STREAMING PERFORMANCE SENSITIVITY ANALYSIS OF HDDS
SUBMITTED TO SHOCK & VIBRATIONS

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ABSTRACT

Future Consumer Electronics (CE) applications will make widespread use of existing desktop Hard Disk Drive (HDD) technology for audiovisual (A/V) recording and playback purposes. In mobile applications storage drives may encounter more shock & vibrations compared to office or in home applications. Philips as a system integrator has applied a new tool to test the sensitivity of storage devices under such conditions. In this tool the Streaming Performance of the drive is monitored. It is concluded that some hard disk drives will have difficulties in meeting AV streaming criteria at vibration levels below those provided in the Shock & Vibration specifications. This tool is also useful to analyze specific frequencies for which the drive is particularly sensitive and for which special excitation prevention measures should be considered in the end product design.

1. INTRODUCTION

The use of HDDs in CE applications is much different to that of PC applications. PC applications require foremost data integrity, capacity and speed. To achieve this, HDDs are growing in capacity, rotational speed and have extensive error recovery procedures. In AV applications not data integrity but a reliable streaming performance is of importance. However, vendor specifications on shock and vibrations refer to the sensitivity in data integrity only and not to streaming performance. Disruptions in digital streaming performance may result in image distortions, which we can already observe in broadcasting today. Such occurrences are expected to increase as storage devices handle more broadcasting digitally.

Being a system integrator and looking towards AV applications Philips analyzes the streaming performance of for instance disk drives and their possible sensitivity to external disturbances. The problem in analyzing drives is that proprietary knowledge and tools are required to perform dedicated shock and vibration tests on specific drives. Furthermore different HDD vendors use somewhat different vibration specifications, sometimes even drive specific. Generalized tools to make a comparison between drives are not readily available or are not designed for analyzing streaming performance.

This restricts the independent product analysis performed by integrators such as Philips while negotiating with different suppliers on the technologies required for the upcoming AV market.

2. THE ANALYSIS TOOL

To be able to test drives of different vendors as well as different type of storage engines, Philips Research in the Netherlands devised a dedicated analysis tool [1]. To properly integrate an A/V drive in a CE product the drive should be primarily predictable in its servicing time behaviour. Note that this does not mean fast since today’s drives can easily support the single or double streams of current video applications. Buffering or the redundancy in the A/V stream can to a certain extent correct for service delays or missing data. However a drive must not remain apparently inactive for too long since this would disturb the A/V stream, which is unacceptable. The tool uses a characterisation model for the drive to predict the command completion time for a given command.

![Fig. 1: Graphical output command completion time delay histogram for a HDD.](image_url)

In Figure 1 a typical outcome of the analysis tool is...
presented. All commands completed before $\Delta t=0$ are predictable by the characterization model of the drive. The bulk uncertainty is due to the rotational latency, since we do not know the position of the actuator at the time the command is issued. This is fully acceptable and is taken into consideration in the design of the product. All commands that take longer are due to unknown delays. One reason may be that the drive is sensitivity for certain external conditions, which automatically initiate retries (additional rotations) and other operations commanded by the drives embedded error correction table. Such tables are generally so well tuned to PC applications that indeed no data errors are produced. However to meet the stringent data integrity requirement in PC applications, this results in rather uncontrollable delays. For A/V integration disk vendors are asked to review such schemes to watch out for unnecessary long delays.

As a performance indicator the dedicated tool is very suitable for the vibro-acoustic sensitivity analysis of a product design [2, 3]. Recently the tool used to analyze the shock and vibration behavior of storage engines such as optical drives and hard disk drives.

### 3. EXPERIMENTAL SETUP

![Schematic drawing of a vibration test setup.](image)

A test rig as schematically presented in figure 2 was used for the sensitivity analysis. It consisted of a heavy base plate on which the HDD could be mounted in any Z-axis rotational orientation. This plate is hanging on three wires to achieve a low rotational stiffness. We oriented the drive such that we tested excitations perpendicular to the actuator arm (off-track direction), which we expect the drive to be the most sensitive. A shaker excited the base plate in its center of gravity and the performance of the drive was analyzed by sweeping through a range of excitation frequencies of interest. By zooming-in specific drive sensitive frequencies could be found and analyzed in more detail.

### 4. RESULTS

Nominal behavior of a drive is when the bulk of the relative service times are before $\Delta t=0$. In Figure 3 is shown how the command completion time has changed due to the sensitivity of the drive for a certain vibration excitation frequency, in this case a rotational acceleration. We see that the bulk of the completion times take longer than the model predicted.

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**Fig. 3:** Detected frequency selective vibration sensitivity (rotational acceleration).

Drive sensitive frequencies found in this way could for instance be correlated to drive dynamics, mountings or application box mechanics. This case is not special but only shown here to illustrate the methodology. We have found this kind of behavior for all kinds of drives and are using this tool to improve our understanding of drives and in our communication with various drive vendors.

### 5. CONCLUSIONS

The analysis above show that the tool developed at Philips is disk-generic, sensitive and therefore suitable for analyzing hard disk drives on shock&vibrations as well as complete product designs including drive mountings. Important to mention is that in our experiments no data integrity errors were found. In this exercise we did not test to levels that caused failure. Some drives showed performance degradation at vibration levels below the specification, which are after all based on data integrity. In few cases severe time delays were observed which, when translated into image quality, would be considered unacceptable if no precautions were to be taken in the product design. We found our tool to be very informative and user friendly for evaluating different brands of disk drives. Often test results are discussed with specific vendors. Philips continuously communicates with HDD vendors in order to make the storage industry aware of the specific requirements of A/V applications in the near future. In this way we strive to improve our products and ask the attention of the disk drive industry for the upcoming A/V market.

**REFERENCES**

