



TPC Benchmark™ E
Full Disclosure Report for

FUJITSU Server
PRIMERGY RX4770 M3

Using

Microsoft SQL Server 2016
Enterprise Edition

Using

Microsoft Windows Server 2012 R2
Standard Edition

TPC-E Version 1.14.0

Submitted for Review

July 12, 2016

First Edition July 2016

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Benchmark results are highly dependent upon workload, specific application requirements, system design and implementation. Relative system performance will vary as a result of these and other factors. Therefore, TPC Benchmark™ E should not be used as a substitute for a specific customer application benchmark when critical capacity planning and/or product evaluation decisions are contemplated.

All performance data contained in this report were obtained in a rigorously controlled environment. Results obtained in other operating environments may vary significantly. We do not warrant or represent that a user can or will achieve similar performance expressed in transactions per second (tpsE) or normalized price/performance (\$/tpsE). No warranty of system performance or price/performance is expressed or implied in this report.

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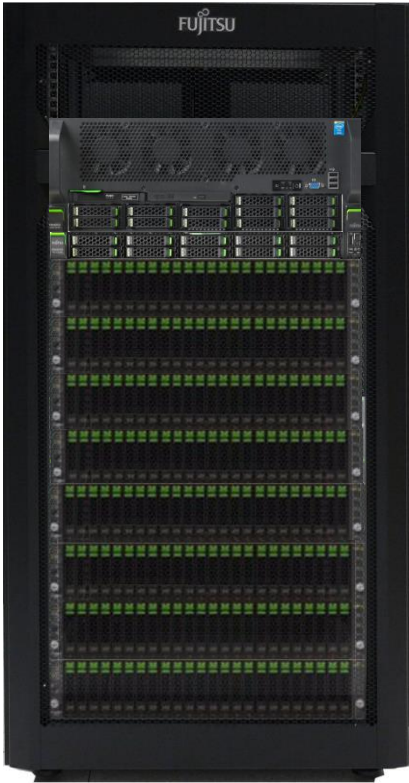
Abstract

This report documents the TPC Benchmark™ E results achieved by Fujitsu using Microsoft SQL Server 2016 Enterprise. The TPC Benchmark™ E tests were run on a PRIMERGY RX4770 M3 system using the Microsoft Windows Server 2012 R2 Standard Edition operating system.

The results, summarized below, show the number of TPC Benchmark™ E transactions per second (tpsE) and the price per tpsE (\$/tpsE).

| Hardware | Software | Total System Cost | tpsE | \$ USD/tpsE | Availability Date |
|---|--|--------------------------|-----------------|----------------------|--------------------------|
| Fujitsu PRIMERGY RX4770 M3 | Microsoft SQL Server 2016 Enterprise Edition Microsoft Windows Server 2012 R2 Standard Edition | \$ 1,025,815 USD | 8,796.47 | \$ 116.62 USD | July 31, 2016 |

The benchmark implementation and results were audited by Doug Johnson for InfoSizing Inc. (www.sizing.com). The auditor's attestation letter is contained in Section 8 of this report.

| | | | | |
|---|---|--|--|---|
|  | | FUJITSU Server PRIMERGY RX4770 M3 | | TPC-E 1.14.0 TPC Pricing 2.0.0 |
| | | | | Report Date July 12, 2016 |
| TPC-E Throughput 8,796.47 tpsE | Price/Performance \$ 116.62 USD per tpsE | Availability Date July 31, 2016 | Total System Cost \$ 1,025,815 USD | |
| Database Server Configuration | | | | |
| Operating System Microsoft Windows Server 2012 R2 Standard Edition | Database Manager Microsoft SQL Server 2016 Enterprise Edition | Processors/Cores/Threads 4/96/192 | Memory 2048 GB | |
| SUT | | | | |
|  | | Tier A PRIMERGY RX2530 M1 2x Intel Xeon E5-2697 v3 2.60 GHz 64 GB Memory 2x 300 GB 15k rpm SAS Drive 2x onboard LAN 10 Gb/s 1x Dual Port LAN 1 Gb/s 1x SAS RAID controller | | |
| | | Tier B PRIMERGY RX4770 M3 4x Intel Xeon E7-8890 v4 2.20 GHz 2048 GB Memory 2x 300 GB 15k rpm SAS Drives 6x 600 GB 15k rpm SAS Drives 2x onboard LAN 10 Gb/s 8x SAS RAID Controller | | |
| Storage 1x PRIMECENTER Rack 7x ETERNUS JX40 S2 168x 400 GB SSD Drives | | | | |
| Initial Database Size 36,951 GB | Redundancy Level 1 RAID-5 data and RAID-10 log | Storage 168 x 400 GB SSD 6 x 600 GB 15k rpm HDD | | |



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PRIMERGY RX4770 M3**

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| Description | Part Number | Price Source | Unit Price | Qty | Extended Price | 3-yr. Maint. Price |
|---|--------------------------|--------------|------------|---------------------|----------------|--------------------|
| Database Server (Tier B) Hardware | | | \$ | | \$ | \$ |
| PRIMERGY RX4770 M3 | | | | | | |
| PY RX4770 M3 | S26361-K1504-V200 | 1 | 5,970.00 | 1 | 5,970.00 | |
| Power Supply Module 1600W w/o power cord | S26113-F5295-E160 | 1 | 483.00 | 2 | 966.00 | |
| Cable powercord (USA), 1.8m, grey | T26139-Y1742-E10 | 1 | 13.00 | 2 | 26.00 | |
| Intel Xeon E7-8890v4 24C/48T 2.20GHz | S26361-F3896-E490 | 1 | 11,727.00 | 4 | 46,908.00 | |
| Memory Board RX4770 M2 | S26361-F5295-E200 | 1 | 623.00 | 6 | 3,738.00 | |
| 64GB (2x32GB) 2Rx4 DDR4-2400 R ECC | S26361-F3898-E642 | 1 | 1,435.00 | 32 | 45,920.00 | |
| Memory Independent Mode Installation | S26361-F5295-E4 | 1 | 7.00 | 1 | 7.00 | |
| HD SAS 12G 300GB 15K HOT PL 2.5' EP | S26361-F5531-E530 | 1 | 545.00 | 2 | 1,090.00 | |
| HD SAS 12G 600GB 15K HOT PL 2.5' EP | S26361-F5531-E560 | 1 | 942.00 | 6 | 5,652.00 | |
| PRAID EP400i | S26361-F5243-E1 | 1 | 454.00 | 1 | 454.00 | |
| PRAID EP420e FH | S26361-F3847-E2 | 1 | 735.00 | 7 | 5,145.00 | |
| Rack Mount Kit F2-C LV | S26361-F2735-E285 | 1 | 119.00 | 1 | 119.00 | |
| Mounting of RMK in symmetrical racks | S26361-F4530-E10 | 1 | 2.00 | 1 | 2.00 | |
| region-kit America | S26361-F1452-E130 | 1 | 13.00 | 1 | 13.00 | |
| PYRX4770 Series during normal business hours, Primergy Installation, Mdrange Server, w/o OS, One Time billing | PYR477-N038005-0NA | 1 | 350.00 | 1 | | 350.00 |
| PYRX4770 Series Warranty Uplift, 36 Months, Enhanced Plus Level, 24x7 4hr Onsite, Prepaid billing | PYR477_S26361-K1484-V200 | 1 | 1,309.00 | 1 | | 1,309.00 |
| | | | | Subtotal (*) | 116,010 | 1,659 |
| Storage | | | | | | |
| PRIMECENTER RACK | | | | | | |
| PRIMECENTER M1 Rack 724S 24U-1050x700 | S26361-K827-V220 | 1 | 2,704.00 | 1 | 2,704.00 | |
| Dummy panel, plastics, 1U + assembly | S26361-F4530-L131 | 1 | 17.00 | 3 | 51.00 | |
| Dummy panel, plastics, 2U + assembly | S26361-F4530-L132 | 1 | 23.00 | 2 | 46.00 | |
| Socket strip 8x IEC320 + IEC319 plug 32A | S26361-F2262-L45 | 1 | 326.00 | 2 | 652.00 | |
| PYPRIMECENTER during normal business hours, PRIMERGY Installation, Racks, One Time billing | PYPCTR-N076005-0NA | 1 | 265.00 | 1 | | 265.00 |
| PYPRIMECENTER Warranty Uplift, 36 Months, Enhanced Plus Level, 24x7 4hr Onsite, Prepaid billing (PYPCTR-U004361-0NA) | PYPCTR-U004361-0NA | 1 | 540.00 | 1 | | 540.00 |
| | | 1 | | | | |
| ETERNUS JX40 | | | | | | |
| ETERNUS JX40 S2 Enclosure w 1x IOM | FTS:ETJEADU | | 2,234.00 | 7 | 15,638.00 | |
| JX40 S2 MLC SSD 400GB | FTS:ETJ4SA4 | 1 | 2,032.00 | 168 | 341,376.00 | |
| MiniSAS-HD cable1.1m | FTS:ETJ4KM11-L | 1 | 73.00 | 7 | 511.00 | |
| PYJX40 Warranty Uplift, 24 Months, Enhanced Plus Level, 24x7x365 Phone Support (Sev1 - Live Transfer), 24x7x365 Onsite and Parts (Sev1 Resp. Time - 4 Hours), Incl. Holidays, Prepaid billing | PYJX40-U004121-0NA | 1 | 1,218.00 | 7 | | 8,526.00 |
| PYJX40 Post Warranty, 12 Months, Enhanced Plus Level, 24x7x365 Phone Support (Sev1 - Live Transfer), 24x7x365 Onsite and Parts (Sev1 Resp. Time - 4 Hours), Incl. Holidays, Prepaid billing | PYJX40-P004241-0NA | 1 | 950.00 | 7 | | 6,650.00 |
| PYJX40 during normal business hours, Primergy storage installation, One Time billing | PYJX40-N043005-0NA | 1 | 450.00 | 7 | | 3,150.00 |
| | | | | Subtotal(*) | 360,978 | 19,131 |



FUJITSU Server PRIMERGY RX4770 M3

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| Database Server (Tier B) Software | | | | | | |
|--|--------------------------|-----|-----------|--------------------|------------|--------|
| SQL Server 2016 Enterprise Edition 2 Core License | 7JQ-00256 | 2 | 13,472.50 | 48 | 646,680.00 | |
| Microsoft Windows Server 2012 R2 Standard Edition 2 Processor License | P72-06284 | 2 | 735.00 | 2 | 1,470.00 | |
| Microsoft Problem Resolution Services | n/a | 2 | 259.00 | 1 | | 259.00 |
| | | | | Subtotal | 648,150 | 259 |
| Application Server (Tier A) Hardware | | | | | | |
| PRIMERGY RX2530 M1 | | | | | | |
| PY RX2530 M1 4x 2.5" expandable | S26361-K1492-V301 | 1 | 1,227.00 | 1 | 1,227.00 | |
| Modular PSU 450W platinum hp | S26113-F575-E13 | 1 | 292.00 | 2 | 584.00 | |
| Cable powercord rack, 4m, grey | T26139-Y1968-E100 | 1 | 13.00 | 2 | 26.00 | |
| Cool-safe Advanced Thermal Design | S26361-F3776-E101 | 1 | 4.00 | 1 | 4.00 | |
| Intel Xeon E5-2697v3 14C/28T 2.60 GHz | S26361-F3849-E197 | 1 | 4,072.00 | 2 | 8,144.00 | |
| Cooler Kit 2nd CPU | S26361-F3849-E100 | 1 | 35.00 | 1 | 35.00 | |
| 8GB (1x8GB) 2Rx8 DDR4-2133 R ECC | S26361-F3843-E515 | 1 | 202.00 | 8 | 1,616.00 | |
| Performance Mode Installation | S26361-F3694-E2 | 1 | 7.00 | 2 | 14.00 | |
| DVD ROM Ultralim | S26361-F3718-E2 | 1 | 104.00 | 1 | 104.00 | |
| HD SAS 12G 300GB 15K HOT PL 2.5" EP | S26361-F5531-E530 | 1 | 545.00 | 2 | 1,090.00 | |
| PRAID EP400i | S26361-F5243-E1 | 1 | 454.00 | 1 | 454.00 | |
| PLAN EM 2x10Gb T OCl14000-LOM interface | S26361-F5302-E210 | 1 | 640.00 | 1 | 640.00 | |
| PLAN CP 2x1Gbit Cu Intel I350-T2 LP | S26361-F4610-E202 | 1 | 264.00 | 1 | 264.00 | |
| Rack Mount Kit F1-CMA Slim Line | S26361-F2735-E400 | 1 | 92.00 | 1 | 92.00 | |
| Mounting of RMK in symmetrical racks region-kit America | S26361-F4530-E10 | 1 | 7.00 | 1 | 7.00 | |
| | S26361-F1452-E130 | 1 | 13.00 | 1 | 13.00 | |
| PYRX2530 M1 during normal business hours, Primergy Installation, Midrange Server, w/o OS, One Time billing | PYR253-N038005-ONA | 1 | 350.00 | 1 | | 350.00 |
| PYRX2530 M1 Warranty Uplift, 36 Months, Enhanced Plus Level, 24x7 4hr Onsite, Prepaid billing | PYR253_S26361-K1492-V301 | 1 | 931.00 | 1 | | 931.00 |
| | | | | Subtotal(*) | 14,314 | 1,281 |
| Application Server (Tier A) Software | | | | | | |
| Microsoft Windows Server 2012 R2 Standard Edition 2 Processor License | P72-06284 | 2 | 735.00 | 1 | 735.00 | |
| | | | | Subtotal | 735 | |
| Miscellaneous | | | | | | |
| Display E24T-7 LED, Cross Trade (incl 2spares) | S26361-K1543-V140 | 1 | 332.00 | 3 | 996.00 | |
| Infrastructure or Connectivity | | | | | | |
| KB900 Keyboard USB USA (incl 2 spares) | S26381-K560-L402 | 1 | 27.00 | 3 | 81.00 | |
| Mouse MC200 (incl 2 spares) | S26381-K463-L100 | 1 | 16.00 | 3 | 48.00 | |
| StarTech.com Shielded Cat6a Molded STP Patch Cable - patch cable - 7 ft - b (incl 2 spares) | C6ASPA7BL | 3 | 12.99 | 4 | 51.96 | |
| | | | | Subtotal(*) | 1,177 | 0 |
| | | | | Total | 1,141,364 | 22,330 |
| Dollar Volume Discount (see Notes) | | 28% | 1 | | 137,880 | |
| | | | | | 1,003,484 | |

| | | |
|--|---|-------------|
| Notes: Price Source: 1=Fujitsu, 2=Microsoft Corporation, 3=www.cdw.com Discount applies to all subtotal marked with (*). Pricing is for these or similar quantities. Discounts for similar sized configurations will be similar to what is quoted here, but may vary based on the specific components priced. | Three-Year Cost of Ownership USD | \$1,025,815 |
| | TPC-E Throughput | 8796.47 |
| | \$ USD/tpsE | \$116.62 |

The benchmark results and test methodology were audited by Doug Johnson for InfoSizing Inc. (www.sizing.com)

Prices used in TPC benchmarks reflect the actual prices a customer would pay for a one-time purchase of the stated components. Individually negotiated discounts are not permitted. Special prices based on assumptions about past or future purchases are not permitted. All discounts reflect standard pricing policies for the listed components. For complete details, see the pricing section of the TPC benchmark pricing specifications. If you find that the stated prices are not available according to these terms, please inform the TPC at pricing@tpc.org. Thank you.



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PRIMERGY RX4770 M3**

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Availability Date
July 31, 2016

Numerical Quantities Summary

| Reported Throughput: | 8,796.47 tpsE | Configured Customers: | | 4,500,000 |
|--|--------------------------|------------------------------|------------------|------------------|
| Response Times (in seconds) | Minimum | Average | 90th%tile | Maximum |
| Broker Volume | 0.01 | 0.01 | 0.02 | 1.08 |
| Customer Position | 0.01 | 0.01 | 0.01 | 0.24 |
| Market Feed | 0.01 | 0.01 | 0.04 | 1.41 |
| Market Watch | 0.01 | 0.01 | 0.02 | 0.21 |
| Security Detail | 0.01 | 0.01 | 0.01 | 0.20 |
| Trade Lookup | 0.01 | 0.04 | 0.07 | 0.66 |
| Trade Order | 0.01 | 0.02 | 0.03 | 1.08 |
| Trade Result | 0.01 | 0.02 | 0.04 | 1.08 |
| Trade Status | 0.01 | 0.01 | 0.01 | 1.06 |
| Trade Update | 0.01 | 0.05 | 0.08 | 1.14 |
| Data Maintenance | 0.01 | 0.01 | N/A | 0.04 |
| Transaction Mix | Transaction Count | | Mix % | |
| Broker Volume | | 31,034,733 | | 4.900% |
| Customer Position | | 82,336,641 | | 13.000% |
| Market Feed | | 6,333,464 | | 1.000% |
| Market Watch | | 114,004,688 | | 18.000% |
| Security Detail | | 88,670,421 | | 14.000% |
| Trade Lookup | | 50,668,499 | | 8.000% |
| Trade Order | | 63,969,074 | | 10.100% |
| Trade Result | | 63,334,591 | | 10.000% |
| Trade Status | | 120,337,660 | | 19.000% |
| Trade Update | | 12,666,991 | | 2.000% |
| Data Maintenance | | 120 | | N/A |
| Test Duration and Timings | | | | |
| Ramp-up Time (hh:mm:ss) | | 0:20:13 | | |
| Measurement Interval (hh:mm:ss) | | 2:00:00 | | |
| Business Recovery Time (hh:mm:ss) | | 0:29:26 | | |
| Total Number of Transactions Completed | | 633,356,762 | | |

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Clause 0: Preamble

Introduction

TPC Benchmark™ E (TPC-E) is an On-Line Transaction Processing (OLTP) workload. It is a mixture of read-only and update intensive transactions that simulate the activities found in complex OLTP application environments. The database schema, data population, transactions, and implementation rules have been designed to be broadly representative of modern OLTP systems. The benchmark exercises a breadth of system components associated with such environments, which are characterized by:

- The simultaneous execution of multiple transaction types that span a breadth of complexity; Moderate system and application execution time;
- A balanced mixture of disk input/output and processor usage; Transaction integrity (ACID properties);
- A mixture of uniform and non-uniform data access through primary and secondary keys;
- Databases consisting of many tables with a wide variety of sizes, attributes, and relationships with realistic content;
- Contention on data access and update.

The TPC-E operations are modelled as follows: The database is continuously available 24 hours a day, 7 days a week, for data processing from multiple Sessions and data modifications against all tables, except possibly during infrequent (e.g., once a month) maintenance Sessions. Due to the worldwide nature of the application modelled by the TPC-E benchmark, any of the transactions may be executed against the database at any time, especially in relation to each other.

Goal of the TPC-E Benchmark

The TPC-E benchmark simulates the OLTP workload of a brokerage firm. The focus of the benchmark is the central database that executes transactions related to the firm's customer accounts. In keeping with the goal of measuring the performance characteristics of the database system, the benchmark does not attempt to measure the complex flow of data between multiple application systems that would exist in a real environment.

The mixture and variety of transactions being executed on the benchmark system is designed to capture the characteristic components of a complex system. Different transaction types are defined to simulate the interactions of the firm with its customers as well as its business partners. Different transaction types have varying run-time requirements.

The benchmark defines:

- Two types of transactions to simulate Consumer-to-Business as well as Business-to-Business activities
- Several transactions for each transaction type
- Different execution profiles for each transaction type
- A specific run-time mix for all defined transactions

For example, the database will simultaneously execute transactions generated by systems that interact with customers along with transactions that are generated by systems that interact with financial markets as well as administrative systems. The benchmark system will interact with a set of driver systems that simulate the various sources of transactions without requiring the benchmark to implement the complex environment.

The Performance Metric reported by TPC-E is a "business throughput" measure of the number of completed Trade-Result transactions processed per second (see Clause 6.7.1). Multiple Transactions are used to simulate the business activity of processing a trade, and each Transaction is subject to a Response Time constraint. The Performance Metric for the benchmark is expressed in transactions-per-second-E (tpsE). To be compliant with the TPC-E standard, all references to tpsE Results must include the tpsE rate, the associated price-per-tpsE, and the Availability Date of the Priced Configuration (See Clause 6.7.3 for more detail).

Although this specification defines the implementation in terms of a relational data model, the database may be implemented using any commercially available Database Management System (DBMS), Database Server, file

system, or other data repository that provides a functionally equivalent implementation. The terms "table", "row", and "column" are used in this document only as examples of logical data structures.

TPC-E uses terminology and metrics that are similar to other benchmarks, originated by the TPC and others. Such similarity in terminology does not imply that TPC-E Results are comparable to other benchmarks. The only benchmark Results comparable to TPC-E are other TPC-E Results that conform to a comparable version of the TPC-E specification.

Restrictions and Limitations

Despite the fact that this benchmark offers a rich environment that represents many OLTP applications, this benchmark does not reflect the entire range of OLTP requirements. In addition, the extent to which a customer can achieve the Results reported by a vendor is highly dependent on how closely TPC-E approximates the customer application. The relative performance of systems derived from this benchmark does not necessarily hold for other workloads or environments. Extrapolations to any other environment are not recommended.

Benchmark Results are highly dependent upon workload, specific application requirements, and systems design and implementation. Relative system performance will vary because of these and other factors. Therefore, TPC-E should not be used as a substitute for specific customer application benchmarking when critical capacity planning and/or product evaluation decisions are contemplated.

Benchmark Sponsors are permitted various possible implementation designs, insofar as they adhere to the model described and pictorially illustrated in this specification. A Full Disclosure Report (FDR) of the implementation details, as specified in Clause 9.1, must be made available along with the reported Results.

Clause 1: Overview

Order and Titles

The order and titles of sections in the Report and Supporting Files must correspond with the order and titles of sections from the TPC-E Standard Specification (i.e., this document). The intent is to make it as easy as possible for readers to compare and contrast material in different Reports (9.1.1.1).

The order and titles in this report correspond to those in the TPC-E specification.

Executive Summary Statement

The TPC Executive Summary Statement must be included near the beginning of the Report (9.2).

The Executive summary has been included near the beginning of this FDR.

Benchmark Sponsor

A statement identifying the benchmark sponsor(s) and other participating companies must be provided (9.3.1.1).

Fujitsu is the sponsor of this TPC Benchmark™ E result.
Thank you to all who supported over the time and farewell - DS

Configuration Diagram

Diagrams of both measured and Priced Configurations must be reported in the Report, accompanied by a description of the differences (9.3.1.2).

The measured and priced configurations are shown in the following figures. There are differences between both configurations at additional storage used for database setup and backup in the measured configuration. This storage is not used during measurement and not required for pricing.



Tier A

PRIMERGY RX2530 M1
2x Intel Xeon E5-2697 v3 2.60 GHz
64 GB Memory
2x 300 GB 15k rpm SAS Drive
2x onboard LAN 10 Gb/s
1x Dual Port LAN 1 Gb/s
1x SAS RAID controller

Tier B

PRIMERGY RX4770 M3
4x Intel Xeon E7-8890 v4 2.20 GHz
2048 GB Memory
2x 300 GB 15k rpm SAS Drives
6x 600 GB 15k rpm SAS Drives
2x onboard LAN 10 Gb/s
8x SAS RAID Controller

Storage

1x PRIMECENTER Rack
7x ETERNUS JX40 S2
168x 400 GB SSD Drives

Figure 1-1: Priced Configuration



Tier A

PRIMERGY RX2530 M1
2x Intel Xeon E5-2697 v3 2.60 GHz
64 GB Memory
2x 300 GB 15k rpm SAS Drive
2x onboard LAN 10 Gb/s
1x Dual Port LAN 1 Gb/s
1x SAS RAID controller

Tier B

PRIMERGY RX4770 M3
4x Intel Xeon E7-8890 v4 2.20 GHz
2048 GB Memory
2x 300 GB 15k rpm SAS Drives
6x 600 GB 15k rpm SAS Drives
2x onboard LAN 10 Gb/s
8x SAS RAID Controller

Storage

1x PRIMECENTER Rack
7x ETERNUS JX40 S2
168x 400 GB SSD Drives

Figure 1-2: Measured Configuration

Hardware Configuration

A description of the steps taken to configure all the hardware must be reported in the Report (9.3.1.4).

Driver

The driver system is not part of the System Under Test (SUT) and priced configuration. This system was connected with Tier A system, using onboard LAN with 2 x 1 Gb/s Ethernet. There are two LAN segments for these connections.

Tier A

The Tier A server is a Fujitsu PRIMERGY RX2530 M1 with two Intel Xeon E5-2697 v3 Fourteen-Core Processor and 64 GB of memory. Two SAS 300 GB 15k rpm disk drives are connected to an onboard SAS controller. One 1 Gb/s dual port Ethernet LAN card is plugged in a PCI-E slot. These two 1 Gb/s LAN ports are used for driver connection. There are two onboard 10 Gb/s LAN ports. Each of the two ports is directly connected with one of the 10 Gb/s Ethernet onboard LAN ports of Tier B using a LAN crossover cable.

Tier B

The Tier B or database server is a Fujitsu PRIMERGY RX4770 M3 with four Intel Xeon E7-8890 v4 24-Core Processors and 2048 GB memory. The entire eight onboard 2.5" disk bays are used with 2x SAS 300 GB 15k rpm and 6x SAS 600 GB 15k rpm disk drives connected to PRAID EP400i. Two drives are configured with RAID1 for OS and database. The six drives with 600 GB are configured with RAID10 for database log. Seven RAID Controllers PRAID EP420e are used to connect the external disk drives to the server. The controller cache of all RAID controllers is configured with Write Through. The two onboard 10 Gb/s Ethernet LAN ports are connected to the Tier A system as described above.

Storage

7 Fujitsu ETERNUS JX40 are used, each with 24x 400GB SSD 2.5" RAID5. The enclosures are connected to the controllers PRAID EP420e. For details see table 2-2 Disk Configuration. The disk configuration can be done with the ServerView RAID Manager, which is shipped on ServerStart DVD together with the Server.

Software Configuration

A description of the steps taken to configure all the software must be reported in the Report (9.3.1.5).

The default installation of the operating system was executed on Tier A and B as well as the installation of the database SW on Tier B and the database client connectivity on Tier A. Information about changes to the software, settings and BenchCraft can be found in the SupportingFiles directory Introduction - Software.

Windows Server 2012 R2 Update (KB2919355) is required for SQL Server 2016 and checked during installation (e.g. see <https://www.microsoft.com/en-US/download/details.aspx?id=42335>). In addition KB815436 has been used (e.g. see <https://support.microsoft.com/en-us/kb/815436>)

Clause 2: Database Design, Scaling and Population

Database Creation

A description of the steps taken to create the database for the Reported Throughput must be reported in the Report (9.3.2).

The physical organization of tables and indices, within the database, must be reported in the Report. (9.3.2.1)

The database has been created for 4,500,000 customers. The SQL Server scripts and setup command files are included in the SupportingFiles\Clause2 folder. Two file groups are used for the tables and indices. The distribution is shown in table 2-1.

Partitioning

While few restrictions are placed upon horizontal or vertical partitioning of tables and rows in the TPC-E benchmark (see Clause 2.3.3), any such partitioning must be reported in the Report. (9.3.2.2)

There is no partitioning implemented in this configuration.

Replication and Duplicated Attributes

Replication of tables, if used, must be reported in the Report (9.3.2.3).

Additional and/or duplicated attributes in any table must be reported in the Report along with a statement on the impact on performance (9.3.2.4).

There is no replication implemented in this configuration.
No duplications or additional attributes were used.

Cardinality of Tables

The cardinality (e.g. the number of rows) of each table, as it existed after database load (see Clause 2.6), must be reported in the Report (9.3.2.5).

The database was configured for 4,500,000 customers. The cardinality of the tables after database load is as shown in the following table 2-1.

| Table | Cardinality after database load | File Group |
|--------------------|---------------------------------|------------|
| ACCOUNT_PERMISSION | 31951708 | 1 |
| ADDRESS | 6750004 | 1 |
| BROKER | 45000 | 1 |
| CASH_TRANSACTION | 71539158008 | 2 |
| CHARGE | 15 | 1 |
| COMMISSION_RATE | 240 | 1 |
| COMPANY | 2250000 | 1 |
| COMPANY_COMPETITOR | 6750000 | 1 |
| CUSTOMER | 4500000 | 1 |
| CUSTOMER_ACCOUNT | 22500000 | 1 |
| CUSTOMER_TAXRATE | 9000000 | 1 |
| DAILY_MARKET | 4022662500 | 1 |
| EXCHANGE | 4 | 1 |
| FINANCIAL | 45000000 | 1 |
| HOLDING | 3980979421 | 2 |
| HOLDING_HISTORY | 104211690668 | 2 |
| HOLDING_SUMMARY | 223801057 | 2 |
| INDUSTRY | 102 | 1 |
| LAST_TRADE | 3082500 | 1 |
| NEWS_ITEM | 4500000 | 1 |
| NEWS_XREF | 4500000 | 1 |
| SECTOR | 12 | 1 |
| SECURITY | 3082500 | 1 |
| SETTLEMENT | 77760000000 | 2 |
| STATUS_TYPE | 5 | 1 |
| TAXRATE | 320 | 1 |
| TRADE | 77760000000 | 2 |
| TRADE_HISTORY | 186624107089 | 2 |
| TRADE_REQUEST | 0 | 2 |
| TRADE_TYPE | 5 | 1 |
| WATCH_ITEM | 450064676 | 1 |
| WATCH_LIST | 4500000 | 1 |
| ZIP_CODE | 14741 | 1 |

Table 2-1: Table Cardinality and File Groups

Distribution of Tables, Partitions and Logs

The distribution of tables, partitions and logs across all media must be explicitly depicted for the measured and Priced Configurations (9.3.2.6).

| HBA - Port | Disk# | Drives | Partition | Size | Use |
|-----------------------|-------|-------------------------|--------------------|---------|-----------------|
| Ctrl 0 onboard | 1 | 2x300GB 15K SAS, RAID1 | C:\ | 278 GB | OS, DB |
| | 0 | 6x600GB 15K SAS, RAID10 | L:\ | 1675 GB | DB Log |
| Ctrl 1 Port 0 JX40 S2 | 2 | 24x400GB SSD, RAID5 | C:\j\p\tpce11 | 175 GB | Filegroup1 |
| | | | C:\j\p\tpce12 | 8382 GB | Filegroup2 |
| Ctrl 1 Port 1 JX40 S2 | 3 | 8x1200GB HDD, RAID5 | C:\j\p\help01 | 7821 GB | DB Setup,Backup |
| | 4 | 7x400GB SSD RAID0 | C:\j\p\temp01 | 2604 GB | DB Setup tempdb |
| | 5 | 8x1200GB HDD, RAID5 | C:\j\p\help02 | 7821 GB | DB Setup,Backup |
| Ctrl 2 Port 0 JX40 S2 | 6 | 24x400GB SSD, RAID5 | C:\j\p\tpce21 | 175 GB | Filegroup1 |
| | | | C:\j\p\tpce22 | 8382 GB | Filegroup2 |
| Ctrl 2 Port 1 JX40 S2 | 7 | 8x1200GB HDD, RAID5 | C:\j\p\help03 | 7821 GB | DB Setup,Backup |
| | 8 | 7x400GB SSD RAID0 | C:\j\p\temp02 | 2604 GB | DB Setup tempdb |
| | 9 | 8x1200GB HDD, RAID5 | C:\j\p\help04 | 7821 GB | DB Setup,Backup |
| Ctrl 3 Port 0 JX40 S2 | 10 | 24x400GB SSD, RAID5 | C:\j\p\tpce31 | 175 GB | Filegroup1 |
| | | | C:\j\p\tpce32 | 8382 GB | Filegroup2 |
| Ctrl 3 Port 2 JX40 S2 | 11 | 8x1200GB HDD, RAID5 | C:\j\p\help05 | 7821 GB | DB Setup,Backup |
| | 12 | 7x400GB SSD RAID0 | C:\j\p\temp03 | 2604 GB | DB Setup tempdb |
| | 13 | 8x1200GB HDD, RAID5 | C:\j\p\help06 | 7821 GB | DB Setup,Backup |
| Ctrl 4 Port 0 JX40 S2 | 14 | 24x400GB SSD, RAID5 | C:\j\p\tpce41 | 175 GB | Filegroup1 |
| | | | C:\j\p\tpce42 | 8382 GB | Filegroup2 |
| Ctrl 4 Port 0 JX40 S2 | 15 | 8x1200GB HDD, RAID5 | C:\j\p\help07 | 7821 GB | DB Setup,Backup |
| | 16 | 7x400GB SSD RAID0 | C:\j\p\temp04 | 2604 GB | DB Setup tempdb |
| | 17 | 8x1200GB HDD, RAID5 | C:\j\p\help09 | 7821 GB | DB Setup,Backup |
| Ctrl 5 Port 0 JX40 S2 | 18 | 24x400GB SSD, RAID5 | C:\j\p\tpce51 | 175 GB | Filegroup1 |
| | | | C:\j\p\tpce52 | 8382 GB | Filegroup2 |
| Ctrl 5 Port 1 JX40 S2 | 19 | 8x1200GB HDD, RAID5 | C:\j\p\help10 | 7821 GB | DB Setup,Backup |
| | 20 | 7x400GB SSD RAID0 | C:\j\p\temp05 | 2604 GB | DB Setup tempdb |
| | 21 | 8x1200GB HDD, RAID5 | C:\j\p\help01 1 | 7821 GB | DB Setup,Backup |
| Ctrl 6 Port 0 JX40 S2 | 22 | 24x400GB SSD, RAID5 | C:\j\p\tpce61 | 175 GB | Filegroup1 |
| | | | C:\j\p\tpce62 | 8382 GB | Filegroup2 |
| Ctrl 6 Port 1 JX40 | 23 | 8x1200GB HDD, RAID5 | C:\j\p\help12 | 7821 GB | DB Setup,Backup |
| | 24 | 7x400GB SSD RAID0 | C:\j\p\temp06 | 2604 GB | DB Setup tempdb |
| | 25 | 8x1200GB HDD, RAID5 | C:\j\p\help13 | 7821 GB | DB Setup,Backup |
| Ctrl 7 Port 0 JX40 S2 | 26 | 24x400GB SSD, RAID5 | C:\j\p\tpce71 | 175 GB | Filegroup1 |
| | | | C:\j\p\tpce72 | 8382 GB | Filegroup2 |

Disk# 4, 8, 12, 16, 20 and 24 are only used for database setup

Disk# 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23 and 25 are only used for database setup and database backup

Table 2-2: Disk Configuration

Database Interface, Data Model and Load Methodology

A statement must be provided in the Report that describes:

The Database Interface (e.g., embedded, call level) and access language (e.g., SQL, COBOL read/write) used to implement the TPC-E Transactions. If more than one interface / access language is used to implement TPC-E, each interface / access language must be described and a list of which interface /access language is used with which Transaction type must be reported.

The data model implemented by the DBMS (e.g., relational, network, hierarchical) (9.3.2.7).

The methodology used to load the database must be reported in the Report (9.3.2.8).

Microsoft SQL Server 2016 Enterprise Edition is a relational database. The interface used was Microsoft SQL Server stored procedures accessed with Remote Procedure Calls embedded in C++ code using the Microsoft ODBC interface.

The methodology used to load the database is described in Clause2 of the SupportingFiles directory.

Clause 3: Transactions

Vendor-Supplied Code

A statement that vendor-supplied code is functionally equivalent to Pseudo-code in the specification (see Clause 3.2.1.6) must be reported in the Report (9.3.3.1).

The vendor supplied code is functionally equivalent to the pseudo-code.

Database Footprint Requirements

A statement that the database footprint requirements (as described in Clause 3.3) were met must be reported in the Report (9.3.3.2).

Database footprint requirements were met as described in the specification.

Clause 4: SUT, Driver and Network

Network Configuration

The Network configurations of both the measured and Priced Configurations must be described and reported in the Report. This includes the mandatory Network between the Driver and Tier A (see Clause 4.2.2) and any optional Database Server interface networks (9.3.4.2):

Figures 1-1 and 1-2 show the configuration of the measured and priced configurations. Both are identical in case of the network configuration. Tier B system PRIMERGY RX4770 M3 has an onboard Ethernet controller with two 10 Gb/s ports. Tier A system PRIMERGY RX2530 M1 has an onboard Ethernet controller with two 10 Gb/s ports. These two ports were directly connected with the two onboard ports of Tier B using different LAN segments. Tier A system was extended with one dual-port 1 Gb/s Ethernet controller card for driver system connection.

Clause 5: EGen

EGen Version

The version of EGen used in the benchmark must be reported (9.3.5.1).

The EGen version used was 1.14.0.

EGen Code

A statement that all required TPC-provided EGen code was used in the benchmark must be reported (9.3.5.2).

All the required TPC-provided code was used in the benchmark.

EGen Modifications

If the Test Sponsor modified EGen, a statement EGen has been modified must be reported in the Report. All formal waivers from the TPC documenting the allowed changes to EGen must also be reported in the Report (see Clause 5.3.7.1). If any of the changes to EGen do not have a formal waiver that must also be reported (9.3.5.3).

If the Test Sponsor extended EGenLoader (as described in Appendix A.6), the use of the extended EGenLoader and the audit of the extension code by an Auditor must be reported (9.3.5.4).

Clause 6: Performance Metrics and Response time

EGen Driver

The number of EGenDriverMEE and EGenDriverCE instances used in the benchmark must be reported in the Report (see Clause 6.2.5) (9.3.1.1).

One Tier A system was used and configured to drive 16 EGenDriverMEE and 16 EGenDriverCE instances.

Measured Throughput

The Measured Throughput must be reported in the Report (see Clause 6.7.1.2) (9.3.6.2).

The measured throughput was 8,796.47 tpsE.

Test Run Graph

A Test Run Graph of throughput versus elapsed wall clock time must be reported in the Report for the Trade-Result Transaction (see Clause 6.7.2) (9.3.6.3).

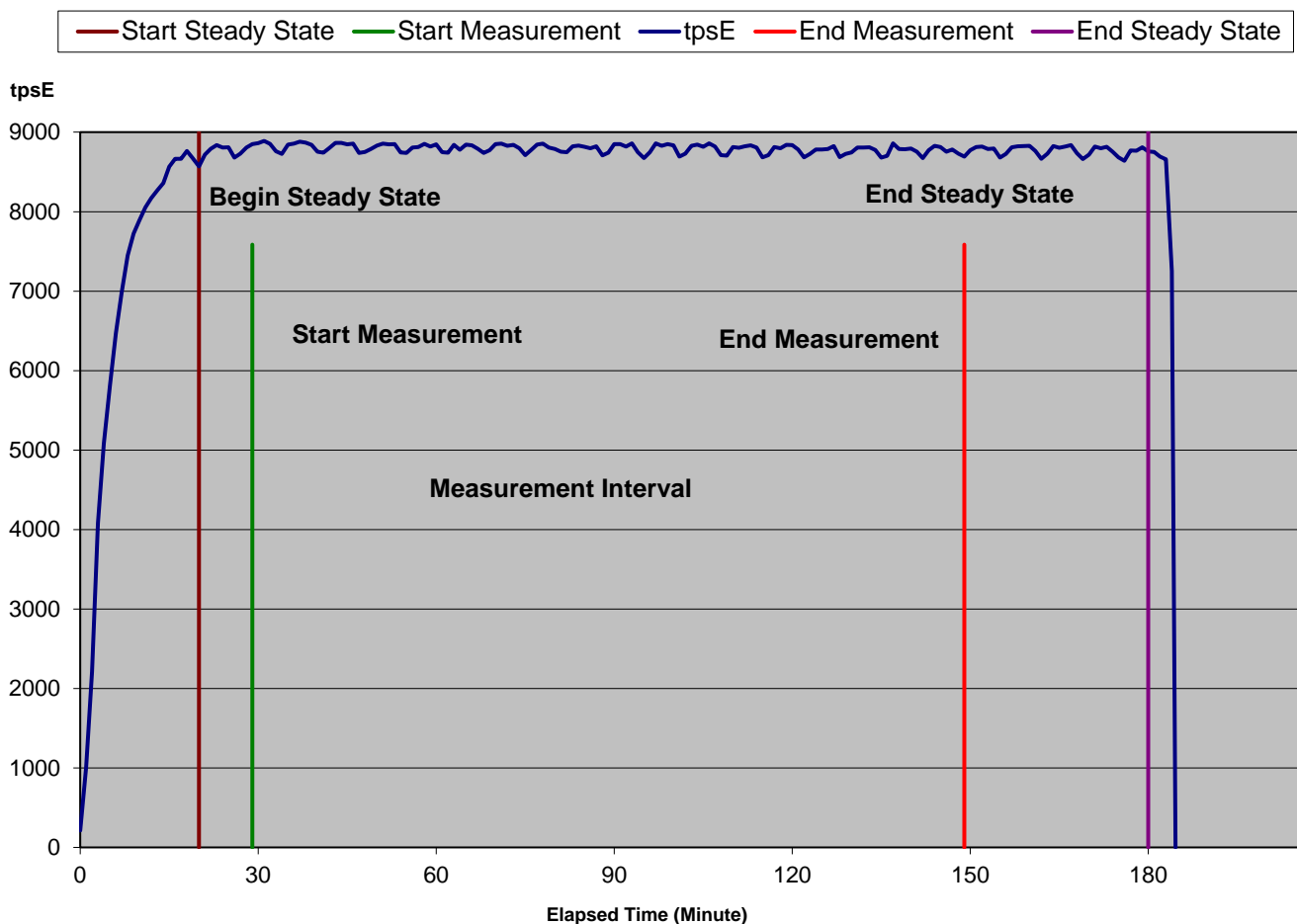


Figure 6-1: Test Run Graph

Steady State

The method used to determine that the SUT had reached a Steady State prior to commencing the Measurement Interval must be reported in the Report (9.3.6.4).

During the run the tpsE throughput was observed to determine steady state. After the run steady state was confirmed by:

1. Looked at the Test Run Graph and verified that tpsE was steady prior to commencing the Measurement Interval.
2. Calculated 60 minute average tpsE during the Steady State moving the time window 10 minutes each time. Then confirmed that the minimum 60 minute average tpsE was not less than 98% of the Reported Throughput, and that the maximum 60 minute average tpsE was not greater than 102% of the Reported Throughput.
3. Calculated 10 minute average tpsE during the Steady State moving the window 1 minute each time. Then confirmed that the minimum 10 minute average tpsE was not less than 80% of the Reported Throughput, and that the maximum 10 minute average tpsE was not greater than 120% of the Reported Throughput.

Work Performed During Steady State

A description of how the work normally performed during a Test Run, actually occurred during the Measurement Interval must be reported in the Report (for example checkpointing, writing Undo/Redo Log records, etc.) (9.3.6.5).

The Microsoft SQL Server recovery interval parameter was set to the maximum allowable value to perform checkpoint at specific intervals. Checkpoints were automatically issued at specified intervals (449 seconds) and specified duration (440 seconds). SQL Server was started with trace flag 3502, which caused it to log the occurrence of the checkpoints. This information was used to verify that the checkpoints occurred at the appropriate times and duration during steady state.

Transaction Input Parameter Averages

The recorded averages over the Measurement Interval for each of the Transaction input parameters specified by clause 6.4.1 must be reported (9.3.6.6).

| Transaction | Parameter | Range Min | Range Max | Value | Check |
|-------------------|---------------------|-----------|-----------|--------|-------|
| Customer Position | By Tax ID | 48.00% | 52.00% | 49.99% | Ok |
| | Get History | 48.00% | 52.00% | 50.00% | Ok |
| | Overall | | | | Ok |
| Market Watch | By Watch List | 57.00% | 63.00% | 60.00% | Ok |
| | By Customer Account | 33.00% | 37.00% | 35.00% | Ok |
| | By Industry | 4.50% | 5.50% | 5.00% | Ok |
| | Overall | | | | Ok |
| Security Detail | Access LOB | 0.90% | 1.10% | 1.00% | Ok |
| | Overall | | | | Ok |
| Trade Lookup | Frame 1 | 28.50% | 31.50% | 30.00% | Ok |
| | Frame 2 | 28.50% | 31.50% | 30.01% | Ok |
| | Frame 3 | 28.50% | 31.50% | 30.00% | Ok |
| | Frame 4 | 9.50% | 10.50% | 9.99% | Ok |
| | Overall | | | | Ok |
| Trade Update | Frame 1 | 31.00% | 35.00% | 32.99% | Ok |
| | Frame 2 | 31.00% | 35.00% | 33.01% | Ok |
| | Frame 3 | 32.00% | 36.00% | 34.00% | Ok |
| | Overall | | | | Ok |
| Trade Order | By Non-Owner | 9.50% | 10.50% | 10.00% | Ok |
| | By Company Name | 38.00% | 42.00% | 40.00% | Ok |
| | Buy On Margin | 7.50% | 8.50% | 8.00% | Ok |
| | Rollback | 0.94% | 1.04% | 0.99% | Ok |
| | LIFO | 33.00% | 37.00% | 35.00% | Ok |
| | Trade Qty 100 | 24.00% | 26.00% | 25.00% | Ok |
| | Trade Qty 200 | 24.00% | 26.00% | 25.01% | Ok |
| | Trade Qty 400 | 24.00% | 26.00% | 24.99% | Ok |
| | Trade Qty 800 | 24.00% | 26.00% | 25.00% | Ok |
| | Market Buy | 29.70% | 30.30% | 30.00% | Ok |
| | Market Sell | 29.70% | 30.30% | 30.00% | Ok |
| | Limit Buy | 19.80% | 20.20% | 20.00% | Ok |
| | Limit Sell | 9.90% | 10.10% | 10.00% | Ok |
| | Stop Loss | 9.90% | 10.10% | 10.00% | Ok |
| Overall | | | | Ok | |

Table 6-2: Transaction Input Parameter Averages.

Clause 7: Transaction and System Properties

ACID Tests

The results of the ACID tests must be reported in the Report along with a description of how the ACID requirements were met, and how the ACID tests were run (9.3.7.1).

The TPC Benchmark™ E Standard Specification defines a set of transaction processing system properties that a system under test (SUT) must support during the execution of the benchmark. Those properties are Atomicity, Consistency, Isolation and Durability (ACID). This section quotes the specification definition of each of those properties and describes the tests done as specified and monitored by the auditor, to demonstrate compliance. See also file MSTPCE ACID Procedures.pdf in the SupportingFiles directory.

Redundancy Level and Data Accessibility

The Test Sponsor must report in the Report the Redundancy Level (see Clause 7.5.7.1) and describe the Data Accessibility test(s) used to demonstrate compliance (9.3.7.2).

A Data Accessibility Graph for each run demonstrating a Redundancy Level must be reported in the Report (see Clause 7.5.7.2) (9.3.7.3).

Redundancy Level 1 was used for the storage system. To prove Redundancy Level 1, the following steps were successfully performed on a database data, log and tempdb disk. The test for Redundancy Level 1 is the test for Permanent Irrecoverable Failure of any single Durable Medium. The different steps and the various states of the three disks are reported by ServerView RAID and written to the system event (see SupportingFiles).

1. Determine the current number of completed trades in the database by counting the rows in SETTLEMENT.
2. Start submitting Transactions and ramp up to the Durability Throughput Requirements (as defined in Clause 7.5.3) and satisfy those requirements for at least 5 minutes with a throughput above 95% of reported throughput.
3. Induce the failure described for the redundancy level being demonstrated. In this case fail a disk in the database tempdb array. Since RAID1 is used, the transactions continue. Run for at least 5 minutes with throughput above 95% of reported throughput.
4. Induce the failure described for the redundancy level being demonstrated. In this case fail a disk in a database log array. Since RAID10 is used, the transactions continue. Run for at least 5 minutes with throughput above 95% of reported throughput.
5. Induce the failure described for the redundancy level being demonstrated. In this case fail a disk in the database data array. Since RAID5 is used, the transactions continue. Run for at least 5 minutes.
6. Begin the necessary recovery process, by replacing the failed drives in the database data array and start the rebuild process.
7. Begin the necessary recovery process, by replacing the failed drives in the database log array and start the rebuild.
8. Continue running the Driver for at least 20.
9. Terminate the run gracefully from the Driver.
10. Wait until rebuild process has finished.
11. Determine the current number of completed trades in the database by counting the rows in SETTLEMENT.
12. Run the evaluation of Trade-Result Transactions executed and compare it with the difference of the SETTLEMENT rows counted.

The Graph in Figure 7-1 show the measured throughput versus time and the different test stated.

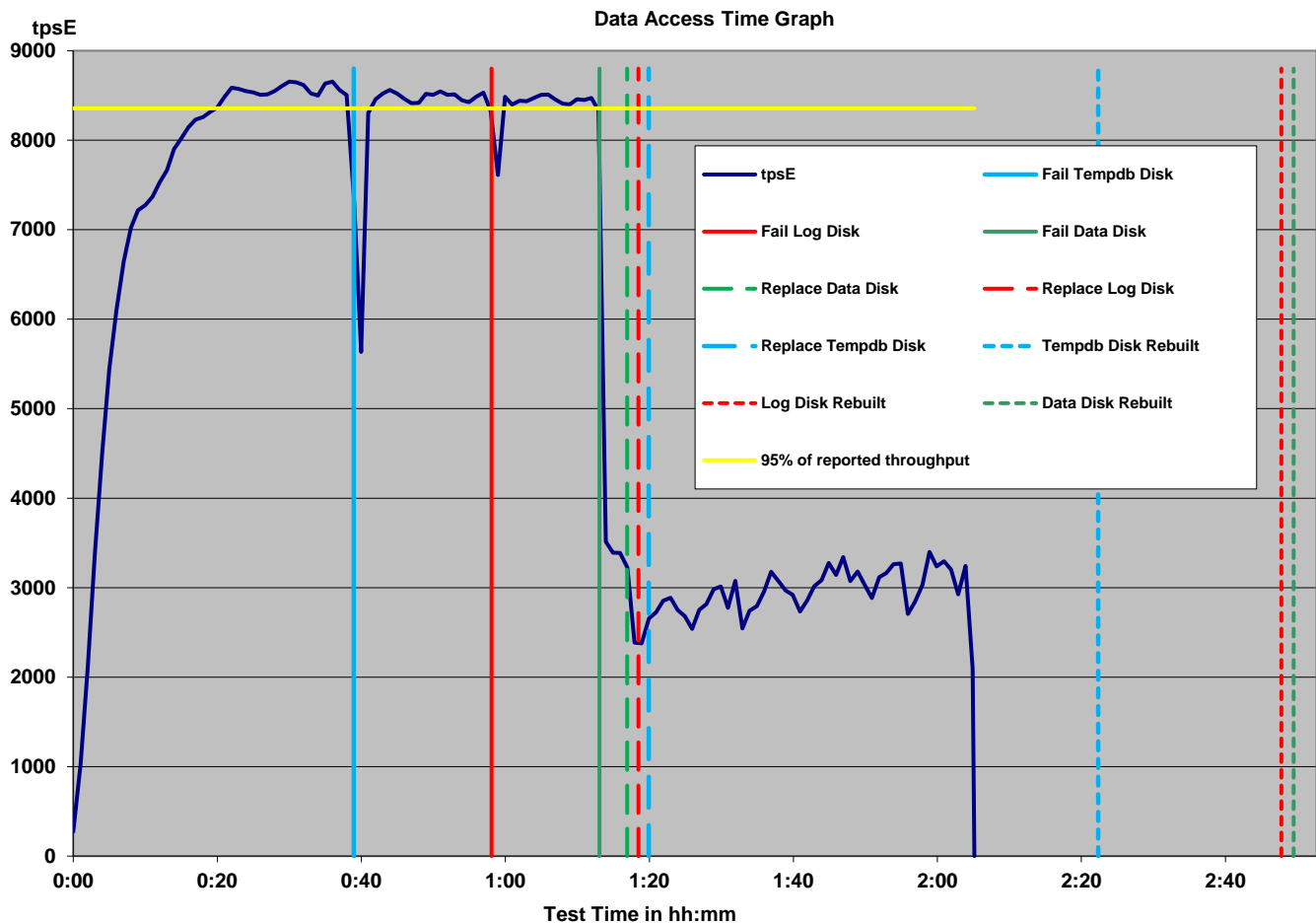


Figure 7-1: Redundancy Level and Data Accessibility Graph

Business Recovery

The Test Sponsor must describe in the Report the test(s) used to demonstrate Business Recovery (9.3.4.7). The Business Recovery Time must be reported on the Executive Summary Statement and in the Report. If the failures described in Clauses 7.5.2.2, 7.5.2.3 and 7.5.2.4 were not combined into one Durability test (usually powering off the Database Server during the run), then the Business Recovery Time for the failure described for instantaneous interruption is the Business Recovery Time that must be reported in the Executive Summary Statement. All the Business Recovery Times for each test requiring Business Recovery must be reported in the Report (9.3.7.6). 9.3.7.6 The Business Recovery Time Graph (see Clause 7.5.7.4) must be reported in the Report for all Business Recovery tests (9.3.7.7).

The tests for "Instantaneous interrupt," "Failure of all or part of memory," and "Loss of external power to the SUT" were combined by power off Tier A and B.

1. Determine the current number of completed trades in the database by counting the rows in SETTLEMENT.
2. Start submitting transactions and ramp up to the Durability Throughput Requirements (as defined in Clause 7.5.3) and satisfy those requirements for at least 20 minutes.
3. Induce the failures by power off Tier B.
4. On the driver side the number of MEE connections is captured and after transaction failures is noted by the drivers, terminate the run and collect the data for Pre-Failure Run.
5. Re-power and restart Tier B.

6. When restarting the database on Tier B, it automatically starts the recovery and records timestamps. The Database Recovery Time was 00:14:48 (hh:mm:ss).
7. After recovery has completed Trade-Cleanup has been executed. A new run started again submitting transactions and ramp up to the Durability Throughput Requirements (as defined in Clause 7.5.3) and satisfy those requirements for at least 20 minutes. The Application Recovery Time was 00:14:38 (hh:mm:ss).
8. Terminate the run gracefully from the Driver and collect the data for Post-Failure Run.
9. Verify that there are no errors in the Post-Failure run and check the consistency of the database as specified in Clause 7.3.1.1.
10. Determine the current number of completed trades in the database by counting the rows in SETTLEMENT.
11. Run the evaluation of Trade-Result Transactions executed in both runs and compare it with the difference of the SETTLEMENT rows counted. The difference must be less than or equal to the maximum number of Transactions which can be simultaneously in-flight from the Driver to the SUT.

The Business Recovery Time (per Clause 7.5.7 Step15) was 00:29:26 (hh:mm:ss).

The Graph in Figure 7-2 shows the measured throughput versus time and the Business Recovery.

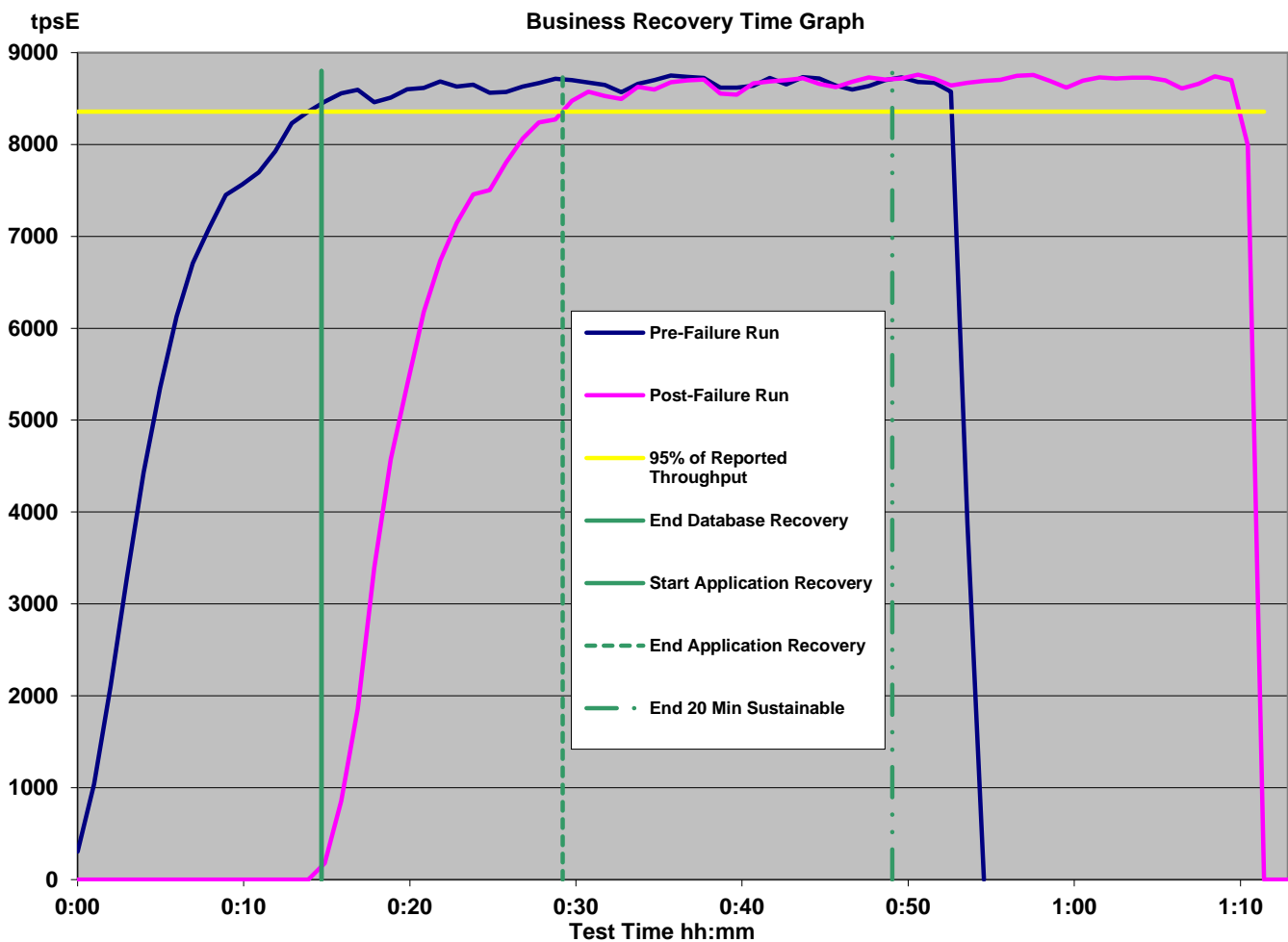


Figure 7-2: Business Recovery Graph

Clause 8: Pricing Related Items

60-Day Space

Details of the 60-Day Space computations along with proof that the database is configured to sustain a Business Day of growth must be reported (9.3.8.1).

| | | TPC-E Disk Space Requirements | | | | | | | | | |
|-----------------------------|-----------------|--|-----------------|-----------------------|-----------------|---------------------|------------|-------------|-------------------|----------------|--|
| Customers Used | 4,500,000 | | | | | | | | | | |
| Performance | 8796.47 TpsE | settlements after 8 hours (Business Day) | | | | | | 253,338,336 | | | |
| Table | Initial Rows | Data (KB) | Index size (KB) | Extra 5% (KB) | Total + 5% (KB) | initial size | grow size | Growth (KB) | 1 Day Growth (KB) | Req. Add. (KB) | |
| ACCOUNT_PERMISSION | 31,951,708 | 1,759,488 | 9,616 | 88,455 | 1,857,559 | 1,769,160 | 56 | 151 | 88,455 | | |
| ADDRESS | 6,750,004 | 389,480 | 1,616 | 19,555 | 410,651 | 391,128 | 32 | 86 | 19,555 | | |
| BROKER | 45,000 | 4,608 | 4,888 | 475 | 9,971 | 9,496 | 0 | 0 | 475 | | |
| CASH_TRANSACTION | 71,544,875,267 | 7,448,598,032 | 15,706,400 | 373,215,222 | 7,837,519,654 | 7,480,607,112 | 16,302,680 | 43,669,530 | 43,669,530 | | |
| CHARGE | 15 | 8 | 8 | 1 | 17 | 16 | 0 | 0 | 1 | | |
| COMMISSION_RATE | 240 | 16 | 56 | 4 | 76 | 72 | 0 | 0 | 4 | | |
| COMPANY | 2,250,000 | 480,624 | 142,392 | 31,151 | 654,167 | 623,016 | 0 | 0 | 31,151 | | |
| COMPANY_COMPETITOR | 6,750,000 | 181,328 | 164,480 | 17,290 | 363,098 | 345,808 | 0 | 0 | 17,290 | | |
| CUSTOMER | 4,500,000 | 737,576 | 216,040 | 47,681 | 1,001,297 | 953,656 | 40 | 108 | 47,681 | | |
| CUSTOMER_ACCOUNT | 22,500,000 | 2,038,928 | 497,736 | 126,833 | 2,663,497 | 2,536,664 | 0 | 0 | 126,833 | | |
| CUSTOMER_TAXRATE | 9,000,000 | 187,784 | 1,592 | 9,469 | 198,845 | 189,512 | 136 | 365 | 9,469 | | |
| DAILY_MARKET | 4,022,662,500 | 188,818,608 | 551,744 | 9,468,518 | 198,838,870 | 189,371,600 | 1,248 | 3,343 | 9,468,518 | | |
| EXCHANGE | 4 | 8 | 8 | 1 | 17 | 16 | 0 | 0 | 1 | | |
| FINANCIAL | 45,000,000 | 5,071,216 | 14,656 | 254,294 | 5,340,166 | 5,086,160 | 288 | 772 | 254,294 | | |
| HOLDING | 3,981,137,264 | 266,850,072 | 182,175,072 | 22,451,257 | 471,476,401 | 454,586,496 | 5,561,352 | 14,897,037 | 14,897,037 | | |
| HOLDING_HISTORY | 104,220,069,838 | 3,789,793,168 | 2,532,095,544 | 316,094,436 | 6,637,983,148 | 6,341,330,056 | 19,441,344 | 52,076,981 | 52,076,981 | | |
| HOLDING_SUMMARY | 223,801,068 | 9,825,312 | 36,856 | 493,108 | 10,355,276 | 9,862,168 | 0 | 0 | 0 | | |
| INDUSTRY | 102 | 8 | 24 | 2 | 34 | 32 | 0 | 0 | 2 | | |
| LAST_TRADE | 3,082,500 | 192,272 | 1,328 | 9,680 | 203,280 | 193,600 | 0 | 0 | 9,680 | | |
| NEWS_ITEM | 4,500,000 | 487,882,136 | 5,096 | 24,394,362 | 512,281,594 | 487,887,272 | 40 | 108 | 24,394,362 | | |
| NEWS_XREF | 4,500,000 | 112,200 | 1,584 | 5,689 | 119,473 | 113,784 | 0 | 0 | 5,689 | | |
| SECTOR | 12 | 8 | 24 | 2 | 34 | 32 | 0 | 0 | 2 | | |
| SECURITY | 3,082,500 | 427,896 | 118,032 | 27,296 | 573,224 | 545,952 | 24 | 65 | 27,296 | | |
| SETTLEMENT | 77,766,215,055 | 3,708,522,104 | 7,819,424 | 185,817,076 | 3,902,158,604 | 3,725,422,776 | 9,081,248 | 24,325,684 | 24,325,684 | | |
| STATUS_TYPE | 5 | 8 | 8 | 1 | 17 | 16 | 0 | 0 | 1 | | |
| TAXRATE | 320 | 32 | 56 | 4 | 92 | 96 | 8 | 22 | 22 | | |
| TRADE | 77,766,460,070 | 9,284,819,936 | 5,206,368,968 | 724,559,445 | 15,215,748,349 | 14,507,309,296 | 16,120,392 | 43,181,240 | 43,181,240 | | |
| TRADE_HISTORY | 186,639,610,069 | 5,613,881,536 | 14,639,192 | 281,426,036 | 5,909,946,764 | 5,644,730,224 | 16,209,496 | 43,419,921 | 43,419,921 | | |
| TRADE_REQUEST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| TRADE_TYPE | 5 | 8 | 1,032 | 52 | 1,092 | 1,040 | 0 | 0 | 52 | | |
| WATCH_ITEM | 450,064,676 | 12,653,800 | 46,968 | 635,038 | 13,335,806 | 12,701,016 | 248 | 665 | 635,038 | | |
| WATCH_LIST | 4,500,000 | 112,216 | 101,712 | 10,696 | 224,624 | 213,928 | 0 | 0 | 10,696 | | |
| ZIP_CODE | 14,741 | 488 | 56 | 27 | 571 | 544 | 0 | 0 | 27 | | |
| Grow ing Tables | | Initial Database Size | | | | Settlements | | 94,576,101 | | | |
| | | 37,875,062 (MB) | | | | Grown Database Size | | | | | |
| | | 36,987 (GB) | | | | 37,955,842 (MB) | | | | | |
| | number | partition size (MB) | file size (MB) | alloc total (MB) | loaded (MB) | required (MB) | | | | | |
| filegroup1 | 7 | 180,091 | 1,260,000 | 1,260,636 | 686,457 | 720,779 | | space OK | | | |
| filegroup2 | 7 | 8,583,332 | 60,083,100 | 60,083,323 | 37,188,605 | 37,404,982 | | space OK | | | |
| | | Number of disks | 168 | | | | | | | | |
| | | Disk Capacity (MB) | 381,024 | | | | | | | | |
| | | RAID5 Overhead | 4% | | | | | | | | |
| Initial Grow ing Space (MB) | 37,188,605 | Total Space-1 (MB) | 61,344,864 | | | | | | | | |
| Final Grow ing Space (MB) | 37,269,383 | Number of disks | - | Initial Log Size (MB) | 134,716 | Log units | 1 | | | | |
| Delta (MB) | 80,778 | Disk Capacity (MB) | - | Final Log Size (MB) | 748,595 | Disks per unit | 6 | | | | |
| Data Space per Trade (MB) | 0.000854 | RAID5 Overhead | - | Log Grow th (MB) | 613,879 | Disk Capacity (MB) | 571,808 | | | | |
| 1 Day Data Grow th (MB) | 216,377 | Total Space-2 (MB) | - | Log Space per Trade | 0.006491 | RAID10 Overhead | 50.0% | | | | |
| 60 Day Space (MB) | 50,857,702 | Total Space (MB) | 61,344,864 | 1 Day Log Space (MB) | 1,644,381 | Log Space (MB) | 1,715,424 | | | | |

Table 8-1: Space Requirements

Attestation Letter

The Auditor's Attestation Letter, which indicates compliance, must be included in the Report (9.3.8.2).



Detlev Seidel
Fujitsu Technology Solutions
Heinz-Nixdorf-Ring 1
33106 Paderborn, Germany

July 11, 2016

I verified the TPC Benchmark™ E v1.14.0 performance of the following configuration:

Platform: Fujitsu Server PRIMERGY RX4770 M3
Operating System: Microsoft Windows Server 2012 R2 Standard Edition
Database Manager: Microsoft SQL Server 2016 Enterprise Edition

The results were:

Performance Metric 8,796.47 tpsE
Trade-Result 90th %-tile 0.04 Seconds

| | | | |
|-------------------------------|---|-------------|-----------------|
| <u>Tier B (Server)</u> | <u>Fujitsu Server PRIMERGY RX4770 M3</u> | | |
| CPU | 4 x Intel Xeon E7-8890 v4 (2.20 GHz, 24-core, 60 MB L3) | | |
| Memory | 2048 GB | | |
| Storage | Qty | Size | Type |
| | 2 | 300 GB | 15K rpm SAS HDD |
| | 6 | 600 GB | 15K rpm SAS HDD |
| | 168 | 400 GB | SAS SSD |

| | | | |
|-------------------------------|---|--|--|
| <u>Tier A (Client)</u> | <u>PRIMERGY RX2530 M1</u> | | |
| CPU | 2 x Intel Xeon E5-2697 v3 (2.60 GHz, 14-core, 35 MB L3) | | |
| Memory | 64 GB | | |
| Storage | 2 x 300 GB 15K rpm SAS HDD | | |

In my opinion, these performance results were produced in compliance with the TPC requirements for the benchmark.

The following verification items were given special attention:


- All EGen components were verified to be v1.14.0
- The transaction were correctly implemented
- The database was properly scaled and populated for 4,500,000 customers
- The mandatory network between the driver and the SUT was configured

- The ACID properties were met
- Input data was generated according to the specified percentages
- The reported response times were correctly measured
- All 90% response times were under the specified maximums
- The measurement interval was 120 minutes
- The implementation used Redundancy Level 1
- The Business Recovery Time of 00:29:26 was correctly measured
- The 60-day storage requirement was correctly computed
- The system pricing was verified for major components and maintenance

Additional Audit Notes:

None.

Respectfully Yours,



Doug Johnson, Auditor



François Raab, President

Clause 9: Supporting Files

Supporting Files Index table

An index for all files required by Clause 9.4 Supporting Files must be provided in the Report. The Supporting Files index is presented in a tabular format where the columns specify the following:

- The first column denotes the clause in the TPC Specification
- The second column provides a short description of the file contents
- The third column contains the path name for the file starting at the SupportingFiles directory.

If there are no Supporting Files provided then the description column must indicate that there is no supporting file and the path name column must be left blank (9.3.9.1).

| Clause | Description | Path | Filename |
|--------------|--------------------------------------|--|--|
| | overview | SupportingFiles | SupportingFiles.doc |
| Introduction | System Configuration | SupportingFiles/Introduction/ | SysInfo_TierA.txt SysInfo_TierB.txt |
| | Disk Configuration | SupportingFiles/Introduction/Hardware/ | DiskConfiguration.docx flatfilelocations.txt makehelpdir.cmd makehelpdirff.cmd maketpcdir.cmd Readme.txt tempdb18.sql |
| | Parameter OS Tunables Database Setup | SupportingFiles/Introduction/Software/ | CountOperations.reg DiskManagement01.jpg DiskManagement02.jpg DiskManagement03.jpg DiskManagement04.jpg DiskManagement05.jpg MemoryManagement.reg MSTPCE Database Setup Reference.doc SQL_IP.reg SQL_LargePages.req SQL_Nodes.reg SQL_Server_Configuration.ver TierA_MSSQL_ConnectTo.reg TierA_W32Time.reg |
| | Startup Scripts Tier A | SupportingFiles/Introduction/Software/ | start_all_RX4770M3-16DR.cmd |
| | Startup Scripts Tier B | SupportingFiles/Introduction/Software/ | Sqlstart2016.cmd |
| Clause 2 | Create Database | SupportingFiles/Clause2 | Backup_Database.sql Check_tempdb.sql Checkpoint_TPCE_Database.SQL Count_Customers.sql Create_Database.sql Create_DM_Audit_Table.sql Create_TID_Ranges_Table.sql Create_Timer_Table.sql Create_TL_TU_Warnings_Table.sql Create_TPCE_VERSIONS_Table.sql Database_Options_1.sql Database_Options_2.sql Drop_and_Create_TPCE_INFO.sql End_Load_Timer.sql Get_Next_T_ID.sql Install_Load_Timer_Proc.sql Load_TPCE_Info.sql Output_TPCE_VERSIONS_Table.SQL Remove_Database.sql Restore_Database.sql SpaceUsed_Extended.sql SQL_Server_Configuration.sql |

| | | | |
|--|------------------------|----------------------------------|---|
| | | | TPCE_Setup.cmd Trade_Cleanup.sql Version.sql |
| | Create Database output | SupportingFiles/Clause2/DB_setup | 450000Customers_Load_Timer.log Backup_Database.log BrokerVolume.log Build_Steps.log BulkInsert_1.out ... BulkInsert_180.out Check_Constraints_Fixed.log Check_Constraints_Growing.log Check_Constraints_Scaling.log Convert_NI_ITEM_Data.log Create_DB_Audit_Tables.log Create_DM_Audit_Tables.log Create_Indexes_Fixed_Tables.log Create_Indexes_Growing_Tables.log Create_Indexes_Scaling_Tables.log Create_TID_Ranges_Table.log Create_TL_TU_Warnings_Table.log Create_TPCE_VERSIONS_Table.log CreateDB.log CustomerPosition.log Database_Options_1.log Database_Options_2.log DataMaintenance.log DB_Check.log DB_FK_Constraints.log DB_Primary_Key_Check.log DB_Tables.log Drop_DB_Audit_Tables.log Drop_Fixed_Tables.log Drop_FK_Constraints.log Drop_Growing_Tables.log Drop_Scaling_Tables.log EGenLoaderFrom1To25000.log EGenLoaderFrom25001To50000.log EGenLoaderFrom4475001To4500000.log ERRORLOG.txt FK_Constraints.log Get_Next_T_ID.log Insert_Duplicates_Tests.log Install_SpaceUsed_Extended.log Load_Timer.log Load_Timer_Proc.log Load_TPCE_Info.log MarketFeed.log MarketWatch.log Referential_Integrity_Tests.log RemoveDB.log SecurityDetail.log spfiles.log splog.log SQL_Server_Configuration.log Tables_Fixed.log Tables_Growing.log Tables_Scaling.log TPCE_Table_Sizes.log TPCE_VERSIONS.log TradeLookup.log TradeOrder.log TradeResult.log TradeStatus.log TradeUpdate.log Version.log |
| | Index Creation Scripts | SupportingFiles/Clause2/DDL | BulkInsert_<1..180>.sql Convert_NI_ITEM_Data.SQL Create_Check_Constraints_Fixed.sql Create_Check_Constraints_Growing.sql Create_Check_Constraints_Scaling.sql |

| | | | |
|---------|------------------------|--|---|
| | | | Create_FK_Constraints.sql Create_Indexes_Fixed_Tables.sql Create_Indexes_Growing_Tables.sql Create_Indexes_Scaling_Tables.sql Create_Tables_Fixed.sql Create_Tables_Growing.sql Create_Tables_Scaling.sql Drop_FK_Constraints.sql Drop_Tables_Fixed.sql Drop_Tables_Growing.sql Drop_Tables_Scaling.sql |
| | Database Audit Scripts | SupportingFiles/Clause2/Audit_Scripts/Database | Create_DB_Audit_Tables.SQL DB_Check.sql DB_FK_Constraints.sql DB_Primary_Key_Check.SQL DB_Tables.sql Drop_DB_Audit_Tables.SQL Insert_Duplicates_Tests.sql Referential_Integrity_Tests.sql |
| | Database Space Scripts | SupportingFiles/Clause2/Audit_Scripts/Space | Get_Table_Sizes.sql SPFiles.sql SPLog.sql SPUsed.sql |
| Clause3 | Transaction Frames | SupportingFiles/Clause3 | BrokerVolume.sql CustomerPosition.sql DataMaintenance.sql MarketFeed.sql MarketWatch.sql SecurityDetail.sql TradeLookup.sql TradeOrder.sql TradeResult.sql TradeStatus.sql TradeUpdate.sql |
| | BaseServer | SupportingFiles/Clause3/BaseServer | BaseServer.cpp BaseServer.h BaseServer.vcproj stdafx.cpp stdafx.h SUTServersLocals.h |
| | SUT_CE_Server | SupportingFiles/Clause3/SUT_CE_Server | Release\SUT_CE_Server.exe CEServer.cpp CEServer.h CEServerMain.cpp PortDefinitions.h stdafx.cpp stdafx.h SUT_CE_Server.vcxproj SUTServer.sln SUTStructs.h |
| | SUT_MEE_Server | SupportingFiles/Clause3/SUT_MEE_Server | Release\SUT_MEE_Server.exe MEEServer.cpp MEEServer.h MEEServerMain.cpp stdafx.cpp stdafx.h SUT_MEE_Server.vcproj SUT_MEE_Server.vcxproj |
| | TransactionsSP | SupportingFiles/Clause3/TransactionsSP | BrokerVolumeDB_SP.cpp BrokerVolumeDB_SP.h CheckpointDB_SP.cpp CheckpointDB_SP.h CustomerPositionDB_SP.cpp CustomerPositionDB_SP.h DataMaintenanceDB_SP.cpp DataMaintenanceDB_SP.h MarketFeedDB_SP.cpp MarketFeedDB_SP.h MarketWatchDB_SP.cpp MarketWatchDB_SP.h SecurityDetailDB_SP.cpp |

| | | | |
|---------------------------------------|---------------------------|---|--|
| | | | SecurityDetailDB_SP.h stdafx.cpp stdafx.h TradeLookupDB_SP.cpp TradeLookupDB_SP.h TradeOrderDB_SP.cpp TradeOrderDB_SP.h TradeResultDB_SP.cpp TradeResultDB_SP.h TradeStatusDB_SP.cpp TradeStatusDB_SP.h TradeUpdateDB_SP.cpp TradeUpdateDB_SP.h TransactionsSP.vcproj TransactionsSP.vcxproj TxnHarnessDBBase.cpp TxnHarnessDBBase.h TxnHarnessDBConn.cpp TxnHarnessDBConn.h |
| | TxnHarness | SupportingFiles/Clause3/TxnHarnes | TxnHarness.vcproj TxnHarness.vcxproj TxnHarness_stdafx.cpp TxnHarness_stdafx.h TxnHarnessSendToMarket.cpp TxnHarnessSendToMarket.h |
| Clause4 | | | |
| Clause5 | EGen Driver Configuration | SupportingFiles/Clause5 | RX4770_4500KCus_16x56_spiderc.xml |
| | EGenLoader Parameter | SupportingFiles/Clause5 | BuildSteps.log EGenLoaderFrom1To25000.log EGenLoaderFrom25001To50000.log EGenLoaderFrom4475001To4500000.log |
| | EGenLogger Output | SupportingFiles/Clause5 | TxnReportE-MI.xls |
| Clause6 | EGenValidate | SupportingFiles/Clause6 | EGenValidate.txt |
| Clause7 | ACID | SupportingFiles/Clause7 | MSTPCE ACID Procedures.doc |
| | ACID Procedures | SupportingFiles/Clause7/AcidProcs | AcidProc.cmd AcidProc.out Remove_AcidProcs.cmd |
| | ACID Scripts | SupportingFiles/Clause7/AcidProcs/Scripts | AcidProc.vbs CustomerPosition_Iso3.sql CustomerPosition_Iso4.sql Drop_SPROC.sql Remove_AcidProcs.vbs TradeOrder_C.sql TradeOrder_Iso1_1.sql TradeOrder_Iso1_2.sql TradeOrder_Iso2.sql TradeOrder_Iso3.sql TradeOrder_Iso4.sql TradeOrder_RB.sql TradeResult_Iso1_1.sql TradeResult_Iso1_2.sql TradeResult_Iso2_1.sql TradeResult_Iso2_2.sql TradeResult_Iso3.sql TradeResult_Iso4.sql |
| | Atomicity | SupportingFiles/Clause7/Atomicity | Atomicity.cmd Atomicity_C.out Atomicity_RB.out |
| | | SupportingFiles/Clause7/Atomicity/Scripts | atom.vbs Atomicity_C.sql Atomicity_RB.sql |
| | Consistency | SupportingFiles/Clause7/Consistency | Consistency.cmd Consistency.out |
| SupportingFiles/Clause7/Consistency/S | | Consistency.sql | |

| | | | |
|---------|-------------------------------|---|---|
| | | cripts | Consistency.vbs |
| | Durability Business Recovery | SupportingFiles/Clause7/Durability/BusinessRecovery | BR_BenchCraft_Config.xml BR_Consistency.out BR_Count_Settlement1.ver BR_Count_Settlement2.ver BR_ERRORLOG1.txt BR_ERRORLOG2.txt BR_ERRORLOG3.txt BR_SQL_Server_Configuration.ver BR_SystemEvents_TierB.txt BusinessRecov_Part1_step60.xlt BusinessRecov_Part1_TxnReportE_20.xls BusinessRecov_Part1_TxnReportE_all.xls BusinessRecov_Part2_step60.xlt BusinessRecov_Part2_TxnReportE_20.xls BusinessRecov_Part2_TxnReportE_all.xls BusinessRecov_TimeGraph.xls |
| | Durability Data Accessibility | SupportingFiles/Clause7/Durability/Data Accessibility | DA_BenchCraft_Config.xml DA_Count_Settlement1.ver DA_Count_Settlement2.ver DA_ERRORLOG.txt DA_SQL_Server_Configuration.ver DataAccess_TimeGraph.xls DataAccess_TxnReportE_5min1.xls DataAccess_TxnReportE_5min2.xls DataAccess_TxnReportE_5min3.xls DataAccess_TxnReportE_20min.xls DataAccess_TxnReportE_all.xls SystemEvents_Application.txt |
| | Isolation | SupportingFiles/Clause7/Isolation | Isolation1_S1.rpt Isolation1_S2.rpt Isolation1_S3.rpt Isolation1_S4.rpt Isolation2_S1.rpt Isolation2_S2.rpt Isolation2_S3.rpt Isolation2_S4.rpt Isolation3_S1.rpt Isolation3_S2.rpt Isolation3_S3.rpt Isolation4_S1.rpt Isolation4_S2.rpt Isolation4_S3.rpt |
| | | SupportingFiles/Clause7/Isolation/Scripts | Isolation1_S1.sql Isolation1_S2.sql Isolation1_S3.sql Isolation1_S4.sql Isolation2_S1.sql Isolation2_S2.sql Isolation2_S3.sql Isolation2_S4.sql Isolation3_S1.sql Isolation3_S2.sql Isolation3_S3.sql Isolation4_S1.sql Isolation4_S2.sql Isolation4_S3.sql |
| Clause8 | 60-Day Space Calculations | SupportingFiles/Clause8 | tpce_space.xlsx |
| | | | |

Appendix: Third Party Price Quotations

Microsoft Corporation
 One Microsoft Way
 Redmond, WA 98052-6399

Tel 425 882 8080
 Fax 425 936 7329
<http://www.microsoft.com/>

Microsoft

July 5, 2016

Fujitsu
 Detlev Seidel
 Heinz-Nixdorf-Ring 1
 Paderborn Germany 33106

Here is the information you requested regarding pricing for several Microsoft products to be used in conjunction with your TPC-E benchmark testing.

All pricing shown is in US Dollars (\$).

| Description | Unit Price | Quantity | Price |
|--|-------------|----------|--------------|
| Database Management System | | | |
| SQL Server 2016 Enterprise Edition 2 Core License Open Program - Level C | \$13,472.50 | 48 | \$646,680.00 |
| Database Server Operating System | | | |
| Windows Server 2012 R2 Standard Edition 2 Processor License Open Program - Level C Unit Price reflects a 17% discount from the retail unit price of \$882. | \$735.00 | 2 | \$1,470.00 |
| Tier-A Operating System(s) | | | |
| Windows Server 2012 R2 Standard Edition 2 Processor License Open Program - Level C Unit Price reflects a 17% discount from the retail unit price of \$882. | \$735.00 | 1 | \$735.00 |
| Support | | | |
| Microsoft Problem Resolution Services Professional Support (1 Incident). | \$259.00 | 1 | \$259.00 |

SQL Server 2016 Enterprise Edition and Windows Server 2012 R2 Standard Edition are currently orderable and available through Microsoft's normal distribution channels. A list of Microsoft's resellers can be found in the Microsoft Product Information Center at <http://www.microsoft.com/products/info/render.aspx?view=22&type=how>

Defect support is included in the purchase price. Additional support is available from Microsoft PSS on an incident by incident basis at \$259 call.

This quote is valid for the next 90 days.
 Reference ID: TPCE_qhtplylGYLKTUVUKf58742dhey_2016_fds.



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StarTech.com Shielded Cat6a Molded STP Patch Cable - patch cable - 7 ft - b



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