The Phi Fan Performance Standard (PFPS)

Revision 1.1

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Revision History

Version	Release Date	Notes
1.1	June 2024	Change in the badges. Fan diameter was omitted.
1.0	May 2024	First draft

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Prologue

Fans are everywhere, cooling down sensitive to heat electronic devices. They are often overlooked unless noisy because they just do their job for long periods until they stop spinning. This article aims to explain in detail how we evaluate cooling fans and how we rate them according to their performance.

Fan Operation & Bearing Types

The most crucial components of every fan are its bearing and shaft, to which the fan blade is attached. The bearing is a stationary cylinder inside which the shaft rotates. To provide high reliability and decreased noise output, friction between the shaft and the bearing has to be minimized. In most cases, oil is used as a lubricant. However, other methods can be used as well (for instance, Teflon-coated surfaces). If the oil isn't sealed properly inside the bearing, its quantity will diminish as time passes, increasing friction, leading to slower fan rotation and increased noise, until the fan breaks down and stops rotating.

The most popular bearing types used in PC cooling fans are the following:

- Sleeve bearing
- Rifle bearing
- Double ball (DBB) bearing
- Fluid dynamic bearing (FDB) and hydro dynamic bearing (HDB)
- Magnetic bearing

It is beyond this article’s purpose to explain in detail the various bearing types, but briefly, sleeve bearing fans are the less reliable ones. Rifle-bearing fans offer enhanced reliability, while FDB and HDB fans are even more reliable.

Double ball bearing fans are highly tolerant to increased temperatures but typically have bearing noises at low speeds, while magnetic bearing fans have the same tolerance at high temperatures as DBB fans, without any bearing noises at low speeds.

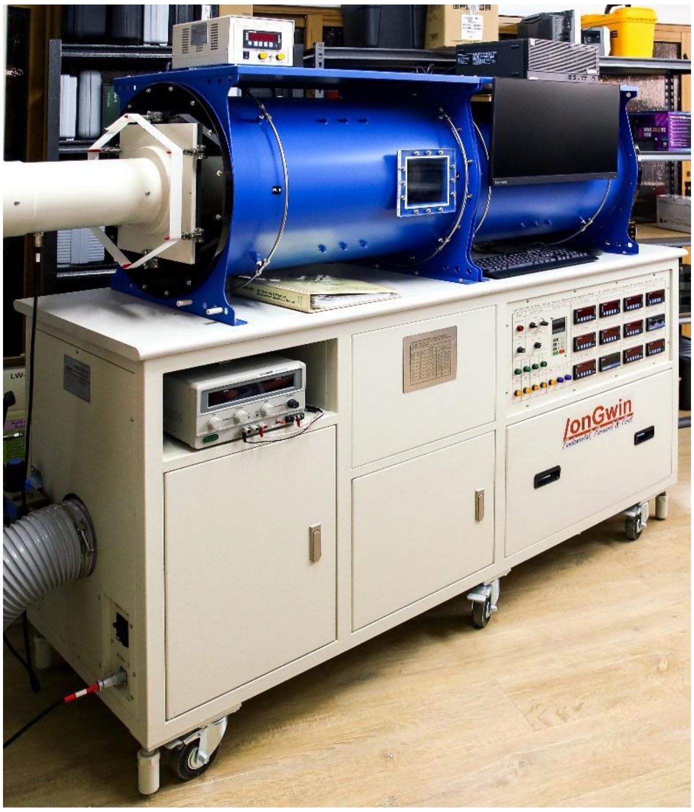
Other bearing types exist, but they are usually improved versions of the bearing listed above, under a different name.

Test Equipment

The main instrument we use for fan measurements is an LW-9266 Fan PQ performance measurement apparatus [1]. This is a highly sophisticated scientific instrument made in Taiwan by Long Win.

LW-9266 Technical Specifications

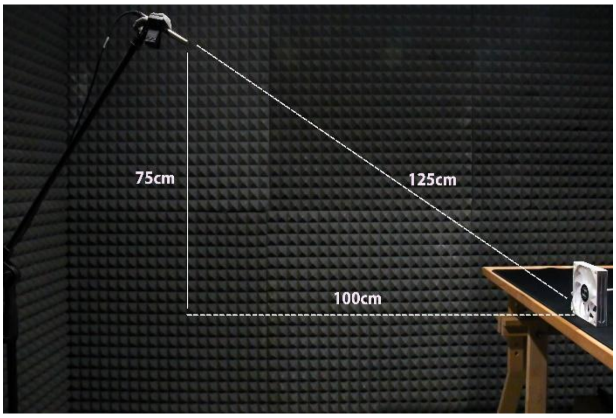
- Manufacturer: Long Win Science & Technology Corporation
- Air Flow Rate: 2.4 – 250 CFM
- Accuracy of Air Flow Rage: <3.5% INFS
- Repeatability error: < 2%
- Static pressure: 0-20mmAq (100mmAq with the high static pressure throttle device)
- Overall Dimensions: 0.7 (W) x 2.2 (L) x 1.6 (H) m
- Power Source: 220VAC, 5A, Single Phase, 50/60Hz
- Based on Standards: ISO 5801-2007, AMCA 210-0, ASHRAE 51-2007, IEC 61591-2005, GB/T 1236-200

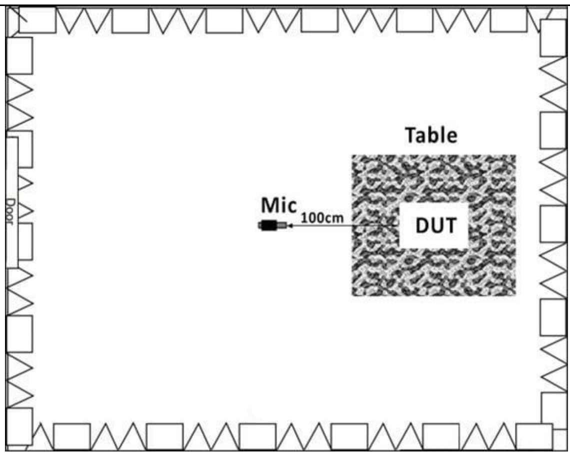


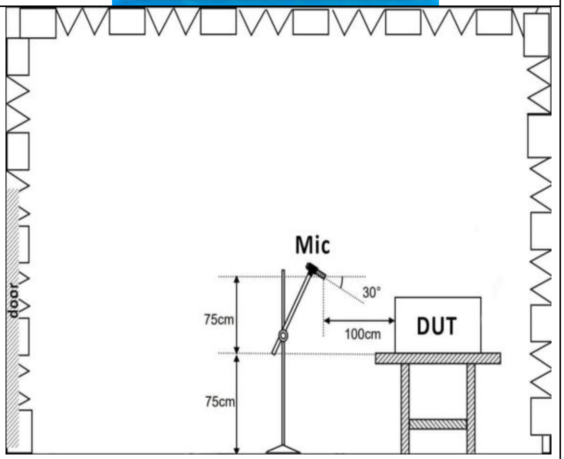
Besides the Long Win machine, we also use the following equipment.

- Noise Test Environment: Hemi-Anechoic Chamber with < 6 dB(A) noise floor
- Conditions: 25 (+-2) degrees Celsius, 40-50% humidity
- Sound Analyzer: Bruel & Kjaer 2270-S G4
- Microphone: Bruel & Kjaer Type 4955-A
- Mic Calibrator: Bruel & Kjaer Type 4231

- Data Logger: Picoscope TC-08 [2]



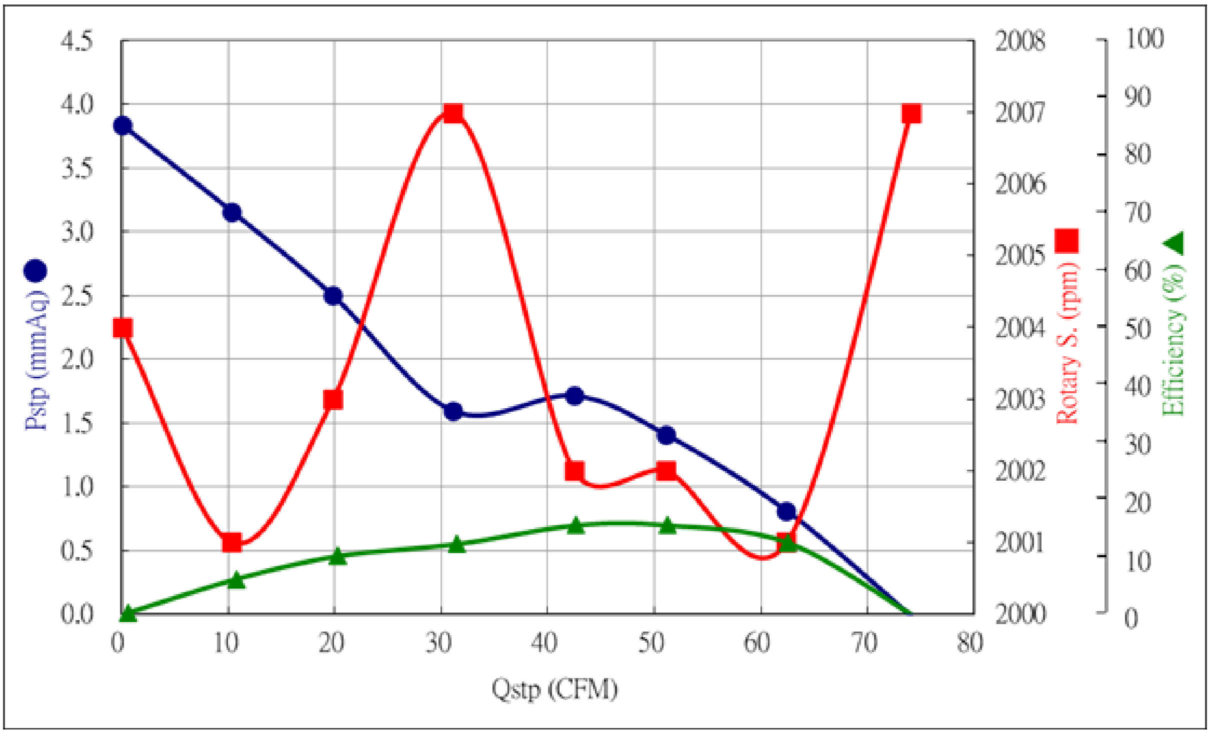




The measuring microphone is positioned in such a way that it forms a 30° to 45° degree angle to the horizontal axis, and its vertical distance from the Device Under Test (DUT) is one meter.

Fan Performance: P-Q Curve

Regardless of its dimensions, every fan, whether DC or AC-powered, has a characteristic curve called P-Q. This curve shows the correlation between the fan's airflow and its static pressure. With the letter "P," we describe static pressure, and with "Q," airflow.



When we refer to a fan's airflow, we speak about the total amount of air the fan pushes or produces per unit of time. Airflow is usually measured in Cubic Feet per Minute (CFM). Fan manufacturers measure a fan's CFM in an open environment without any obstacles in front of it, and this plays a huge role, as you will soon find out through our reviews. When there is no resistance in front of a fan, its airflow is at its maximum, but this is not the case for most fans, especially for those used in heatsinks and AIO radiators. Most of the fans that are used in chassis don't face significant resistance.

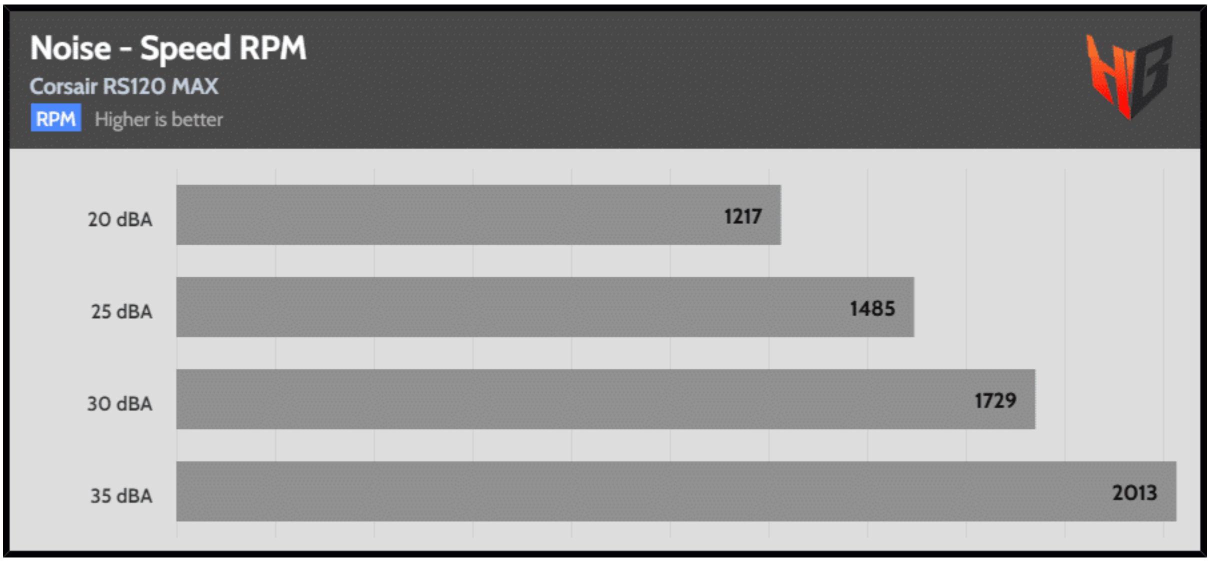
The maximum static pressure is the fan's wind pressure in a fully enclosed channel. Static pressure is the air pressure the fan can produce in an enclosure. It is measured in Pascals (Pa), inches of water (inH2O), or millimeters of water (mmAq). We will use the latter. The most important thing you need to know is that the fan will not simultaneously output maximum airflow and static pressure values. Airflow and static pressure have a negative correlation. When airflow increases, static pressure decreases, and when static pressure increases, airflow decreases.

Both airflow and static pressure have to do with airflow resistance, called impedance. When parts block the fan's airflow, we have impedance, so to find out the complete P-Q curves of a fan, we have to be somehow able to simulate this impedance. Some users use custom-made filters or AIO radiators, but these techniques only simulate a single impedance scenario, so they cannot offer complete P-Q curves. The only way to get the entire P-Q curve of a fan is to have variable impedance, which is what an instrument like the LW-9266 does, based on established measuring standards and with full calibration reports.

Normalized Noise Testing

Testing the fan(s) at full speed only shows a small part of their performance since, in most cases, cooling fans do not operate at full speed. In case they do, their lifetime will be greatly affected besides high noise output. Subsequently, fan speed is typically regulated according to the thermal loads. This is why it is of imperative importance to test and compare each fan under the same conditions. It would be unfair to compare a fan spinning at 3000 RPM with a fan spinning at 1500 RPM. You also have to include the noise output parameter in the comparison, since the fan's rotation speed is not a stable parameter either. E.g., comparing two fans spinning at 1500 RPM is not fair either, since one can output 30 dBA of noise and the other 33 dBA. Noise output has to do with the fan's design too, not only its speed.

Before conducting a complete fan performance evaluation, we have to measure its noise output, since the most important performance of each fan is its performance in normalized noise output. For the normalized noise output tests, we set the fan to speeds with noise output at the following predefined levels: 20/25/30/35/40/45 dBA. We skip the corresponding tests if the fan under the test cannot reach certain noise levels. The speeds shown in the example graph below are measured with the fan in a clear space inside our hemi-anechoic chamber without any obstacles. We set these speed settings on the Long Win machine, but the results can have some minor variance due to external uncontrollable parameters and slight differences in the machine's operations, always within the margin of error.



Picture 1

Noise Measurements Procedure

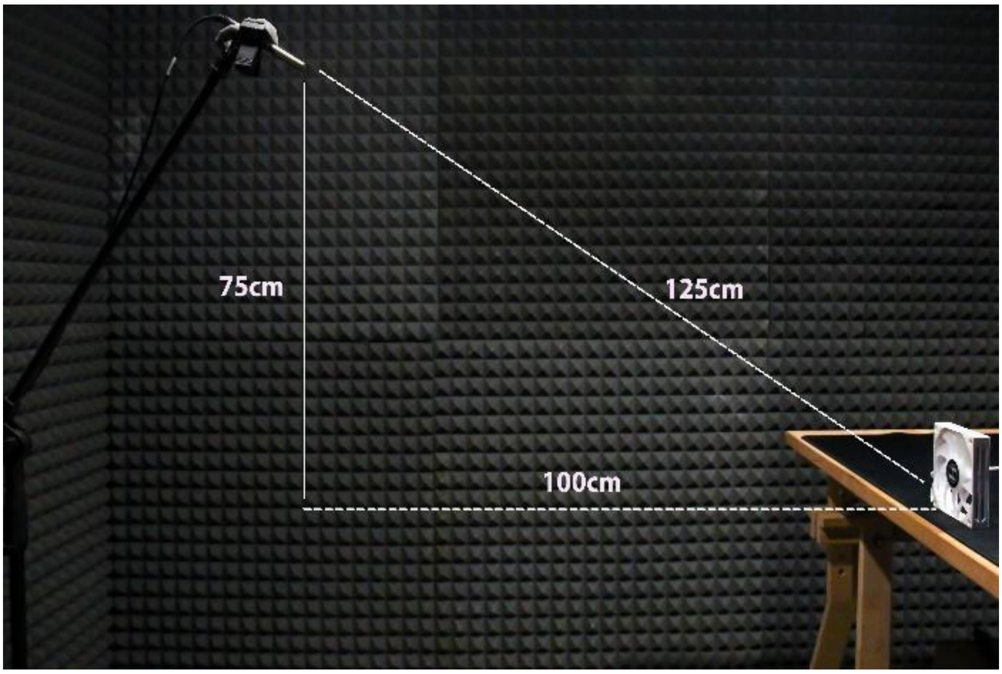
We turn on the sound meter, Bruel & Kjaer G-4 Type 2270 [3], 15 to 30 minutes before starting the measurements to allow it to reach operational temperature. Before we start the measurements, we calibrate the sound meter using the Bruel & Kjaer Sound Calibrator Type 4231 [4].

We install the fan in the chamber in such a position that its airflow goes in the opposite direction to the microphone. We make sure the microphone is installed correctly and in general, we follow all noise testing requirements of the ECMA-74 and ISO 9296 standards [5][6].

We use Corsair's Commander Pro [7] 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 from their lowest speed up to their maximum speed using 10% intervals. Next, we change the fan speed by reversing the measurements' logic to achieve the corresponding noise output levels for our normalized noise tests, and we record the corresponding fan speeds for later use.



Picture 2

The Phi Fan Performance Standard - PFPS

We named our fan performance Standard, Phi, after the Greek letter «Φ» which among others represents the Golden ratio [8].

The Phi Fan Performance Standard, or PFPS in short, includes both 120mm and 135-140mm fans, but with different requirements for each level. The requirements are set for both airflow and static pressure since these two are the key performance factors for each fan.

All fans are tested under 25 dBA normalized noise output, and we take into account these results to rank them in the following categories. Why did we choose this specific noise level for our standard? Because at 25 dBA, a fan can spin fast enough to achieve decent performance, while this noise level isn't high enough to annoy the majority of users. Anything higher or lower than this noise level would be too noisy, or performance would be hugely affected.

What about the fans that don't even reach 25 dBA noise output? Unfortunately, we cannot rate them, and these fans are not performance-oriented anyway, so there is no need to have a performance badge. Currently, our fan database only includes a handful of fans that cannot reach 25 dBA noise output.

PFPS – 120mm Fan Airflow Levels/Requirements – 25 dBA Normalized Noise Output

Performance Levels	Requirements
Bronze	≥34 CFM & <38 CFM
Silver	≥38 CFM & <42 CFM
Gold	≥42 CFM & <46 CFM
Platinum	≥46 CFM & <50 CFM
Titanium	≥50 CFM & <55 CFM
Diamond	≥55 CFM

PFPS – 120mm Fan Static Pressure Levels/Requirements – 25 dBA Normalized Noise Output

Performance Levels	Requirements
Bronze	≥0.8 mmAq & <1.0 mmAq
Silver	≥1.0 mmAq & <1.25 mmAq
Gold	≥1.25 mmAq & <1.5 mmAq
Platinum	≥1.5 mmAq & <1.75 mmAq
Titanium	≥1.75 mmAq & <2.0 mmAq
Diamond	≥2 mmAq

PFPS – 135/140mm Fan Airflow Levels/Requirements – 25 dBA Normalized Noise Output

Performance Levels	Requirements
Bronze	≥45 CFM & <50 CFM
Silver	≥50 CFM & <55 CFM
Gold	≥55 CFM & <60 CFM
Platinum	≥60 CFM & <65 CFM
Titanium	≥65 CFM & <70 CFM
Diamond	≥70 CFM

PFPS – 135/140mm Fan Static Pressure Levels/Requirements – 25 dBA Normalized Noise Output

Performance Levels	Requirements
Bronze	≥0.7 mmAq & <0.9 mmAq
Silver	≥0.9 mmAq & <1.1 mmAq
Gold	≥1.1 mmAq & <1.3 mmAq
Platinum	≥1.3 mmAq & <1.5 mmAq
Titanium	≥1.5 mmAq & <1.7 mmAq
Diamond	≥1.7 mmAq

Performance Badges & Ratings

Since we don't want to confuse users, we used the highly familiar metal and carbon ratings that we already use for our PSU efficiency ratings: Bronze, Silver, Gold, Platinum, Titanium, and Diamond.

There are two fan categories, the most popular ones: 120mm and 135/140mm. There are also two badges for the fan's main performance factors: airflow and static pressure.

CYBENETICS Airflow DIAMOND	CYBENETICS Static Pressure DIAMOND

Epilogue

This article was a brief introduction to the world of fan testing and a first look at our testing methodology. Providing an objective representation of a fan's performance is a delicate task, requiring experience in both sound measurement and aerodynamics. The equipment used for our testing is the industry standard, of the highest quality, and properly maintained and operated. Moreover, we have tested numerous fans so far, in the process of refining our methods. Subsequently, the information and testing results we provide are both accurate and indicative of real-world performance.

References

[1] LW-9266 Fan PQ Performance Measurement Apparatus. http://www.longwin.com/english/product/9266.html (*last accessed on* 30 May 2024)
[2] Picoscope TC-08. https://www.picotech.com/data-logger/tc-08/thermocouple-data-logger (*last accessed on* 30 May 2024)
[3] https://www.bksv.com/en/products/sound-and-vibration-meters/sound-level-meters-and-vibration-meters/2270-series/Type-2270-S (*last accessed on* 30 May 2024)
[4] https://www.bksv.com/en/products/transducers/acoustic/calibrators/4231 (*last accessed on* 30 May 2024)
[5] Standard ECMA-74 Measurement of Airborne Noise Emitted by Information Technology and Telecommunications Equipment https://www.ecma-international.org/publications/standards/Ecma-074.htm (*last accessed on* 30 May 2024)
[6] ISO 9296:2017 Acoustics - Declared noise emission values of information technology and telecommunications equipment https://www.iso.org/standard/32303.html (*last accessed on* 30 May 2024)
[7] https://www.corsair.com/eu/en/Categories/Products/Accessories-%7C-Parts/iCUE-CONTROLLERS/iCUE-Commander-PRO-Smart-RGB-Lighting-and-Fan-Speed-Controller/p/CL-9011110-WW(*last accessed on* 30 May 2024)
[8] Golden ratio https://en.wikipedia.org/wiki/Golden_ratio (*last accessed on* 30 May 2024)