Advanced Memory Test on Xeon-Based ThinkSystem Servers

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Abstract

The latest firmware updates for Lenovo ThinkSystem servers have introduced a new feature called Advanced Memory Test (AMT) within Lenovo XClarity Provisioning Manager (LXPM). This feature enables in-depth memory tests to be performed on all the Dual In-line Memory Modules (DIMMs) present in the server, which will result in reduced memory errors on Lenovo ThinkSystem servers. To enable this test option, XClarity Controller (XCC), Unified Extensible Firmware Interface (UEFI), and LXPM firmware should be updated to the same release cycle.

This whitepaper explains the process of enabling AMT, the Memory Repair it performs and the various result cases it produces.

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Advanced Memory Test on Xeon-Based ThinkSystem servers

The Intel Advanced Memory Test (AMT) feature is supported on the following servers: Lenovo ThinkSystem 1st generation (with Intel 1st Generation Xeon® Processors – codenamed Skylake, and 2nd Generation Xeon® Processors – codenamed Cascade Lake), ThinkSystem 2nd generation (with Intel 3rd Generation Xeon® Processors – codenamed Ice Lake-SP or Cooper Lake), and ThinkSystem 3rd generation (with Intel 4th Generation Xeon® Processors – codenamed Sapphire Rapids-SP). The matrix below details the appropriate UEFI version for AMT support in ThinkSystem for each generation:

ThinkSystem Generation	CPU	UEFI Release
ThinkSystem 1st generation	Sky Lake	July/2020* and later version
	Cascade Lake	July/2020* and later version
ThinkSystem 2nd generation	Cooper Lake	Apr/2021* and later version
	Ice Lake-SP	May/2021* and later version
ThinkSystem 3rd generation	Sapphire Rapids-SP	Feb/2023* and later version

*Note: detailed release time may vary for different platforms, please consult with Lenovo support team.

Intel Advanced Memory Test (AMT) contains both Intel memory test algorithms and Dual In-line Memory Module (DIMM) vendors' memory test algorithms. AMT-related code is integrated in Unified Extensible Firmware Interface (UEFI). Therefore, AMT is executed in the Power On Self Test (POST) phase of UEFI. It screens DIMMs, and attempts to repair marginal DIMMs during the test.

Lenovo XClarity Provisioning Manager (LXPM) is an UEFI application embedded tool and is a graphical user interface for UEFI setup configuration. By default, LXPM user interface is displayed when F1 is pressed during ThinkSystem boot up. On ThinkSystem, Intel AMT function is enabled together by LXPM, UEFI and Lenovo XClarity Controller (XCC). The AMT feature can be enabled on the related page of LXPM (the system must be rebooted for enablement). UEFI triggers Intel AMT and reports the System Event Log to XCC to indicate the start and end of AMT. It then stores the AMT final results in XCC. Following is the high-level flow chart of AMT implementation:

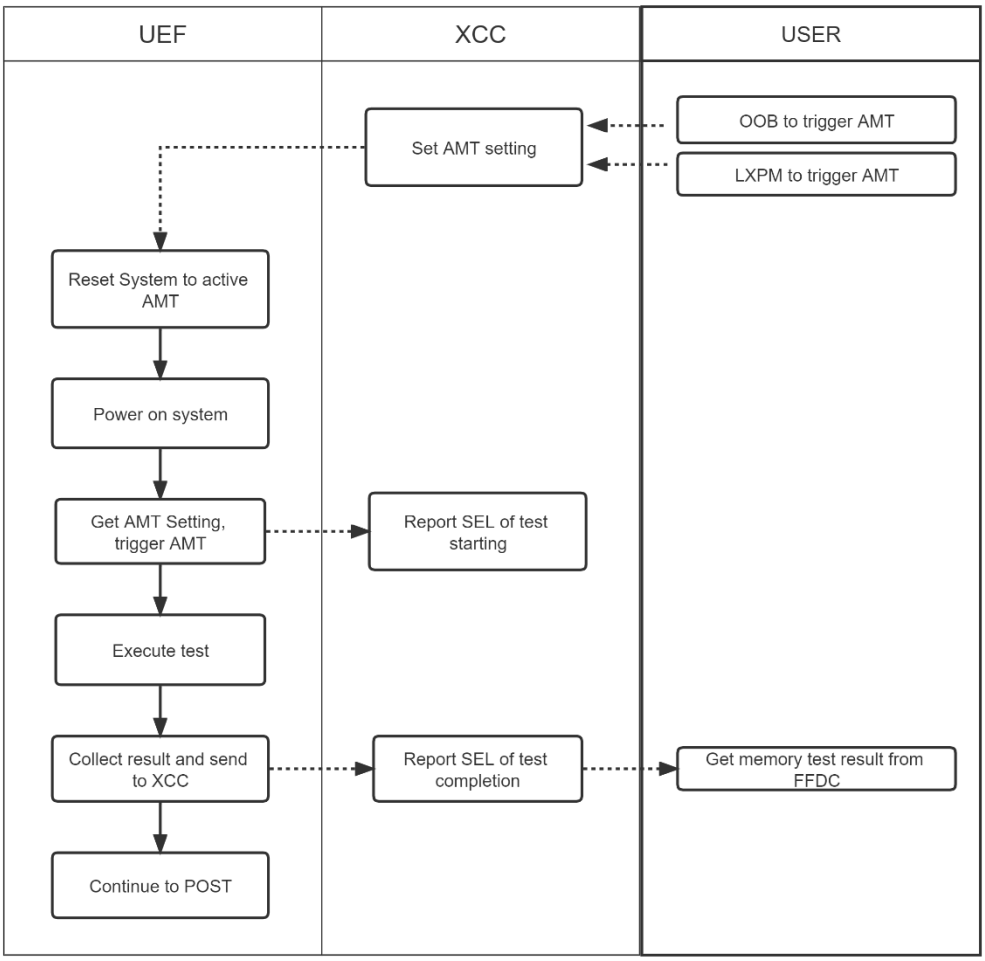


Figure 1: ThinkSystem AMT High Level Flowchart

Enabling Advanced Memory Test

The Advanced Memory Test feature enables in-depth memory tests to be performed on all DDR4 and DDR5 memory modules present in the server. It should be noted that the entire code stack needs to be updated to the same release cycle in order to enable this test option which includes: XCC, UEFI and LXPM firmware. As a result of this test, memory errors will be reduced on Lenovo ThinkSystem Servers. System Events associated with memory errors are:

Event ID	Severity	Message String	Notes
FQXSFMA0002M	Error	An uncorrectable memory error has been detected on DIMM [arg1] at address [arg2]. [arg3]	[arg1]: DIMM silk label [arg2]: System address [arg3]: DIMM identifier
FQXSFMA0012L	Warning	The [arg1] PFA Threshold limit has been exceeded on DIMM [arg2] at address [arg3]. [arg4]	[arg1]: high or low [arg2]: DIMM silk label [arg3]: System address

			[arg4]: DIMM identifier
FQXSFMA0013I	Info	Mirror Fail-over complete. DIMM [arg1] has failed over to the mirrored copy. [arg2]	[arg1]: DIMM silk label [arg2]: DIMM identifier
FQXSFMA0026G	Warning	Multi-bit CE occurred on DIMM [arg1], need to restart the system for DIMM Self-healing to attempt post package repair (PPR)	[arg1]: DIMM silk label
FQXSFMA0027M	Warning	DIMM [arg1] Self-healing, attempt post package repair (PPR) failed at Rank [arg2] Sub Rank [arg3] Bank [arg4] Row [arg5] on Device [arg6]. [arg7]	[arg1]: DIMM silk label [arg2]: Rank ID [arg3]: sub Rank ID [arg4]: Bank ID [arg5]: Row ID [arg6]: Device ID [arg7]: DIMM identifier
FQXSFMA0028M	Warning	DIMM [arg1] Self-healing, attempt post package repair (PPR) exceeded DIMM level threshold [arg2] at Rank [arg3] Sub Rank [arg4] Bank [arg5] Row [arg6] on Device [arg7]. [arg8]	[arg1]: DIMM silk label [arg2]: Threshold value [arg3]: Rank ID [arg4]: sub Rank ID [arg5]: Bank ID [arg6]: Row ID [arg7]: Device ID [arg8]: DIMM identifier

Lenovo suggests that customers run Advanced Memory Tests at least once every six months, as well as prior to new system deployment or system maintenance.

AMT is run by each socket of the Central Processing Unit (CPU) in parallel. Therefore, the AMT run time varies depending on DIMM configuration. For example, on the ThinkSystem SR950, each CPU socket can have 12 DIMMs. In total, SR950 can have 96 numbers of 256GB DIMMs. In this case, it takes about 40 minutes for AMT to run, as each CPU socket carries out memory training and AMT on its own.

ThinkSystem has another feature called POST watchdog timer. XCC starts the POST watchdog timer to monitor UEFI booting. If UEFI boot hangs and the watchdog timer elapses, XCC resets the system. POST watchdog timer is disabled by default and its value, in minutes, can be set to a specified range. Therefore, while running an AMT, if larger than 16 GB DIMM modules are used, it is necessary to ensure that the POST watchdog timer is disabled and hence cannot unexpectedly interrupt AMT execution. This can be done by LXPM, OneCLI and Redfish, as described in the following sections.

Using LXPM to trigger AMT

Restart ThinkSystem Server, go to F1 Setup (for text mode) or LXPM (for graphics mode), click on System Settings -> Recovery and RAS -> System Recovery -> POST Watchdog Timer and check its setting.

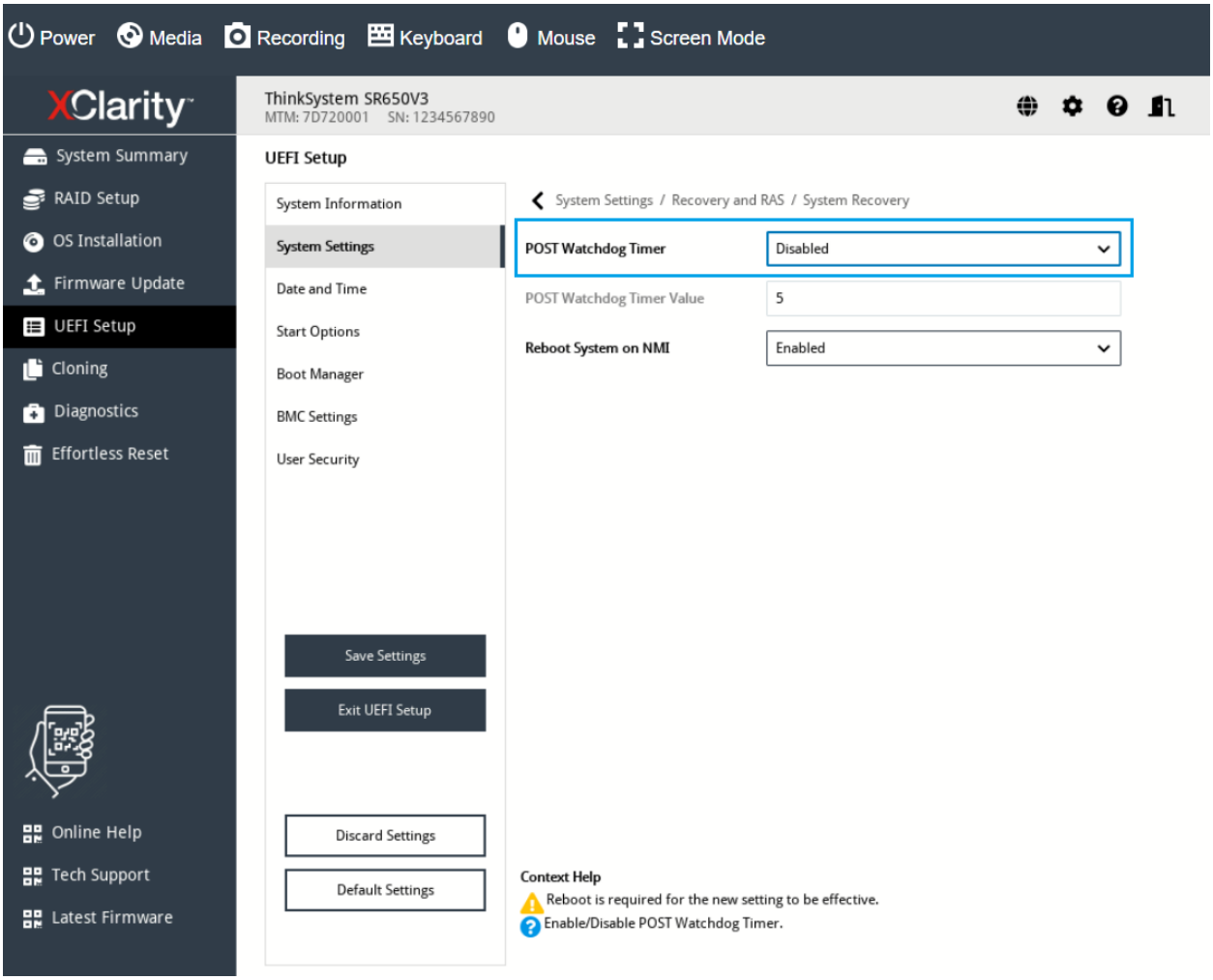


Figure 2: POST Watchdog Timer Setting in LXPM

Then, in LXPM environment, select **Diagnostics** → **Run Diagnostics** → **Memory Test** → **Advanced Memory Test** to enable the Advanced Memory Test.

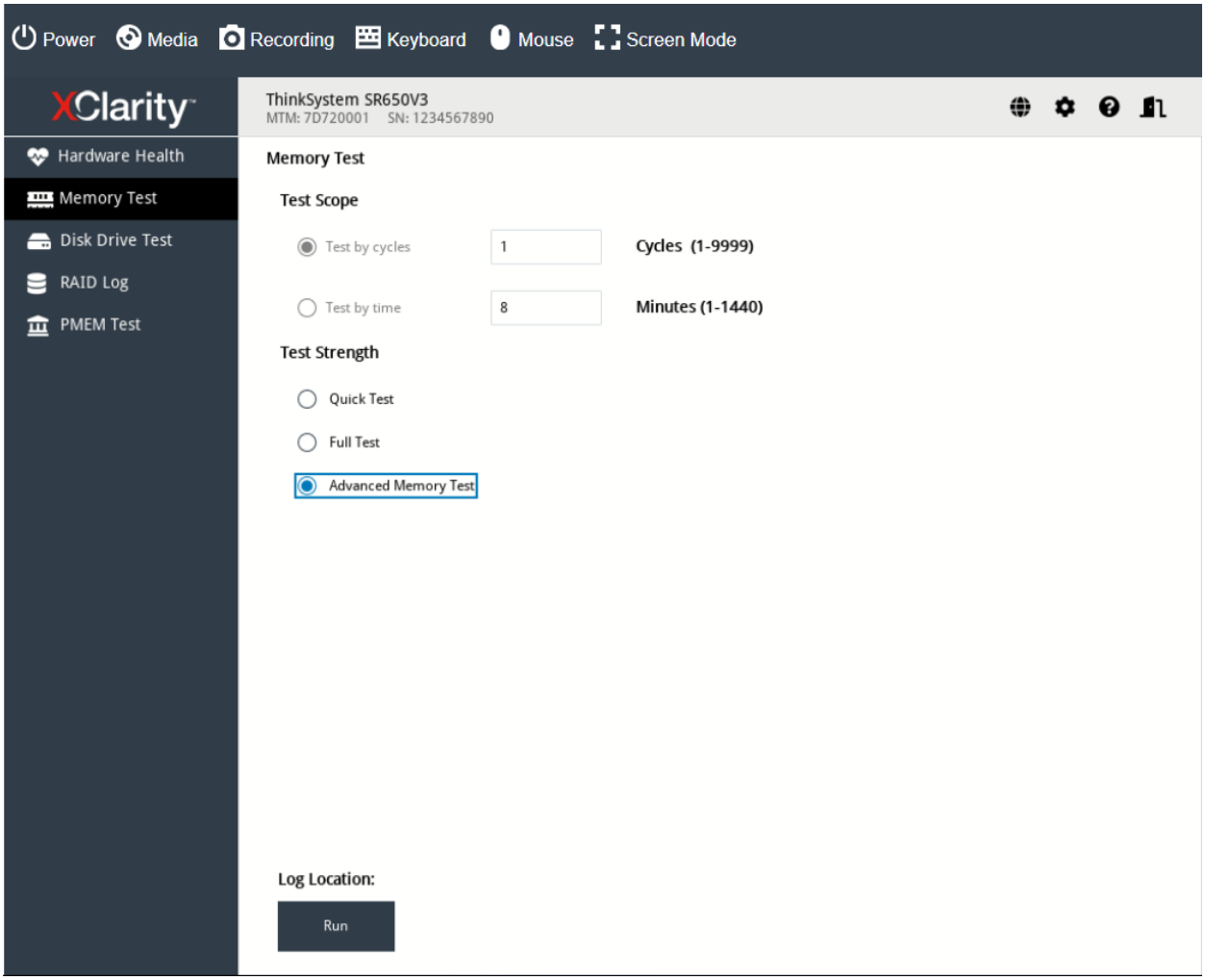


Figure 3: AMT Option in LXPM

Reboot the system to perform AMT in the next UEFI boot. While running the Advanced Memory Test, UEFI shows the message “Advanced memory test in progress, please stand by” on the splash screen as shown below:

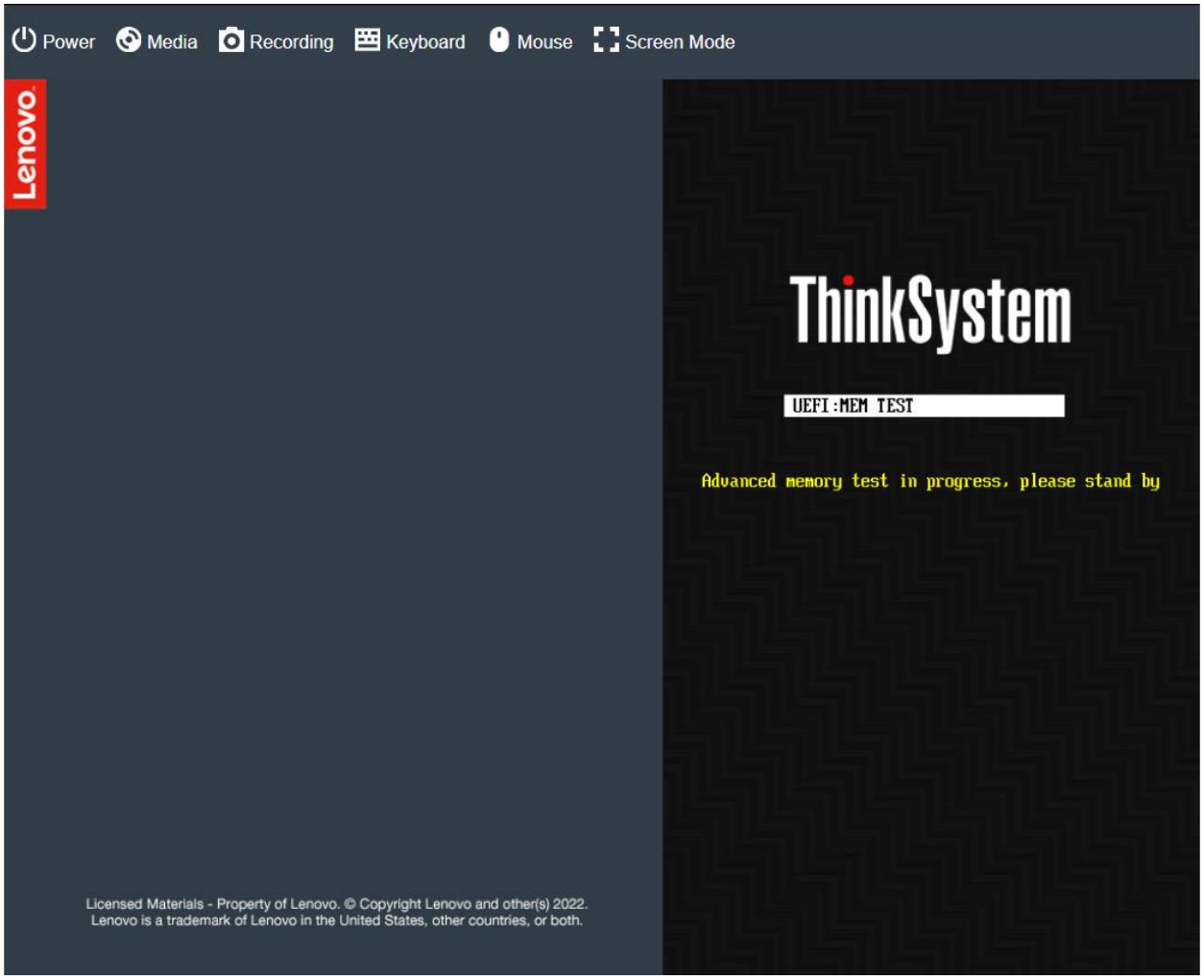


Figure 4: UEFI Running AMT

Meanwhile, UEFI reports the AMT starting progress code to XCC. XCC reports the following System Event Log on its web interface to indicate that the Advanced Memory Test is running:

Event ID	Severity	Message String
FQXSPFW0004I	Info	UEFI advanced memory test is running.

After the AMT is finished, UEFI reports the AMT-ending progress code to XCC. XCC reports the following System Event Log on its web interface to indicate that the Advanced Memory Test is completed:

Event ID	Severity	Message String
FQXSPFW0005I	Info	UEFI advanced memory test is completed.

Using OneCLI to trigger AMT

Command to enable AMT:

```
OneCli.exe config set Memory.MemoryTest Enable --imm
xcc_user_id:xcc_password@xcc_external_ip

OneCli.exe config set Memory.AdvMemTestOptions 0xF0000 --override --imm
xcc_user_id:xcc_password@xcc_external_ip ; This enables DIMM vendor
supplied tests

OneCli.exe config set SystemRecovery.PostWatchdogTimer Disable --imm
xcc_user_id:xcc_password@xcc_external_ip
```

Command to disable AMT:

```
OneCli.exe config set Memory.MemoryTest Disable --imm
xcc_user_id:xcc_password@xcc_external_ip

OneCli.exe config set Memory.AdvMemTestOptions 0 --override --imm
xcc_user_id:xcc_password@xcc_external_ip

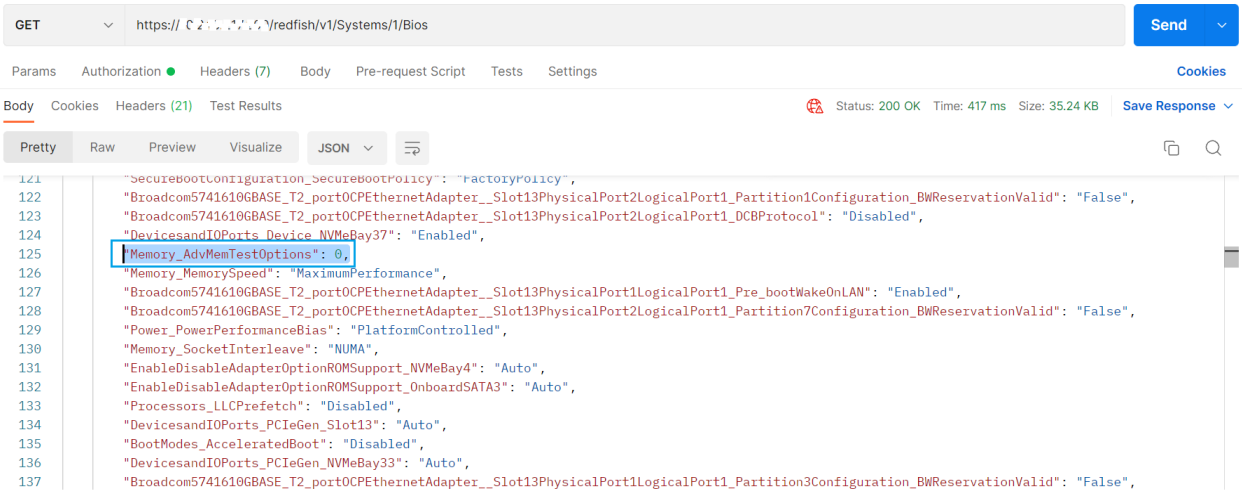
OneCli.exe config set SystemRecovery.PostWatchdogTimer Enable --imm
xcc_user_id:xcc_password@xcc_external_ip
```

Using Redfish to trigger AMT

Command to retrieve current settings:

GET method: Retrieve AMT test options

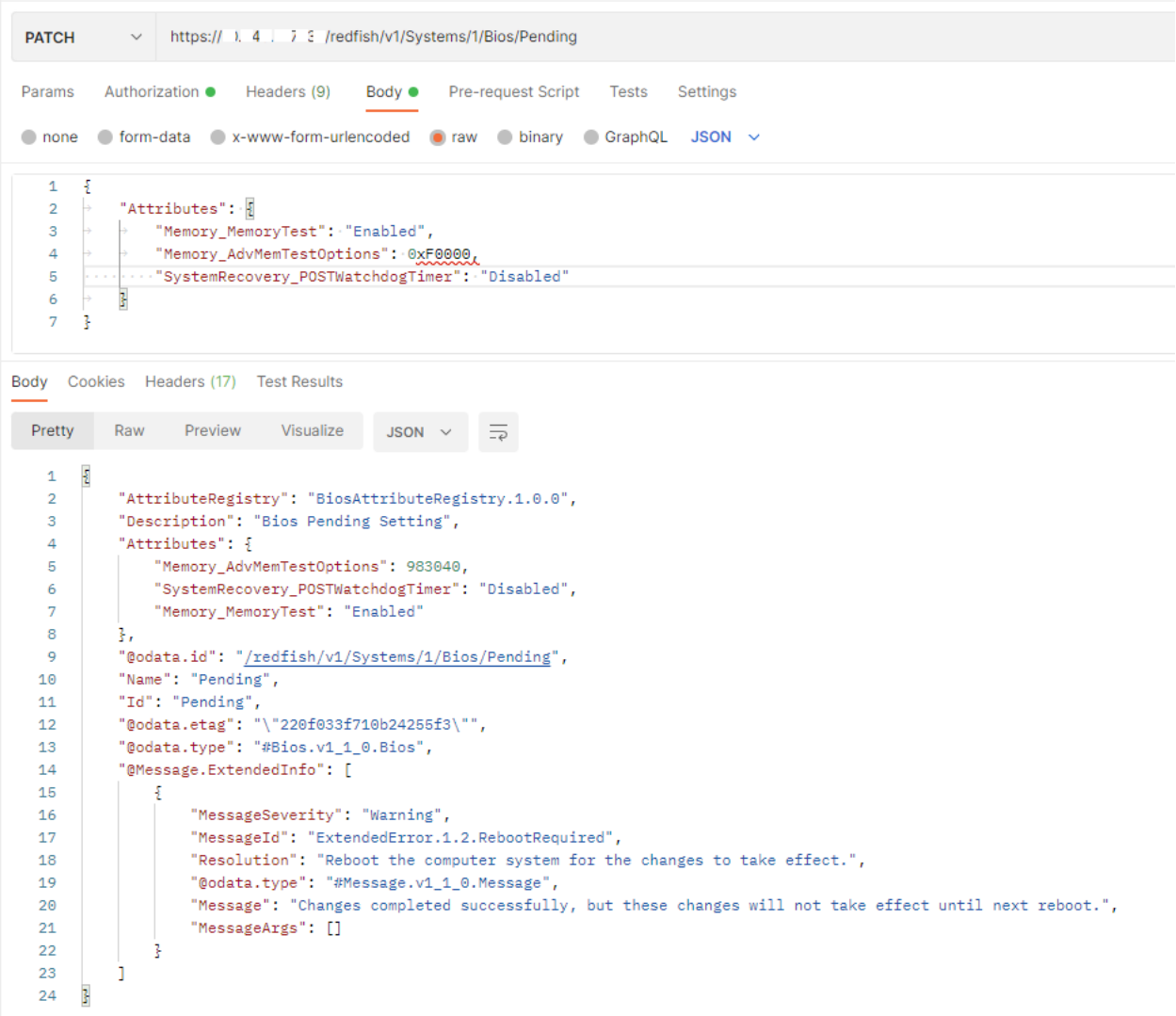
URL:https://{{xcc_external_ip }}/redfish/v1/Systems/1/Bios*



Command to configure AMT settings:

PATCH method: Configure AMT test options

URL: https://{{xcc_external_ip }}/redfish/v1/Systems/1/Bios/Pending*



*Note: detailed URL may vary for different platforms.

Memory Repair with Advanced Memory Test

The Joint Electron Device Engineering Council (JEDEC) defines a method called Post Package Repair (PPR) for Double Data Rate 4 (DDR4) /DDR5 specifications. Post Package Repair supports Fail Row address repair. It is an optional feature for a 4Gbit Dynamic Random Access Memory (DRAM) die and a required one for DRAM die of 8Gbit and above. PPR-Support is specified in DIMM datasheet and Serial Presence Detect (SPD) in Module.

There are two kinds of PPR features: soft Post Package Repair (sPPR) and hard Post Package Repair (hPPR). sPPR is a way to repair a row element in a Bank Group on a DDR4/DDR5 DRAM device quickly but temporarily. sPPR works if DIMM's voltage is within Operating Range and is erased when DIMM's voltage is removed, or the device is reset. On the other hand, hard Post Package Repair is a permanent repair of a row element. With hPPR, the Fail Row address

is repaired by the electrical programming of the Electrical-fuse scheme and cannot be switched back to un-fused states once programmed.

If Intel AMT screens out weak or bad cells/rows during the test, it uses PPR to repair the failing row for that DIMM. ThinkSystem sets the PPR to hPPR by default. Thus, once AMT finds any weak or bad cells/rows, it uses hPPR to repair the related rows for the DIMMs permanently thereby improving the memory reliability of the system.

When a PPR is performed in AMT, UEFI reports the following System Event Log:

Event ID	Severity	Message String	Notes
FQXSFMA0026I	Info	DIMM [arg1] Self-healing, attempt post package repair (PPR) at Rank [arg2] Sub Rank [arg3] Bank [arg4] Row [arg5] on Device [arg6]. [arg7]	[arg1]: DIMM silk label [arg2]: Rank ID [arg3]: sub Rank ID [arg4]: Bank ID [arg5]: Row ID [arg6]: Device ID [arg7]: DIMM identifier

In case a PPR operation fails during AMT, UEFI reports the following System Event Log indicating the PPR's failure:

Event ID	Severity	Message String	Notes
FQXSFMA0027M	Warning	DIMM [arg1] Self-healing, attempt post package repair (PPR) failed at Rank [arg2] Sub Rank [arg3] Bank [arg4] Row [arg5] on Device [arg6]. [arg7]	[arg1]: DIMM silk label [arg2]: Rank ID [arg3]: sub Rank ID [arg4]: Bank ID [arg5]: Row ID [arg6]: Device ID [arg7]: DIMM identifier

ThinkSystem UEFI also defines a thresholder for the PPR operation in a DIMM. If the operation reaches the thresholder, UEFI reports the following System Event Log for the last PPR operation of that DIMM:

Event ID	Severity	Message String	Notes
FQXSFMA0028M	Warning	DIMM [arg1] Self-healing, attempt post package repair (PPR) exceeded DIMM level threshold [arg2] at Rank [arg3] Sub Rank [arg4] Bank [arg5] Row [arg6] on Device [arg7]. [arg8]	[arg1]: DIMM silk label [arg2]: Threshold value [arg3]: Rank ID [arg4]: sub Rank ID [arg5]: Bank ID [arg6]: Row ID [arg7]: Device ID [arg8]: DIMM identifier

If a DIMM fails AMT and cannot be repaired by PPR, UEFI reports the following System Event Log to identify the faulty part:

Event ID	Severity	Message String	Notes
FQXSFMA0008M	Error	DIMM [arg1] has failed the POST memory test. [arg2]	[arg1]: DIMM silk label [arg2]: DIMM identifier

Final Output of Advanced Memory Test

After AMT is completed, ThinkSystem UEFI collects the test results and saves them in the XCC storage. The system then returns to the Diagnostic Page of LXPM and reminds the user to save the AMT log to a USB disk.

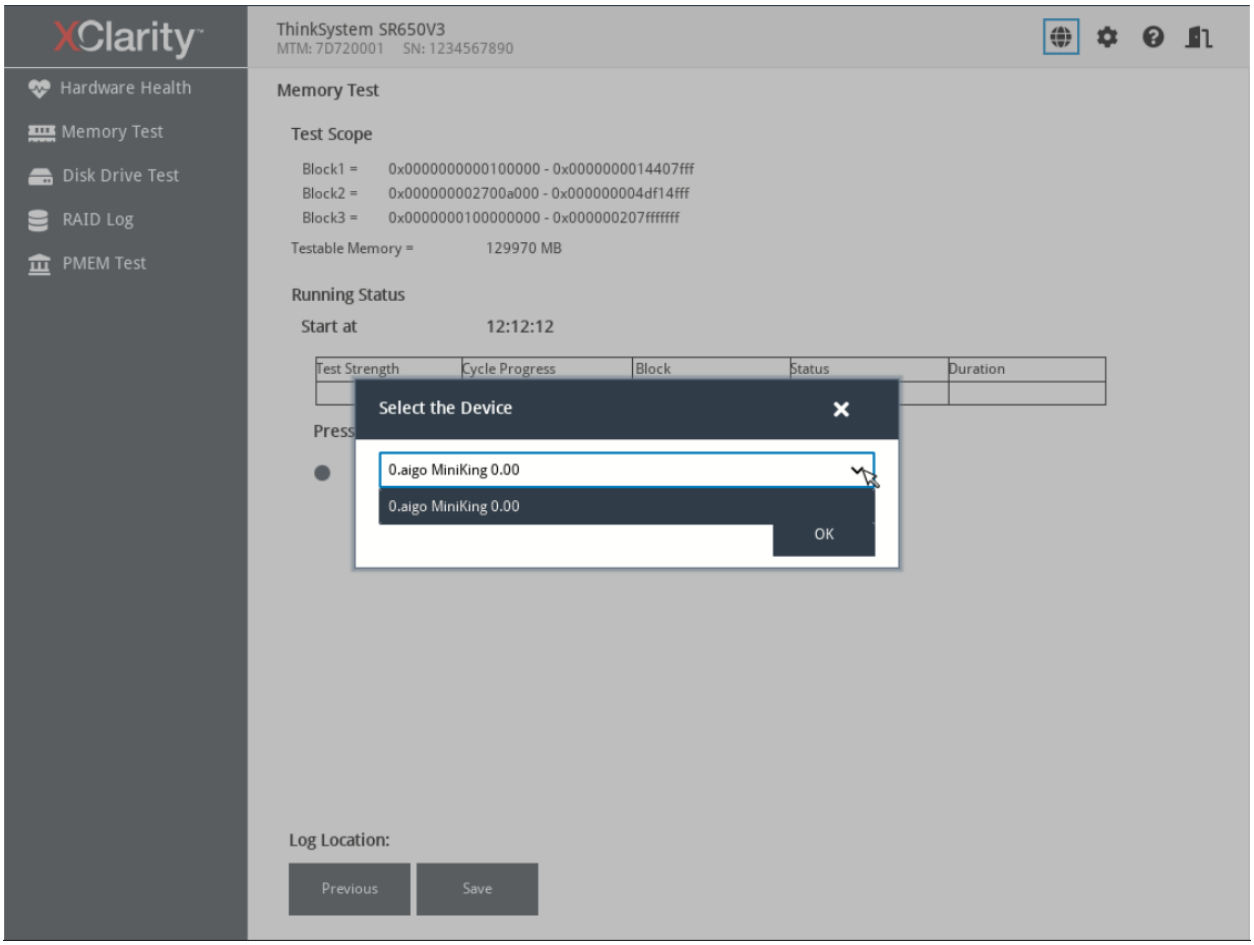


Figure 5: Saving AMT Log

Once saving the AMT log is confirmed, the log is saved into USB disk and its file path is specified by “Log location”

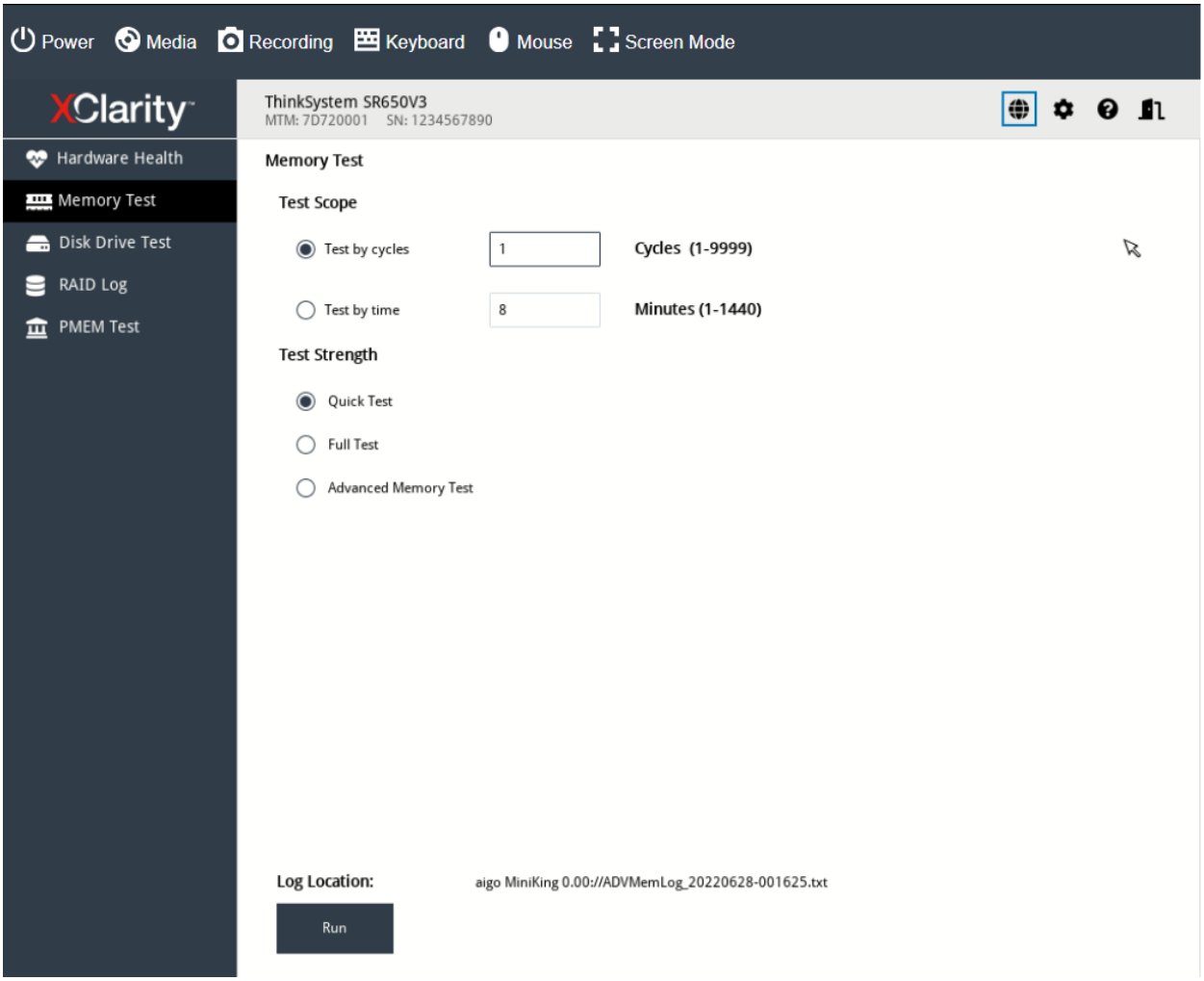
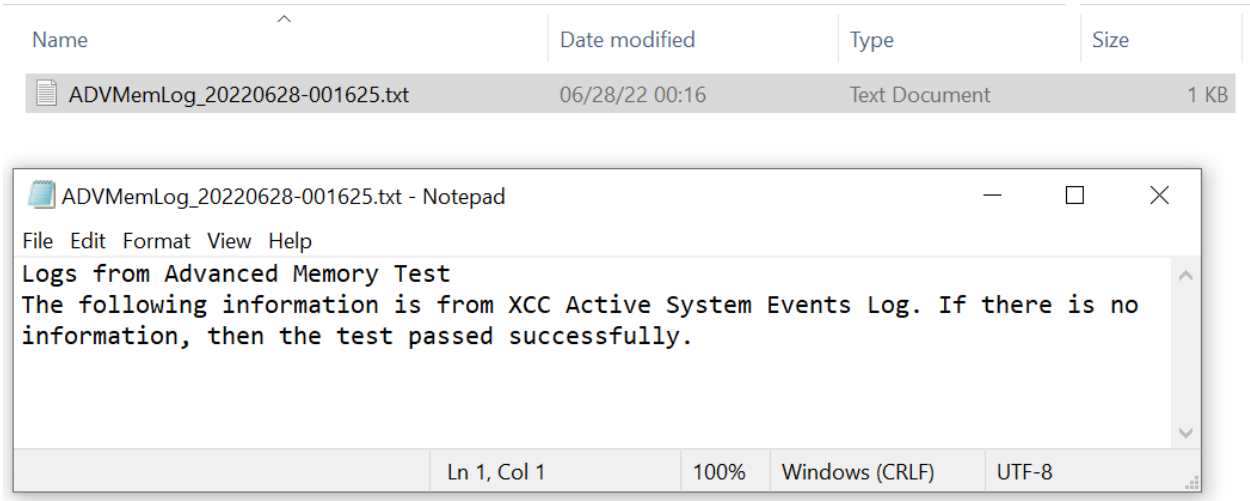
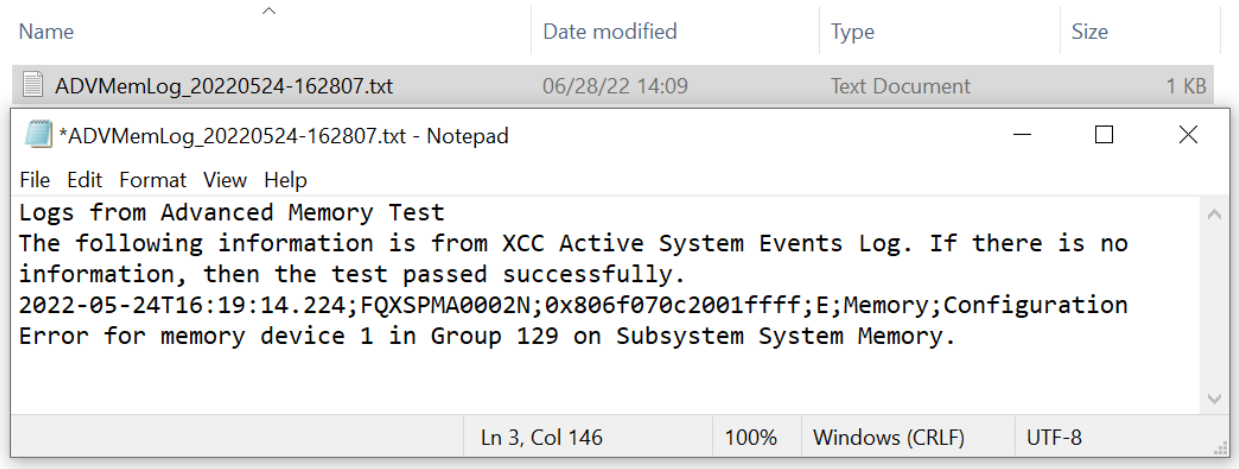


Figure 6: AMT log location

Following is the log file indicating the success of AMT.



If AMT fails, following is an example of log file:



Every DIMM will have any one of the following memory test results:

Result	**Comment**
PASS	The DIMM has passed the memory test
SKIPPED	The DIMM is not in the support list
FAIL_PPR_DISABLED	The DIMM failed the memory test, but “Repair” was NOT specified
FAIL_PPR_PASS	The DIMM failed the memory test, “Repair” was specified, and the DIMM was repaired
FAIL_PPR_FAIL	The DIMM failed the memory test, “Repair” was specified but the DIMM was NOT able to be repaired

Following is an example of a result (Following test result log is in FFDC /var/DS/memory-test-results):

```
N0.C0.D0: [MfgId: CE00] [S/N: 0347D030] [P/N: M393ABG40M5B-CYF    ] [ww44 2018] PASS

N0.C1.D0: [MfgId: CE00] [S/N: 03473A8D] [P/N: M393ABG40M5B-CYF    ] [ww44 2018] PASS

N0.C2.D0: [MfgId: CE00] [S/N: 03473A44] [P/N: M393ABG40M5B-CYF    ] [ww44 2018] PASS

N0.C3.D0: [MfgId: CE00] [S/N: 0347D05A] [P/N: M393ABG40M5B-CYF    ] [ww44 2018] PASS
```

DIMM Manufacture ID is specified by DIMM SPD. The following table maps the Manufacture ID to DIMM vendor.

DIMM Manufacture ID	DIMM Vendor
0xCE00	Samsung
0xAD00	Hynix
0x2C00	Micron
0x9801	Kingston
0x8900	Intel
0x9401	Smart Modular

Note:

1. ThinkSystem supports Intel Optane PMEM. Although PMEM diagnostic is not supported by AMT, it is supported by a dedicated PMEM diagnostic tool provided by LXPM at: **Diagnostics → Run Diagnostics → PMEM Test**.
2. Platforms may slightly differ from one another in System Event Log or in test scope.

References

For further information, refer to the following documents:

1: Lenovo XClarity Provisioning Manager (LXPM) Introduction

https://datacentersupport.lenovo.com/us/en/products/solutions-and-software/software/lenovo-xclarity-provisioning-manager/lxpm/solutions/ht504674

2: Lenovo's best practices in response to the Intel® uncorrectable memory error handling on Gen 1, Gen 2 or "H" SKUs of Gen 3 Xeon® Scalable processors

https://support.lenovo.com/us/en/solutions/HT512486

3: LXPM Advanced Memory Test reduces DIMM errors - Lenovo ThinkSystem and Lenovo ThinkAgile Servers

https://datacentersupport.lenovo.com/cn/en/solutions/ht511056

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