GRAPHICS PROCESSING UNIT COOLING SOLUTIONS: ACOUSTIC CHARACTERISTICS

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1. INTRODUCTION

The utilization of the graphics processing unit (GPU) has evolved from supporting interactive games and complex engineering design applications in personal computers to console gaming and home entertainment systems. The functions of a GPU require a great deal of processing power and a major setback of the advancement of this technology is the production of greater amounts of heat. This is a trend that will continue in the foreseeable future. Currently, GPU cards are produced with dedicated active cooling solutions in order to alleviate this concern. These consist of a metal heat sink with an attached fan that represents a new source of noise within the computer. This research involved testing three commercially available GPUs for their acoustic emission characteristics. It will be shown how the acoustic characteristics of the overall system change as a result of changing the GPU.

2. EXPERIMENTAL SETUP

All tests were performed using identical configurations of the software and system hardware. The hardware used for this project consisted of the following components.

Table 1: Hardware Components

CPU	AMD Athlon 64 X2 3800+ Dual Core S939
Motherboard	ASUS A8R-MVP ATX
HDD	Western Digital Caviar SE16 250 GB SATA2 7200 RPM 16 MB
Memory	OCZ Performance PC3200 2GB DDR400
Power Supply	OCZ PowerStream 520W
Optical Drive	Pioneer DVR-111D DVD+DL
Additional Cooling	Generic 120mm Rear Case Fan

All three cards were operated under the conditions of a graphics benchmarking program called 3DMark 2005. The tests were performed in a semi-anechoic environment. The computer case was positioned on the hard floor in the centre of a ten point measurement hemisphere. Measurements were made at each of the ten microphone locations in accordance with the International Standards ISO 3745:2003 [1] for performing measurements in a hemi-anechoic room, and ISO 7779 [2] for performing measurements of airborne noise emitted by information and technology equipment. For each case, the system was allowed to run until thermal stability occurred. Then data was acquired using analysis software made by 01dB called dB-RTA. Acoustic metrics including loudness were measured.

3. EXPERIMENTS PERFORMED

The screen resolution was 1280x1024 pixels. Three experiments were performed: GPU in-system running 3DMark 2005; GPU in-system running Microsoft Windows OS.; and GPU stand-alone running at 12 volts DC. Acquiring data at all ten microphone locations around the computer compensated directionality characteristics associated with the noise source. Frequency spectrum data was also acquired. In this work, the results from the measurements taken for each GPU tested are analysed and compared.

4. RESULTS AND DISCUSSION

Table 2 shows the revolutions per minute of the cooling fans for each of the GPUs. These results were obtained using a photo tachometer and reflective tape adhered to one particular fan blade.

Table 2: RPM Data

	Fan 1	Fan 2	Fan 3
3V	1595	1325	N/A
4V	2705	1845	1765
5V	3550	2270	2265
6V	4190	2632	2735
7V	4685	2950	3175
8V	5100	3270	3585
9V	5455	3500	3960
10V	5780	3735	4035
11V	6070	3930	4370
12V	6320	4105	4680

Table 3: Fan Characteristics

	Fan 1	Fan 2	Fan 3
Type of Fan	Axial	Axial	Radial
Number of Blades	13	13	29

Some observations may be made based on this RPM data. Fan 1 has a significantly greater angular velocity compared to fan 2 at similar voltage levels. Both fans have 13 blades, however, fan 2 is larger in diameter. These results may be due to the presence of similar electric motors in both cooling solutions. It is expected that the acoustic emissions from fan 2 will be more acceptable than those from fan 1. Fan 3 is designed to produce a much greater air flow rate than the other fans. It is a much heavier fan than the others and thus its electric motor cannot overcome the momentum of the fan with the starting voltage of 3V. Initially, the rpm values of fan 3 are less than that of fan 2. At 6V however, the rpm values surpass those of fan 2. The values never exceed those for fan 1.

For the measurements taken, all ten microphone signals are kept as data and not combined to derive any overall sound quality metrics. Although it may be useful to combine the data some time in the future, there is no reason to do so now. It should be noted that microphone 1 is located at the back of the computer case and so it should be expected that the most useful GPU cooling fan information would be detected there. One of the most useful pieces of information that may be gathered from these measurements is sound pressure level versus frequency spectrum data. For microphone 1, the prominent frequency and loudness data is given in the following table.

Table 4: Prominent Frequency and Loudness Data

Fan Number and Test	Prominent Frequency (Hz)	Loudness (sones)
Fan 1 – 3DMark 2005	1374	5.77
Fan 1 – Windows	1374	4.22
Fan 1 – Stand - Alone	1374	3.41
Fan 2 – 3DMark 2005	433, 866	3.39
Fan 2 – Windows	433, 866	3.19
Fan 2 – Stand - Alone	866	3.70
Fan 3 – 3DMark 2005	1456, 1542	4.23
Fan 3 – Windows	433, 866, 1542	3.25
Fan 3 – Stand - Alone	687, 1029, 1374	7.12

The results for fan 1 make logical sense as the blade passing frequency of the fan at 12V is nearly equal to 1374 Hz. Similarly, for fan 2, the blade passing frequency is approximately equal to 866 Hz. The appearance of the 433 Hz prominent tone is unknown and somewhat peculiar as it is exactly half of the blade passing frequency. The results for fan 3 are very different from the other two. There are several prominent frequencies in the spectrum which may be the result of the flow of air exiting from the cooling fan duct. The primary difference between this fan and the first two is how it is designed to cool the GPU, and how it removes the warm air. In the case of fans 1 and 2, warm air remains in the computer case where it circulates with the air being drawn in by the front case fan. Fan 3 however brings in air from within the case, cools the GPU, and then blows the warm air out through the rear of the case. This style of cooling solution acts as like an exhaust for the computer case, ensuring that warm air is not re-circulated in the interior of the case. The frequency results may simply be a result of unusual aeroacoustic interactions of the jet of air at the back of the case. Further testing and analysis is needed to explain the source of the unusual prominent frequencies in fan 3.

In the previous table, loudness results were shown. Loudness is a psychoacoustic metric developed by Zwicker and Fastl which aims to quantify how loud a sound is perceived to be in comparison to a standard sound [3]. Thus, the higher the value of loudness, the more undesirable a sound is. Its calculation is described in the International Standard ISO 532B [4].

As may be seen in each of the three cases, the loudness value is less when the system is idle as opposed to when the software application is running. This is intuitive since the cooling fan does not need to remove as much excess heat. In the case of fan 1, the loudness for the stand-alone test is less than for the in-system tests. This makes sense because the fan is operating at its 12V speed. It is clear however that fan 3 is not operating at its 12V speed during the in-system tests performed as its loudness has a much higher value during the stand-alone test.

CONCLUSIONS

These results show that it is not merely the size or cooling requirements of the fan that determines the loudness of a corresponding sound. The fans' rotational velocity as well as the design of the entire cooling solution are important variables also. If the complexity of the cooling solution increases, so does the inherent noise generation mechanism.

REFERENCES

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