secure AES encryption than servers using previous-generation processors.

### FDE helps keep your data safe

Full disk encryption refers to a drive that has been encrypted, either via hardware or via encryption software such as BitLocker, which we used in our testing. Most FDE methods encrypt everything on the drive except the master boot record (i.e., they encrypt swap space, temporary files, etc.). This avoids scenarios where users forget to encrypt certain folders, which unauthorized individuals can access after a data breach. FDE ensures that data on a lost or stolen server hard drive will be unreadable, thus helping your company to comply with the numerous federal and industry regulations designed to protect consumers' confidential data (see sidebar).

Because any server using FDE must encrypt and decrypt data while also running applications, FDE has typically imposed a substantial performance hit on disk-intensive database operations. The more disk-intensive the activity, the greater the impact FDE has had on servers. Until now.

## TEST RESULTS IN MORE DETAIL

Figure 5 shows our detailed test results, with and without FDE, for the older Intel Xeon processor X7460-based server and the newer Intel Xeon processor E7-4870-based server. Higher JPM is better, while lower times and processor utilization are better. We used Benchmark Factory to create our workload.

The Intel Xeon processor E7-4870-based server delivered 3.59 times more JPM than the Intel Xeon processor X7460-based server when neither ran FDE, and delivered 4.42 times more JPM when both ran FDE. The Intel Xeon processor E7-4870-based server utilized its processors more efficiently, using 8.41 percent less of its processor than the Intel Xeon processor X7460-based processor when neither ran FDE, and 7.65 percent less of its processor when both ran FDE.

Benchmark Factory results			
Intel Xeon processor-based server	Jobs per minute	Time to run 132 jobs (seconds)	Processor utilization
Intel Xeon processor X7460-based server without FDE	1.96	4,035	99.39%
Intel Xeon processor X7460-based server with FDE	1.53	5,166	99.09%
Intel Xeon processor E7-4870-based server without FDE	7.05	1,123	91.03%
Intel Xeon processor E7-4870-based server with FDE	6.78	1,168	91.51%

Figure 5: Detailed Benchmark Factory results for the two servers, with and without FDE.

Figure 6 shows the power and K-jobs-per-watt results. Lower power and higher K-jobs-per-watt results are better. The power numbers are approximately 100 watts higher for the Intel Xeon processor E7-4870-based server—an acceptable tradeoff for a four-fold performance increase. We calculated K-jobs per watt as jobs per minute divided by the wattage.

Power and K-jobs-per-watt results		
Intel Xeon processor-based server	Power (W)	K-jobs per watt
Intel Xeon processor X7460-based server without FDE	912.68	2.15
Intel Xeon processor X7460-based server with FDE	924.37	1.66
Intel Xeon processor E7-4870-based server without FDE	1,015.48	6.95
Intel Xeon processor E7-4870-based server with FDE	1,024.22	6.62

Figure 6: Detailed power and K-jobs-per-watt results for the two servers, with and without FDE.

We explain our system specs in [Appendix A](#), our test tools in [Appendix B](#), and our test methodology in [Appendix C](#).

## FINAL THOUGHTS

The Intel Xeon processor E7-4870-based servers show how Intel AES-NI increases database performance on server hard drives that are also running FDE, while also saving power. Compared with servers circa 2008 based on the Intel Xeon processor X7460 series, fully encrypted performance improved by over 4 times, along with increased K-jobs per watt and lower total time to encrypt RAID storage. Simply stated, the Intel Xeon processor E7-4870 processor eliminates the either/or choice of great performance or FDE, allowing you to enjoy both.

Encrypting your server drives puts your organization on the right side of numerous government and industry regulations, and makes you more confident in your ability to protect sensitive information. The accompanying performance increase, as well as the decreased processor and power utilization, means you'll be running demanding database applications at top speeds with FDE.

## APPENDIX A – SERVER AND STORAGE CONFIGURATION INFORMATION

Figure 7 provides detailed configuration information about the test servers.

Servers	Intel Xeon processor X7460-based server	Intel Xeon processor E7-4870-based server
<b>General processor setup</b>		
Number of processor packages	4	4
Number of cores per processor package	6	10
Number of hardware threads per core	1	2
<b>CPU</b>		
Vendor	Intel	Intel
Name	Xeon X7460	Xeon E7-4870
Stepping	A1	F2
Socket type	Socket PGA604	Socket LGA1567
Core frequency (GHz)	2.66	2.40
Bus frequency	1,066	6.4 GT/s Intel QuickPath Interconnect
L1 cache (KB)	32 KB + 32 KB (per core)	32 KB +32 KB (per core)
L2 cache (KB)	3 x 3 MB (each 3 MB shared by 2 cores)	256 KB (per core)
L3 cache (MB)	16	30
Thermal design power (TDP, in watts)	130	130
<b>Platform</b>		
Vendor and model number	Intel S7000FC4UR	Quanta QCI QSSC-S4R
Motherboard model number	D56804-302	31S4RMB00A0
Motherboard chipset	Intel 7300 Chipset	Intel 7500 Chipset
BIOS name and version	SFC4UR.86B.01.00.0033 (11/24/2010)	Intel QSSC-S4RQCI.01.00.S012.031420111618 (03/14/2011)
BIOS settings	Default	Default
<b>Memory modules</b>		
Vendor and model number	Kingston KVR667D2D4F5/8G	Samsung M393B1K70CH0-YH9
Type	PC2-5300F DDR2	PC3-10600 DDR3
Speed (MHz)	667	1,333
Speed in the system currently running @ (MHz)	667	1,066
Timing/Latency (tCL-tRCD-iRP-tRASmin)	5-5-5-15	7-7-7-37.5
Size (GB)	256	256
Number of RAM modules	32 x 8 GB	32 x 8 GB
Chip organization	Double-sided	Double-sided

Servers	Intel Xeon processor X7460-based server	Intel Xeon processor E7-4870-based server
<b>Solid state drive</b>		
<b>Disk #1</b>		
Vendor and model number	Intel SSDA2CW600G3	Intel SSDA2CW600G3
Number of disks in system	2	2
Size (GB)	600	600
Type	SATA 3GB/s	SATA 3GB/s
Controller	Intel RAID Controller RS2BL080 6Gb/s SAS	Intel RAID Controller RS2BL080 6Gb/s SAS
<b>Disk #2</b>		
Vendor and model number	Intel SSDSA2SH064G1GC	Intel SSDSA2SH064G1GC
Number of disks in system	8	8
Size (GB)	64	64
Type	SATA 3GB/s	SATA 3GB/s
Controller	Intel RAID Controller RS2BL080 6Gb/s SAS	Intel RAID Controller RS2BL080 6Gb/s SAS
<b>Operating system</b>		
Name	Windows Server 2008 R2 Enterprise	Windows Server 2008 R2 Enterprise
Build number	7601	7601
File system	NTFS	NTFS
Language	English	English
<b>Network card/subsystem</b>		
Vendor and model number	Intel PRO/1000 EB	Intel 82576NS Gigabit Ethernet Controller
Type	Integrated	Integrated
<b>USB ports</b>		
Number	5	5
Type	USB 2.0	USB 2.0

Figure 7: Detailed configuration information for the test servers.

## APPENDIX B – THE TEST TOOLS WE USED

In this section, we discuss the tools we used in our tests.

### Benchmark Factory TPC-H-like workload

We used Quest Software® Benchmark Factory® as our test engine, using its custom load scenario feature to create a TPC-H-like business intelligence database workload. (While Benchmark Factory's workload is similar to the more widely known Transaction Processing Performance Council (TPC) benchmarks, the results are not directly comparable.) We used Benchmark Factory's workload because it focuses on decision support systems, which run complex queries, examine large data volumes, and provide answers to important business questions.

The workload results show the time taken in seconds to complete a defined 22-query workload. We call these queries jobs to avoid confusion with metrics from other benchmarks. Taking less time to perform the same task is better. We converted this run time to a jobs-per-minute (JPM) metric, making a repeatable real-world measurement of the actions our servers carried out. We ran six test users for testing, each running the 22 jobs, for a total of 132 jobs. We calculate JPM by multiplying the 132 jobs times 60 (the number of seconds in a minute), and then dividing that number by the run time in seconds.

For more details about the Benchmark Factory software, see <http://www.quest.com/benchmark-factory/>.

### BitLocker

Microsoft includes BitLocker™ full disk Drive Encryption with the following operating systems: Ultimate and Enterprise editions of Windows Vista and Windows 7, and Windows Server 2008 and Server 2008 R2. BitLocker uses 128-bit key AES encryption, and allows you to easily and transparently encrypt entire volumes, either on a single drive or across multiple drives, and to encrypt removable drives. BitLocker automatically encrypts any new files you add to a drive (or drives), and checks the drive(s) for security threats each time you start up the computer. Note that BitLocker locks down the drive if it detects a security hazard, and you must then use a recovery key in gain access to your data. Like all FDE methods, BitLocker exacts a performance hit on any drive that uses it.

To learn more about BitLocker, visit

<http://windows.microsoft.com/en-US/windows7/products/features/bitlocker>

## APPENDIX C – DETAILED TEST METHODOLOGY

Here, we explain the detailed steps we followed to set up our test scenario.

### Setting up the servers

We installed a fresh copy of Windows Server 2008 R2 Enterprise Edition on each server.

#### Installing Windows Server 2008 R2 Enterprise Edition

1. Boot the server, and insert the Windows Server 2008 R2 installation DVD in the DVD-ROM drive.
2. At the Language Selection Screen, click Next.
3. Click Install Now.
4. Select Windows Server 2008 R2 Enterprise (Full Installation), and click Next.
5. Click the I accept the license terms check box, and click Next.
6. Click Custom.
7. Click Drive options (advanced).
8. Ensure you select the proper drive, and click New.
9. Click Apply.
10. Click Next.
11. At the User's password must be changed before logging on warning screen, click OK.
12. Type `Password1` as the new password in both fields, and click the arrow to continue.
13. At the Your password has been changed screen, click OK.

#### Installing system updates in Windows Server 2008 R2

We installed all available updates on each server using the Windows Update feature.

#### Installing SQL Server 2008 R2 on the server

1. Insert the installation DVD for SQL Server 2008 R2 (X64) into the DVD drive.
2. If autoplay does not begin the installation, navigate to the SQL Server 2008 DVD, and double-click.
3. If a .NET installation prompt appears, click Yes to enable the .NET Framework Core role.
4. At the SQL Server Installation Center screen, click Installation.
5. Click New installation or add features to an existing installation.
6. At the Setup Support Rules screen, click OK.
7. At the Product Key screen, specify the free Enterprise edition evaluation, and click Next.
8. At the License Terms screen, accept the license terms, and click Next.
9. At the Setup Support Files screen, click Install.
10. At the Setup Support Rules screen, click Next.
11. At the Setup Role screen, choose SQL Server Feature Installation, and click Next.
12. At the SQL Server 2008 R2 Feature Selection screen, select the following features: Database Engine Services, Full-Text Search, Client Tools Connectivity, Client Tools Backwards Compatibility, Management Tools – Basic, Management Tools – Complete, and click Next.
13. At the Installation Rules screen, click Next.
14. At the Instance Configuration screen, leave the defaults, and click Next.
15. At the Disk Space Requirements screen, click Next.
16. At the Server Configuration screen, choose the service account, fill in a password if necessary, and click Next.
17. At the Database Engine Configuration screen, select Mixed Mode, fill in a password for the system administrator (sa) account, click Add Current User, and click Next.
18. At the Error Reporting screen, click Next.
19. At the Installation Configuration Rules screen, click Next.

20. At the Installation screen, click Install.
21. At the Complete screen, click Close.

### Configuring SQL Server to run Benchmark Factory 6.5

1. Click Start→All Programs→Microsoft SQL Server 2008 R2→SQL Server Management Studio.
2. Select SQL Server Authentication, type sa and Password1 as your login and password respectively, and click Connect.
3. Use the script below to create a blank database.

```
CREATE DATABASE tpch150s ON
PRIMARY
(name=tpch150s_data1,filename='e:\tpch150s_data1.mdf',size=30000mb,filegrowth
h=100mb),
(name=tpch150s_data2,filename='e:\tpch150s_data2.mdf',size=30000mb,filegrowth
h=100mb),
(name=tpch150s_data3,filename='e:\tpch150s_data3.mdf',size=30000mb,filegrowth
h=100mb),
(name=tpch150s_data4,filename='e:\tpch150s_data4.mdf',size=30000mb,filegrowth
h=100mb),
(name=tpch150s_data5,filename='e:\tpch150s_data5.mdf',size=30000mb,filegrowth
h=100mb),
(name=tpch150s_data6,filename='e:\tpch150s_data6.mdf',size=30000mb,filegrowth
h=100mb),
(name=tpch150s_data7,filename='e:\tpch150s_data7.mdf',size=30000mb,filegrowth
h=100mb),
(name=tpch150s_data8,filename='e:\tpch150s_data8.mdf',size=30000mb,filegrowth
h=100mb)
LOG ON
(name=tpch150s_log,filename='c:\logs\tpch150s_log.ldf',size=1000mb,filegrowth
h=100mb)
GO

ALTER DATABASE tpch150s SET RECOVERY BULK_LOGGED
GO
```

### Setting up the client

We installed a fresh copy of Windows 7 Ultimate Edition on the client machine.

### Installing Benchmark Factory on the client

1. Right-click BenchmarkFactory\_6\_5\_0\_332.msi, and select Install.
2. At the Welcome screen, click Next.
3. Accept the License Terms, and click Next.
4. At the Destination Folder screen, click Next.
5. At the Ready to Install the Program screen, select Yes, install the default repository database, and click Install.
6. At the Installation Wizard Completed screen, click Finish.
7. Click Start→All Programs →Quest Software→Benchmark Factory for Databases.
8. At the Benchmark Factory repository tables prompt, click OK.
9. At the Load Scenario Wizard screen, click Cancel.
10. Click Help and Select Licensing.
11. Select Modify→Edit Key, and enter Benchmark factory Authorization Key, and Site Message.

12. Click OK, and click Close. Restart Benchmark Factory.

### Configuring Benchmark Factory

1. Click Start→All Programs→Quest Software→Benchmark Factory for Databases.
2. At the Welcome to the Load Scenario Wizard screen, click Next.
3. At the Select Load Scenario screen, select Industry standard benchmarks (TPC-C, TPC-E, TPC-H...), and click Next.
4. At the Select Benchmark screen, select TPC-H, and click Next.
5. At the Select Profile screen, click New.
6. At the Welcome to the Profile Creation wizard screen, click Next.
7. Choose Microsoft SQL Server (Obsolete), and click Next.
8. At the Connection Information screen, enter the server name, select SQL Server Authentication as the Authentication mode, and enter login credentials.
9. Select the TPC-H database, and click Next.
10. At the Profile Name screen, enter a name for the newly created profile, and click Next.
11. Click Finish.
12. At the Select Profile screen, select the newly created profile, and click Next.
13. At the Benchmark Scale screen, enter the appropriate benchmark scale, and click Next.
14. Select Create a new Benchmark Factory Script file, and click Next.
15. Uncheck Do you want the job to be automatically submitted to the jobs Queue?, and click Finish.
16. Click Create Objects for TPC-H, click the Submit to jobs queue icon, and click Submit.

### Backing up the database

1. Start SQL Server Management Studio by selecting Start→All Programs→Microsoft SQL Server 2008 R2→SQL Server Management Studio.
2. In the Object Explorer pane, browse to Databases node and right-click the database.
3. Choose Properties→Options
4. Scroll down to Restrict Access and choose SINGLE\_USER.
5. Click OK, and accept the warning to disconnect other users.
6. Right-click on the database again and choose Tasks→Back up...
7. Specify the desired path to your backup file.
8. Choose to compress the backup file, and click OK to begin the backup.
9. When the backup is finished, click OK to close the success message.

### Executing the benchmark

We completed the following steps each time we executed a full run in order to ensure that each run was uncontaminated by the previous run. We performed three runs on each server to ensure that our results were valid representations of server performance.

### Encrypting the data drive

We encrypted the data drive anew for each run to ensure a clean start.

1. Start perfmon.
2. Click Start→Control Panel→System and Security→BitLocker.
3. Encrypt drive E:
4. Choose to save the key to a password, and fill in a password.
5. Choose save to a file.

6. Click Yes on the pop-up.
7. Click Next.
8. Start power for encryption.
9. Wait 2 minutes.
10. Click Start to begin encrypting.

### Starting the run

Once the drive finished encrypting, we performed the following steps to run Benchmark Factory:

1. Click Start→All Programs→SQL Server 2008 R2→SQL Server Configuration Manager, and start the SQL service.
2. Start perfmon.
3. Start power recording.
4. Open Benchmark Factory
5. Queue up the 10 minute wait task.
6. Queue up the Power task.
7. Queue up the 10 minute wait task.
8. Queue up the six user task.
9. Wait until Benchmark Factory finishes.

### Cleaning up after the run

Once Benchmark Factory finished, we performed the following steps to restore the server to its beginning state.

Be sure to re-encrypt the data drive before running Benchmark Factory again.

1. On the server, pull up the SQL manager and drop the database (tpch150s) by choosing Delete and checking Close existing connections.
2. Click Start→All Programs→SQL Server 2008 R2→SQL Server Configuration Manager, and stop the SQL service.
3. Wait for memory and CPU utilization to stabilize.
4. Open the disk manager, and delete the data drive (E).
5. Reboot the server.
6. Log into the RAID console.
7. Click the Logical tab→VD\_0.
8. Right-click the RAID, and click Delete.
9. Go to the dashboard wizard, and select the raid controller (non-embedded).
10. Create a new virtual drive.
11. Click Advanced.
12. Choose RAID 5 and "Auto" Power-save mode from the dropdown menus.
13. Select all drives, and click Add.
14. Click create drive group.
15. Click Next.
16. Choose Full Initialization, No read ahead policy, Always write back, and disabled disk cache policy from the dropdown menus.
17. Click Create drive.
18. Click Yes on the pop-up.
19. Click Next.
20. Click Finish.
21. Format the drive once the RAID has finished forming. Choose GPT on the popup, and click OK.
22. Choose New Simple Volume.
23. Click Next.

24. Click Next.
25. Label the volume, and uncheck Quick Format.
26. Click Next.
27. Click Finish.
28. Click Start→All Programs→SQL Server 2008 R2→SQL Server Configuration Manager, and start the SQL service.
29. Open the management studio.
30. Open File→Recent files sql\_files\restore150s.sql.  

```
RESTORE DATABASE [tpch150s] FROM DISK = N'C:\tpch150s.bak' WITH FILE = 1,  
NOUNLOAD, STATS = 1  
GO  
USE [master]  
GO  
ALTER DATABASE [tpch150s] SET AUTO_CREATE_STATISTICS OFF  
GO  
ALTER DATABASE [tpch150s] SET AUTO_UPDATE_STATISTICS OFF  
GO  
ALTER DATABASE [tpch150s] SET DATE_CORRELATION_OPTIMIZATION ON  
GO
```
31. Click Execute.
32. When SQL is finished, click Start→All Programs→SQL Server 2008 R2→SQL Server Configuration Manager, and stop the SQL service.
33. Reboot the server.

## ABOUT PRINCIPLED TECHNOLOGIES



Principled Technologies, Inc.  
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Our founders, Mark L. Van Name and Bill Catchings, have worked together in technology assessment for over 20 years. As journalists, they published over a thousand articles on a wide array of technology subjects. They created and led the Ziff-Davis Benchmark Operation, which developed such industry-standard benchmarks as Ziff Davis Media's Winstone and WebBench. They founded and led eTesting Labs, and after the acquisition of that company by Lionbridge Technologies were the head and CTO of VeriTest.

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