Behind the Report—Testing Addendum:

Life After SATA: KIOXIA PCIe® 4.0 NVM Express® (NVMe®) vs. 6 Gb/s SATA Application Benefits

This document provides the system-configuration details and step-by-step procedures that Prowess Consulting used to perform benchmark testing on the following solid-state drives (SSDs):

- 3.84 TB KIOXIA KCD8XRUG3T84 SSDs
- 3.84 TB Samsung® MZ7LH3T8 SSDs

For the full analysis, read the report.

Testing was concluded on December 19, 2022.

Server Configurations

	Dell™ PowerEdge™ R6525 with KIOXIA SSDs	Dell™ PowerEdge™ R6515 with Samsung® SSDs
Server	Dell™ PowerEdge™ R6525	Dell™ PowerEdge™ R6515
Processor	AMD EPYC™ 7543 processor	AMD EPYC™ 7702P processor
Number of CPUs	1	1
Cores/Threads Per CPU	32/64	32/64
Cores/Threads Total	32/64	32/64
Frequency (Base/SCT/MCT)	2.80 GHz	2.00 GHz
Storage Controller 01	PCIe® Gen4 SSD shared backplane	PCIe® Gen3 SSD shared backplane
Disk	3.84 TB KIOXIA KCD8XRUG3T84	3.84 TB Samsung® MZ7LH3T8
Number of Disks	4	4
Installed Memory	256 GB error correction code (ECC) DDR4	256 GB error correction code (ECC) DDR4
Memory DIMM	32 GB Hynix® HMAA4GR7CJR8N-XN	16 GB Micron® 18ASF2G72PDZ-3G2J3
Memory Speed	3,200 megatransfers per second (MT/s)	2,933 MT/s (max 3,200 MT/s)
Number of Memory DIMMs	8	16
Operating System (OS)	Windows Server® 2022	Windows Server® 2022

OS Version	Version 21H2	Version 21H2
OS Kernel	OS build 20348.1547	OS build 20348.1194
BIOS Version	2.7.3	2.8.5
DiskSpd	DiskSpd 2.0.21a 9/21/2018	DiskSpd 2.0.21a 9/21/2018
Iometer	1.1.0.0	1.1.0.0

Testing Summary

Prowess Consulting engineers ran tests comparing the following two configurations:

- Dell™ PowerEdge™ R6525 server with four 3.84 TB KIOXIA KCD8XRUG3T84 drives running Windows Server® 2022 and Hyper-V®, hosting three Windows® 11 virtual machines (VMs), a single Microsoft® Active Directory® VM, a single file-server VM, and a single Microsoft® SQL Server® VM. In addition to the VM workloads, we used DiskSpd to run a series of benchmark performance tests.
- PowerEdge R6515 server with four 3.84 TB Samsung MZ7LH3T8 drives running Windows Server 2022 and Hyper-V, hosting three Windows 11 VMs, a single Active Directory VM, a single file-server VM, and a single SQL Server VM. In addition to the VM workloads, we used DiskSpd to run a series of benchmark performance tests.

We tested KIOXIA NVM Express® (NVMe®) drives against Samsung Serial ATA (SATA) drives with the hypothesis that using the NVMe drives would provide a better experience for virtualized workloads than the SATA drives.

Testing Procedures

The Prowess Consulting engineers completed the testing procedures to test DiskSpd on the PowerEdge R6525 server with four 3.84 TB KIOXIA drives and the PowerEdge R6515 server four 3.84 TB Samsung drives.

The PowerEdge R6515 and PowerEdge 6525 servers were tested with Windows Server 2022 version 21H2 preinstalled.

Setup and Configuration for Hyper-V® and Workload VMs

1. Log in to the server with administrator credentials.
2. Right-click the **Start** menu, and then select **Windows PowerShell (Admin)**.
3. At the **User Account Control** prompt, click **Yes**.
4. Run the following command to install required Windows Server roles and features:

```
Install-WindowsFeature -Name "Hyper-V", "Hyper-V-PowerShell"
```
5. Run the following command to restart the server:

```
shutdown /r /t 0
```
6. Log in to the server with administrator credentials.
7. Launch **Server Manager**.
8. Select **File and Storage Services**.
9. Select **Storage Pools**.
10. Under the **Storage Pools** view, click **Tasks**, and then select **New Storage Pool**.
    a. At the **Before You Begin** page, click **Next**.
    b. At the **Specify a Storage Pool Name and Subsystem** page, enter a name, and then click **Next**.
    c. At the **Select Physical Disks for the Storage Pool** page, select the four available disks, and then click **Next**.
    d. At the **Confirm Selections** page, click **Create**.
    e. At the **View Results** page, click **Close**.
11. Under the **Virtual Disks** view, click **Tasks**, and then select **New Virtual Disk**.
    a. At the **Select the storage pool** page, click **OK**.
    b. At the **Before you Begin** page, click **Next**.

      c.   At the **Specify the Virtual Disk Name** page, enter a name, and then click **Next**.

      d.   At the **Specify Enclosure Resiliency** page, click **Next**.

      e.   At the **Select the Storage Layout** page, select **Mirror**, and then click **Next**.

12. At the **Specify the Provisioning Type** page, click **Fixed**, and then click **Next**.

      a.   At the **Specify the Size of the Virtual Disk** page, select **Maximum size**, and then click **Next**.

      b.   At the **Confirm Selections** page, click **Create**.

      c.   At the **View Results** page, click **Close**.

13. The New Volume wizard will automatically launch.

      a.   At the **Before You Begin** page, click **Next**.

      b.   At the **Select the Server and Disk** page, click **Next**.

      c.   At the **Specify the Size of the Volume** page, click **Next**.

      d.   At the **Assign to a Drive Letter or Folder** page, click **Next**.

      e.   At the **Select File System Settings** page, enter a name in the **Volume label** field, and then click **Next**.

      f.   At the **Confirm Selections** page, click **Create**.

      g.   At the **Completion** page, click **Close**.

14. Launch **Hyper-V Manager**.

15. Click **Virtual Switch Manager**.

16. Create two virtual switches with the following parameters:

    •   Switch 1:

        »   **Name: Internal**

        »   **Connection type: Internal**

    •   Switch 2:

        »   **Name: External**

        »   **Connection Type: External Network**; select a network-connected network adapter

17. Click **OK**.

18. If prompted that **Pending changes may disrupt network connectivity**, click **Yes**.

19. Create a base VM with the following parameters:

      a.   Click **New** > **Virtual Machine**.

      b.   At the **Before You Begin** page, click **Next**.

      c.   At the **Specify Name and Location** page, enter **Base** in the **Name** field, and then click **Next**.

      d.   At the **Specify Generation** page, select **Generation 2**, and then click **Next**.

      e.   At the **Assign Memory** page, enter **8192**, and then click **Next**.

      f.   At the **Configure Networking** page, select **External**, and then click **Next**.

      g.   At the **Connect Virtual Hard Disk** page, click **Next**.

      h.   At the **Installation Options** page, click **Install an operating system from a bootable image file**, click **Browse**, select **Windows Server 2022 installation media**, and then click **Next**.

      i.   At the **Completing the New Virtual Machine Wizard** page, click **Finish**.

20. Select the VM, and then click **Settings**.

21. Select **Security**, select **Enable Trusted Platform Module**, and then click **OK**.

22. Click **Start**.

23. Complete the installation of Windows Server 2022 with the following parameters:

      a.   At the **Microsoft Server Operating System Setup** page, click **Next**.

      b.   Click **Install Now**.

      c.   At the **Activate Microsoft Server Operating System Setup** page, click **I don't have a product key**.

      d.   At the **Select the Operating System You Want to Install** page, select **Windows Server Standard (Desktop Experience)**, and then click **Next**.

      e.   At the **Applicable notices and license terms** page, click **I accept the Microsoft License Terms**, and then click **Next**.

      f.   At the **Which Type of Installation Do You Want** page, click **Custom**.

      g.   At the **Where Do You Want to Install the Operating System** page, click **Next**.

      h.   At the **Customize Settings** page, enter a password, confirm the password for the Administrator account, and then click **Finish**.

      i.   Press **Ctrl+Alt+Del**, and then log in to the server.

      j.   Right-click the **Start** menu, and then click **Settings**.

      k.   Select **Windows Updates**, and then click **Install updates**.

      l.   Right-click the **Start** menu, and then select **Windows PowerShell (admin)**.

      m.   Change directory using the following command:

```
cd c:/windows/system32/sysprep
```

      n.   Run the following command:

```
sysprep
```

      o.   Select **Generalize**, and then click **OK**.

      p.   Shut down the VM.

24. Copy the VHDX file three additional times for a domain controller, a SQL Server environment, and a file server.

25. Start the domain controller.

      a.   At the **Hi There** page, click **Next**.

      b.   At the **It's Time to Enter the Product Key** page, click **Do this later**.

      c.   At the **License Terms** page, click **Accept**.

      d.   At the **Customize Settings** page, enter a password, confirm the password, and then click **Finish**.

      e.   From the **Start** menu, search for **Network Connections**.

      f.   Right-click the connected network adapter, and then assign an internal non-routable IP.

      g.   Click **OK**.

      h.   From the **Server Manager** > **Dashboard**, click **Add roles and features**.

      i.   At the **Before You Begin** page, click **Next**.

      j.   At the **Select Installation Type** page, select **Role-based or feature-based installation**, and then click **Next**.

      k.   At the **Select Destination Server** page, click **Next**.

      l.   At the **Select Server Roles** page, select **Active Directory Domain Services**, and then click **Next**.

      m.   At the **Add features that are required for Active Directory Domain Services** prompt, click **Add Features**.

      n.   Click **Next**.

      o.   At the **Select Features** page, click **Next**.

      p.   At the **Active Directory Domain Services** page, click **Next**.

      q.   At the **Confirm Installation Selections** page, click **Install**.

      r.   At the **Installation Progress** page, click **Close**.

      s.   From **Server Manager** > **Post-deployment configuration**, click **Promote this server to a domain controller**.

      t.   At the **Deployment Configuration** page, select **Add a new forest**, enter **test.local** in the **Root domain name**, and then click **Next**.

      u.   At the **Domain Controller Options** page, enter a password, confirm the password, and then click **Next**.

      v.   At the **DNS Options** page, click **Next**.

      w.   At the **Additional Options** page, click **Next**.

      x.   At the **Paths** page, click **Next**.

      y.   At the **Review Options** page, click **Next**.

      z.   At the **Prerequisites Check** page, click **Install**.

      aa.   When prompted to restart, click **OK**.

26. Click **New** > **Virtual Machine**.

27. Follow step 19 to create the SQL Server VM; when prompted for the VHDX location, select the previously copied VHDX file.

28. Start the SQL Server VM, and then log in.

      a.   From the **Start** menu, search for **Network Connections**.

      b.   Right-click the connected network adapter, and then assign an internal non-routable IP.

      c.   Click **OK**.

      d.   From **Server Manager**, click **Local Server**.

      e.   Click **Domain**.

      f.   Join the server to **test.local**.

      g.   Restart the server when prompted.

      h.   Launch a browser.

      i.   Search for **Microsoft SQL Server 2022 eval**.

      j.   Download the Microsoft SQL Server 2022 evaluation media installation file (SQL2022-SSEI-Eval.exe).

    k.   Double-click the file to start the installation process.

        i.   At the **Evaluation Edition** page, select **Basic**.

        ii.   At the **Microsoft SQL Server License Terms** page, click **Accept**.

        iii.   At the **Specify SQL Server install Location** page, click **Install**.

        iv.   At the **Installation Has Completed Successfully** page, click **Install SSMS**.

    l.   Double-click **SSMS-Setup-ENU.exe** to install SQL Server Management Studio (SSMS).

    m.   Download **HammerDB 4.5 Windows**.

    n.   Launch **SQL Server Management Studio**.

    o.   At the **Connect to Server** page, click **Connect**.

    p.   Expand **Security** > **Logins**.

    q.   Right-click **sa**, and then click **Properties**.

    r.   Enter a password, and then confirm the password.

    s.   Select the **Status** page, and then click **Login: Enabled**.

    t.   Click **OK**.

    u.   From the **Start** menu, search for **ODBC**.

    v.   Launch **ODBC Data Source Administrator**.

    w.   Click **Add**.

    x.   Search for **ODBC Driver 17 for SQL Server**, and then click **Finish**.

    y.   Continue with the following parameters:

        i.   At the **Create a New Data Source to SQL Server** page, enter a name in the **Name** field, enter **localhost** in the **Server** field, and then click **Next**.

        ii.   At the **How Should SQL Server Verify the Authenticity of the Login ID** page, select **With SQL Server authentication using a login ID and password entered by the user**.

        iii.   In the **Login ID** field, enter **sa**.

        iv.   In the **Password** field, enter the sa password.

        v.   Click **Next**.

        vi.   Click **Next**.

        vii.   Click **Finish**.

        viii.   Click **Test Data Source**.

    z.   Go to the HammerDB directory location.

    aa.   Double-click **hammerdb.bat** to launch **HammerDB**.

    bb.   Double-click **SQL Server**.

    cc.   Select **SQL Server** and the **TPROC-C benchmark** option, and then click **OK**.

    dd.   Expand **TPROC-C** > **Schema Build**.

    ee.   Double-click **Options**, and then use the following parameters:

        i.   **SQL Server: VM Name**

        ii.   **Authentication: SQL Server Authentication**

        iii.   **SQL Server User ID:** *sa*

        iv.   **SQL Server User Password:** *sa password*

        v.   **Number of warehouses: 15**

        vi.   **Virtual Users to Build Schema: 4**

    ff.   Click **OK**.

    gg.   Double-click **Build** to build the schema.

29. From **Hyper-V Manager,** click **New** > **Virtual Machine**.

30. Follow step 19 to create the file-server VM; when prompted for the VHDX location, select the previously copied VHDX file.

31. Start the file-server VM and log in.

32. From the **Start** menu, search for **Network Connections**.

33. Right-click the connected network adapter, and then assign an internal non-routable IP.

34. Click **OK**.

35. From **Server Manager,** click **Local Server**.

36. Click **Domain**.

37. Join the server to **test.local**.

38. From **Server Manager** > **Dashboard**, click **Add roles and features**.
39. At the **Before You Begin** page, click **Next**.
40. At the **Select Installation Type** page, click **Next**.
41. At the **Select Destination Server** page, click **Next**.
42. Expand **File and Storage Services**, select **File Server**, and then click **Next**.
43. At the **Select Features** page, click **Next**.
44. At the **Confirm Installation Selections** page, click **Install**.
45. Click **Close**.
46. Expand **File and Storage Services**.
47. Under **Shares**, click **Tasks**, and then click **New Share**.
48. Click **SMB Share – Quick**, and then click **Next**.
49. Click **Type a Custom Path**, and then click **Browse**.
50. Create a new file-server folder, and then click **Next**.
51. At the **Specify Share Name** page, click **Next**.
52. At the **Configure Share Settings** page, click **Next**.
53. At the **Specify Permissions to Control Access** page, click **Next**.
54. At the **Confirmation Selections** page, click **Create**.
55. Launch a browser and search for **Windows 11 ISO**.
56. From <u>Download Windows 11 (microsoft.com)</u>, download the Windows 11 Disk Image (ISO) installation file (English language: **Win11_22H2_English_x64v1.iso**).
57. From **Hyper-V Manager**, click **New** > **Virtual Machine**.
58. Follow step 23 to create the base VM; when prompted for the install ISO, use the Windows 11 ISO to install the operating system (OS). Follow the installation prompts.
    a.   Once the OS is installed, log in.
    b.   Click the **Start** menu, and then select **Settings**.
    c.   Select **Windows Updates**, and then click **Install updates**.
    d.   Launch a web browser and search for **HDXPRT**.
    e.   From <u>www.principledtechnologies.com/benchmarkxprt/hdxprt/2019/HDXPRT4_1_2_Install_11_13_2019.zip</u>, download the zipped HDXPRT file (**HDXPRT4_1_2_Install_11_13_2019.zip**) and extract the installation files.
    f.   Double-click **HDXPRTsetup** to begin the installation:
        i.   At the **Welcome** page, click **Next**.
        ii.   At the **License Agreement** page, click **I agree**.
        iii. At the **Completing Setup** page, click **Finish**.
        iv.   From the **Start** menu, search for **Network Connections**.
        v.   Right-click the connected network adapter, and then assign an internal non-routable IP.
        vi.   Click **OK**.

Setup and Configuration for Hyper-V Host DiskSpd

1. From the **Start** menu, search for **Windows PowerShell**, right-click on the app icon, and then select **Run As Administrator**.
2. Run the following commands to download DiskSpd:

```
$client = new-object System.Net.WebClient
$client.DownloadFile("https://github.com/microsoft/diskspd/releases/download/v2.0.21a/DiskSpd.
zip","c:\diskspd\DiskSpd-2.0.21a.zip")
```

3. Run the following command to extract DiskSpd:

```
Expand-Archive –LiteralPath c:\diskspd\DiskSpd-2.0.21a.zip –DestinationPath c:\diskspd
```

4. Run the following DiskSpd workloads to test the storage performance for the Samsung SATA SSD and the KIOXIA NVMe SSD:
    • 100 percent random read:

```
.\diskspd –t64 –o8 –b4k –r4k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o16 –b4k –r4k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –r4k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
```

    • 100 percent random write:

```
.\diskspd –t64 –o8 –b4k –r4k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
```

```
.\diskspd –t64 –o16 –b4k –r4k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –r4k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
```

- 70 percent random read:

```
.\diskspd –t64 –o8 –b4k –r4k –w30 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o16 –b4k –r4k –w30 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –r4k –w30 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
```

- 50 percent random read:

```
.\diskspd –t64 –o8 –b4k –r4k –w50 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o16 –b4k –r4k –w50 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –r4k –w50 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
```

- 30 percent random read:

```
.\diskspd –t64 –o8 –b4k –r4k –w70 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o16 –b4k –r4k –w70 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –r4k –w70 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
```

- 100 percent sequential read:

```
.\diskspd –t64 –o8 –b4k –si128k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o8 –b4k –si512k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o8 –b4k –si1024k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o16 –b4k –si128k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o16 –b4k –si512k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o16 –b4k –si1024k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –si128k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –si512k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –si1024k –w0 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
```

- 100 percent sequential write:

```
.\diskspd –t64 –o8 –b4k –si128k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o8 –b4k –si512k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o8 –b4k –si1024k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o16 –b4k –si128k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o16 –b4k –si512k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o16 –b4k –si1024k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –si128k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –si512k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
.\diskspd –t64 –o32 –b4k –si1024k –w100 –d300 –Sh –D –L –c6700G D:\disktest\IO.dat
```

Hyper-V VM Startup Scripts

Configure the following startup scripts on the VMs:

File server:

```
$amount = "50"
$folder = "c:\FileSvr\"
$file = "temp"
$ext = "txt"

get-childitem –path $folder –include *.txt –recurse | remove-item

1..$amount | % { $out = new-object byte[] 1073741824; (new-object Random).NextBytes($out);
[IO.File]::WriteAllBytes("$folder$file.$_.$ext", $out)}
```

SQL Server:

```
Try{
    Do{
        $mssql = Get-Service –Name MSSQLSERVER –ErrorAction SilentlyContinue
    }
    While($mssql.Status –ne "Running")
}
Catch{

}
start-process cmd –WorkingDirectory "C:\Users\administrator.TEST\Desktop\HammerDB-4.5-Win\
HammerDB-4.5" –argumentlist "/C hammerdbcli.bat auto hammerdb_script.tcl"
```

Windows 11:

```
Set-location -path "c:\program files (x86)\HDXPRT4\HDXPRT4_Workloads\HDXPRT4_Tests\"
cmd /c hdxprt4.exe testname=test
```

Windows scheduled task:

1. From the **Start** menu, search for **Task Scheduler** and open the app.
2. On the **Action** tab, choose **Create task...**
3. On the **General** tab, select **Run whether user is logged on or not**.
4. On the **Triggers** tab, click **New**.
5. From the **Task** drop-down menu, select **At Startup**.
6. On the **Actions** tab, click **New**.
7. In **Program/Script**, enter:

```
C:\Windows\System32\WindowsPowerShell\v1.0\powershell.exe
```
8. In **Add arguments**, enter:

```
–command "C:\scripts\startup.ps1"
```
9. Click **OK** to save the task.