1995

A Study in the application of shock response, spectrum analysis to disk drive shipping and handling shock tests

Kenneth Neuburg

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A STUDY IN THE APPLICATION OF SHOCK RESPONSE SPECTRUM ANALYSIS TO DISK DRIVE SHIPPING AND HANDLING SHOCK TESTS

A THESIS
Submitted to the Faculty of the Department of Packaging Science, Rochester Institute of Technology

In Partial Fulfillment of the Requirements for the Degree of Master of Science

by
Kenneth Earl Neuburg
August 1995
The M.S. degree thesis of Kenneth E. Neuburg has been examined and approved by the thesis committee as satisfactory for the thesis requirements for the Master of Science degree.

Dan Goodwin

____________________________

David Olsson

____________________________

August 10, 1995
Date
Thesis Release Permission

ROCHESTER INSTITUTE OF TECHNOLOGY
COLLEGE OF APPLIED SCIENCE AND TECHNOLOGY

Title of Thesis: A STUDY IN THE APPLICATION OF SHOCK RESPONSE SPECTRUM ANALYSIS TO DISK DRIVE SHIPPING AND HANDLING SHOCK TESTS

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Date: August 15, 1995
Disk drives have been around since the 1950's. Since their inception, disk drives have undergone significant improvements and considerable downsizing. Personal computers and lap top versions have fueled increased demand for smaller, more powerful disk drives. To keep up with this demand and the need for greater disk drive performance, many electronic firms are sourcing OEM drives for their product lines.

Although the basic disk drive components are similar, one should not assume that all drives are created or evaluated equally. Beyond the obvious mechanical design differences, supplier fragility specifications seem to be creating a form of "specmanship". This term is intended to denote or suggest that some of the shock data appear to give one OEM design a more robust or rugged character than that of a competitor.

With the help of GHI's Shock Response Spectrum software, several shock signals were created and evaluated against each other in the frequency domain. Various shock signal parameters including pulse width, wave shape, peak or faired acceleration and filtering were compared against each other for effects on input energy. Beyond this initial comparison, the IBM Model 0663 3.5" fixed disk drive was instrumented for shock response to these various inputs in an effort to improve package design evaluation efficiency.

A major finding of this study is that by altering the method of acceleration measurement (peak g, vs. "faired" g), the length of the shock pulse (11, 20 ms), the application of signal filters and the type of waveform shape, dramatically different shock results can be created. These findings lead one to ask, "just what is a 50g product?"

Without specifically stating each of these parameters in a "50g" shock specification, the users of OEM disk drives really don't know what shock fragility conclusions to draw. These omissions will lead to unequal conclusions.
DEDICATION

To my wife Lisa, thank you for always believing in me, and for giving me all your encouragement, love and support.
ACKNOWLEDGMENTS

This work would not have been attempted were it not for the exposure and opportunities provided by my former employer, IBM. My job allowed me to interact almost daily with key engineers who created an atmosphere of technical excellence. Each of these individuals has increased my interest in disk drive fragility assessment and packaging design analysis in general.

I’d like to thank an earlier manager, Al Voss for creating an excellent environment for growth during our short time together at the Rochester, Minnesota facility. Never before, nor since, have I worked under an atmosphere that fostered such genuine support of the higher need, the team.

Several people deserve recognition for helping me with this project directly or as an influence via earlier interaction. Special thanks go out to Mark Kerr, Peter Berends, Bill Bakken, Bill Kipp, and Brian Ting.
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INTRODUCTION

Today’s disk drive demands have led many personal computer builders to source original equipment manufacturer’s (OEM) drives. An important consideration with this component is its fragility level. Being used in products like lap top computers, the drive will see its share of bumps and abuses in its product life cycle.

Of concern to computer manufacturers, is the fact that many products are being specified as far as non-operational shock goes in vague terms. “50g’s” for example can mean a lot of different things when put into proper context.

The primary goal of this project was to create a variety of shock inputs, and, by controlling and varying certain parameters, learn the effect of the differences created. This thesis is a discussion of the research which should aid the reader in creating more accurate non-operational shock fragility specifications. This technical accuracy will provide greater insight for those who are attempting to more directly compare two different manufacturer’s disk drives.
THE PROBLEM AND ITS SETTING

BACKGROUND INFORMATION:

A modern practice employed by electronics firms is the use of original equipment manufacturer (OEM) components in their product designs. Among OEM components, commonly in use today, is the disk drive.

Since their inception in the early 1950's, disk drives have undergone significant improvements.\(^1\) In spite of improvements, the basic construction has remained unchanged throughout the years.\(^2\) Even today, rigid disk drives consist of five basic sub-systems, including:

1). Spindle (with rotational motor and bearings);
2). Circular disks (aluminum substrate covered with some magnetic compound);
3). Read/Write heads (with sliders and suspensions);
4). Electronic circuitry (read/write channels, servocontrol, power supply, etc.); and a
5). Servo mechanism.\(^3\)

Although the basic components are similar, all disk drives are not created or evaluated equally. Beyond the obvious mechanical design differences, supplier fragility specifications seem to be creating a form of "specmanship". This term is intended to denote or suggest that some of the shock data appear to give one design a more robust or rugged character than that of a competitor.

One key difference exists in the fragility data, because some manufacturers specify critical acceleration levels using half sine shock input pulses rather than trapezoids.
Additional differences exist in the shock pulse width characteristics, the use of peak versus faired acceleration data, and some manufacturers use of "filtered" data.

Because disk drive manufacturers continue to make comparisons on an unequal basis, the OEM user should not necessarily conclude that a 50g drive is more rugged than a 35g drive design.

THE PROBLEM STATEMENT:

With the above listed ambiguities in mind, this research studies the application of shock response spectrum analysis to disk drive shipping and handling shock tests.

THE SUBPROBLEMS:

The first step in this study was to obtain nonoperating shock fragility information from various disk drive manufacturers.

In an effort to compare non-operating shock fragility levels on an equal basis, the input signals were then reproduced and compared against each other in the frequency domain.

The application of shock response spectrum (SRS) analysis allowed for the direct comparison between half sine and trapezoid wave forms. Pulse width duration characteristics and the application of signal filters were two additional variables that were compared using SRS analysis.

Finally, disk drive mechanical responses to these fragility inputs were created using SRS techniques and used as a tool for package design evaluation.
HYPOTHESES:

Disk drive manufacturers are publishing data that can lead to misleading conclusions as to a product's ruggedness when compared to a competitor.

A second hypothesis is that shock response spectrum analysis would allow for comparison of half sine, trapezoid, peak acceleration, and faired acceleration (signal variables) to get a truly accurate comparison between non-operating shock fragility levels (of various disk drive manufacturers).

A final hypothesis is that by creating shock response spectrum plots of the product response to the fragility inputs, and comparing them to the product response in a package, more informed conclusions could be made with regard to the packaging design.

DELIMITATIONS:

Disk drive evaluation will center around the newer, smaller disk drive families, specifically the 3.5” form factor with multiple platens. No attempt will be made to conduct actual fragility tests on disk drives from a variety of manufacturers. Disk drive response data will be recorded from an IBM Model 0663 disk drive.

THE DEFINITION OF TERMS:

Acceleration – Is a vector quantity that specifies the time rate of change of velocity. That is, it is the measure of the rapidity with which a velocity is changing. It is usually expressed in “g’s”. 4

Damage Boundary – A two-dimensional index of fragility which takes both the amplitude and duration of the shock into account. 5
Disk Drive – A mechanical device used for storing and retrieving system and customer information. Its design is comprised basically of a rotating spindle with magnetic disks, recording heads which fly above the disks, media/air filtration system, read/write control electronics and a closed-loop positioning actuator system.6

Faired Acceleration – The graphical smoothing of the amplitude of a recorded pulse still containing high frequency components even though electronic filtering may have been performed. This amplitude is used to evaluate the basic recorded pulse features with respect to the specified pulse.7

Frequency Domain – Representation of shock response data charting frequency in the horizontal axis and g’s in the vertical axis.

Non-operating Shock – Test level characterization of a disk drive, stating acceleration level, wave shape, and velocity change. Testing is conducted to verify the integrity of the drive and is useful for packaging design and system chassis considerations for the drive’s non-operational shock environment.8

Shock Response Spectrum – A plot of the maximum response experienced by a single degree-of-freedom system, as a function of its own natural frequency, in response to an applied shock. The response may be expressed in terms of acceleration, velocity, or displacement.9

Time Domain – Representation of shock response data charting pulse duration (time) in the horizontal axis and g’s in the vertical axis.

Velocity – A vector quantity that specifies the time rate of change of displacement with respect to a reference frame.10
ABBREVIATIONS:

HDA – Head Disk Assembly

IBM – International Business Machines Corporation

OEM – Original Equipment Manufacturer

SRS – Shock Response Spectrum

ASSUMPTIONS:

There exists ambiguous fragility information among the various disk drive manufacturers. Some specifications use half sine, some trapezoidal shock input signals. Other variations include the use of peak versus faired acceleration values, and the use of signal filters.

In their present expression, not all supplier specification statements are presented on an equal basis.

Perhaps some packaging engineers are failing to see better material alternatives for package designs or they might be discrediting them based on pure acceleration values provided in supplier specifications.

IMPORTANCE OF THIS STUDY:

If the application of SRS analysis techniques provides commonality for specification evaluation, “true” fragility comparisons can be made between products. In a world of ever-growing OEM use, a common form of product comparison is important.

The application of SRS data to disk drive fragility specifications could lead packaging engineers and product designers to a better understanding of how
mechanical systems will respond to shock inputs.

This work could lead to modifications in industry standards like ASTM D-3332, or perhaps foster a new practice on the application of the shock response spectrum tool as an improvement to package design and evaluation.
REVIEW OF THE RELATED LITERATURE

DISK DRIVE BACKGROUND:

A Fixed Disk (sometimes called a Hard Disk) is a storage medium using rigid aluminum disks coated with iron oxide. The disks are permanently mounted in a metal or plastic housing, which is why they are referred to as “fixed” disks. Air is circulated through the disk to provide a “cushion” upon which the read/write heads float. The air is filtered to eliminate (as completely as possible) any particulates that are present, as even a particle of cigarette smoke would be large enough to interfere with the operation of the disk. The heads fly close to the disk, maintaining a constant height of three or four micrometers above a surface that is rotating several thousand times a minute.

Fixed disks are often called “Winchester Disks”. It was rather preposterous to label a whole technology by the code name (Winchester) of a single model (the IBM 3340), which had a first customer shipment in the year 1973, because the misnomer ignored the previous 16 years of development that made the Winchester possible, as well as the following years of similar improvements.

The first Direct Access Storage Device (Disk Drive RAMAC 350) was conceived and designed by IBM personnel in San Jose, California during the early 1950’s. The feasibility models were a hodgepodge of components available at the time: the spindles were obtained from juke boxes, the disks were aluminum pizza plates with a hole in the middle, the magnetic recording materials (liquid) were poured on paper drinking cups and deposited manually, the first read/write heads were assembled by
former watchmakers, etc. In fact, some of the early servomotors consisted of coils obtained from hi-fi loudspeakers whose cones had been removed.\textsuperscript{11}

In 1957, the capacity of the disk drive was only five megabytes. Today's storage capacity has become \textgreater 7,500 megabytes.\textsuperscript{12} Over the years, disk diameters have been diminished from 40 inches to 1.25 inches.\textsuperscript{13}

Since their inception in the early 1950's, disk drives have undergone significant improvements. Beyond these technical performance improvements, the market demand for these items has doubled every two years.\textsuperscript{14}

**SHOCK FRAGILITY BACKGROUND (HISTORY):**

The standard shock fragility test procedure in use today is ASTM D-3332. The object of these tests is to find the shock level at which the weakest component in the product fails.\textsuperscript{15} In the case of disk drives, the head disk assembly (HDA) is of critical concern.

These shock sensitivities are reported in the form of a damage boundary curve. Historically, the damage boundary technique is based on the shock response spectrum (SRS) method of analyzing the effects of earthquakes on buildings, which was developed in the 1940's.\textsuperscript{16}

Later, the advent of improved instrumentation and computers led engineers to apply the SRS method to the task of protecting high value military hardware, but the approach was still too costly to use for optimizing packaging of commercial products.\textsuperscript{17}
In the late 1960's, Robert E. Newton, recently deceased and former professor emeritus at the U.S. Naval Postgraduate School (Monterey, California), considered means by which product shock fragility could be measured. Newton, who had used the SRS technique extensively for the U.S. Navy, developed a simplified envelope type variation of the method for packaging, now called the damage boundary theory.\(^\text{18}\)

Though the damage boundary procedure is widely used today, some of the assumptions inherent in the procedure are coming under reexamination.\(^\text{19}\)

The peak G-level measured during a system or package drop test cannot be simply compared to the G-level from the fragility test. The damage potential of a shock depends on the pulse shape and velocity change, as well as the G-level.\(^\text{20}\)

With this in mind, OEM disk drive manufacturers and users are looking for improved ways to standardize their product fragility specifications and methods of evaluation.\(^\text{21}\)
GENERAL PROCEDURE

PRIMARY DATA COLLECTION:

The primary data generated in this project was created in the University of Wisconsin – Stout’s ISTA certified test lab facility #ST-2134 by the author.

Shock signals were generated using a Lansmont programmable shock machine. This system is fitted with an infra-red scanning bar for easy duplication and repeatability of input signals. Instrument settings were recorded for each shock signal setup (see Table 1).

<table>
<thead>
<tr>
<th>Acceleration</th>
<th>Duration</th>
<th>Wave Shape</th>
<th>Felt Pads</th>
<th>Table Position</th>
<th>Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 g (faired)</td>
<td>20 ms</td>
<td>Trapezoid</td>
<td>3</td>
<td>21.0”</td>
<td>100 psi</td>
</tr>
<tr>
<td>30 g (faired)</td>
<td>20 ms</td>
<td>Trapezoid</td>
<td>3</td>
<td>26.0”</td>
<td>140 psi</td>
</tr>
<tr>
<td>35 g (faired)</td>
<td>20 ms</td>
<td>Trapezoid</td>
<td>3</td>
<td>31.0”</td>
<td>163 psi</td>
</tr>
<tr>
<td>40 g (faired)</td>
<td>11 ms</td>
<td>Trapezoid</td>
<td>3</td>
<td>15.0”</td>
<td>240 psi</td>
</tr>
<tr>
<td>40 g (peak)</td>
<td>11 ms</td>
<td>Half-sine</td>
<td>18</td>
<td>8.5”</td>
<td></td>
</tr>
<tr>
<td>50 g (faired)</td>
<td>11 ms</td>
<td>Trapezoid</td>
<td>3</td>
<td>20.0”</td>
<td>290 psi</td>
</tr>
<tr>
<td>50 g (peak)</td>
<td>11 ms</td>
<td>Half-sine</td>
<td>18</td>
<td>9.5”</td>
<td></td>
</tr>
<tr>
<td>60 g (peak)</td>
<td>11 ms</td>
<td>Half-sine</td>
<td>19</td>
<td>11.0”</td>
<td></td>
</tr>
<tr>
<td>70 g (peak)</td>
<td>11 ms</td>
<td>Half-sine</td>
<td>21</td>
<td>14.4”</td>
<td></td>
</tr>
<tr>
<td>80 g (peak)</td>
<td>11 ms</td>
<td>Half-sine</td>
<td>21</td>
<td>16.0”</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Shock Signal Set-up Parameters

By changing the drop height and the nitrogen pressure in the square wave programmer, trapezoidal shock pulses of various duration and amplitudes were produced. Half-sine signal variations were created by changing the table drop height and through the addition of felt programmer pads.
TEST EQUIPMENT USED:

Lansmont Model 65 programmable shock test system (reference Figure 1).

Infra-red scanning bar and push button controls.

Kistler accelerometer: Model 815A2, Serial #: 1285 Piezotron.

Kistler cable: # 1761A4.

Piezotron Coupler: Kistler 5116, Serial # C16144 (Channel 1).


Figure 1. Lansmont Model 65 Programmable Shock Test System
RECORDING PROCEDURES:

An accelerometer was mounted underneath the shock table (screwed in place using a threaded post) into a fitting drilled into the base of the table. (See Figure 2).

![Shock Table Accelerometer Location](image)

Figure 2. Shock Table Accelerometer Location

The table was then dropped from a set table position and pressure for trapezoid signals. Various felt programmer pads were positioned on the programmer for halfsine shock signals.
The computer displayed the resulting halfsine and trapezoid shock pulse signals from the accelerometer. (See Figures 3 & 4 for signal specifics). Note that the 10% analysis rule was utilized in signal review (per ASTM D-3332-94).
THE DATA GENERATED

REPRODUCTION OF NON-OP SHOCK SPECIFICATIONS:

A variety of disk drive “non-operational” shock signals were recreated for this evaluation. Competitive disk drive designs can be qualified for product development for use as OEM sources through non-operational shock evaluation. Various manufacturers represented their disk drives as rated at 35 g’s, 50 g’s, etc. The “PACKRND” discussion forum on the Internet was utilized to help in obtaining more contacts and information in the industry regarding manufacturer rating of disk drive fragility.

Attached is a request for information document and some examples of replies from fellow “PACKRND” users. (See Figures 5 through 8)

Rather than recreate an endless variety of signals, the following ten variations were utilized, in order to represent common responses. (See Table 2)

<table>
<thead>
<tr>
<th>Acceleration Level</th>
<th>Pulse Duration</th>
<th>Wave Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 g’s</td>
<td>20 ms</td>
<td>Trapezoidal</td>
</tr>
<tr>
<td>30 g’s</td>
<td>20 ms</td>
<td>Trapezoidal</td>
</tr>
<tr>
<td>35 g’s</td>
<td>20 ms</td>
<td>Trapezoidal</td>
</tr>
<tr>
<td>40 g’s</td>
<td>11 ms</td>
<td>Trapezoidal</td>
</tr>
<tr>
<td>40 g’s</td>
<td>11 ms</td>
<td>Half-sine</td>
</tr>
<tr>
<td>50 g’s</td>
<td>11 ms</td>
<td>Trapezoidal</td>
</tr>
<tr>
<td>50 g’s</td>
<td>11 ms</td>
<td>Half-sine</td>
</tr>
<tr>
<td>60 g’s</td>
<td>11 ms</td>
<td>Half-sine</td>
</tr>
<tr>
<td>70 g’s</td>
<td>11 ms</td>
<td>Half-sine</td>
</tr>
<tr>
<td>80 g’s</td>
<td>11 ms</td>
<td>Half-sine</td>
</tr>
</tbody>
</table>

Table 2. Shock Signals Evaluated
I'm currently looking for Development Engineering contacts at manufacturers of 3.5" form factor (and smaller) disk drives. Does anyone work with development contacts at Conner, Seagate, Western Digital, IBM, etc.? Beyond contacts, I'm also looking for fragility information on a variety of drives on the market today. Specifically, do they use trapezoid or half sine shock pulses to qualify their products, peak or "faired" acceleration, what target level, (ie. 35g, 50g, 80g, 100g, etc.). I'd also like information on the duration of their pulse signals (ie. 2ms, 11ms, 20ms, etc.).

I'm not looking for company confidential information! Any contacts, Development or Packaging Engineering, or shock fragility information would be most appreciated.

Regards,

Ken E. Neuburg
Packaging Program Coordinator
University of Wisconsin - Stout
NEUBURG6UWSTOUT.EDU

Figure 5. “PACKRND” Information Request Document

Ken, call Pete Berends in San Jose for the info you requested. Pete's phone number is 408-256-6295.

Figure 6. “PACKRND” Reply Example
From: IN"PACKRND@VM1.NoDak.EDU" "Packaging Research and Development" 20-FEB-
To: IN"PACKRND@VM1.NoDak.EDU" "Multiple recipients of list PACKRND"
CC: 
Subj: Disk Drive Engineering Contacts

Return-path: <owner-packrnd@VM1.NODAK.EDU>
Received: from VM1.NODAK.EDU by UHSTOUT.EDU (PMDF V4.3-7 #4883) id <0JJffl9KRTPG5S0002FNeuwSTOUT.EDU>; Mon, 20 Feb 1995 08:08:07 CST
Received: from VM1.NODAK.EDU by VM1.NoDak.EDU (IBM VM SMTP V2R2) with BSMTP id 7222; Mon, 20 Feb 95 07:43:03 CST
Received: from VM1.NODAK.EDU (NJE origin LISTSVR@VM1) by VM1.NODAK.EDU (LMail V1.2a/1.6a) with BSMTP id 4324; Mon, 20 Feb 1995 07:43:02 -0600
Date: Mon, 20 Feb 1995 07:43:59 -0600
From: PACKRND@UHSTOUT.EDU
Subject: Disk Drive Engineering Contacts
Sender: Packaging Research and Development <PACKRND@VM1.NoDak.EDU>
To: Multiple recipients of list PACKRND <PACKRND@VM1.NoDak.EDU>
Reply-to: Packaging Research and Development <PACKRND@VM1.NoDak.EDU>
Message-id: <01HN9KDKAAM410002FNeuwSTOUT.EDU>
Content-transfer-encoding: 7BIT

From: IN"DennYoung@aol.com" 18-FEB-1995 18:00:33.68
To: IN"PACKRND@VM1.NoDak.EDU"
Subj: RE: Disk Drive Engineering Co...

Ken:
For disk drives, I would check, among others, Terry Baird at H-P and Don Smith at Conner. Of course you probably know who to ask at IBM...

Dennis

Figure 7. “PACKRND” Reply Example

From: IN"EAChurch@aol.com" 5-MAR-1995 20:40:12.24
To: IN"PACKRND@VM1.NoDak.EDU"
CC: 
Subj: RE: Disk Drive Engineering Co...

------------------------ Message requiring your approval (5 lines) ------------------------
Ken, give Daniel Nicely at Lansmont Technical Center in Monterey a call. (408) 655-6675. He has conducted loads of fragility testing on disk drives for years now. In addition, he knows a lot of people from the various drive companies in silicon valley. I don’t think Daniel is on packrnd, but I am sure you could convince him to join.

Figure 8. “PACKRND” Reply Example

Figures 9-28 represent the table input characteristics listed in Table 2. The input responses are in the same order as the levels listed in the table. Following each time domain response plot, is a frequency domain plot of the appropriate signal under evaluation.
Figure 9. Computer Printout from Shock Machine, 25g, 20ms Trapezoid Wave Form
Figure 10. Shock Response Spectrum, 25g, 20ms Trapezoid Input
Figure 11. Computer Printout from Shock Machine, 30g, 20ms Trapezoid Wave Form
SR8 Test Report
SRI SYSTEMS, INC. TRIGG DAT SYSTEM

Date: Sat Mar 11, 1995
TEST ITEM: Table Set Up
IMPACT LOC.: Table Response

TEST ENGINEER: Ken Neuburg
TEST TYPE: Trapezoidal Shock
TEST MACHINE: Lansamont Shock Table

Channel Number: 1
Damping: 0.05
Max Type: Maxi-Max

Model = Acceleration
Plot = 6th Oct. with Bars
Samples from Screen

Remarks:
Channel 1 = unfiltered SRS of a 30g, 20ms faired acceleration trapezoid input shock signal.
Lab test conditions: 72 degrees F, 49% RH.

Figure 12. Shock Response Spectrum, 30g, 20ms Trapezoid Input
Figure 13. Computer printout from shock machine, 35g, 20ms trapezoid wave form
Figure 14. Shock Response Spectrum, 35g, 20ms Trapezoid Input
Figure 15. Computer Printout from Shock Machine, 40g, 11ms Trapezoid Wave Form
Figure 16. Shock Response Spectrum, 40g, 11ms Trapezoid Input
Date: Tues, March 14, 1995
TEST ITEM: Table Set Up
IMPACT LOC: Table Response
TEST ENGINEER: Ken Neuburg
TEST TYPE: Half Sine Shock
TEST MACHINE: Lansmont Drop Tester

Sensitivity:
Ch. 1: 28.88 g's/Div

Filter:

Trigger Ch.: ALL
Polarity: Window
Level: 25.88 g's
Mode: Short Memory
Pretrigger: 25

- 11.08 mS 3.22 g's 48.87 g's 65.33 In/s 18 mS

Remarks:
Channel 1 = instrumented table response to a 40g (peak acceleration) half sine shock signal. 16 felt pads (10 thick, 6 thin) were utilized to create the half sine pulse duration.
Lab Conditions: 72 degrees F, 56% RH.

Figure 17. Computer Printout from Shock Machine, 40g, 11ms Half Sine Wave Form
Figure 18. Shock Response Spectrum, 40g, 11ms Half Sine Input
Waveform Test Report

Date: Tues. Feb. 7, 1995
TEST ITEM: Table Set Up
IMPACT LOC.: Table Response

TEST ENGINEER: Ken Neuburg
TEST TYPE: Trapezoid Shock
TEST MACHINE: Lansmont Tester

Sensitivity:
Ch. 1: 48.88 g's/Div

Filter:

Trig. Ch.: ALL
Polarity: Window
Level: 25.88 g's
Mode: Short Memory
Pretrigger: 25 %

CH | TIME | CUR AMP | PEAK AMP | 1ST INT | FAIRED G'S | TIME/DIV
---|------|---------|----------|---------|------------|---------
1  | 11.84 ms | 4.97 g's | 64.86 g's | 184.44 in/s | 49.68 g's | 4 ms

Remarks:
Channel 1 = table response for a 50g, 11ms trapezoid input.
Acceleration value is a "faired" input, no filter, accelerometer 81285.
Instrument settings: 790 psi N2 and 20" table height.
Lab environment conditions: 72 degrees F, 45% RH.

Figure 19. Computer Printout from Shock Machine, 50g, 11ms Trapezoid Wave Form
Figure 20. Shock Response Spectrum, 50g, 11ms Trapezoid Input
Remarks:
- Channel 1 = instrumented table response to a 50g (peak acceleration), 11ms half sine shock signal. 18 felt pads (10 thick, 8 thin) were utilized to create the film pulse duration.
- Lab Conditions: 72 degrees F, 62% RH.

Figure 21. Computer Printout from Shock Machine, 50g, 11ms Half Sine Wave Form
SR8 Test Report
SHI SYSTEMS, INC. TRIAD CAT SYSTEM

Date: Tues, March 14, 1995
TEST ITEM: Table Set Up
IMPACT LOC: Table Response

TEST ENGINEER: Ken Neuburg
TEST TYPE: Half Sine Shock
TEST MACHINE: Lansmont Drop Tester

Channel Number = 1
Damping = 0.05
Max Type = Maxi-Max

Model = Acceleration
Plot = 6th Oct. with Bars
Samples from Screen

Remarks:
Channel 1 = instrumented table response to a 50g (peak acceleration), 11ms half sine shock signal. 10 felt pads (10 thick, 0 thin) were utilized to create the 11ms pulse duration.
Lab Conditions: 72 degrees F, 6521 RH.

Figure 22. Shock Response Spectrum, 50g, 11ms Half Sine Input
Figure 23. Computer Printout from Shock Machine, 60g, 11ms Half Sine Wave Form
Figure 24. Shock Response Spectrum, 60g, 11ms Half Sine Input
Figure 25. Computer Printout from Shock Machine, 70g, 11ms Half Sine Wave Form
Figure 26. Shock Response Spectrum, 70g, 11ms Half Sine Input
Date: Tues., March 14, 1995
Test Item: Table Set Up
Impact Loc.: Table Response
Test Type: Half Sine Shock
Test Machine: Lansmont Drop Tester

Sensitivity:
Ch. 1: 20.00 g's/Div

Filter:

Trig. Ch.: ALL
Polarity: Window
Level: 25.00 g's
Mode: Short Memory
Pretrigger: 25%

<table>
<thead>
<tr>
<th>CH</th>
<th>TIME</th>
<th>CUR AMP</th>
<th>PEAK AMP</th>
<th>1ST INT</th>
<th>2ND INT</th>
<th>TIME/DIV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.88 ms</td>
<td>2.90 g's</td>
<td>89.76 g's</td>
<td>130.85 In/s</td>
<td>10 mS</td>
<td></td>
</tr>
</tbody>
</table>

Remarks:
Channel 1 = instrumented table response to a 80g (peak acceleration), half sine shock signal. 21 felt pads (12 thick, 9 thin) were utilized to create the half sine pulse duration.
Lab Conditions: 72 degrees F, 62% RH.

Figure 27. Computer Printout from Shock Machine, 80g, 11ms Half Sine Wave Form
Figure 28. Shock Response Spectrum, 80g, 11ms Half Sine Input
0663 DISK DRIVE SHOCK RESULTS:

It is important to understand the shock input signal, but perhaps even more crucial is knowledge of a disk drive's instrumented response to these input parameters.

An IBM Model 0663 disk drive (3.5" form factor) was utilized for this evaluation. The drive was fixtured to the Lansmont shock table and instrumented for response. Each of the three disk drive product axes was exposed to various inputs for evaluation and comparison. See Figure 29 for the orientation identification.

Figure 29. Disk Drive Orientations for Instrumented Response
Fixturing was accomplished using threaded rods and wooden hold down bars along with aluminum bars (Figure 30).

Test data results, showing product response to the various dynamic inputs (dynamic test conditions), is shown in Figures 31 - 60.

Figure 30. Disk Drive Fixturing Methodology
Figure 31. Disk Drive Instrumented Response to 50g, 11ms Trapezoid
**SRB Test Report**

**Date:** Sun, April 16, 1995  
**TEST ITEM:** 0663 Disk Drive  
**IMPACT LOC.:** Bottom Down Response  
**TEST ENGINEER:** Ken Neuburg  
**TEST TYPE:** 50g, 11ms Trapezoid  
**TEST MACHINE:** Lansmont Shock

<table>
<thead>
<tr>
<th>Channel Number</th>
<th>Model</th>
<th>Damping</th>
<th>Plot</th>
<th>Max Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Acceleration</td>
<td>0.05</td>
<td>6th Oct. with Bars</td>
<td>Maxi-Max</td>
<td>Channel 1 = 50g (faiired acceleration), 11ms trapezoid input.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Channel 2 = Model 0663 disk drive response to the input.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Disk drive was mounted rigidly to the table surface with hold down bar and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>threaded rods. Response accelerometers S/N C45331 mounted to center of hda.</td>
</tr>
</tbody>
</table>

Figure 32. Disk Drive SRS (Bottom Down) Response to 50g, 11ms Trapezoid
Date: Sun, April 16, 1995
TEST ITEM: 0663 Disk Drive
TEST TYPE: 50g, 11ms Trapezoid
IMPACT LOC.: HDA End Down
TEST MACHINE: Lansmont Shock

Sensitivity:
Ch. 1: 28.88 g's/Div
Ch. 2: 28.88 g's/Div

Filter:

Trig. Ch.: ALL 1
Polarity: Window
Level: 25.88 g's
Mode: Short Memory
Pretrigger: 25 µs

<table>
<thead>
<tr>
<th>CH</th>
<th>TIME</th>
<th>CUR AMP</th>
<th>PEAK AMP</th>
<th>1ST INT FAIRED</th>
<th>TIME/DIV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.28 ns</td>
<td>4.35 g's</td>
<td>64.45 g's</td>
<td>182.38 in/s</td>
<td>49.76 g's</td>
</tr>
<tr>
<td>2</td>
<td>11.84 ns</td>
<td>1.46 g's</td>
<td>71.78 g's</td>
<td>182.73 in/s</td>
<td>49.76 g's</td>
</tr>
</tbody>
</table>

Remarks:
Channel 1 = 50g (faired acceleration), 11ms trapezoid input.
Channel 2 = Model 0663 disk drive response to the input.
Disk drive was mounted rigidly to the table surface with hold down bar and threaded rods. Response accelerometer: S/N C45331 mounted to center of hda.

Figure 33. Disk Drive Instrumented Response to 50g, 11ms Trapezoid
Figure 34. Disk Drive SRS (HDA End Down) Response to 50g, 11ms Trapezoid
Waveform Test Report
SCHI SYSTEMS, INC. TRIAD CAT SYSTEM

Date: Sun, April 16, 1995
TEST ITEM: 0663 Disk Drive
IMPACT LOC.: Right Side Down

TEST ENGINEER: Ken Neuburg
TEST TYPE: 50g, 11ms Trapezoid
TEST MACHINE: Lansmont Shock

Sensitivity:
Ch. 1: 28.00 g's/Div
Ch. 2: 20.00 g's/Div

Filter:
Trig. Ch.: ALL
Polarity: Window
Level: 25.00 g's
Mode: Short Memory
Pretrigger: 25 %

CH TIME CUR AMP PEAK AMP 1ST INT FAIRED G'S TIME/DIV
1 11.12 mS 1.37 g's 62.60 g's 180.52 In/s 49.00 g's 4 nS
2 11.76 mS 1.87 g's 66.75 g's 170.46 In/s 4 nS

Remarks:
Channel 1 = 50g (faired acceleration), 11ms trapezoid input.
Channel 2 = Mode 0663 disk drive response to the input.

Disk drive was mounted rigidly to the table surface with hold down bar and threaded rods. Response accelerometers S/N C45313 mounted to center of hda.

Figure 35. Disk Drive Instrumented Response to 50g, 11ms Trapezoid
Figure 36. Disk Drive SRS (Right Side Down) Response to 50g, 11ms Trapezoid
Waveform Test Report

Date: Sun, April 16, 1995
TEST ITEM: 0663 Disk Drive
IMPACT LOC.: Bottom Down Response

TEST ENGINEER: Ken Neuburg
TEST TYPE: 50g, 11ms Half Sine
TEST MACHINE: Lansmont Shock

Sensitivity:
Ch. 1: 20.00 g's/Div
Ch. 2: 20.00 g's/Div

Filter:

Trig. Ch.: ALL
Polarity: Window
Level: 25.00 g's
Mode: Short Memory
Pretrigger: 25 µs

CH | TIME | CUR AMP | PEAK AMP | 1ST INT | FAIRED G'S | TIME/DIV
---|------|---------|----------|---------|------------|--------
1  | 11.04 ms | 4.18 g's | 51.07 g's | 181.75 In/s | 4 ms
2  | 11.36 ms | 4.20 g's | 54.35 g's | 181.33 In/s | 4 ms

Remarks:
Channel 1 = 50g (peak acceleration), 11ms half sine input.
Channel 2: Model 0663 disk drive response to the input.
Disk drive was mounted rigidly to the table surface with hold down bar and
threaded rods. Response accelerometer: S/N C4533I mounted to center of hda.

Figure 37. Disk Drive Instrumented Response to 50g, 11ms Half Sine
Figure 38. Disk Drive SRS (Bottom Down) Response to 50g, 11ms Half Sine
Figure 39. Disk Drive Instrumented Response to 50g, 11ms Half Sine
Figure 40. Disk Drive SRS (Right Side Down) Response to 50g, 11ms Half Sine
Sensitivity:
Ch. 1: 28.88 g's/Div
Ch. 2: 28.88 g's/Div

Filter:
Trig. Ch.: ALL 1
Polarity: Window
Level: 25.00 g's
Mode: Short Memory
Pretrigger: 25 %

Remarks:
Channel 1 = 50g (peak acceleration), 11ms half sine input.
Channel 2 = Model O663 disk drive response to the input.
Disk drive was mounted rigidly to the table surface with hold down bar and threaded rods. Response accelerometers S/N C45331 mounted to center of hda.

Figure 41. Disk Drive Instrumented Response to 50g, 11ms Half Sine
Figure 42. Disk Drive SRS (HDA End Down) Response to 50g, 11ms Half Sine
Waveform Test Report

Date: Sun, April 16, 1995
TEST ITEM: 0663 Disk Drive
IMPACT LOC.: Bottom Down Response
TEST ENGINEER: Ken Neuburg
TEST TYPE: 40g, 11ms Trapezoid
TEST MACHINE: Lanemont Shock

Sensitivity:
Ch. 1: 20.00 g's/Div
Ch. 2: 20.00 g's/Div

Filter:
Trig. Ch.: ALL
Polarity: Window
Level: 25.00 g's
Mode: Short Memory
Pretrigger: 25 μs

<table>
<thead>
<tr>
<th>CH</th>
<th>TIME (mS)</th>
<th>CUR AMP</th>
<th>PEAK AMP</th>
<th>1ST INT</th>
<th>FAIRED G'S</th>
<th>TIME/Div</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.80</td>
<td>4.25 g's</td>
<td>45.41 g's</td>
<td>147.18</td>
<td>39.99 g's</td>
<td>4 mS</td>
</tr>
<tr>
<td>2</td>
<td>12.80</td>
<td>0.59 g's</td>
<td>59.72 g's</td>
<td>150.84</td>
<td>39.99 g's</td>
<td>4 mS</td>
</tr>
</tbody>
</table>

Remarks:
Channel 1 = 40g (faired acceleration), 11ms trapezoid input.
Channel 2 = Model 0663 disk drive response to the input.
Disk drive was mounted rigidly to the table surface with hold down bar and threaded rods. Response accelerometers S/N 045331 mounted to center of hda.

Figure 43. Disk Drive Instrumented Response to 40g, 11ms Trapezoid
Figure 44. Disk Drive SRS (Bottom Down) Response to 40g, 11ms Trapezoid
Figure 45. Disk Drive Instrumented Response to 40g, 11ms Trapezoid
**Figure 46. Disk Drive SRS (Right Side Down) Response to 40g, 11ms Trapezoid**
Waveform Test Report

Date: Sun, April 16, 1995
TEST ITEM: 0663 Disk Drive
IMPACT LOC.: HDA End Down
TEST ENGINEER: Ken Neuburg
TEST TYPE: 40g, 11ms Trapezoid
TEST MACHINE: Lamsont Shock

Sensitivity:
Ch. 1: 28.6 g's/Div
Ch. 2: 20.66 g's/Div

Filter:

Trig. Ch.: ALL
Polarity: Window
Level: 25.00 g's
Mode: Short Memory
Pretrigger: 25 %

CH TIME CUR AMP PEAK AMP 1ST INT FAIRED G'S TIME/DIV
1 10.96 ms -0.49 g's 48.93 g's 148.87 In/s 39.99 g's 4 ms
2 11.28 ms 3.08 g's 69.89 g's 150.49 In/s 4 ms

Remarks:
Channel 1 = 40g (faired acceleration), 11ms trapezoid input.
Channel 2 = Model 0663 disk drive response to the input.
Disk drive was mounted rigidly to the table surface with hold down bar and threaded rods. Response accelerometer S/N C45331 mounted to center of hda.

Figure 47. Disk Drive Instrumented Response to 40g, 11ms Trapezoid
Figure 48. Disk Drive SRS (HDA End Down) Response to 40g, 11ms Trapezoid
Waveform Test Report

Date: Sun, April 16, 1995
TEST ITEM: 0663 Disk Drive
IMPACT LOC.: HDA End Down

TEST ENGINEER: Ken Neuburg
TEST TYPE: 30g, 20ms Trapezoid
TEST MACHINE: Lansmont Shock

Sensitivity:
Ch. 1: 28.00 g's/Div
Ch. 2: 28.00 g's/Div

Filter:
Trig. Ch.: ALL
Polarity: Window
Level: 25.00 g's
Mode: Short Memory
Pretrigger: 25 μs

<table>
<thead>
<tr>
<th>CH</th>
<th>TIME</th>
<th>CUR AMP</th>
<th>PEAK AMP</th>
<th>1ST INT</th>
<th>FAIRED G'S</th>
<th>TIME/DIV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28.00 mS</td>
<td>-1.46 g's</td>
<td>45.12 g's</td>
<td>219.13 In/s</td>
<td>30.22 g's</td>
<td>4 mS</td>
</tr>
<tr>
<td>2</td>
<td>29.56 mS</td>
<td>-0.15 g's</td>
<td>62.11 g's</td>
<td>214.73 In/s</td>
<td>38.22 g's</td>
<td>4 mS</td>
</tr>
</tbody>
</table>

Remarks:
Channel 1 = 30g (squared acceleration), 20ms trapezoid input.
Channel 2 = Model 0663 disk drive response to the input.
Disk drive was mounted rigidly to the table surface with bolt down bar and threaded rods. Response accelerometers S/N C45331 mounted to center of hda.

Figure 49. Disk Drive Instrumented Response to 30g, 20ms Trapezoid
Figure 50. Disk Drive SRS (HDA End Down) Response to 30g, 20ms Trapezoid
Waveform Test Report

Date: Sun, April 16, 1995
TEST ITEM: Model 0663 Disk Drive
IMPACT LOC.: Right Side Down

TEST ENINER: Ken Neuburg
TEST TYPE: 30g, 20ms Trapezoid
TEST MACHINE: Lansmont Shock

Sensitivity:
Ch. 1: 20.00 g's/Div
Ch. 2: 20.00 g's/Div

Filter:

Trig. Ch.: ALL 1
Polarity: Window
Level: 25.00 g's
Mode: Short Memory
Pretrigger: 25 %

CH TIME CUR AMP PEAK AMP 1ST INT FAIRED G'S TIME/DIV
1 20.00 ms -1.61 g's 44.09 g's 220.55 In/s 30.00 g's 4 ms
2 20.64 ms -2.64 g's 56.45 g's 218.25 In/s 30.00 g's 4 ms

Remarks:
Channel 1 = 30g (faired acceleration), 20ms trapezoid input.
Channel 2 = Model 0663 disk drive response to the input.
Disk drive was mounted rigidly to the table surface with hold down bar and threaded rods. Response accelerometer S/N C45351 mounted to center of hda.

Figure 51. Disk Drive Instrumented Response to 30g, 20ms Trapezoid
Figure 52. Disk Drive SRS (Right Side Down) Response to 30g, 20ms Trapezoid
Waveform Test Report

Date: Sun, April 16, 1995
TEST ITEM: 0663 Disk Drive
IMPACT LOC.: Bottom Down Response
TEST ENGINEER: Ken Neuburg
TEST TYPE: 30g, 20ms Trapezoid
TEST MACHINE: Lansmont Shock

Sensitivity:
Ch. 1: 20.00 g/s/Div
Ch. 2: 20.00 g/s/Div

Filter:

Remarks:
Channel 1 = 30g (faired acceleration), 20ms trapezoid input.
Channel 2 = Model 0663 disk drive response to the input.
Disk drive was mounted rigidly to the table surface with hold down bar and threaded rods. Response accelerometer; S/N CH331 mounted to center of hda.

Figure 53. Disk Drive Instrumented Response to 30g, 20ms Trapezoid
Figure 54. Disk Drive SRS (Bottom Down) Response to 30g, 20ms Trapezoid
**Waveform Test Report**

**Test Item:** 0663 Disk Drive  
**Impact Loc:** Bottom Down  
**Test Type:** 35g, 20ms Trapezoid  
**Test Machine:** Lansmont Shock  
**Test Engineer:** Ken Neuburg  
**Date:** Thur, April 13, 1995

**Sensitivity:**
- Ch. 1: 29.80 g's/Div
- Ch. 2: 20.00 g's/Div

**Filter:**
- Trig. Ch.: ALL
- Polarity: Window
- Level: 25.00 g's
- Mode: Short Memory
- Pretrigger: 25

<table>
<thead>
<tr>
<th>CH</th>
<th>TIME</th>
<th>CUR AMP</th>
<th>PEAK AMP</th>
<th>1ST INT</th>
<th>FAIRED G'S</th>
<th>TIME/DIV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.16 mS</td>
<td>1.07 g's</td>
<td>50.88 g's</td>
<td>230.18 In/s</td>
<td>35.06 g's</td>
<td>4 mS</td>
</tr>
<tr>
<td>2</td>
<td>21.12 mS</td>
<td>1.42 g's</td>
<td>63.57 g's</td>
<td>237.74 In/s</td>
<td>4 mS</td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:**
Channel 1 = 35g (faired acceleration), 20ms trapezoid input.
Channel 2 = Model 0663 disk drive response to the input.
Disk Drive was mounted rigidly to the table surface with hold down bar and threaded rods. Response accelerometer S/N C4351 mounted to center of hda.

Figure 55. Disk Drive Instrumented Response to 35g, 20ms Trapezoid
Figure 56. Disk Drive SRS (Bottom Down) Response to 35g, 20ms Trapezoid
Figure 57. Disk Drive Instrumented Response to 35g, 20ms Trapezoid
Figure 58. Disk Drive SRS (Right Side Down) Response to 35g, 20ms Trapezoid
Waveform Test Report
S&I SYSTEMS, INC. TRIAD CAT SYSTEM

Date: Thur, April 13, 1995
TEST ITEM: 0663 Disk Drive
IMPACT LOC.: HDA End Down
TEST ENGINEER: Ken Neuburg
TEST TYPE: 35g, 20ms Trapezoid
TEST MACHINE: Lansmont Shock

Sensitivity:
Ch. 1: 28.00 g's/Div
Ch. 2: 28.00 g's/Div

Filter:
Trig. Ch.: ALL
Polarity: Window
Level: 25.00 g's
Mode: Short Memory
Pretrigger: 25

<table>
<thead>
<tr>
<th>CH</th>
<th>TIME</th>
<th>CUR AMP</th>
<th>PEAK AMP</th>
<th>1ST INT</th>
<th>FAIRED G'S</th>
<th>TIME/DIV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.32 ms</td>
<td>3.56 g's</td>
<td>50.93 g's</td>
<td>238.88 In/s</td>
<td>35.86 g's</td>
<td>4 ms</td>
</tr>
<tr>
<td>2</td>
<td>20.96 ms</td>
<td>-1.32 g's</td>
<td>61.38 g's</td>
<td>239.95 In/s</td>
<td></td>
<td>4 ms</td>
</tr>
</tbody>
</table>

Remarks:
Channel 1 = 35g (faired acceleration), 20ms trapezoid input.
Channel 2 = Model 0663 disk drive response to the input.
Disk Drive was mounted rigidly to the table surface with hold down bar and threaded rods. Response accelerometer: S/N C415331 mounted to center of hda.

Figure 59. Disk Drive Instrumented Response to 35g, 20ms Trapezoid
Figure 60. Disk Drive SRS (HDA End Down) Response to 35g, 20ms Trapezoid
PACKAGED 0663 DISK DRIVE RESPONSES:

Using an ADE suspension package design, (reference Figure 61) as an example, the IBM Model 0663 disk drive was instrumented, packaged, and subjected to free fall drops from varying heights on an L.A.B. free fall drop tester.

The packaged disk drive responses were converted into the frequency domain using SRS software. Conversion allows for the response signals to be directly compared to the disk drive responses generated during the fragility input signal tests. Figures 62 - 69 represent the packaged disk drive response data.

Figure 61. ADE Suspension Package
**Waveform Test Report**

**Date**: Sat. April 1, 1995

**TEST ITEM**: 3.5" Disk Drive

**IMPACT LOC.**: Bottom Down

**TEST ENGINEER**: Ken Neuburg

**TEST TYPE**: Free Fall Shock

**TEST MACHINE**: L.A.B. Tester

---

**Sensitivity:**

Ch. 1: 48.00 g's/Div

**Filter:**

Trig. Ch.: ALL

Polarity: Window

Level: 25.00 g's

Mode: Short Memory

Pretrigger: 25 %

---

**CH** | TIME | CUR AMP | PEAK AMP | 1ST INT | 2ND INT | TIME/DIV
---|---|---|---|---|---|---
1 | 35.40 mS | 0.78 g's | 33.58 g's | 246.01 In/s | | 10 mS

**Remarks:**

36" free fall drop on LAB drop tester.

Cradle suspension package design evaluation.

Channel 1 = disk drive instrumented response to this drop in the package.

Disk drive monitored at the HDA with accelerometer 9C45331.

---

Figure 62. Packaged Drive Response to 36" Free Fall Drop
Figure 63. SRS of 36” Drop Response
Figure 64. Packaged Drive Response to 42" Free Fall Drop
**SRS Test Report**

**SHI SYSTEMS, INC. T/RAD DAT SYSTEM**

- **Date**: Sat. April 1, 1995
- **TEST ITEM**: 3.5" Disk Drive
- **IMPACT LOC.**: Bottom Down
- **TEST ENGINEER**: Ken Neuburg
- **TEST TYPE**: Free Fall Shock
- **TEST MACHINE**: L.A.B. Tester

---

### Graph

![Graph](image-url)

- **Channel Number**: 1
- **Model**: Acceleration
- **Damping**: 0.05
- **Plot**: 6th Oct. with Bars
- **Max Type**: Maxi-Max
- **Samples from Screen**: 

**Remarks:**

- 42" free fall drop on L.A.B. drop tester.
- Cradle suspension package design evaluation.
- Channel 1 = disk drive instrumented response to this drop in the package.
- Disk drive monitored at the MDA with accelerometer 40453331.

---

**Figure 65. SRS of 42" Drop Response**
Figure 66. Packaged Drive Response to 48" Free Fall Drop
**SRS Test Report**

**Date:** Sat. April 1, 1995  
**TEST ITEM:** 3.5" Disk Drive  
**IMPACT LOC.:** Bottom Down  
**TEST ENGINEER:** Ken Neuburg  
**TEST TYPE:** Free Fall Shock  
**TEST MACHINE:** L.A.B. Tester

---

<table>
<thead>
<tr>
<th>Channel Number</th>
<th>Model</th>
<th>Damping</th>
<th>Max Type</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 1              | Acceleration | 0.05  | Maxi-Max | 48" free fall drop on LAB drop tester.  
|                |        |         |          | Cradle suspension package design evaluation.  
|                |        |         |          | Channel 1 = disk drive instrumented response to this drop in the package.  
|                |        |         |          | Disk drive monitored at the HDA with accelerometer #245331. |

---

**Figure 67. SRS of 48" Drop Response**
Figure 68. Packaged Drive Response to 54” Free Fall Drop
SRS Test Report
SRI SYSTEMS, INC. TRIAD CAT SYSTEM

Date: Sat. April 1, 1995
TEST ITEM: 3.5" Disk Drive
IMPACT LOC.: Bottom Down

TEST ENGINEER: Ken Neuburg
TEST TYPE: Free Fall Shock
TEST MACHINE: L.A.B. Tester

Channel Number = 1
Damping = 0.85
Max Type = Maxi-Max
Model = Acceleration
Plot = 6th Oct. with Bars
Samples from Screen

Remarks:
- 54" free fall drop on LAB drop tester.
- Cradle suspension package design evaluation.
- Channel 1 = disk drive instrumented response to this drop in the package.
- Disk drive monitored at the HDA with accelerometer KC45331.

Figure 69. SRS of 54" Drop Response
ANALYSIS OF THE DATA

SRS COMPARISONS:

Since all of the data collected in this study was converted to frequency domain using shock response spectrum software, direct comparisons can be made between all signal responses. A review of Figures 15 and 17 offers a comparison of the effects of “peak” versus “faired” acceleration. Both signals recreate the “40g, 11ms” target specification level, but the trapezoid with the 40g’s “faired” over the entire 11ms pulse width creates greater input energy than the halfsine variation using “peak” acceleration values for an instant in time. Velocity change differences in these signals is also apparent, (157.55”/sec versus 85.33”/sec).

A review of the SRS plots of each of these signals, (see Figures 16 and 18), indicates that the trapezoid signal creates more shock energy. In fact, the trapezoid SRS seems to envelope the half sine version. In Figure 70, the superimposed SRS characteristics of both signals show this enveloping situation.

The same relationship held true when signals at 50g, 11ms were compared against each other. Referencing figure 71, SRS characteristics of both signals are superimposed. The trapezoid, using faired acceleration levels, clearly creates more shock input energy than the half sine variation of the same pulse width with a peak acceleration level.

EFFECTS OF SIGNAL FILTERS:

Referencing Figure 72, the 40g, 11ms half sine signal was left unfiltered, filtered
Figure 70. Combination of SRS Responses at 40g, 11ms
SRS Test Report

Date: Tues. Feb. 7, 1995
TEST ITEM: Table Set Up
IMPACT LOC: Table Response

TEST ENGINEER: Ken Neuburg
TEST TYPE: Trapezoid Shock
TEST MACHINE: Lansmont Tester

Table of Values:

<table>
<thead>
<tr>
<th>Channel Number</th>
<th>Model</th>
<th>Plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Acceleration</td>
<td>6th Oct. with Bars</td>
</tr>
</tbody>
</table>

Channel 1 represents the SRS for a 50g, 11ms trapezoid input.
Channel 2 (located lower on the screen) is the SRS for a 50g, 11ms halseine input response.
Chart highlights the SRS differences of waveshape and peak vs faired acceleration.

Remarks:

Figure 71. Combination of SRS Responses at 50g, 11ms
correctly using the half sine filter frequency formula: \( \frac{1}{2 \text{ dur}} \times 5 \), equaling 227 Hz and over-filtered at 100 Hz for comparison. These changes can be viewed in time domain (Figure 72) and frequency domain (Figure 73). The point of these two figures is to note that filtering does have an effect on frequency domain information (although, a minor one for half sine shock signals).

For comparison, the 40g, 11ms trapezoid signal was left unfiltered, filtered at 800 Hz, and filtered at 100 Hz, (reference Figures 74 & 75). Again, the effect of filtration on the input data is very apparent.

**SHOCK TRANSMISSIBILITY:**

Transmissibility represents an output/input relationship. With regard to shock this value is the output response measured at the disk drive divided by the input measured at the shock table.

Transmissibility differences exist when the disk drive is subjected to trapezoid and halfsine signal inputs. Using the example 50g, 11ms signals, (reference Figures 31 through 42), the following transmissibility characteristics surfaced:

<table>
<thead>
<tr>
<th>Input</th>
<th>Peak g’s</th>
<th>Orientation</th>
<th>Response</th>
<th>Transmissibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>50g faired</td>
<td>63.38 g’s</td>
<td>Bottom Down</td>
<td>79.15 g’s</td>
<td>1.58 X</td>
</tr>
<tr>
<td>50g faired</td>
<td>64.45 g’s</td>
<td>HDA End Down</td>
<td>71.78 g’s</td>
<td>1.44 X</td>
</tr>
<tr>
<td>50g faired</td>
<td>62.60 g’s</td>
<td>Right Side Down</td>
<td>66.75 g’s</td>
<td>1.34 X</td>
</tr>
</tbody>
</table>

Table 3. Trapezoid Transmissibility

In general, the bottom drop is the worst, because eight disks (platens) are stacked parallel to the impact surface. Sides and end impacts have the hda components
Figure 72. Time Domain Filtration Comparison for 40g, 11ms Half-sine Signal
Figure 73. Frequency Domain Filtration Comparison for 40kHz 11ms Half-Sine Signal
Figure 74. Time Domain Filtration Comparison for 40g, 11ms Trapezoid Signal
Figure 75. Frequency Domain Filtration Comparison for 40g, 11ms Trapezoid Signal
running perpendicular to the impact surface, (less interference of components).

The half sine response characteristics are very different. The disk drive responds to half sine signals in more of a one-to-one sequence. There appears to be little transmissibility in the half sine relationship and less energy content, when compared to the trapezoid data, leaving less potential for damage. This situation appears to hold true for all drop orientations.

<table>
<thead>
<tr>
<th>Input</th>
<th>Peak g's</th>
<th>Orientation</th>
<th>Response</th>
<th>Transmissibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>51g peak</td>
<td>51 g's</td>
<td>Bottom Down</td>
<td>54 g's</td>
<td>1.06 X</td>
</tr>
<tr>
<td>51g peak</td>
<td>51 g's</td>
<td>HDA End Down</td>
<td>52 g's</td>
<td>1.02 X</td>
</tr>
<tr>
<td>51g peak</td>
<td>51 g's</td>
<td>Right Side Down</td>
<td>51 g's</td>
<td>1.00 X</td>
</tr>
</tbody>
</table>

Table 4. Half Sine Transmissibility

Engineers should be more concerned with the drives response to the shock inputs, than the inputs themselves. In the early 1930's, M.A. Biot, proposed that, rather than be concerned with the shape (time history) of input shock pulses, we should use a method of describing the response of systems to those pulses. We would then no longer be concerned with the complex shape of a pulse, but merely with its effect. The response to the input is more of a true indication of the fragility level and allows for a more real life comparison when shock responses are measured in a package.

Since the half sine signals were all creating one-for-one drive responses, (these values are already available in this study in the earlier half sine figures), there's no sense in recreating the same data.
RELATIONSHIP TO FREE FALL DROPS IN PACKAGE:

Referring to Figure 64, one might immediately conclude that the package design does not protect the disk drive from a 42” drop height if the product fragility is 35 g’s. This statement stems from the fact that the peak response measured to the drive during the drop in the package actually measured 37.4 g’s. Utilizing Figure 66, the same situation holds true if the product has a fragility of 40 g’s, since the response measured in the package at a 48” drop was 41.21 g’s.

Upon reviewing the SRS characteristics of these events though, the data indicates that some erroneous conclusions were jumped to using only pure time domain acceleration information. By superimposing Figures 56 and 65, (reference Figure 76), using SRS characteristics of these events, leads to a more informed conclusion. Notice that the disk drive response SRS in the package falls below the disk drive response SRS to the 35 g fragility input (for the bottom orientation of the drive). As long as the drive is instrumented in the same location and the results stay below that fragility mapping, the packaged drive will perform successfully.
Figure 76. Comparison of Package Response to Fragility Response
HYPOTHESES REVIEWED:

HYPOTHESIS 1:

Disk drive manufacturers are publishing data that can lead to misleading conclusions as to a product’s ruggedness when compared to a competitor. During one visit to an electronics store, a Conner 3.5” form factor drive listed a “200 g” product ruggedness level right on the outer shipping carton. Per Pete Berends comments at a P2C2 semi-annual meeting, “Some mused that it was strictly a marketing ploy that allowed the fragility level of the drive to be specified at a higher number than if a square wave input was used, thus giving the appearance that the drive was of higher durability.”

HYPOTHESIS 2:

A second hypothesis is that shock response spectrum analysis would allow for comparison of signal variables which leads to a truly accurate comparison between non-operating shock fragility levels. Data analysis section clearly shows how SRS analysis can be applied in an effort to support this assumption.

HYPOTHESIS 3:

A final hypothesis theorized that by comparing SRS plots of a disk drive’s response during shock events (in the package) and the drive’s response to fragility input shocks, better packaging design conclusions could be gained. Data analysis section clearly shows how SRS comparisons can be applied in an effort to support this assumption.
CONCLUSIONS AND RECOMMENDATIONS:

FINDINGS:

A variety of non-operational shock fragility inputs are being used by OEM disk drive manufacturers. While some companies specify half sine shock inputs, others utilize trapezoid signals.

Half sine and trapezoid input shock signals having the same acceleration level and pulse duration will not have the same velocity change characteristics. The trapezoid will always generate a higher velocity change. This greater velocity change will generate more input energy and an increased potential for damage.

Half sine and trapezoid input shock signals excite different responses in the model 0663 disk drive. The data collected in this study shows that the disk drive response to a half sine shock input is essentially the same as the input. This point is clearly shown when comparing the output responses of the disk drive to the input signals of the shock table. The resultant output/input or transmissibility values shown in this study are basically a one to one relationship. The trapezoid excites more peak response as far as transmissibility when compared to half sine inputs of the same duration. The trapezoid input clearly excites the disk drive differently, with more energy content and more potential for damage.

The disk drive’s response to the shock input is the true fragility index or map, and the SRS of this response is the ultimate pass/fail criteria. With this in mind, the disk drive can see more than 50g’s response from a shock input and still have an
acceptable package design even if the “fragility level” is 50g’s, as long as the resultant SRS is lower than the input fragility signal SRS.

Using SRS for packaged product responses can help pinpoint how close the package design is to the damage threshold. Product test specifications requiring a need for shock protection at the 36” drop height level may very well work at higher drop heights. If the container design still works at 54”, then the designer should look at a potential for cost savings through design reductions. The same design passing a 36.5” drop height might pass the test specification but may be too close that an element of risk exists with regard to transit damage potential.

CONCLUSIONS:

Going back some 60+ years to M.A. Biot’s proposed comments …

“Rather than be concerned with the shape (time history) of input shock pulses, we should use a method of describing the response of systems to input shock pulses.” Shock Response Spectrum (SRS) allows us to measure these responses of systems to input shock pulses. All shock ratings are not the same thing. An example of “50g’s” may not be the same “50g’s” to a second evaluator. This study helps show that users must define much more specifically what “50g’s” means. Wave shape, pulse width, “peak” or “faired” acceleration levels, and signal filtering all effect the “50g” test level.
RECOMMENDATIONS FOR PRACTICE:

Based on the findings of this study, non-operating shock specifications need to define more than a target acceleration level in g’s. Creating a statement telling the user that the product meets a “50g” shock target means little in and of itself.

In an effort to provide a technically accurate non-operating shock specification, the pulse shape, the velocity change, the pulse duration, the filtration level, and the identification of peak versus faired determination should all be included with the actual acceleration level.

Unfiltered test data should be saved for future reference. For better packaging design and evaluation, the instrumented response to these input parameters are more crucial than the input.

The use of SRS test data will allow for direct comparisons when evaluating the effects of other common shock phenomena. Examples such as production conveyor line shock impacts, manufacturing line flow rack impacts, or automatic guided vehicle storage container internal movement shock would enhance the direct analysis abilities SRS provides. In-line test screens could also be enhanced with the use of SRS.

RECOMMENDATIONS FOR FURTHER RESEARCH:

This work could lead to modifications in industry test standards like ASTM D-3332. The contents of this study should foster a new practice on the application of the shock response spectrum tool as an improvement to package design and evaluation.

Greater evaluation should be reviewed on the use of signal filters. Should filtering
be used at all? M.A. Biot's 1930's proposal should be put into use today. The response to the input is more of a true indication of the fragility level of a product, and allows for a more real life comparison when shock responses are measured in a package.

END NOTES:

2 Sierra, Ibid. 2.
3 Sierra, Ibid. 2.
7 Kerr, Ibid.
8 Dominguez and Lange, Ibid.
9 Kerr, Ibid.
10 Kerr, Ibid.
11 Sierra, Ibid. xi.
12 Sierra, Ibid. 7.
14 Sierra, Ibid. 2.
15 Ashley, Steven, "Handle With Care: Designing Damage Proof Packaging for Products." Mechanical Engineering, October 1992, p.68.
16 Ashley, Ibid. 68.
17 Ashley, Ibid. 68.
18 Ashley, Ibid. 68.
19 Ashley, Ibid. 68.
24 Tustin and Hieber, Ibid.


Newton, Robert E. (1976), Fragility Assessment, (Minneapolis, MN: MTS Systems Corp.).


SEAGATE ENGINEERING SPECIFICATION:

Non-operating Shock:

The limits of non-operating shock shall apply to all conditions of handling and transportation. This includes both isolated drives and integrated drives.

The drive subjected to non-repetitive shock not exceeding 50 g’s at a maximum duration of 11 ms (half-sine wave) shall not exhibit device damage or performance degradation. Shock may be applied in the X, Y, or Z axis.

The drive subjected to non-repetitive shock not exceeding 100 g’s at a maximum of 2 ms (half-sine wave) shall not exhibit device damage or performance degradation. Shock may be applied in the X, Y, or Z axis.

Note: Information obtained from Seagate Engineering Specification #64403706, revision level B, page 41 of 94.
IBM ENGINEERING SPECIFICATION:

Non-operating Shock:

The drive subjected to non-repetitive shock not exceeding 60 g's at a maximum duration of 11 ms (half-sine wave) shall not exhibit device damage or performance degradation. Shock may be applied in the X, Y, or Z axis.

The drive subjected to non-repetitive shock not exceeding 35 g’s at a maximum duration of 20 ms (trapezoid wave) shall not exhibit device damage or performance degradation. Shock may be applied in the X, Y, or Z axis.

The drive subjected to non-repetitive shock not exceeding 125 g's at a maximum of 3 ms (half-sine wave) shall not exhibit device damage or performance degradation. Shock may be applied in the X, Y, or Z axis.

Note: Information obtained from Brian Ting, a Development Engineer with International Business Machines Corporation.