CPU Cooling Fan Testing Solution
Using Compact Laser Vibrometer Sensor

Along with the development of computing technologies, the personal computer has become part of our everyday life. Thermal management is very important for performance and reliability. Focusing on the most common forced air-cooling solution, this article describes how OmniSensing's compact laser vibrometer sensor can be used to quantify and analyze the performance and quality of cooling fan systems used in modern electronic systems.

Background:

Higher levels of integration and demanding workloads result inlarger thermal loads internally. Overheating components can result in reduced performanceand shortened life. All modern computerssense and regulate the temperature of the CPUvia thermocouples and utilize a method that will trigger a reduction in performance or increased fan speeds toavoid damaging the processor and other components. This safety mechanism known as dynamic frequency scalinguses a closed loop control to protect your processor and internal circuitry from potential damage. This protection results in a performance cost when active.

One of the trade-offs in this type of design is the noise produced by the fan itself. Cooling fans installed in a PC case can produce noise levels of up to 70 dB. Since fan noise increases with the fifth power of the fan rotation speed, reducing revolutions per minute (RPM) by a small amount potentially means a large reduction in fan noise. A minimum threshold must be monitored and actively controlled as excessive reduction in speed will cause a corresponding rise in temperature.

The most common approach is a forced air fan driven with apulse-width modulation (PWM) control. The control signal is a square wave operating at 25 kHz with the duty cycle determining the fan speed. This frequency is used to raise the resulting audible portion of the signal above the range of human hearing whereby use of a lower frequency could produce an audible hum or whine. Typically a fan can be driven between about 30% and 100% of the rated fan speed using a signal with up to 100% duty cycle. Computer/Electronic and fan system manufacturers want to validate the air speed, noise, balance and other parameters of the cooling fan as part of the quality assurance testing. In some instances, the cooling fan system is inaccessible making it very hard to test or determine its specification compliance. Possible failures (low velocity, audible noise, imperfect axis or imbalance at speed..) are harder to diagnose after assembly. Undetected defects can also produce latent effects that are the cause of more catastrophic system failures later.

Omnisensing Solutions:

Partnering with several PC cooling fan manufacturers, OmniSensing Photonics has developed an enhanced function optical testing scheme that can be installed on the current testing station and validate the performance of cooling fan using its MV-H series laser vibration sensor. The MV-H series laser vibration sensor is a digitized compact low-cost laser vibrometer based on our Photonics Integrated Circuits (PIC)

technology. It can perform non-contact vibration measurement from DC to 2.5MHz with sub-nanometer vibration sensitivity.

MV-H Series Laser Vibrometer Sensor:

The key component for this implementation is the MV-H series compact laser vibration sensor developed by OmniSensing Photonics (See Fig. 1).

Figure 1: Compact laser vibrometer sensor

Specs	OSP MV-H
Max. frequency	2.5MHz
Velocity full scale	±1.5 m/s (regular mode) ±5 m/s (extended mode)
Decoder range	Single range continuous
Typical resolution	0.015 $\mu m/s^{-1}/\sqrt{Hz}$ (@5KHz)
Analog output	No (contact for custom model)
Time trigger	Trigger in & out
Size	~80x50x22 (mm^3)
Weight	175 g
Operating temperature	0-50°C
Power supply	12-24V, 3W max
Protection class	IP65
Laser class	Class 1, <5mW output (H1)
Laser wavelength	1310 nm (invisible near infrared, detector card included)
Measurement distance	0.075-4m (fixed lenses, pre-adjusted, contact for adjustable lenses)
Data connection	Ethernet
Control Software	GUI & DLL (for system integration)

Table 1: MV-H laser vibrometer sensor spec

Testing Setup & Results:

The modified cooling fan testing system is shown in Fig.2 (a,b). As shown in Figure 1a, the original cooling fan test station has the capability to measure the detectable audible signature of the cooling fan under different RPM and different position using microphones. Currently the resulting test data suffers from

inherent ambient surrounding noise causing errors in measurement certainty. The upgraded solution is to replace the MIC with a compact laser vibrometer sensor to measurement the vibration of the cooling fan. The cooling fan is still mounted on a rotatable stage along with the MV-H laser vibration sensor installed about 15cm apart on the same plane. The laser beam from the vibration sensor is focused onto the surface of the cooling fan. During the testing, the testing station can simulate CPU temperatures changes with different processing loads and resulting thermal loads while driving the cooling fan to different speeds to compensate. During testing the fixtures can rotate the PC cooling fan mounting stage to different positions and angles simulating the real usage of laptop with different holding positions. The Figure 1b shows the flow of control signals and the vibration testing data.

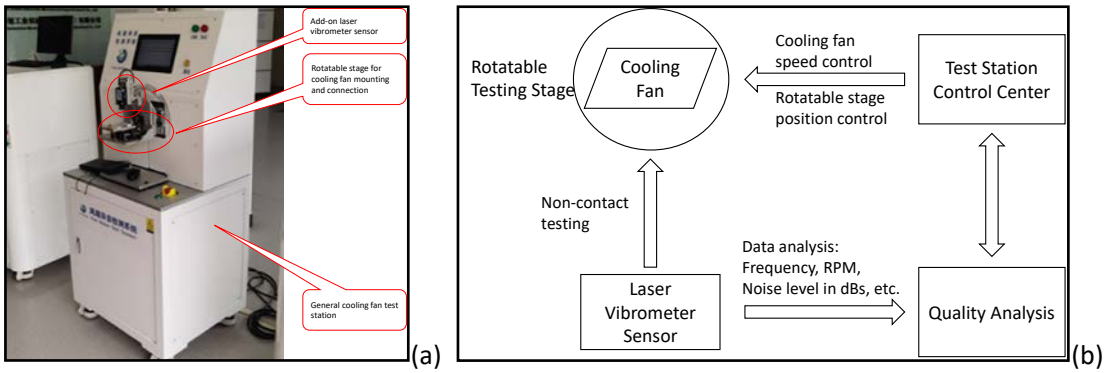


Figure 2: (a) Modified test-station; (b) Schematic of the vibration testing solution

The testing system can record the vibration signals on the cooling fan surface over different testing conditions (See Fig.3). For each defined time period or step, the system will perform spectrum analysis and compare the results with pre-defined pass/fail mask in the frequency domain.

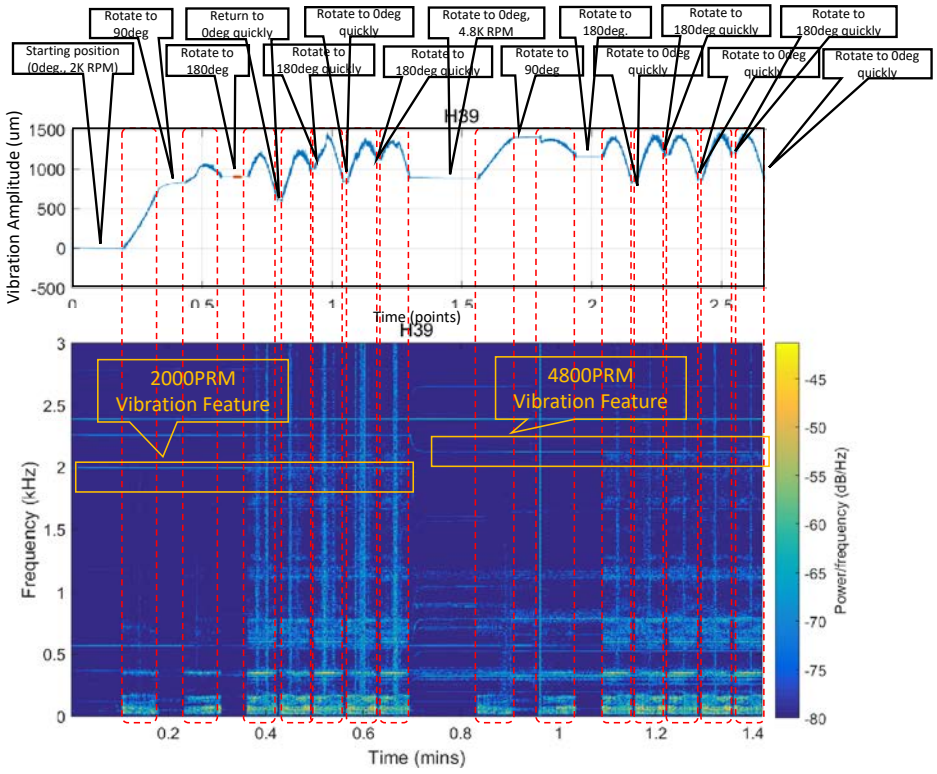


Figure 3: Testing routine (top) and spectrum analysis for each step (bottom)

To validate this testing scheme, 55 samples were tested mixed with “Good” and “Bad” parts that have been previously tested. The vibration data were analyzed and vibration displacement and frequency spectrum

were summarized and plotted against their testing routine yielding a signature (See Fig. 3) where the Pass/Fail standard could be established.

Next, we tested one of the "Good" parts for 9 cycles and the results are highly repeatable (See Fig. 4).

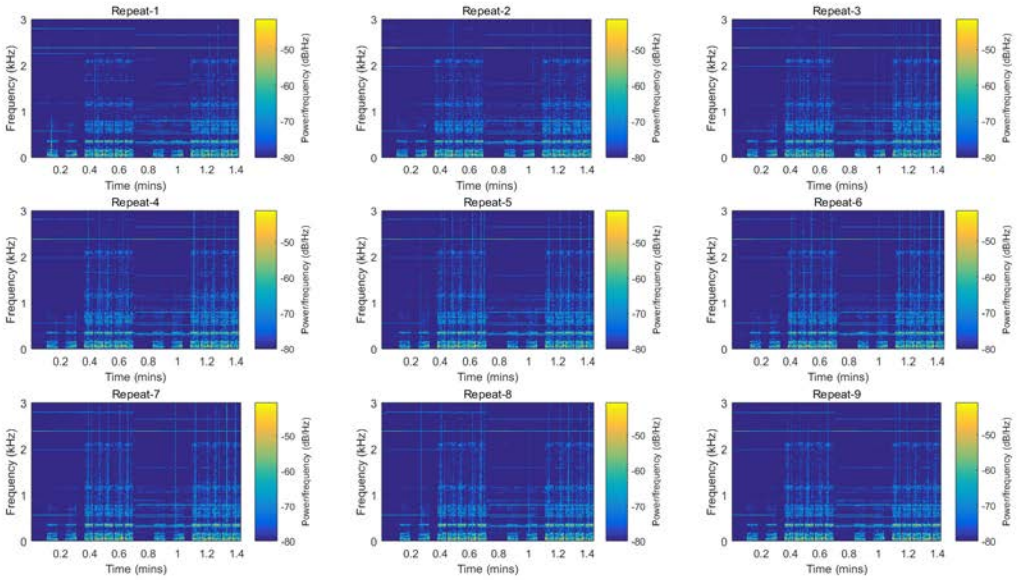
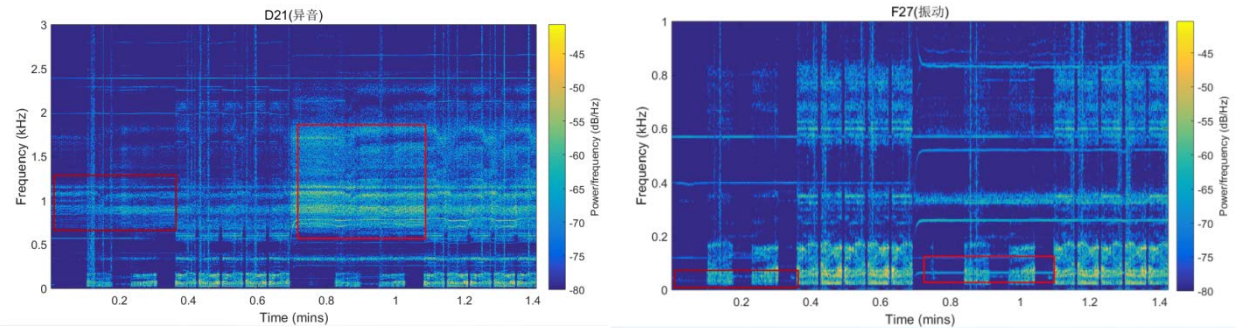


Figure 4: Repeating results for one "Good" sample under 9 cycles of test

Analysis of the data from the above testing routine allows the fan manufacturer to determine important parameters like the RPM's under certain loads and driving signal conditions and the total vibration spectrum energy. If cooling fan has defects causing an observed audible change, it will be shown in the audible spectra and will yield a different signature display. Unlike the fan noise, which is normally created by the fan blades moving air generally behave as a white noise with much wider frequency contents. Those signature anomalies display as unwanted frequency spikes on the spectrum. These could be caused by one or more defects namely bearing system wear out, accumulated contamination of the fan blade, assembly errors or blade deformation. All of which will yield a different signature for comparison. Once characterization of multiple samples have been recorded, the user can observe signature patterns and develop known good signatures as "Golden" or "Benchmark" standards.



(a) (b)

Figure 5: (a)"Bad" sample with unwanted energy spectrum contents over a frequency range; (b) "Bad" sample with an undesirable vibration frequency peak;

Illustrated below using the same modified testing station, we have successfully measured several defective cooling fans in operation. Fig. 5a shows the energy spectra of one cooling fan one with visible defect energy in a specific frequency range comparing to regular known “Good” parts. Fig. 5b shows another sample with an abnormal signature which showing an undesirable vibration frequency peak. Through accumulated data, an analysis model to characterize these cooling fans and detect defects can be built up quickly for incorporating into a QA database.

Summary:

The MV-H series compact laser vibrometer sensor has superior performance with a small footprint and very competitive pricing. Using non-contact measuring techniques, we have demonstrated an alternative test methodology than can provide a better solution for testing and evaluation of cooling fans. Using these modules, our applications engineers can assist in developing a test platform that is unique to your testing needs and quick and easy to implement. For further information please contact us at: info@OmniSensingTech.com.