# Damping Effects on Shock Response Spectra

## Part 2: 1.8-INCH DISK DRIVES

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## INTRODUCTION

This is the second in a series of papers that discuss the effects of shock on small portable hard disk drives (HDDs), a topic especially critical for portable electronics that require large amounts of memory. Here we focus on the 1.8-inch HDD. The aim of this white paper series is to provide guidance for engineers as they design shock protection schemes for the hard drives in their products. Part 1 of this series covers the 2.5-inch HDD—the largest form factor currently available—and Part 3 covers the 1.0-inch HDD—one of the smallest HDDs used in hand-helds with large memory capacity. While the theory discussion for all three drives is virtually the same, the recommended solutions are not.

### Half-Sine Acceleration and Modeling the System

Shock calculations were conducted utilizing computer algorithms for simulating half-sine acceleration shock pulses. The half-sine acceleration pulse was chosen since it is the most common one used in the electronics industry and is easily simulated with a drop table. Various elastomeric springs were evaluated based on their loss factors and their effect on G levels and sway space. The shock load applied to the HDD isolation system's foundation was a 200G half-sine acceleration pulse of three durations: 0.0005 sec, 0.001 sec and 0.002 sec. The mass of the hard drive is considered to be 0.051 kg. Three levels of damping were included in the analysis: loss factor $\eta$ = 0.1, 0.5 and 1.0. The $\eta$ = 0.1 value would correspond to elastomers such as silicone, natural rubber or neoprene, and the $\eta$ = 1.0 value corresponds to E-A-R Specialty Composites' ISODAMP® material. The HDD isolation system is assumed to be a single degree of freedom system (1DOF). The HDD and mounting foundation are assumed to be infinitely rigid. The model for this system is shown in Figure 1.

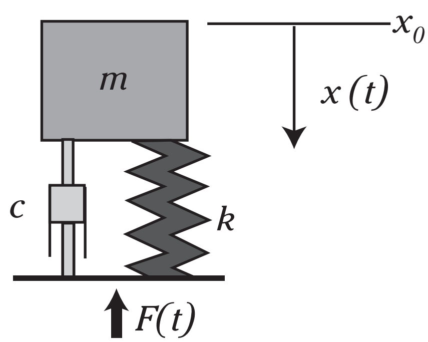


*Figure 1: Single Degree of Freedom System*

The variable *m* represents the mass of the hard drive and *F(t)* represents the forcing function. For a half-sine acceleration pulse of duration *T*:

$$F(t) = F \sin\left(\frac{\pi t}{T}\right) \text{ for } 0 \leq t \leq T$$

and

$$F(t) = 0 \text{ for } T < t$$

*x(t)* represents the position of the mass. Computer algorithms are used to monitor $\ddot{x}(t)$, which is the acceleration experienced by the hard drive usually in units of Gs ($1G = 9.8\ m/s^2$). The maximum displacement experienced by the hard drive, called *sway space*, also is monitored. The variable *c* traditionally represents viscous damping provided by a dashpot, and $k$ represents the spring stiffness. In an elastomeric spring used for shock protection, $c$ and $k$ combine to form a complex stiffness $k^*$. The damping in the material, called loss factor $\eta$, represents the relationship between the real and imaginary components of that complex stiffness. The computer algorithms utilized cannot account for complex stiffness, so viscous damping is used. The variable used to represent viscous damping in the algorithms is $\zeta$ , which is called the critical damping ratio. Equating $\zeta$ to loss factor $\eta$ can be achieved with the following expression:

$$\zeta = \frac{c}{2\sqrt{km}} = \frac{\eta}{2}$$

This relationship is accurate for low levels of damping. Out of necessity, it must be used for high levels of damping as well, because only the differential equations of motion dealing with viscous damping are readily solvable with a closed-form solution. They can be solved numerically, i.e., via non-linear solution techniques.

The equations of motion for the 1DOF system are:

$$\ddot{x}+2\zeta\omega_n\dot{x}+\omega_n x = F\sin\left(\frac{\pi t}{T}\right) \text{ for } 0 \leq t \leq T$$

$$\ddot{x}+2\zeta\omega_n\dot{x}+\omega_n x = 0 \text{ for } T < t$$

$$\text{where } \omega_n = \sqrt{\frac{k}{m}}$$

The time domain response of the two equations above can be solved utilizing the Laplace transformation. The solution is a bit lengthy and is outside the purpose of this paper. Once solved, the resulting equations can be used in a computer algorithm, the time domain response can be plotted and maximum displacement—velocity or G level—can be determined. When enough simulations of the HDD response have been conducted and the maximums determined, the graphs found in this report can be generated.

A typical acceleration time response for this system is shown in Figure 2 using a system natural frequency of 100 Hz. To illustrate the effect of damping on the time response, two curves are shown. The dashed curve reflects a lightly damped system, and the solid curve reflects a highly damped one.

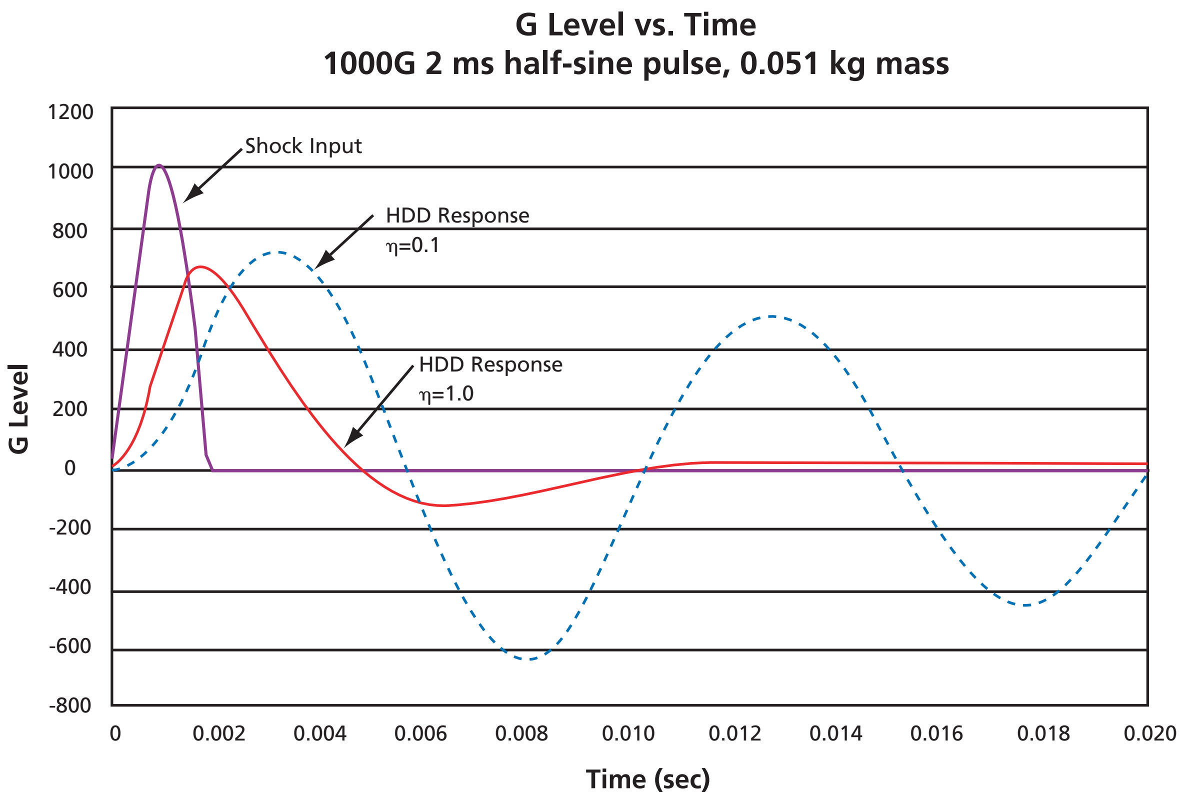


*Figure 2: Time domain response, 1DOF System subjected to half-sine pulse*

Figures 3 through 8 depict the shock response spectrums for three different half-sine shock pulse durations: 0.0005 seconds, 0.001 seconds and 0.002 seconds. For each pulse duration, the peak transmitted G level and deflection are plotted versus system natural frequency. Since the mass is always the same, system natural frequency really represents changing stiffness.

## Shock Spectrum Results

### Shock duration of 0.0005 seconds

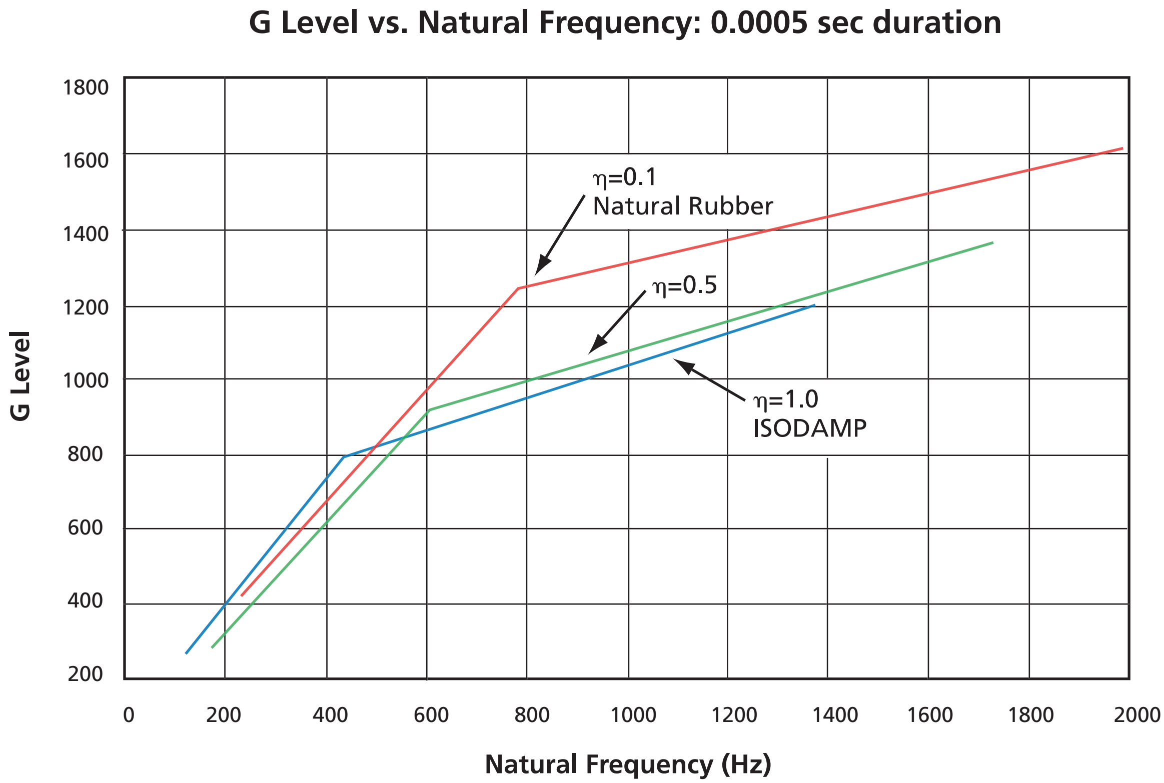


*Figure 3*

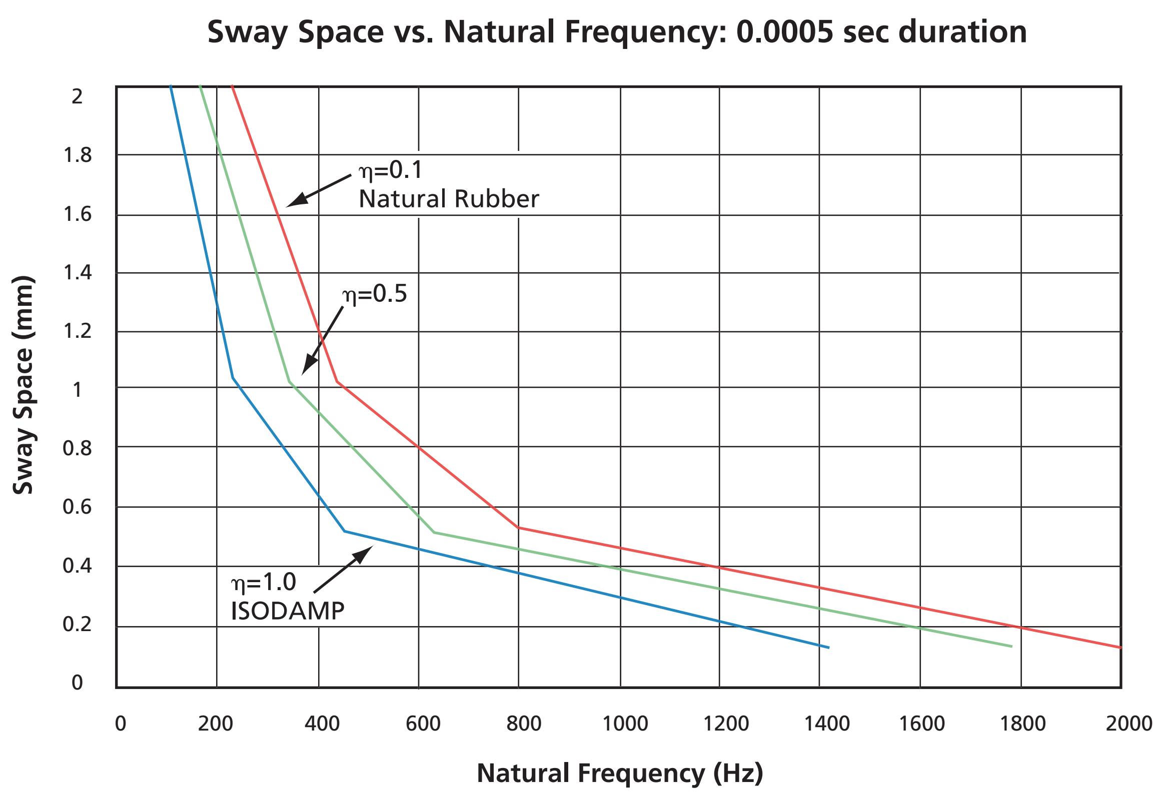


*Figure 4*

## Shock duration of 0.001 seconds

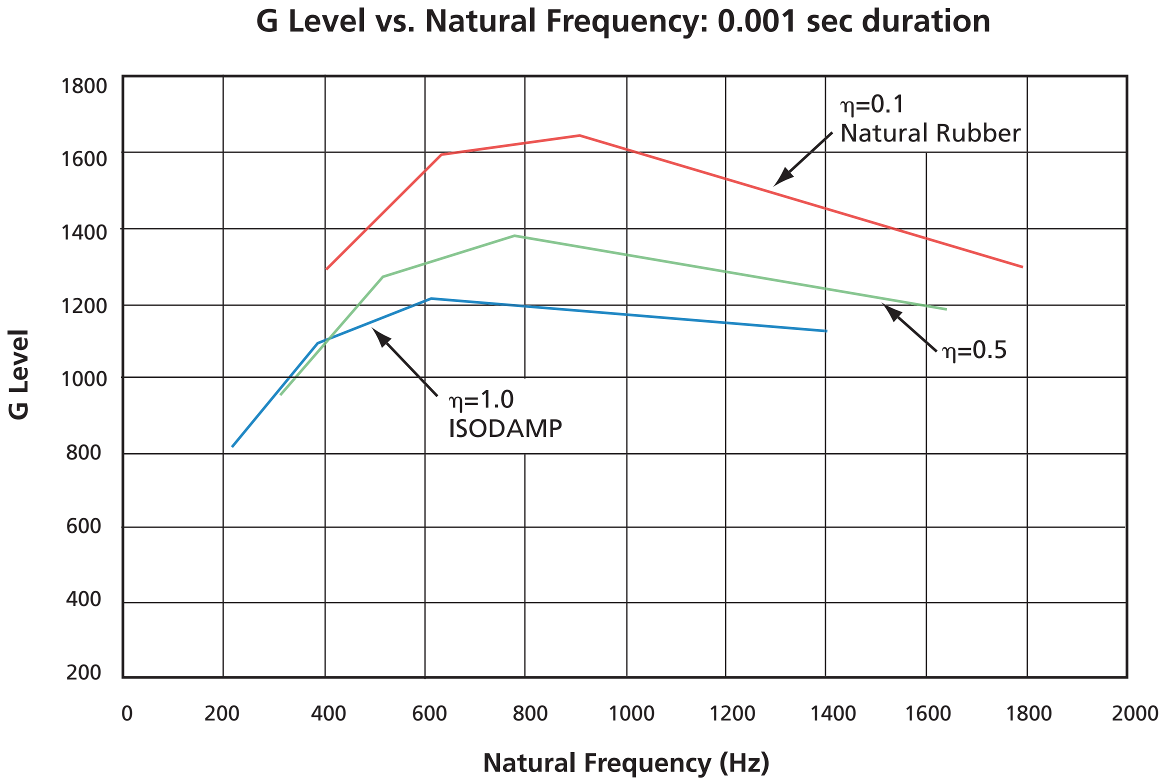


*Figure 5*

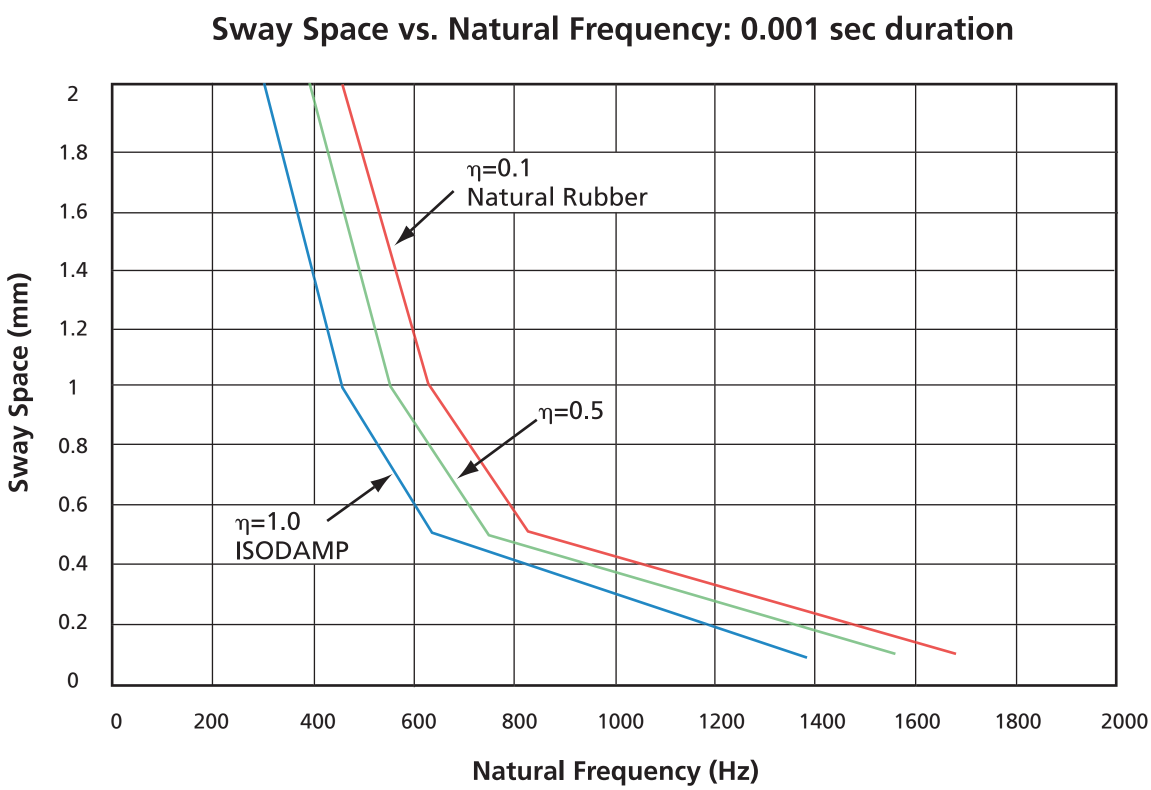


*Figure 6*

## Shock duration of 0.002 seconds

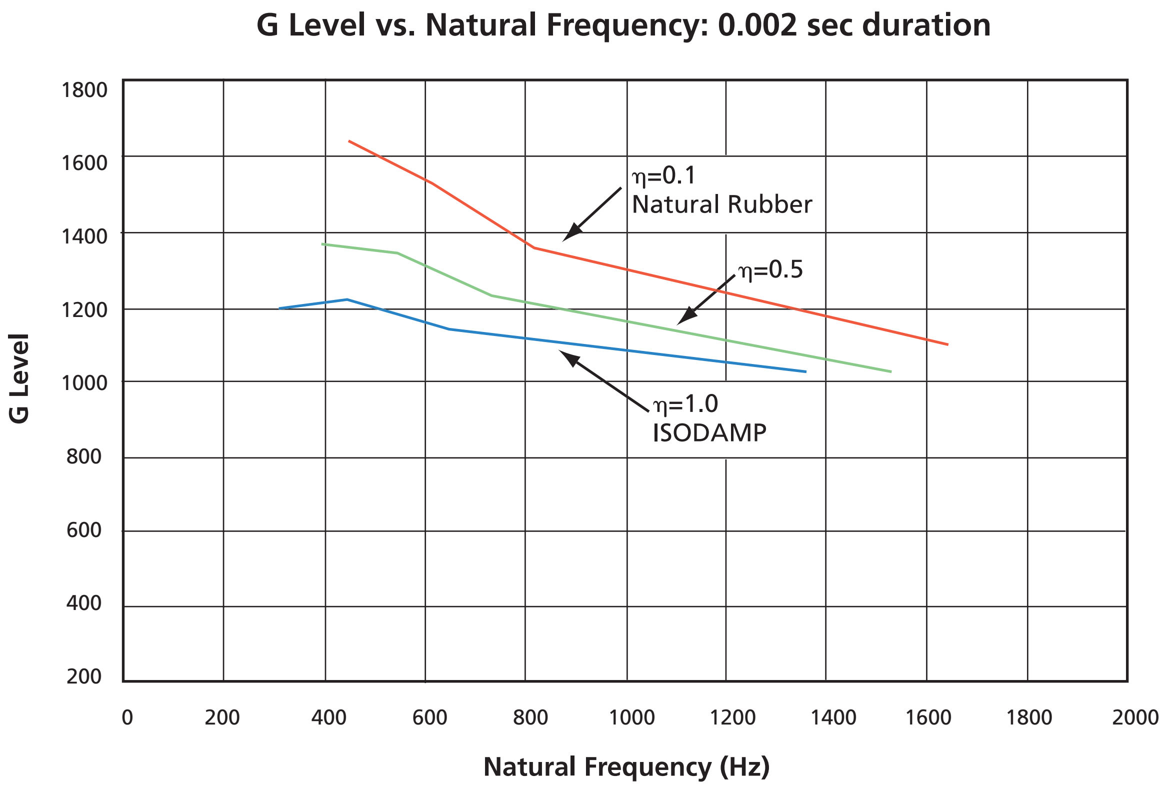


*Figure 7*

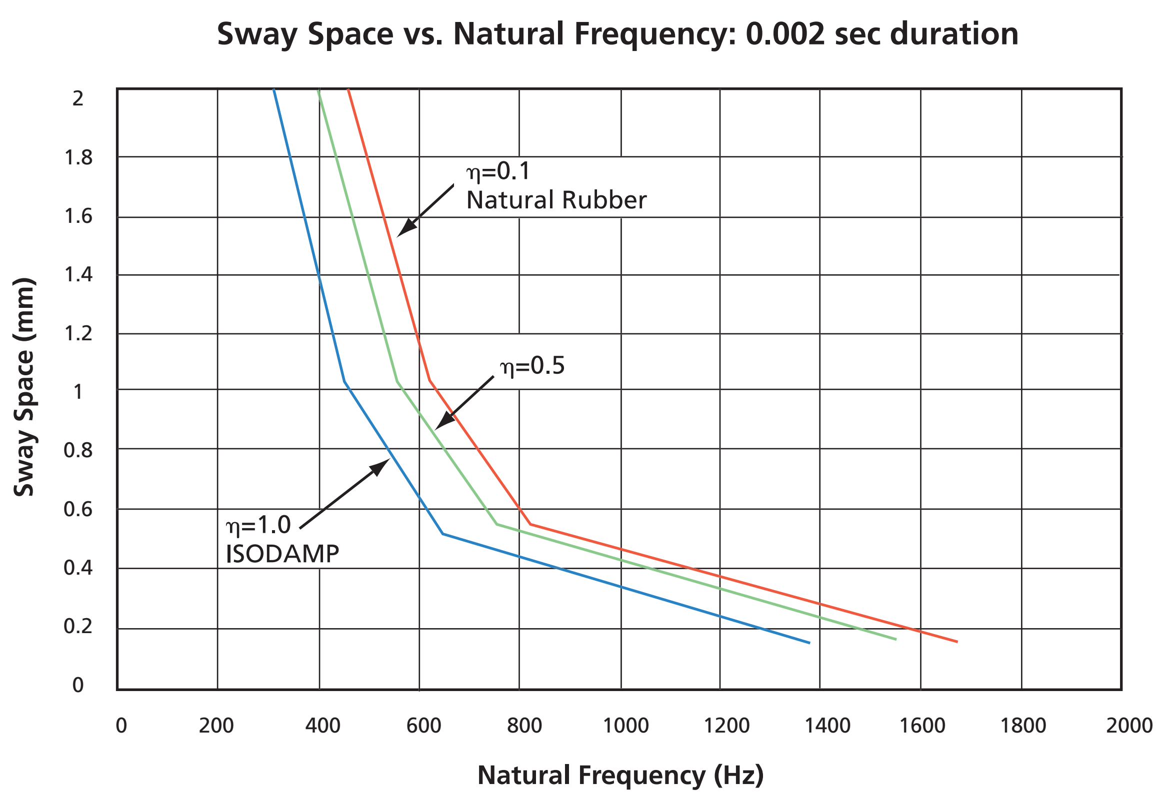


*Figure 8*

The high damping response curves shown in the graphs indicate that for a given natural frequency, i.e., stiffness, a system requires less sway space and will obtain a lower G level than with a material with low damping. Note how much the system response changes when the shock duration changes. An optimum solution for one acceleration pulse is not necessarily optimum for another duration pulse (nor for another pulse shape such as a triangular pulse or versed-sine pulse).

**Solutions Available**

E-A-R Specialty Composites' shock protection solutions typically involve the use of energy absorbing elastomers such as ISODAMP® or VersaDamp™ in the form of grommets, snubbers and sleeves and/or the use of E-A-R's highly damped CONFOR® CF-EG foam.

E-A-R Specialty Composites offers a variety of custom-molded part designs for use with the 1.8-inch HDD. Because of the proprietary nature of many of these designs, only a schematic of a generic isolator is shown here.

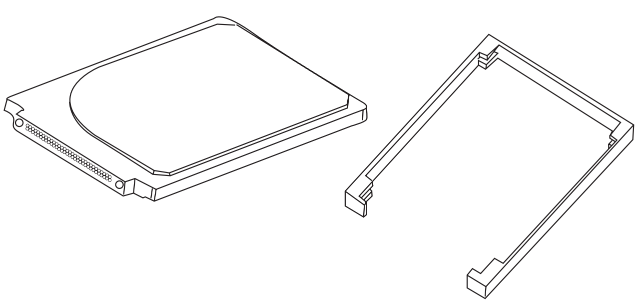

*Figure 9: 1.8-inch HDD and isolator*

Numerous variations of this design can be made, including adding ribs, core and other features.

There often is little available space for any isolation solution. When this happens, CONFOR CF-EG foam is a viable solution. CONFOR CF-EG foam is highly damped and can be cut as thin as 1.5 mm. The proprietary foam can be compressed to 50 percent of its thickness without a dramatic impact on its stiffness properties.

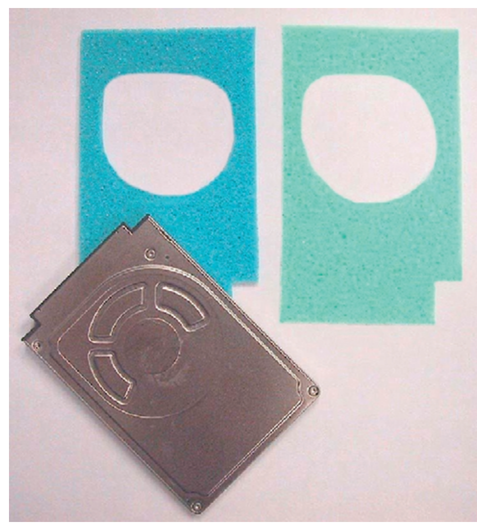

*Figure 10: CONFOR CF-EG foam shock pads for a 1.8-inch HDD. These represent two of the four stiffnesses available.*

See also:
*Damping Effects on Shock Response Spectra*
*Part 1: 2.5-inch Disk Drives*
*Part 3: 1.0-inch Disk Drives*

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