Control System Dynamic Range
The Advantages Offered by the High Performance of SD2550 Shaker Control Systems

Introduction

Choosing a digital Shaker Control system to operate with either an electrodynamic or hydraulic shaker, requires careful consideration of a number of issues. In addition to cost, the two most important factors for a customer to evaluate are *safety* and *performance*. Obviously, a system that does not have adequate built-in safety characteristics should not be considered, due to the expense of test equipment, product being tested, and hazards to personnel.

Key factors from a performance standpoint include:

- Dynamic range
- Equalization speed
- Control accuracy
- Testing/control features

The first, dynamic range, may prove to be the most important. The structural dynamics of a shaker fixture and test article often present a challenging control problem. Due to the wide dynamic range, that is, the amplitude ratio between the amplitude of the highest resonance and the lowest anti-resonance, accurate control requires a Shaker Control system with superior performance. Failure to control the test structure's full dynamic range not only results in out-of-compliance tests but it also causes overtest conditions or even test article damage.

Figure 1 illustrates the severity of the problem. The dynamic range for this shaker fixture exceeds 88 dB. A simple box design, this fixture holds printed circuit boards for vibration stress testing.

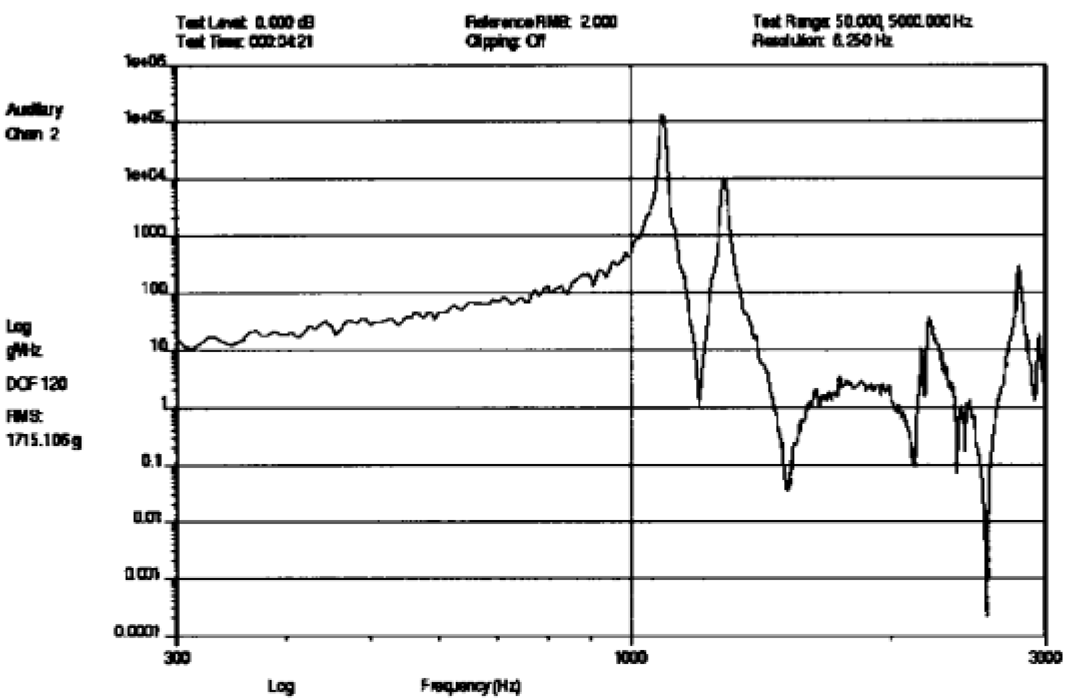


Figure 1: Spectrum for shaker box-fixture to hold circuit cards

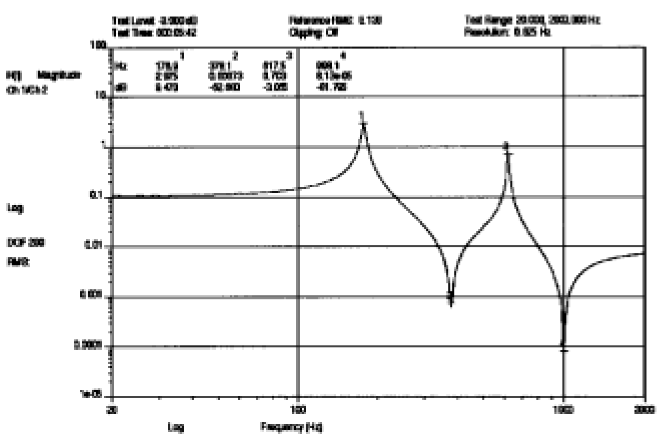
Designed for Superior Performance

Spectral Dynamics has applied its many years of vibration testing experience to vigorously address the requirements for usable dynamic range. As a result, SD2550 Vibration Control Systems make clever use of dedicated hardware at key points in the control loop, including a fully programmable output subsystem. The output subsystem design utilizes a 16-bit Digital-to-Analog Converter (DAC) coupled with digital smoothing filters and a 24-bit amplitude attenuator. Smoothing filters insure signal purity and minimize harmonic distortion. The 24-bit attenuator allows the SD2550 to adjust the full-scale output voltage range in steps as fine as 0.1 dB. Fine output adjustment capability provides accurate control at both full and low test excitations levels.

Also, autoranging of both input and output attenuators maximizes the usefulness of available signal strength and optimizes processing of these signals in the control loop. Automatic input ranging protects against overloading the input subsystem and consequential clipping and distortion of the control accelerometer signals. Autoranging also sets the full-scale voltage range to maximize the accuracy of the 16-bit ADCs (Analog to Digital Converters) and retain the full input dynamic range. Simultaneously, autoranging and scaling of the output DAC provides maximum resolution of the drive signal and assures that no unwanted output signal clipping will take place.

The result is an incredible control dynamic range, up to 90 dB, provided as a standard feature. Naturally, shaker system noise, charge amplifier settings, and several other factors may work against this. However, the more dynamic range the system can generate, the more chance there is of successfully completing a critical vibration testing program.

A Performance Proof Test



Testing with a stable, active dual peak-notch filter, placed as a test article in the feedback loop of the control system, demonstrates the tremendous range of Spectral Dynamic's control systems. The filter design models a mechanical system with two resonance-anti-resonance pairs. Figure 2 shows the filter's frequency response. This filter exhibits a maximum positive gain of over 9 dB, maximum attenuation of almost 82 dB, and a total dynamic range over 90 dB. The highest filter peak occurs at a frequency of 177 Hz and the lowest notch occurs at a frequency of 998 Hz.

Figure 2: Frequency response function of active peak-notch filter used in feedback loop

Closed-loop random tests with the peak-notch filter used a flat reference from 20-2,000 Hz, with 800 lines of control resolution and 160 degrees of freedom. Total level for the reference is 2 g_{rms}.

Figure 3 shows the connection of the peak-notch filter in the feed-back loop. The control system drive output connects to the filter input and to input channel 2 for measurement as an auxiliary input. Response from the filter feeds back to control system channel 1 as the accelerometer control signal. Conducted tests used an input channel sensitivity of 10 mV/g.

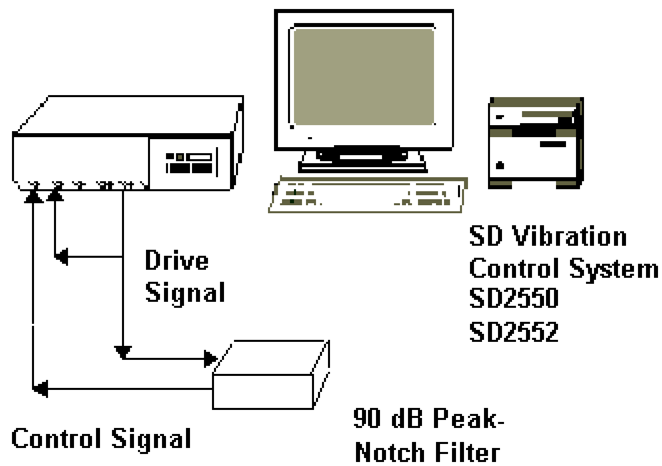


Figure 3: Closed-loop random control test setup

Figure 4 shows a sample of the actual control spectrum achieved with this test setup. The tolerance lines superimposed on the display represent ±2 dB, about the standard spectrum shape. Note that the control achieved was typically within ±1.5 dB. This is further emphasized by looking at the error spectrum shown in Figure 5. Once again, ±2 dB power tolerances are superimposed on the error spectrum indicating excellent control even in the area of the most severe dynamic response.

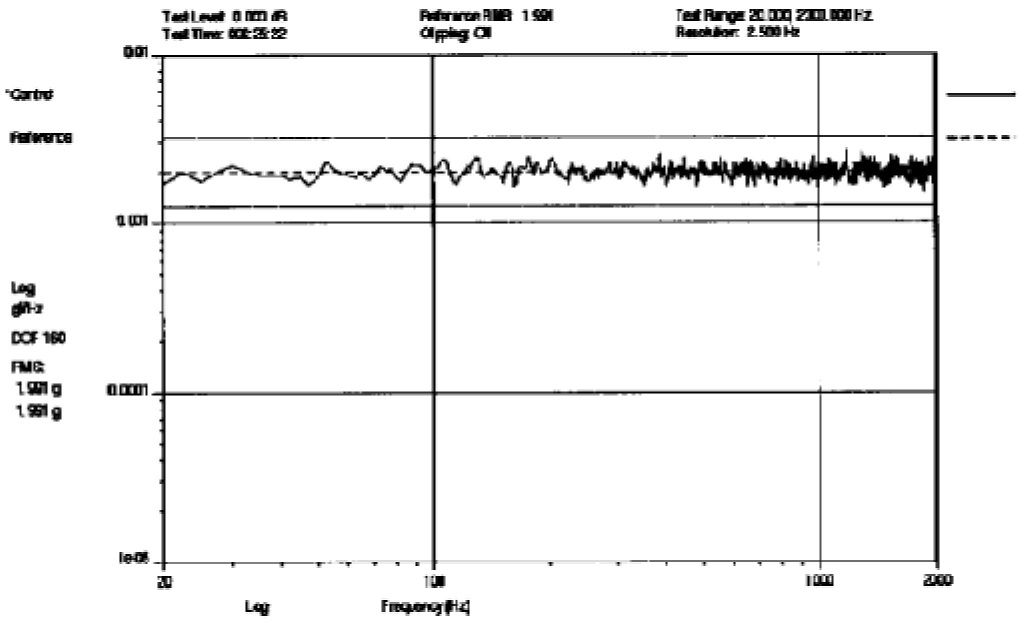


Figure 4: Actual control spectrum with 90 dB of dynamics in the control loop

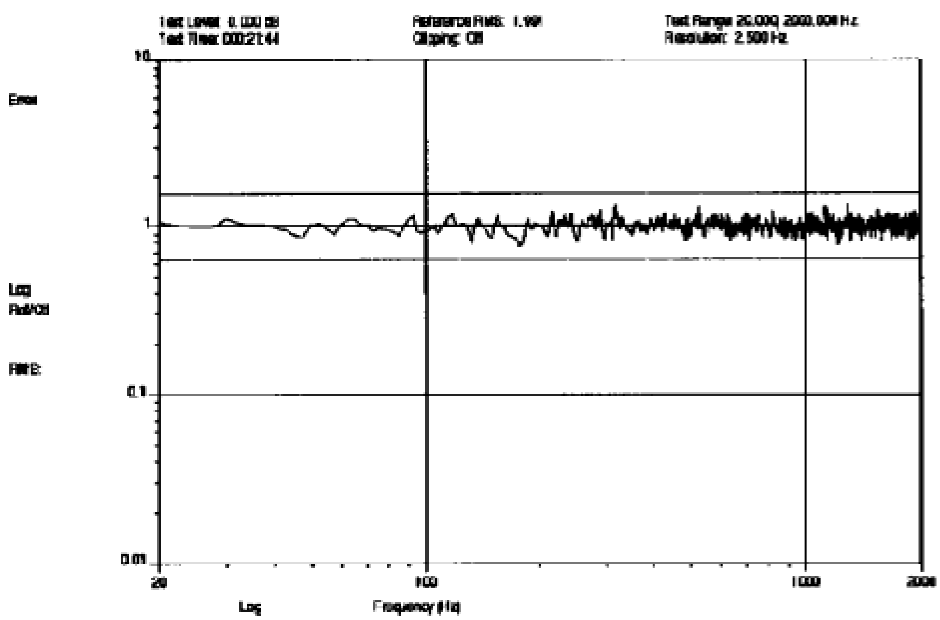


Figure 5: Error spectrum of control with $\pm$ 2 dB tolerances

Perhaps the most telling "proof of performance" in this type of test is to observe the control system's drive spectrum. This tells how hard the control system is working in order to achieve the desired feedback control. It also reveals if the drive clips or has, in some other way, run out of dynamic range. Figure 6 superimposes the drive spectrum as reported by the control system and measured directly as an auxiliary input channel. Note the good agreement between the drive spectrum plots. As Figure 6 indicates, the control system produces an output voltage swing of 90 dB in order to compensate for the peak-notch filter dynamics.

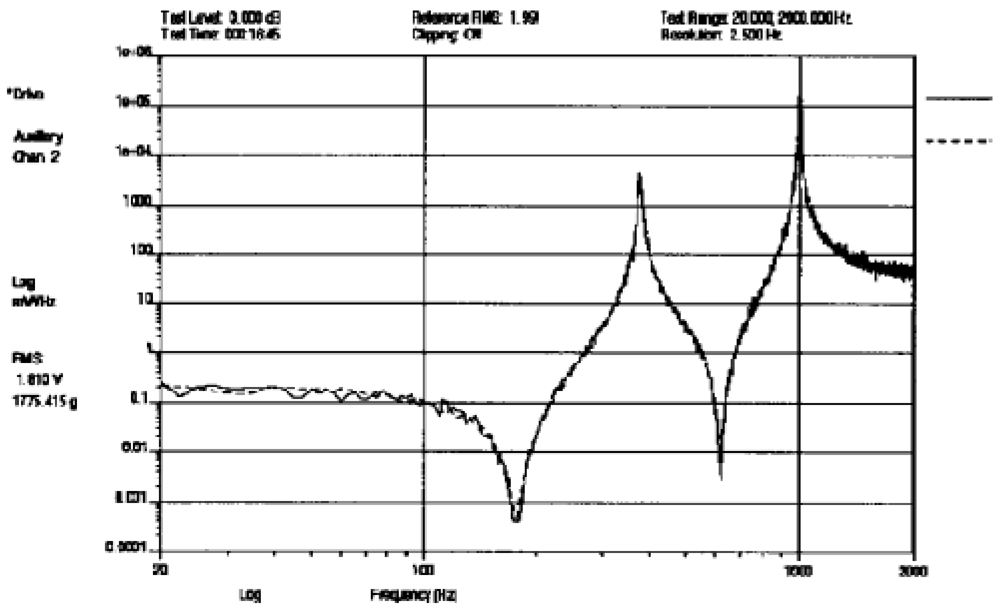


Figure 6: Drive spectrum as reported by control system and measured as an auxiliary input channel

Conclusion

Your digital shaker control system can never have too much dynamic range. Even though not every test article demands 90 dB of dynamic range, a reserve of dynamic range assures that you can run those difficult tests every day - not just on good days. Note also that the test case shown here is difficult or impossible to control with fewer than 800 lines of control resolution. Spectral Dynamics' state-of-the-art vibration control systems, offer up to 3200 lines and 90 dB dynamic range for controlling even the most difficult shaker fixtures and test articles.