SHOCK & VIBRATION TESTING OF AN AIRBORNE INSTRUMENTATION DIGITAL RECORDER

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ABSTRACT

Shock and vibration testing was performed on the Metrum-Datatape Inc. 32HE recorder to determine its viability as an airborne instrumentation recorder. A secondary goal of the testing was to characterize the recorder operational shock and vibration envelope. Both flight testing and laboratory environmental testing of the recorder was performed to make these determinations. This paper addresses the laboratory portion of the shock and vibration testing and addresses the test methodology and rationale, test set-up, results, challenges, and lessons learned.

KEYWORDS

shock, vibration, flight test data recorder, Very Large Data Store (VLDS), Bit Error Rate (BER)

INTRODUCTION

The Test Article Preparation (TAP) Competency, Naval Air Warfare Center Aircraft Division (NAWCAD), Patuxent River, MD provides vehicular instrumentation in support of Navy flight test. The vehicular instrumentation system must be able to acquire data in all of the Navy aircraft during any of the flight tests performed including Carrier Suitability Testing. This places stringent operational requirements on all the components of the vehicular instrumentation system including the on-board recorder. Historically ruggedized longitudinal recorders have been used as the on-board data storage device. These recorders have worked well for many years however they are not able to record data rates much over 1 megabit per second (Mbps). Digital recorders on the other hand are able to record much higher data rates.

There are three high level requirements that should be met in order for any recorder to be considered as a candidate for a vehicular data acquisition system to support Navy flight test. These three requirements are:

- *Employ a medium and data format that complies with IRIG standards to insure interoperability across the T&E community*
- *Have a small form factor*
- *Record data while being subject to the harsh environmental stresses that occur during a flight test such as during a catapult*

The Metrum-Datatape Inc. 32HE recorder is an airborne digital data recorder manufactured to the IRIG 106 Telemetry Standards. IRIG 106 details the format requirements for a helical scan digital magnetic tape recorder/reproducer which records data on a 1/2 inch S-VHS tape such that it is compatible with the Very Large Data Store (VLDS) format. The 32HE recorder also has a small form factor. Given these two facts the 32HE met the first two criteria. Because of this it was a candidate for environmental testing to determine if it met the third criteria. Specifically shock and vibration testing was performed to determine its viability as an airborne instrumentation recorder for Navy flight test. A secondary goal of the testing was to characterize the recorder operational shock and vibration envelope

TEST METHODOLOGY AND RATIONALE

The testing was designed to determine the shock and vibration operational envelope and characterize failure modes. The specifications used are Navy aircraft instrumentation standard shock and vibration specifications. The recorder was tested to these specifications, however additional testing was performed to determine how far those specifications could be exceeded before a failure occurred.

For purposes of this test two types of failures were defined, hard and soft. A hard failure occurs if the recorder stops recording data. A soft failure occurs if the recorded data quality is substantially degraded. The test was designed to provide both an intuitive and quantifiable measure of data quality. The type of errors typically encountered during flight tests are bursted and can usually be correlated with an event that causes environmental stress on the recorder; such as high-G wind-up turn on a fighter aircraft. This fact influenced the structure of the testing and failure criteria definition. For example, an accumulated Bit Error Rate (BER) could be used for a 15-minute frequency sweep test but would not be applicable for shock testing. Multiple runs were performed for each test. This was done to validate repeatability of recorder performance and filter out media related errors from test induced errors.

TESTS TO BE PERFORMED:
Three classes of tests were performed: 1. Sine sweeps, 2. Shock, 3. Random vibration. Each type of test was performed on each axis of the recorder. The baseline shock and vibration specifications used are listed below in Table 1. Constant peak acceleration sine sweeps were also performed to characterize recorder transfer characteristics prior to performing any of the tests. Testing in excess of the baseline specifications was performed as required to characterize any failure modes and determine the operational envelope.

NAME	FREQUENCY RANGE (Hz)	DESCRIPTION
SINE SWEEP	5 - 14	200 mil constant double amplitude
	14 - 33	2 G constant acceleration
	33 - 74	360 mil constant double amplitude
	74 - 2000	10 G constant acceleration
SHOCK	N/A	20 G peak half-sine, 9 mS
SHOCK	N/A	20 G peak half-sine, 11 mS
RANDOM VIBRATION	10 – 171	.025 G^2/Hz
	300 – 1000	.076 G^2/Hz
	2000	.019 G^2/Hz

Table 1. Shock and Vibration Baseline Test Specification

TEST SET-UP:
A block diagram of the test set-up is shown in Figure 1. A Bit Error Rate Tester (BERT) was used to generate a pseudo-random stream (PN-15) at 12 Mbps. A Pulse Code Modulation (PCM) simulator supplied a 12 Mbps data stream. The vibration table and the recorder were instrumented with piezoelectric (PE) and non-PE type accelerometers. Both types of accelerometers were required due to the wide dynamic range between the different tests. The table control frequency signal and acceleration, IRIG-B time, and audio were all recorded in order to correlate recorder performance with table excitation. A laboratory recorder was used to record all of the instrumentation data, voice, and time. The exciter for the shaker
table could rotate 90° to change vibration axis.

REAL TIME MONITOR:
The recorder does not have “read-after-write” capability so the recorded data could not be monitored real-time however several recorder status signals were monitored during the test. A stripchart was used to display these signals as well as table accelerations and control frequency. A CRT in the control room provided a graphical display of the table and recorder vibration levels as the test progressed. A plot of this display is shown in Figure 2.

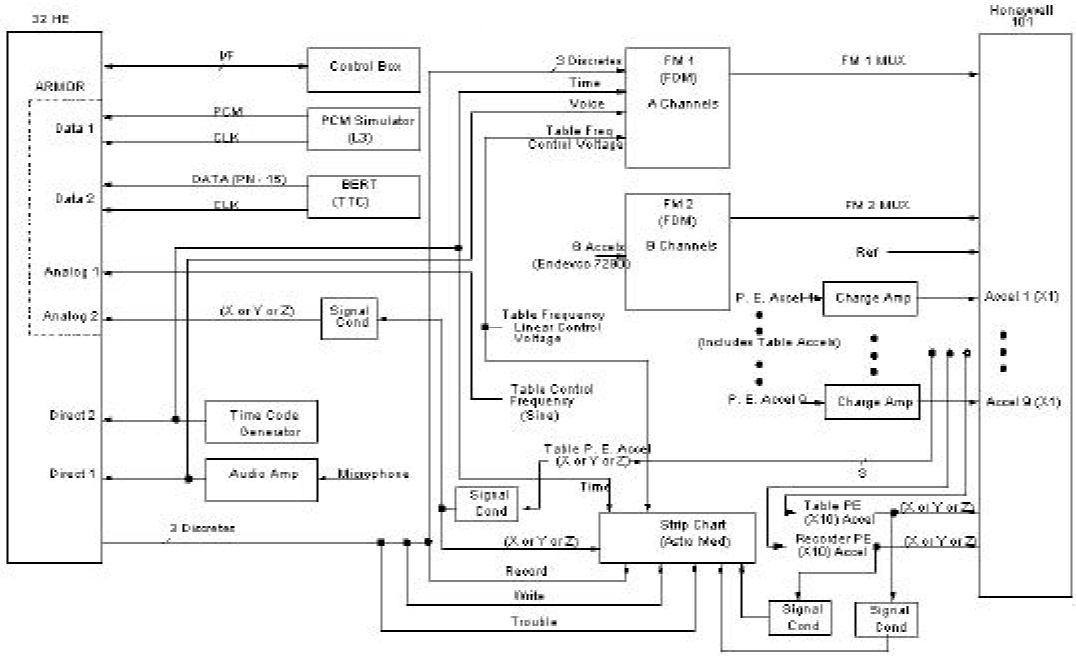

Figure 1. Test Set-Up Block Diagram

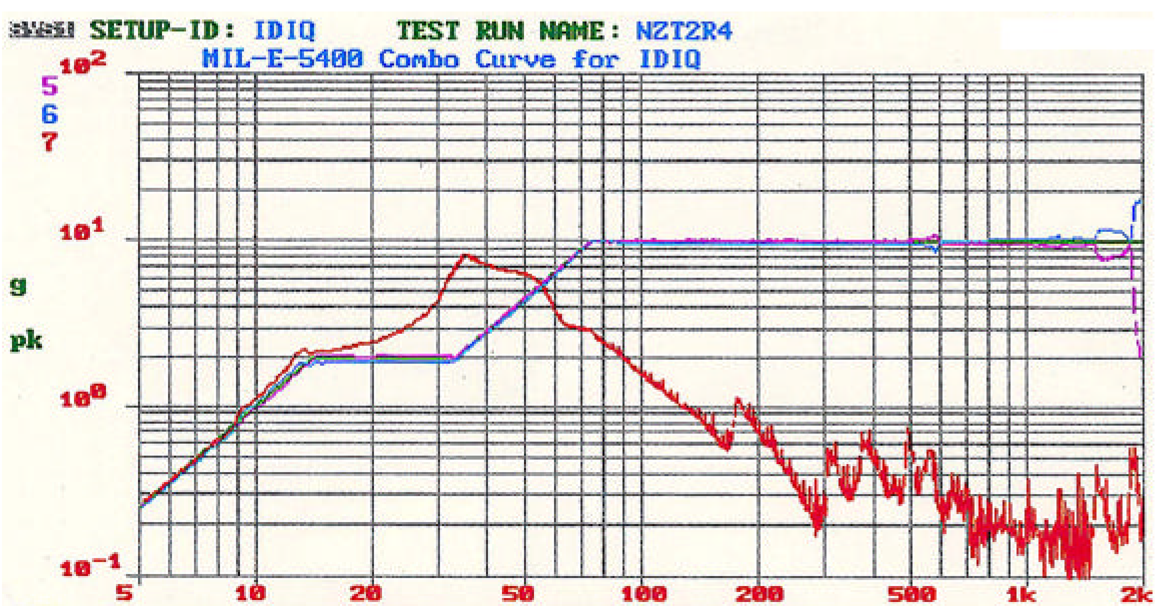

Figure 2. Sine Sweep Graph, Recorder Response Shown In Red

DATA ANALYSIS AND RESULTS

Playback and analysis of the test data was performed in the vibration laboratory to facilitate structuring the test as required. The entire test set-up was designed to address three factors, which are:

- *Identify the occurrence of any errors*
- *Define the table state when the error occurred*
- *Provide a measure of the magnitude of the error*

Graphs of the table test curve and recorder response were plotted as the test progressed. One of these plots is shown in Figure 2. Note that the plot shows that the recorder shock mount mechanical response contains a peak at approximately 35 Hz ($T_r \cong 4$) and starts to attenuate table excitation at approximately 57 Hz. These plots were used during playback to determine approximate table state during any given portion of the test. High bandwidth stripcharts were used for more accurate correlation

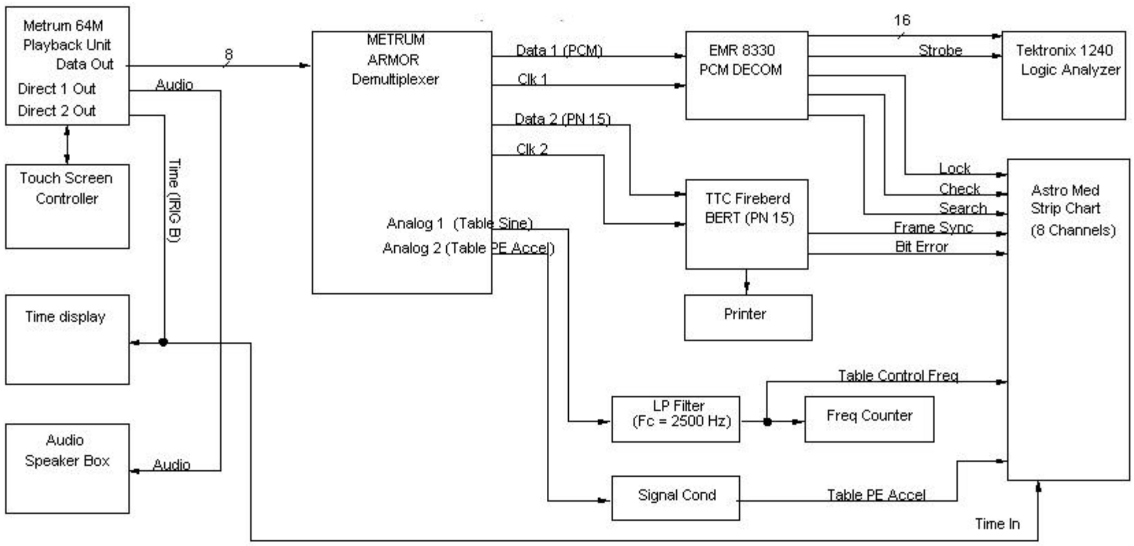

Figure 3. Data Reduction Set-Up Block Diagram

DATA REDUCTION SET-UP:

A block diagram of the tape playback is shown in Figure 3. A Metrum M64 Laboratory Recorder/Reproducer Unit and Asynchronous Real-time Multiplexer and Output Reconstructor (ARMOR) demultiplexer were used to playback the tape from the test. The BERT provided continuous error monitoring/indication and count. The logic analyzer provided error triggers and data capture for the PCM stream. The logic analyzer was continuously running “real time” and checked every bit in the PCM data stream against the pre-determined value. Audio and time were stripped out on playback for correlation. A frequency counter displayed the table frequency of vibration for the sinusoidal sweep tests. Burst errors were noted on the stripchart by a BERT error indication and/or loss of frame lock from the decommutator. The time and table acceleration were displayed on the stripchart. The M64 provided data logging capability. This was used to correlate data with respect to the principal block number (PBN) on tape. This in turn was used to correlate with table state. The fact that the recorder was a buffered type recorder complicated data correlation since there is a delay between the recorder input data clock and when the data is recorded on tape; however this time differential could be calculated and compensated for by the playback system.

RESULTS:

Table 2 lists all the tests conducted and the results of each of the tests. The table notes provide further description of errors. There were no hard failures. The recorder operated without any data dropouts in many of the tests. However data dropouts did occur during some of the shock tests. The exact level at which dropouts occurred was axis dependent; but in general dropouts started at approximately 14 G and above, peak amplitude of shock.

Subsequent to this test Metrum-Datatape Inc. has incorporated several design enhancements to the recorder. The modified version of the recorder was tested to the specifications listed in Table 1 above by an independent laboratory. No uncorrectable errors occurred during any of those tests including the 20 G half-sine shock tests.

Table 2. Test Results

TEST	X-AXIS (1,6)	Y-AXIS (1,6)	Z-AXIS (1,6)
IDIQ SINE	P	P	P
1.5 IDIQ LEVELS SINE	N/A	N/A	P
Flat 1.00 G SINE (5-100 HZ)	N/A	P	N/A
Flat 1.25 G SINE (5-100 HZ)	N/A	P	N/A
Flat 1.50 G SINE (5-100 HZ)	N/A	P	N/A
Flat 1.75 G SINE (5-100 HZ)	N/A	P	N/A
Flat 2.00 G SINE (5-100 HZ)	N/A	P	N/A
IDIQ SHOCK (9 MS/20 G)	P	F(2)	F(4)
STEP LEVEL SHOCK (11MS/10G TO 20G IN 1 DB INCREMENTS)	P	F(3)	F(5)
RANDOM (JET-F18C/D CURVE)	P	P	P
CUSTOME RANDOM (FLAT .05 G^2/HZ; 5-2000 HZ)	N/A	P	N/A

Notes:

(1) “P”indicates pass, which means that no data dropouts occurred during playback of the test tape. “F” indicates fail and means that data dropouts occurred during playback of the test tape and that the dropouts are correlated to the testing (i.e. not media errors). “N/A” in the table indicates that the particular test was not performed for that axis.

(2) Data dropouts for 2 of 3 + 20 G pulses.

(3) Data dropouts starting at 14.1 G pulse. Good at prior step of 12.6 G pulse.

(4) Dropouts for 2 of 3 + 20 G pulses and 2 of 3 - 20 G pulses.

(5) Data dropouts starting at 15.9 G pulses. Good prior step at 14.1 G.

(6) Axis convention: X = side-to-side, Y = front-to-back, Z = vertical

CONCLUSIONS

Several challenges were encountered during this testing; many of them in the test design phase. The most noteworthy was the effort to design a test that emulates the shock and vibration environment encountered in a particular aircraft during a particular type of flight test. The test typically used as the worst case shock and vibration scenario for Navy aircraft testing is the catapult. In general terms the shock and vibration environment for it is a complex function consisting of a multi-axis combination of shock and damped sinusoid accompanied by an offset g level. Of course exact waveform is aircraft and location dependent. Simulating this in the laboratory is a formidable if not impossible task. In the final analysis it was determined that laboratory shock and vibration testing is good as a first level quality assurance check. However the ultimate test is to subject the recorder to the actual operational environment by installing it in the aircraft during flight test.

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