Cybenetics Chassis Test Protocol

Revision 1.4

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Revision History

Version	Release Date	Notes
1.0	September 2020	First draft
1.1	May 2021	Significant changes in testing methodology
1.2	June 2022	Changes in Soundproof levels
1.3	September 2023	Major methodology changes
1.4	June 2024	Various minor changes

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Prologue

Taking accurate noise and thermal measurements in chassis (PC enclosures) is a challenge, and besides experience, it also requires specialized equipment and proper facilities, especially for noise measurements. After extensive research on this subject, we devised the methodologies we analyze in the following paragraphs. It is a work in progress, meaning that we will constantly update the corresponding procedures until we develop the perfect methodologies. Since nothing is perfect in this world, we will never settle down. On the contrary, we will always try to find the optimal testing procedures to reveal every aspect of the Device Under Test (DUT).

Noise Measurement Equipment and DUT Setup

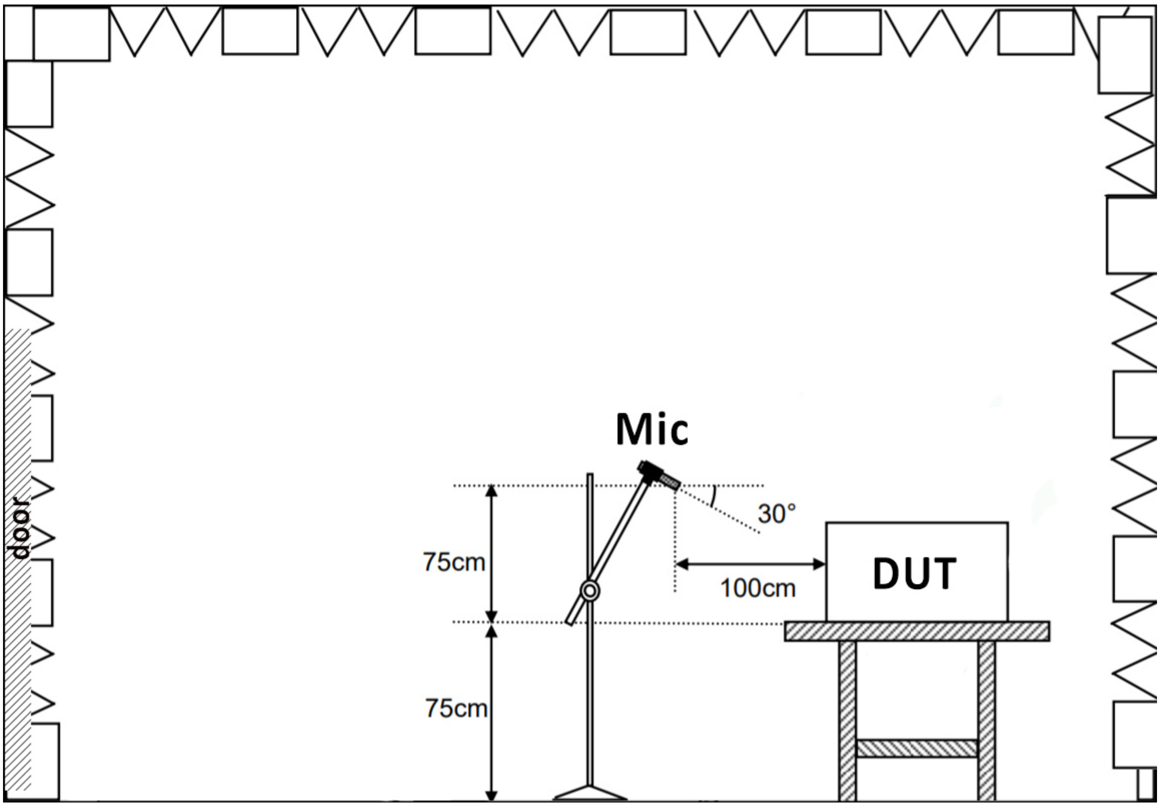
Before conducting our noise measurements, we must install a complete system into the chassis. We do this for two reasons: to check the installation process thoroughly and, secondly, the parts minimize echoes inside the chassis. An empty chassis will have echoes similar to an empty room, notably affecting the noise measurements.

You will find the test system that we use for noise measurements in the following table. For smaller chassis, we use a mini-ITX mainboard.

Noise Test System Specifications	
Mainboard	MSI B760-Plus WIFI-D4
CPU	Intel i9-12900K
GPU	Galax GeForce RTX 4060 EX Ti
NVMe	XPG GAMMIX S50 Lite 1TB
RAM	XPG Lancer DDR5 (2 x 16GB) @ 6000MHz
Power Supply	EVGA SuperNOVA 1000 G7
CPU Cooler	be quiet! Pure Power 2 FX 240mm
Chassis	Device Under Test
Ambient Temperature	25°C ± 0.1°C

We use a hemi-anechoic chamber with an extremely low noise floor at around 6 dBA for all noise measurements. The DUT is installed in the chamber. Picture 1 provides a detailed overview of the microphone's and DUT's positions inside the chamber.

The measuring microphone is positioned in such a way that it forms a 30° to 45° degree angle to the horizontal axis, and its vertical distance from the DUT is one meter.



Picture 1

Noise Measurements Procedure

We turn on the sound meter Bruel & Kjaer G-4 Type 2270 [1] 15 to 30 minutes before starting the measurements to allow it to reach operational temperature. Before we start the measurements, we calibrate the sound meter using the Bruel & Kjaer Sound Calibrator Type 4231 [2].

We place a speaker in the measuring position in which we measure its intensity at the frequencies presented in Table 1. We also measure Chirp [3] signal, Pink [4], and White [5] noise. We use the above measurements as a reference for the speaker's volume in the open air.

Frequencies Tested	
100 Hz	10 KHz
250 Hz	11 KHz
500 Hz	12 KHz
1 KHz	13 KHz
2 KHz	14 KHz
3 KHz	15 KHz
4 KHz	16 KHz
5 KHz	17 KHz
6 KHz	18 KHz
7 KHz	19 KHz
8 KHz	19.5 KHz
9 KHz	20 KHz

Table 1

We install the chassis in the chamber vertically to the microphone in the intended position to have the same conditions in each measurement. Next, we install the speaker we have already measured in an open field inside the chassis. We try to place it as close as possible to the side that the microphone points to without touching the side pane. At the same time, we pay close attention to placing the speaker as close as possible to the chassis floor (see Picture 2).

Picture 2

We repeat the exact measurements; that is, we measure the noise output of the speaker at the above frequencies. Our goal is to find the differences between open-air noise measurements and the speaker inside the chassis. These differences provide a detailed picture of the chassis' soundproofing performance in a wide frequency range, along with pink, white, and chirp noises.

Pink noise is random noise with equal energy per octave, so it is widely used to equalize loudspeakers in rooms and auditoriums. This is why we selected it as the primary performance factor for our soundproofing performance standard in chassis, called DELTA. Pink and White (noise containing many frequencies with equal intensities) noise provides precisely the same soundproofing performance results from our experience.

Chassis Fans Noise Measurements

We use Corsair's Commander Pro [6] to control the chassis fans, using custom software developed by our team. In addition, the Commander Pro is driven by another passively cooled system that doesn't affect the chamber's noise floor.

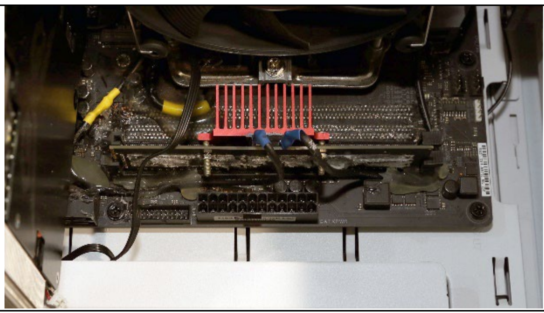
Our software allows for precise fan speed adjustments in both RPM and percentage. Hence, we can set a portion of the speed individually for each fan, e.g., setting the fan speed at 50% for a fan with a maximum speed of 1000 RPM will result in a fan speed of 500 RPM (±1%).

We measure the noise the fans produce at 40%, 50%, 60%, 70%, 75%, 80%, 90%, and 100% of their maximum speed. Next, we change the fan speed by reversing the measurements' logic to achieve 35, 30, and 25 dBA noise output, and we record the corresponding fan speeds for later use.

The last noise measurement deals with the graphics card. In this test, we activate the system, install it in the chassis, and turn off all the fans except those used by the CPU and GPU cooling systems. We keep the CPU's fan speed at the lowest setting to not alter our measurements and change the speed of GPU fans to 40%, 50%, 60%, 70%, 75%, 80%, 90%, and 100% while measuring and logging noise output.

Thermal Performance Testing Setup and Procedure

We used to use a custom-made loader for thermal performance evaluation, with heating elements in the CPU, VGA, VRM, NVMe, RAM, Chipset, and HDD areas. Since installing and operating this system was tough, we decided to use a real system instead. The photos below show the custom-made loader that we used.



Pictures 3, 4

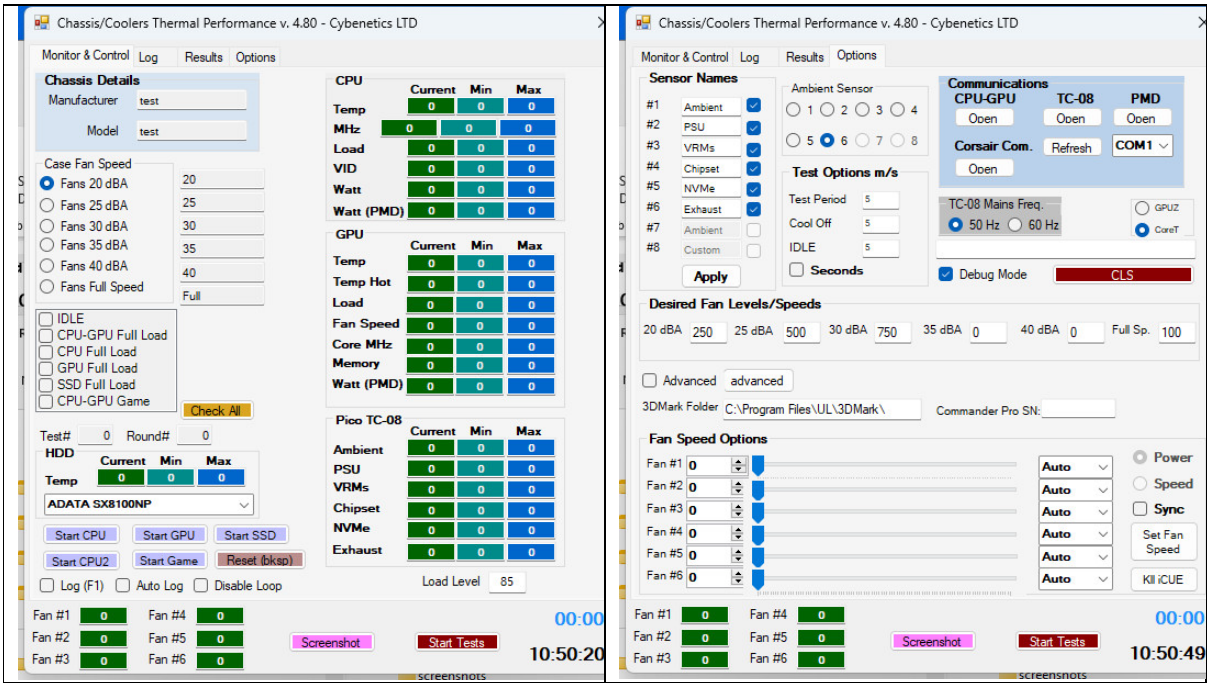
The table below shows the test system configuration for thermal performance evaluation. We have installed thermal probes (K-type) on the mainboard's chipset, VRMs, and the NVMe drive to acquire accurate temperature readings. We get the rest of the temperature readings from the mainboard's sensors. We don't use any additional fans, only the ones that come with the chassis.

Thermal Test System Specifications	
Mainboard	Gigabyte X670E AORUS Master Bios Version: F10a
CPU	AMD Ryzen 9 7950X 3D
GPU	Galax GeForce RTX 4060 EX Ti
NVMe	XPG GAMMIX S50 Lite 1TB
RAM	XPG Lancer DDR5 (2 x 16GB) @ 6000MHz
Power Supply	EVGA SuperNOVA 1000 G7
CPU Cooler	Noctua NH-D15S chromax.black
Chassis	DimasTech Bench
Ambient Temperature	25°C ± 0.1°C
Drivers	AMD Chipset: 5.02.19.2221 NVIDIA: 537.13

First, we install the chassis in a controlled environment, a Giant Force [7] climate chamber, where the temperature is set at 25° C (77° F). Next, we connect the Pico TC-08 thermocouple data logger [8] to get data from all thermal probes installed in designated places inside and outside of the chassis. Specifically, we have probes at the mainboard's VRM, chipset, NVMe drive, chassis exhaust, and PSU's exhaust. Lastly, we have an additional probe measuring the ambient temperature for redundancy.

Our software allows us to run several benchmarks for prolonged periods, fully automatically, to check the chassis thermal performance under different load levels. The toughest test is the one running Prime95 and FurMark simultaneously.

Below are screenshots of our in-house software (Pictures 4 and 5). The chassis fans spin at the speeds recorded in the previous to output the desired 25, 30, and 35 dBA noise levels and at their maximum rotation speed. Hence, it is necessary to conduct noise testing first. The CPU's and GPU's fans operate at their default fan speed profiles, which is the same for every chassis we evaluate.



Pictures 4, 5

All case fans are connected to the Corsair Commander Pro so we have complete control over them. Additionally, both the Corsair Commander Pro and the Pico TC-08 are controlled and monitored by our software.

All tests are carried out automatically through our custom software without the intervention of a test engineer, except for the initial settings that are made at the very beginning of the procedure. The thermal tests consist of six individual tests that run for fifteen minutes each. There is an intermediate 10-minute cool-off period between each test while we allow the system to remain idle for ten minutes before we gather all temperature information.

To explain the procedure we follow thoroughly, first, we input the case-fan speeds corresponding to 35, 30, and 25 dBA noise output, as obtained during the noise measurements. We consider an additional scenario where the fans operate at full speed (100%).

Using standardized noise output levels for all chassis, we can put all relevant products under the same strict operating conditions. It would be unfair to compare cases with pre-installed fans of different characteristics and, subsequently, different noise outputs. There is always the full fan speed test for those who don't care about noise output but only want to know the thermal performance in the best-case scenario.

The thermal performance tests run for several hours. Once everything is finished, we gather the results and enter them into our database for further analysis. All results are collected automatically and can be exported in various formats.

Data Analysis

The data is being analyzed based on the scientific literature on sound [12] [13] and the experience we gained after conducting dozens of tests in PC cases.

As mentioned in the first part, when measuring the chassis sound-damping performance, we measure the chassis behavior in many frequencies. We do this because we want to see at what frequencies the chassis can resonate and be inferred as a noise amplifier and at which ones it acts as a damper. The material selection of a chassis plays a significant part since the behavior of different materials can vary. We also measure the chassis' damping in three necessary signals: Chirp, Pink noise, and White noise.

In more detail:
- The Chirp signal is commonly used in radar applications and sonar applications.
- Pink noise is a signal most common in biological systems. It includes all audio frequencies (20 Hz – 20 KHz), and its power is inversely proportional to its frequency, i.e., the higher the signal frequency, the lower its intensity.
- White noise is the random noise with a continuous spectrum whose spectral power density is independent of frequency.

We use the difference between an open field and the ones we got from each chassis (Delta) to compare the results of different PC cases. Cybenetics has created special badges for this purpose, the Delta Badges, with which we can easily categorize the chassis in terms of the noise attenuation they manage to achieve.

We have decided to use the Pink noise Delta to make the above categorization since it includes all audio frequencies (20 Hz – 20 KHz); thus, we have the overall damping for the range we are interested in and the uniform power it has between the octaves.

Levels	Soundproofing Requirements
A+	≥8 dB(A)
A	≥5 dB(A) to <8 dB(A)
Standard	≥2 dB(A) to <5 dB(A)

Epilogue

In this article, we tried to explain the methodology we follow in our chassis evaluations as straightforward as possible. A few things are required in every sound test procedure: reliability, accuracy, calibrated equipment, knowledge of how to operate it properly, and the experience to recognize problems and measurement errors as soon as possible. Unfortunately, experience only comes after a significant number of test sessions. Thankfully, the members of the Cybenetics team have dealt with chassis for more than a decade now, and their combined knowledge on this subject led to the complete testing protocol that we follow. Since we are after perfection, although we know that there is nothing perfect in this world (cats excluded, of course), we will continue searching for new methodologies and ways that will allow us to explore more aspects of this subject.

References

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