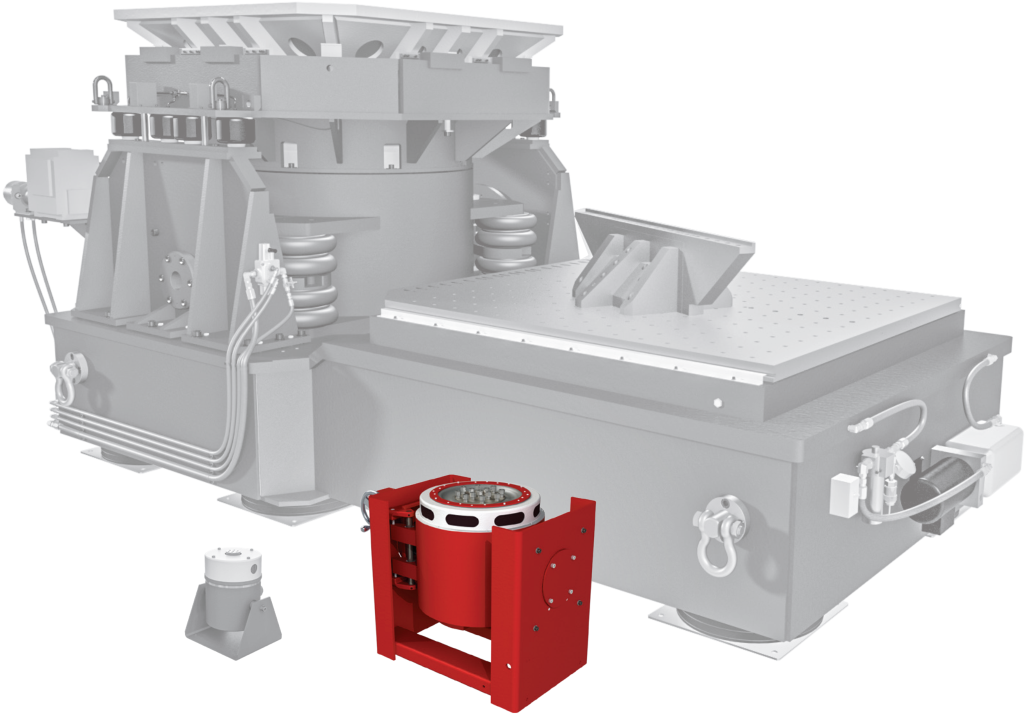
Selection Guide
Shaker Systems

Selection



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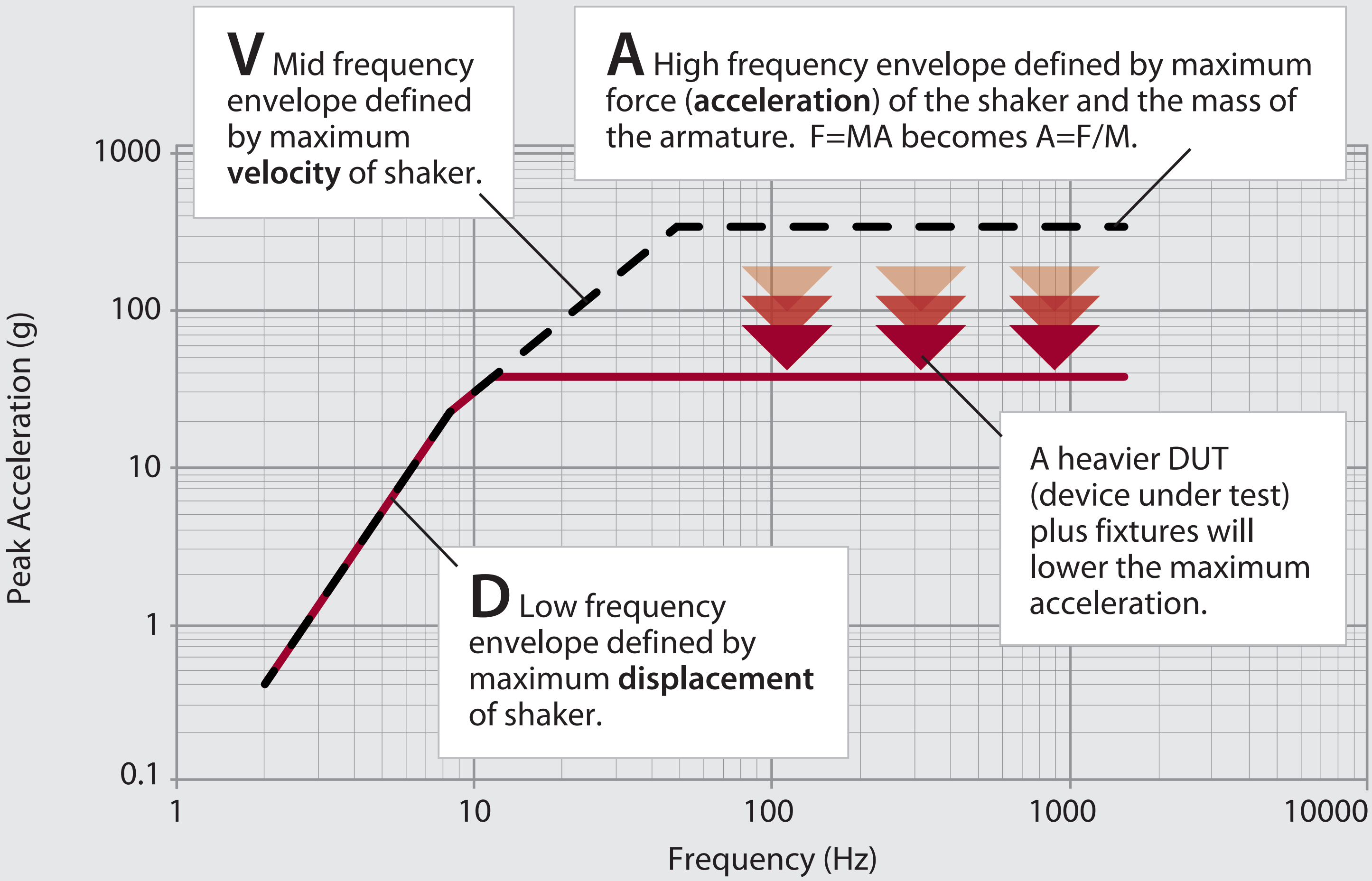
Choosing a shaker system.

Data Physics SignalForce vibration test systems (both air- and water-cooled) are available as turnkey vibration test systems that include shaker tables, power amplifiers, slip tables, shaker head expanders, fixtures, and thermal barriers for environmental testing. Data Physics sales and support are adept at understanding user applications and providing properly configured test solutions to meet both current and future needs.

The first step is to define the test profiles that are to be run (sine, random, shock, replication, etc.) and to gather dimensional information on the test article and fixtures that will need to be used (LxWxH and total mass). For any shaker, the added mass of the DUT and fixtures moves the performance envelope from the black line to wherever the red line might be. Shaker sizing calculations are done to make sure all test profiles will fit within the envelope.



The graph above is a generic (frequency domain) performance envelope for any shaker, as defined by its maximum displacement, maximum velocity, and maximum force.

Data Physics offers many different vibration system configurations — supporting standard testing to specialized requirements involving extreme shock & vibration levels, high velocity, long stroke and other more demanding performance conditions.

Some of the fundamental technical considerations for system selection are reviewed below.

Force = Mass x Acceleration (F = MA)

In general, the selection of a vibration system requires application of Newton's Second Law of Motion: Force = Mass x Acceleration (F = MA). But this basic formula is only a starting point. It may be instructive to describe one example of an incorrect approach to estimating the required system force rating.

Example: "I have a 50 lb test specimen that must be tested @ 10 g. Therefore, I need a vibration system rated at 50 x 10 = 500 lbs force."

After reviewing the following technical discussion you will have a better understanding of why this estimate of system force is incorrect.

System Force Rating

Vibration systems have output force ratings typically expressed in terms of:

Sine force: lbs (kN) pk
Random Force: lbs (kN) rms
Shock Force: lbs (kN) pk

The stated random force rating assumes a certain spectrum shape (usually flat) over a given frequency range (usually 20 Hz – 2,000 Hz) and a certain minimum mass load on the shaker. If these conditions are different from your test requirements, a new calculation of the effective random force rating may be necessary. These output force ratings provide a starting point for the Force (F) parameter in F = MA.

Mass

The mass value (M) in the initial F = MA force calculation must include all of the moving masses involved in the actual test setup: (shaker armature + test specimen + test fixture + any specialized adapters such as a Head Expander or a Slip Plate with its Driver Bar). Getting the right mass (M) value for the initial F = MA force calculation may be different for vertical axis testing compared to horizontal axis testing. Ask a Data Physics applications engineer to confirm that the mass figure used accounts for all of the various components needed for your test.

As the frequency range of the vibration test increases, it is safe to assume that some or all of the mass components included in the estimate of (M) above do not actually behave as "masses." Every mechanical structure has a resonant frequency, which may result in a significant dynamic force absorber effect at certain frequencies. This effect, which must be taken into account as part of the overall force estimating process, increases the F = MA calculated value of force.

Acceleration

The maximum Acceleration figure for the F = MA estimate is taken from the test specification, for sine vibration (g pk), for random vibration (g rms) and for classical shock pulses (g pk).

Two important factors related to the (g) level given in the test specification include the resulting maximum velocity and maximum displacement (stroke) required for your test. The velocity and stroke requirements are sometimes overlooked, leading to a poor system choice. Ask a Data Physics applications engineer to review these important velocity and stroke calculations.

Other Considerations

The preceding review of factors that determine required System Force Output helps to illustrate that many variables are involved in the final, correct selection. As part of your discussions with a Data Physics applications engineer, some or all of the following information will be helpful in order to streamline the selection process:

Product Details
- Product description
- Product test weight
- Product dimensions
- Product center of gravity (CG)
- Product mounting considerations

Fixtures
- Do they exist or will they require design and fabrication?
- Approximate weight (estimate if necessary)
- Approximate dimensions (estimate if necessary)
- Mounting issues
- Sizing issues
- Head expanders

Test Requirements
- Test types:
- Sine
- Resonance dwell
- Random
- Shock
- SRS shock
- Mixed mode (Sine on Random, Random on Random)
- Time replication
- Test magnitude
- Test frequency range
- Test duration
- Three axis testing requirement
  - Product orientation with respect to gravity

Combined Environment Testing
- Ambient only
- Combined vibration / thermal testing conditions

Future Considerations
- Change in product line
- Requirement changes

Expandability
- Higher level test requirements
- Multiple product testing for reduced test time

System Force Rating

Electrodynamic vibration test systems are used to satisfy a wide variety of vibration test requirements. Sine, random, and shock testing are considered the three basic test environments and are reflected in the standard ratings for all Data Physics vibration test systems. All vibration test systems are rated in "peak force" for sine and shock, and in "rms force" for random.

In comparing Data Physics shaker systems with other manufacturer's systems, it is vitally important to investigate more than equivalent overall force rating. Carefully check the individual sine, random and shock rating curves to ensure the selected system will meet the overall desired performance.

Sine Ratings

Sine/random performance curveThe vast majority of all industry standard sinusoidal vibration test specifications are within the 5 - 2,000 Hz frequency range. All Data Physics systems are rated for full performance within this range.

In addition, all Data Physics systems can be operated at lower and higher frequencies but typically at reduced ratings. Some highly specialized Data Physics systems are fully rated below 5 Hz and above 2,000 Hz.

Sine performance is defined by an envelope of maximum displacement, velocity, and acceleration as a function of frequency for a given amplifier/shaker and test load weight combination. The sine performance is bounded by the system maximum displacement at low frequencies (typically two inches), maximum velocity at mid-band frequencies (typically 70-80 in/sec) and maximum acceleration (for various product load weights) at the high frequencies.

Random Ratings

The vast majority of all industry standard random vibration test specifications are within the 2,000 Hz frequency range. Random testing performance depends greatly on the selected power spectral density (PSD) shape, frequency range, amplitude and test load weight and test load structural characteristics. There are an infinite number of such combinations.

To ensure uniformity, Data Physics utilizes a common set of test conditions. These include a flat power spectral density (g2/Hz) from 20 to 2,000 Hz and a heavy, non-resonant load (typically 3 to 4x armature weight). All Data Physics systems can be operated at lower and higher frequencies and with non-flat PSD but typically at reduced ratings.

Other shaker manufacturers sometimes use the less demanding ISO 5344 PSD shape for random rating, which is flat from 100 to 2,000 Hz but rolls off sharply below 100 Hz to 20 Hz. The Data Physics random rating technique provides consistency and ensures high overall system performance.

Shock Ratings

Shock testing utilizing electrodynamic shaker systems in place of drop testers and hydraulic shakers, offers the benefits of:

- Excellent accuracy
- Repeatability
- Convenience of common test fixtures

The higher displacements and velocities available with Data Physics's newer model electrodynamic shaker systems permit even a wider range of shock pulses.

The Shock performance is dependent on many different variables including pulse shape (half-sine, trapezoid, sawtooth, etc.), pulse peak amplitude, pulse duration, test load weight and load dynamics. The pulse shape, amplitude and duration parameters actually determine the velocity and displacement requirements for the specified pulse.

There are an infinite number of shock pulse shapes. However, half-sine and sawtooth shapes are very common examples. Data Physics shaker systems are typically rated with these common pulses and are graphed in terms of peak acceleration amplitude vs. test load weight. It is quite simple to determine shock system test capability from these curves. Note that higher peak amplitudes are achievable with sawtooth vs. half-sine pulses and higher amplitudes are generally achievable for narrow pulses with light loads.

Some other manufacturers offer very misleading or very limited shock performance information. Often, this is defined as a crude force number of 3x random force rating or 2x sine force rating. This general statement may theoretically be valid for some very limited shock transient pulses, but it is totally inadequate because it does not take into consideration the shock pulse shape or duration. The shock rating of 3x random rating is a gross oversimplification derived from generating 3 sigma peaks (3x rms) in a random test. Furthermore, the crde force number (3x random rating) often refers to a theoretical "shaker" limit only, but not the specific amplifier/shaker system combination. Some manufacturers require an optional matching transformer to achieve even moderate shock performance.

All of Data Physics's shock rating performance curves are based on real test data, not theoretical.

It is absolutely critical to evaluate shock pulse curves (peak acceleration vs. test load weight) to judge the real capability of the shaker system. Only when the pulse type, pulse width, peak amplitude and payload weight are evaluated concurrently can the actual maximum system shock performance be fairly determined.

Compensation Pulses

Pre- and post-compensation pulses are critical to shock performance!

Shock pulse capability is also dependent on the pre and post compensation pulses. These pulses are generated by the vibration controller to utilize both the upper and lower half of the shaker stroke (from center) and to initiate and end the pulse at the shaker center position. The pre and post compensation pulse shape, duration and amplitude are critical to optimize the main pulse shock capability without adding significant amplitude and frequency components. The Data Physics controller automatically creates these special compensation pulses to maximize the amplifier/shaker shock performance. Other controllers often can not generate optimum pre and post compensation pulses and therefore can not guarantee full shock capability for a specific amplifier/shaker system.

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