THE NEED FOR ANALOG ANTI-ALIASING FILTERS IN THE PYROTECHNIC SHOCK TESTING OF AVIONICS COMPONENTS

By Tom Irvine
Email: tomirvine@aol.com

June 2, 2008

The following messages were posted at: http://www.eng-tips.com, Mechanical Acoustics/Vibration engineering Forum

31 May 08 17:16

NEWS ALERT: Pyrotechnic Shock Testing of Avionics Components

Avionics components in missiles may be subjected to high-amplitude, high-frequency pyrotechnic shock pulses. The components must thus be qualified to these shock levels per MIL-STD-1540D, 810F, etc.

The qualification levels often have so much margin that the tests must be performed in a "near-field" shock environment using plates with detonation cord.

A particular problem arises if "analog anti-aliasing filters" are NOT used in the data acquisition system. In this case, ultra high frequency shock energy may be folded down about the Nyquist frequency, thereby artificially increasing the "apparent" shock level at lower frequencies. This may result in an under-test even though the SRS plots "appear" to meet the specification.

Please include "analog anti-aliasing filters" as a requirement in your shock test specifications.

Recommended sample rates and filter parameters are given in the: IEST Handbook for Dynamic Data Acquisition, IEST-RP-DTE012.2.

Tom Irvine

* * * * * * * * *

2 Jun 08 8:21

Hi Tom,

I just sat through a SAVIAC class on Mechanical Shock and Data Acquisition a few weeks ago. Excellent class by the way, and we discussed this very topic. Depending on the signal/noise content up to the limit of the accels, the SRS can be off by 10-20 dB or possibly more.

Thanks for the heads up, this is something we all need to be aware of.

Jim Kinney

<u>Reference</u>

1. T. Irvine, Notes on Sample Rate and Aliasing, Revision A, Vibrationdata, 2007.

APPENDIX A

Excerpts from Reference 1

The Nyquist frequency is equal to one-half the sampling rate.

INTRODUCTION

Engineers collect accelerometer data in a variety of settings. Examples from the launch vehicle industry include:

1. Launch vehicle flight data
2. Stage separation and other ground tests where pyrotechnic devices are initiated.
3. Component shock and vibration tests performed in the lab

The accelerometers measure the data in analog form. The accelerometer may have an integral mechanical lowpass filter. Furthermore, the signal conditioning unit may have an analog lowpass filter.

Lowpass filtering of the *analog* signal is necessary to prevent aliasing.

Eventually, the data is passed through an analog-to-digital converter.

The proper lowpass frequency and sampling rate must be selected to ensure that the digitized data is accurate. This report establishes guidelines for selection of these parameters.

FIRST REQUIREMENT FOR SAMPLING RATE

Rule-of-Thumb

The first requirement is that the sampling rate must be greater than the maximum analysis frequency. Industry has established guidelines for this requirement, as discussed in References 1 and 2.

These guidelines are summarized in Table 1, where

$$(\text{minimum sampling rate}) \geq (N)(\text{maximum analysis frequency})$$

Table 1. First Requirement	
Analysis Type	N
Frequency Domain	2
Time Domain	10

Frequency Domain

The frequency domain requirement is based on the fact that at least two time-domain coordinates per cycle are required to resolve a sine wave.

The frequency domain analysis thus extends up to the Nyquist frequency which is one-half the sample rate.

Note that some conservative references specify an N of 2.5 for frequency domain calculation.

Time Domain

A sampling rate of 100 KHz is thus required for a shock response spectrum analysis extending to 10 KHz. Recall that the shock response spectrum is calculated in the time domain.

The IES Handbook for Dynamic Data Acquisition and Analysis gives the following guidelines:

> Unlike other spectral quantities evolving from the discrete Fourier transform computations, the SRS is essentially a time domain quantity.
>
> Hence, the digital sampling rate given by Rs=1/(delta t), introduces errors beyond those associated with aliasing about the Nyquist frequency.
>
> Thus, Rs must be high enough to accurately describe the response of the SRS oscillators.
>
> To minimize potential error, it is recommended that the SRS computations be performed with a sampling rate of Rs $\geq$ 10 fh, where fh is the highest natural frequency of the SRS computation.

SECOND REQUIREMENT FOR SAMPLING RATE

Shannon's Sample Theorem

Shannon's sampling theorem states that a sampled time signal must not contain components at frequencies above the Nyquist frequency.

Again, the Nyquist frequency is equal to one-half the sampling rate. Shannon's theorem applies to frequency domain analysis.

Rule-of-Thumb

Thus, the second requirement is that the sampling rate must be greater than the maximum frequency present in the source energy at the measurement location.

This requirement is independent of the maximum analysis frequency.

The guidelines are summarized in Table 2, where

$$\text{(minimum sampling rate)} \geq (\text{ M })(\text{ maximum frequency in source energy })$$

Table 2. Second Requirement	
Analysis Type	M
Frequency Domain	2
Time Domain	10

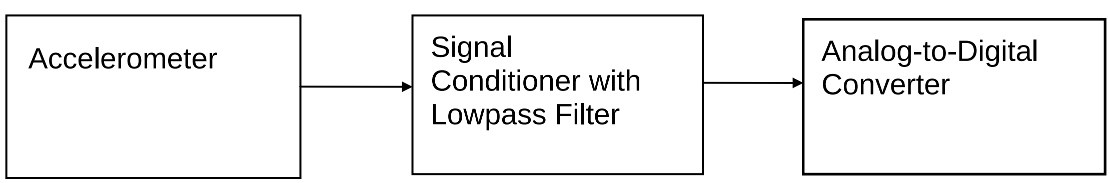
Note the similarity between Tables 1 and 2.

LOWPASS FILTERING

Aliasing can be prevented by lowpass filtering the analog data.

Consider a stage separation test or a launch vehicle flight. The maximum expected frequency in the source energy is essentially unknown. Thus, there is no proper means to set the sampling rate, other than setting it at some exceedingly high value.

The simple solution is to pass the analog data through a lowpass filter as shown in the flowchart.



The filter can be part of the signal conditioning system. Typically, a Butterworth filter is used. The Butterworth filter has a roll-off which attenuates the signal by 3 dB at the cut-off frequency. Further details are given in Reference 3.

The cut-off frequency is typically set at, or slightly above, the maximum analysis frequency.

The IES Handbook for Dynamic Data Acquisition and Analysis gives the following guidelines:

Let

f_c be the cutoff frequency

f_N be the Nyquist frequency

1. A lowpass anti-aliasing filter with a cutoff rate of at least 60 dB/octave should be used for the analog-to-digital conversion of all dynamic data.

2. With a 60 dB/octave cutoff rate, the half-power point cutoff frequency of the filter should be set at $f_c \leq 0.6 f_N$.

If the anti-aliasing filter has a more rapid cutoff rate, a higher cutoff frequency can be used, but the bound $f_c \leq 0.8 f_N$ should never be exceeded.