Vibration Control Catalog

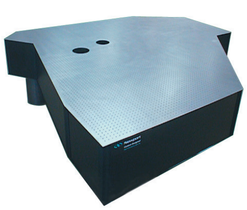
mks | Newport™

Newport – Focusing on the Future of Vibration Control

About the Newport Brand

For 50 years, Newport has been delivering high performance vibration control solutions to the world's leading technology companies. Our portfolio of vibration isolation products and expertise in the design and manufacturing of highly damped composite structures, frames and systems is unmatched. Today, Newport's innovative vibration control solutions and expertise is enabling technology advancements in the bioimaging, semiconductor, photovoltaic and flat panel display manufacturing industries. Innovations like Newport's Guardian™ active isolation technology, patented iQ active dampers and SmartTable® provide unequaled work surface stability for demanding laser-based processing, imaging and inspection applications. Additionally, Newport's expertise in the design and manufacturing of complex composite structures serves as the foundation of some of the world's most challenging applications. We continuously deliver the highest value products, solutions and integrated systems that help OEM's succeed. If vibration is a problem, we have a solution. Put Newport's expertise to work for you – call 877-835-9620.

Newport Corporation is a globally recognized leader in advanced technology products and solutions for fields such as Research, Life and Health Science, Aerospace and Defense, Industrial Manufacturing, Semiconductors and Microelectronics. With decades of experience in motion control, Newport has both the capability and the capacity to provide the optimum solution for your individual needs. Our product portfolio includes standard products, special adaptations, custom systems and OEM solutions.



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Overview

Advanced equipment and processes have made it possible to investigate phenomena with dimensions measured in nanometers. For example, phase-shifting optical interferometers can now measure surface roughness with a resolution of about 1 nm. In the semiconductor field, integrated circuits with submicron linewidths are now being produced. Applications like these have created the demand for equally innovative vibration isolated support structures, which provide the stability needed for such measurements and processes. Successfully meeting this level of stability requires careful attention to the problems of maintaining extremely precise relative alignment of the various elements of the system.

The Problem: Relative Motion

Vibration can be a limiting factor in the performance of a wide variety of research and production applications. Vibration is all around us, from HVAC environmental sources to road vibration and other unavoidable “background” vibrational noise – we live in a noisy, vibrating world! Consider the task of photographing a highly magnified image. The microscope and camera optics together determine where on the film plane each point of the object is imaged. During the exposure time, if every point of the optical system -- illuminator, sample, microscope optics, camera optics and film plane -- move simultaneously, with no relative motion, the image will be clear. On the other hand, if there is relative motion of the sample with respect to the objective lens, the image will be blurred. Further, if an experiment uses elements that mechanically move or vibrate, it’s important that these elements can be vibrationally isolated, as not to disturb other optical elements that are already aligned, in the same area. This issue is critical to the success or failure of delicate, vibrationally-sensitive optical experiments.

The Goal: A Perfectly Rigid Structure

Since the sources of vibrational disturbances cannot completely be eliminated, the goal is to reduce relative motion between elements by connecting them with a rigid structure.

In a perfectly rigid body, theoretically, the distance between any two points remains constant in time. This means that the size and the shape of the body do not change while it is undergoing force inputs from vibrations, static forces or temperature changes. If all of the elements are mounted together to form an ideal rigid body, the individual elements will not move relative to one another and system performance will not be impaired.

Reality: Environmental Effects

Since it is impossible to create a perfectly rigid structure, an effective vibration isolation system must take into consideration these factors:

Dynamic Forces (Vibration)

Dynamic forces cause structural deformations that vary with the frequency of the driving force. Structural resonance can amplify the relative motion between optical components.

- Connect all of the critical elements together in a dynamically rigid structure that is designed to eliminate (damp) structural resonances.
- Isolate the system from vibration using mechanical filters or active cancellation technology.

Static Forces

Static forces cause deformations that are constant in time. However, the addition or movement of equipment in the system will change the static forces and cause misalignment of system elements.

- Build a statically rigid structure that deforms as little as possible when external forces are applied.

Temperature Effects

Non-uniform temperature changes usually cause a slow bending of the structure, with time constants of one hour or more. The key techniques for reducing thermal effects are:

- Control the environment to reduce temperature variation.
- Design the structures to be as insensitive to temperature as possible.

Figure 1: Newport table systems minimize the relative motion of a large array of sensitive scientific and production equipment

Newport Optical Bench Systems - The Most Rigid Isolated Structures Available

Newport pioneered the invention of the honeycomb optical bench and continues to produce the finest vibration control systems available for nano-technology applications. Newport advanced isolation systems offer the best vibration filter systems available. Super rigid honeycomb structures further minimize relative platform motion due to dynamic, static and thermal forces. Unsurpassed attention to detail and quality places Newport optical benches in a class of their own.

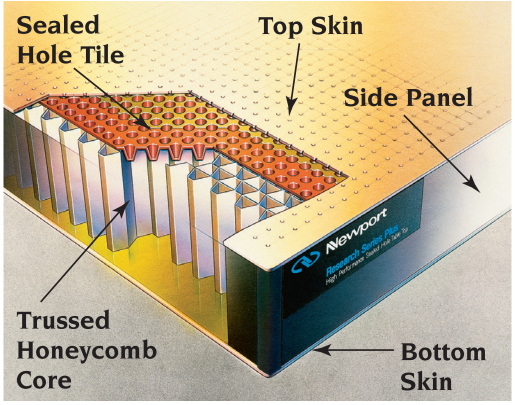


Figure 2: Honeycomb core construction creates exceptionally rigid platform for precision optical experiments

Super Rigid Honeycomb Core Construction

Optical tables provide a rigid platform for high-precision optical experiments and systems. They are designed to eliminate errors caused by relative motion between optical components in the beam path. Rigidity is the primary consideration in optical table design. Table rigidity can be quantified in terms of static or dynamic rigidity.

- Static rigidity describes the optical table's ability to resist deflection when the static or quasi-static load distribution is changed. This also describes the optical table's performance when stages are moved across the table, or when equipment is relocated, added or removed.
- Dynamic rigidity describes the optical table's ability to resist deflection in response to mechanical excitation. This also defines the table's performance in response to floor vibration, acoustic noise and tabletop mechanical sources.

Honeycomb is commonly used to produce very low weight, highly rigid structures. Reduced weight dramatically improves the dynamic rigidity of the structure by moving structural resonance modes to

Tech-Note

higher, less detrimental frequencies. The structural resonance modes are the frequencies at which the platform deflects, causing relative motion across the optical mounting surface. For a given input vibration force, the deflection is reduced as the mode frequency increases. This is the primary reason why steel honeycomb has replaced granite in most high-end optical applications - since granite is relatively heavy, the resonance modes occur at lower frequencies and therefore produce higher amplitudes of surface deflection.

Truss Core Design

Newport introduced the trussed core design to maximize the table's rigidity-to-weight ratio. The trussed core design uses an additional steel member to bridge across the center of the honeycomb cell. This extra mechanical component significantly stiffens the cell, with very little increase in weight. The truss improves both the static and dynamic rigidity and increases the structure's point load carrying ability. Many manufacturers use a traditional open cell construction, which is not as statically rigid, when compared to a Newport table.

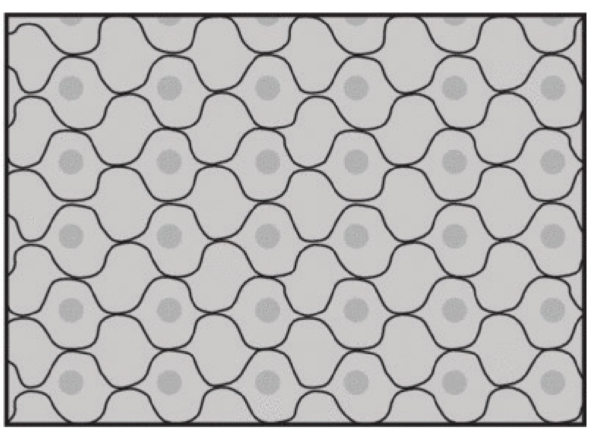


Figure 3: Ordinary small-cell core

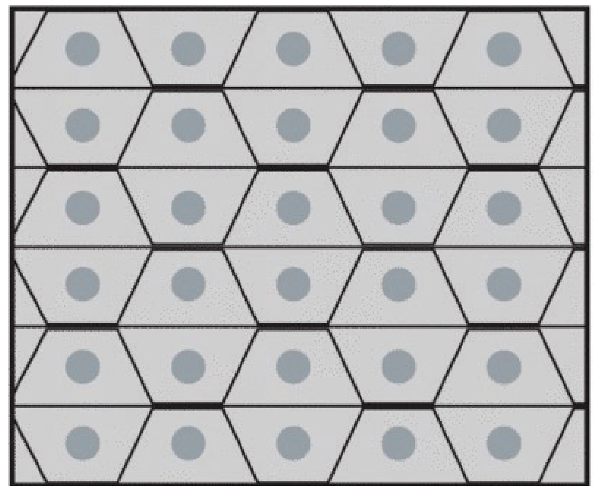


Figure 4: Newport's high-performance trussed core

- **Vertically Bonded Core** – All Newport tables are vertically bonded along the height of the honeycomb core. Many manufacturers forego this extra step, presumably because of added expense and the time required to apply adhesive to each individual core member. However, vertical bonding is the most important step to maximize the table's rigidity-to-weight ratio. An additional benefit is the introduction of constrained layer damping effects into the core construction.

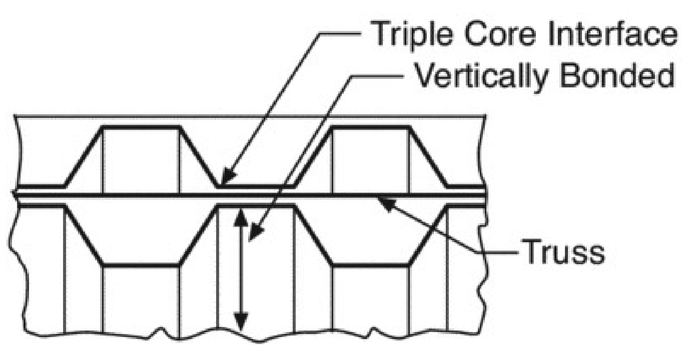


Figure 5: Trussed core design offers superior rigidity

• **Triple Core Interface** – The trussed core design enables a triple core interface at each honeycomb cell. While open core designs only have two structural members at each interface, the Newport table has three. Newport uses a 0.030 inch support member in its interface. This design provides 50% greater local rigidity when compared to other manufacturers, who typically use a 0.010 thick steel sheet, with a core interface thickness of 0.020 inches. Additionally, the three sheets are fully bonded for the full table height, resulting in greater stiffness and constrained layer damping.

• **Custom Cores** – When selecting a custom core, Newport can offer a vast array of experience and numerous core selection options to meet user-specific needs. Newport commonly builds trussed cores in several sizes: open aluminum cores for very lightweight structures and perforated cores for high vacuum or cleanroom applications. Other constructions include egg crate and tubular structure designs. This extends Newport's capabilities beyond optical tables to build honeycomb towers for drawing optical fibers, vertical systems for large laser beam lines, pedestal flooring systems for semiconductor manufacturing equipment and a large variety of instrument platforms, gantries and bridges.

Superior Flatness/Thermal Stability

Beam path stability is a primary requirement for many optical experiments and processes. Newport meets the challenges of leading edge nano-technology by offering the best surface flatness and thermal stability available in a honeycomb structure. While other manufacturers may seek to manufacture tables more quickly, Newport takes the extra steps to concentrate on making the highest quality product.

• **Precision Bonding Platens** – Metrology quality steel assembly platens are used to ensure the exceptional flatness of our optical tables. The platen supports the top surface of the table during the assembly and bonding process and imprints the top surface with the same flatness characteristics. Routinely verified with optical interferometers, these platens are the largest

Figure 6: These precision platens allow the manufacture of large tables on a single, ultra-flat surface instead of multiple granite platens, which can compromise end-to-end flatness.

and flattest in the industry. These platens allow Newport to build the world's largest optical tables.

• **Gravity Pressure Bonding** – The application of constant pressure across the optical table during the bonding process ensures that the top surface conforms to the platen flatness. Newport uses gravity pressure bonding to control the load across the table surfaces. This technique ensures process consistency from table to table. Other manufacturers use hydraulic presses to speed up the assembly process. However, the hydraulic pressure must be monitored for consistency and may apply uneven forces across the table top.

• **Low Thermal Stress Bonding** – Slow curing of the table bonds at room temperature is critical both to maintain table flatness and to ensure long term stability of the table structure. Fast curing adhesives will heat the core and lock thermal stresses into the table. Some manufacturers apply heat to the table to improve their production cycle times. Temperature induces stress, causing the table to bow when it is returned to room temperature. Temperature curing can also induce long term bowing, and in extreme cases, delamination or the core, or the top or bottom surfaces. Newport's slow cure method takes time, and produces the flattest tables available. Each Newport table includes a lifetime guarantee against delamination.

• **Super Invar and other Advanced Materials** – Newport has vast experience with advanced materials, as one of the pioneers of the optical table industry.

Introduction

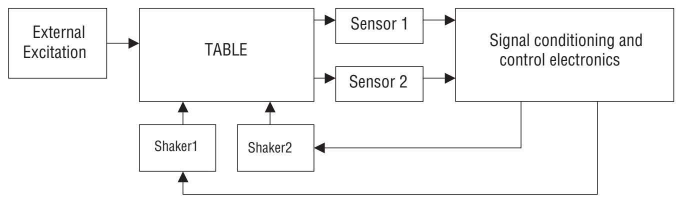
Tech-Note

Newport has a longtime relationship with the Aerospace industry, as well as with university, government and industry laboratories worldwide to allow the Vibration Control Team to provide excellent materials capabilities. Newport supplies tables with advanced materials for the most innovative, cutting edge optical research and applications. Newport has extensive experience with very light, highly stable carbon structures. For the ultimate in flatness, Newport can also provide granite platforms, granite/epoxy composites or granite/honeycomb composites. Custom designs and advanced material combinations are available upon request.

Excellent Damping Properties

Experimental or process disturbances caused by relative motion between optical components generally occur at the structural dominant bending or torsional modes. In addition to pushing these natural modes to higher, less detrimental frequencies, a major advantage of honeycomb over granite is the high level of damping present in the honeycomb structure. Damping attenuates the amplitude of the natural modes and reduces the relative motion across the table surface. In very precise applications such as optical interferometry, maximizing the table's damping properties is absolutely critical.

• **Active and Hybrid Damping** – Newport introduced the first commercially available actively damped optical tables in 2005. Different from the passive methods of broadband or tuned mass damping, active damping is the most advanced damping technique. Instead of absorbing vibrations passively, an active damping system senses vibration in real time and immediately sends out signals to actuators to counteract and cancel the vibrations. It effectively addresses the resonances of optical tables by incorporating two pairs of sensor and actuator in the optical table design and uses an external controller to coordinate the signal processing, enabling the fast and accurate damping response for optical tables. Active damping systems have a much shorter settling time than passive systems and reduce all table resonances within the entire active bandwidth. Hybrid damping incorporates both active and passive damping techniques into the optical table.



• **Narrow Band Tuned Damping Using Vibration Absorbers** – Newport is the only manufacturer to build narrow band vibration absorbers into an optical table. These vibration absorbers allow tuned damping of specific modes. Narrow band tuned damping is the most effective means for eliminating structural resonances. These dampers selectively cancel vibration modes to minimize the Dynamic Deflection Coefficient and make the table behave more like an ideal rigid structure. Narrow band techniques are the only effective means of damping very large structures, such as optical tables over 15 ft. long that exhibit structural resonances below 150 Hz.

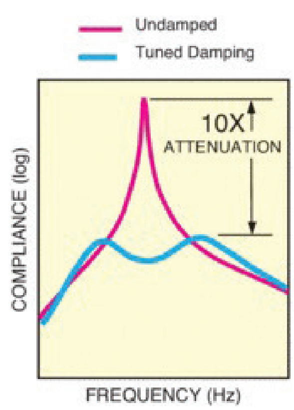


Figure 7: Newport Tuned dampers

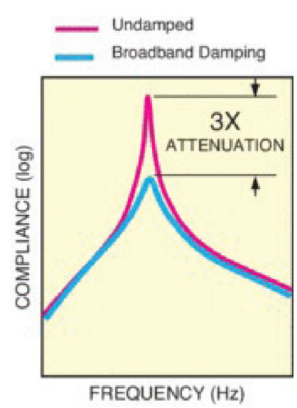


Figure 8: Broadband dampers

Newport tuned dampers (Figure 7) concentrate damping at the frequencies of resonance modes, where it is needed most. Since broadband dampers (Figure

8) are designed to provide moderate damping over a wide range of frequencies, they are not as effective at damping the modes of table vibration.

Narrow band tuned dampers can only be found in Newport RS Series tables. Newport carries in stock over 200 individual dampers, as well as damp modes from 20–480 Hz. Each table is tested by a vibration engineer to determine the natural modes of the structure. Narrow band vibration absorbers are then selected to eliminate these modes and are installed in the highest amplitude position (usually the corners). Different grades are available to offer varying levels of damping. In applications where heavy payloads can significantly affect the table's structural modes, Newport can simulate the load and optimize the tuned damping. When damping doubler systems, where two or more tables are rigidly connected, the tables are assembled and tuned as a monolithic structure.

• **Broadband Damping: Tuned Vibration Absorbers** – Broadband damping is less effective than narrow band techniques. However, Newport tables offer a variety of broadband damping mechanisms that further improve table performance. The dash pot system contained in Newport's tuned vibration absorbers offers higher frequency broadband damping. This broadband damping extends over several octaves, above the tuned frequency of the vibration absorber.

• **Broadband Damping: Constrained Layer Core Interface** – Constrained layer damping structures usually consist of two or more metallic sheets separated by a compliant material. The Newport vertically bonded trussed honeycomb core consists of three metallic sheets separated by an adhesive. Although the adhesive is rigid, its damping factor is much higher than that of steel and introduces substantial damping into the core. This construction produces substantial constrained layer damping at each core interface.

• **Damped Working Surface** – The top of a Newport table is bonded to a polymeric material that serves to seal the honeycomb core and damp the working surface. The polymer experiences the same bending and shear stresses as the stainless-steel top. Since this material's damping factor is much higher than that of steel, considerable damping is introduced into the work surface. This design eliminates the skin resonance problems found with undamped table top designs.

• **Damped Table Sides** – The sides of a laboratory grade Newport table are made of a highly damped, epoxy sealed wood composite. These composite wood materials are acoustically "dead", for maximum sound damping. Compared to the metal sides used by most other table manufacturers, the composite wood sides offer significant damping to the structure and eliminate another source of resonance. Newport offers steel sides on cleanroom and vacuum compatible products.

Clean Construction

Optical laboratories and high technology industries require high levels of product cleanliness.

• **Pre-tapped and Washed Worksurfaces** – All Newport worksurfaces are precision tapped and ground flat with a non-glazed finish before bonding to the sealed honeycomb core. They are then cleaned with automated industrial washing systems to ensure that all cutting fluids and metal particles are removed before bonding. Cleanroom products undergo a patented process to further protect the work surface before it is bonded to the honeycomb structure. Other manufacturers tap the grid on their optical tops after assembly and can potentially introduce contamination into the core or sealed hole cups. Even after extensive cleaning of "post tapped" tables, substantial residues may still remain on competitor tables.

• **Countersunk Mounting Holes** – Each tapped hole in a Newport table is countersunk and deburred. This step ensures easy thread engagement and eliminates a possible contamination problem. Tables without countersunk holes can shed metal particles, as mounting bolts strip burrs from the thread. Non-countersunk holes are also more prone to cross threading and damage.

• **Non-Corrosive Individually Sealed Holes** – Each tapped hole in a Newport optical table is registered to the core and individually sealed with a non-corrosive conical cup. The cup seals the honeycomb cell to prevent laser dyes, cooling fluids or the occasional spilled cup of coffee from contaminating the table's interior. Sealing each hole individually eases cleanup by eliminating places for liquids to hide. The sealing cup's conical design aids in removing any remaining residues. A polymeric cup material is used to prevent particle shedding and any breach of the sealing system due to corrosion. The sealing cup is impervious to acids, bases and common laboratory solvents.

• Newport cups are built into a complete sheet and vacuum bonded to the top surface to eliminate all air contaminants. This step eliminates the leakage problems found in competitive cup techniques.

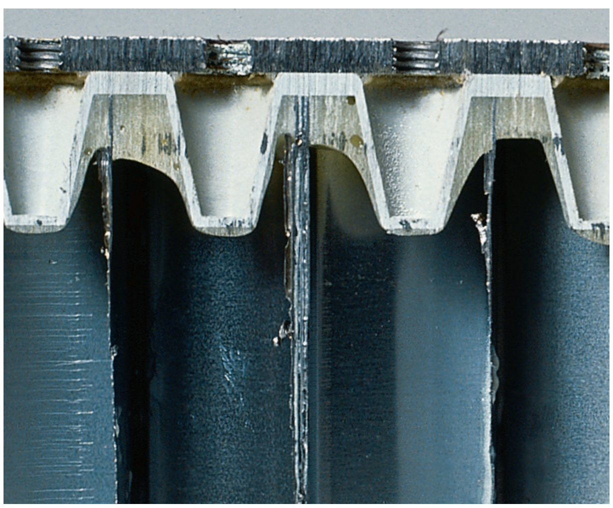


Figure 15: Cross-section view of Newport's cup design.

• **Cleanroom Compatible Bonding Adhesives** – Aerospace grade adhesives are used to bond the core of all Newport optical tables. These adhesives meet NASA low outgassing requirements and are approved for high vacuum use. They are cleanroom compatible and do not shed or cause particulate contamination. Newport uses automated measuring and mixing systems to ensure adhesive batch consistency.

• **Hermetically Sealed Vibration Absorbers** – Tuned damping vibration absorbers are hermetically sealed and fully qualified for cleanroom and high vacuum use.

• **Perforated Core Designs** – Perforated cores are available for high vacuum or cleanroom use. Each honeycomb cell of these special designs is ported to allow a high vacuum to be drawn. Laminar flow designs for cleanroom floor structures (FabFloor™) combine the perforated core with a table airflow system.

Features:	Benefits:
Trussed core design	Enhanced rigidity-to-weight ratio*
Vertically bonded core	Enhanced static rigidity*
Triple core interface	Enhanced dynamic rigidity*
Low thermal stress bonding	Increased point load carrying ability*
Narrow band tuned damping	Compared to traditional honeycomb core, with no truss and no vertical bonding
Broadband damping	Improves table flatness
Damped top skin	Eliminates long term table bowing
Individually sealed holes	Guarantees non-delamination
Non-corrosive sealed holes	

Optical Table Guide

Overview

An optical table is the foundation for building an optical experiment. For over 50 years, Newport's optical tables have contributed to many scientific and industrial success stories across various subjects from fundamental physics to semiconductor manufacturing. Our optical table solutions are designed to fit any performance, budget and delivery need. From very demanding applications like confocal microscopy, spectroscopy or interferometry, to applications under a small budget, Newport has the right optical table for you. When you choose a Newport optical table, you have chosen not only the proven superior performance and quality, but also our wealth of knowledge, experience and committed product support along your way.

After determining your application requirements and understanding how your laboratory environment will affect your experiment, you can select an optical table by specifying:

- Damping
- Table supports
- Separate or combined system
- Size, thickness and additional options

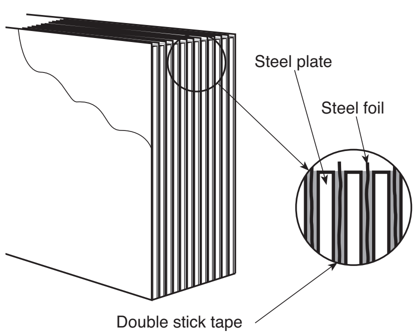
This guide will explain these choices to assist you in selecting the optimal optical table for your application.

Optical Table Damping

An optical table is a stiff platform supporting vibration sensitive equipment. The most critical vibration characteristic of an optical table is its resonances. This is because the table is designed to be as stiff as possible and acts as a rigid body when its resonances are not excited. In other words, when the table is a rigid body there is no dynamic deflection, and the beam alignment on top of the table would not be disturbed. However, a typical optical table has one or sometimes two major resonances and several minor ones. Therefore, damping is needed to reduce the resonance amplitudes and minimize the system deflection when the resonances are excited by ambient vibrations. Three types of damping methodologies are available – broadband, tuned mass, and active/hybrid – and this should be the first consideration when selecting an optical table.

Broadband Damping

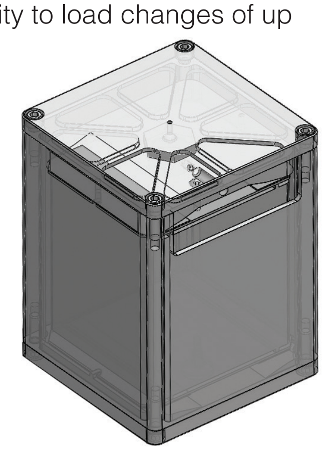
Broadband damping absorbs and dissipates vibration energies across a broad range of frequencies. It is widely used in anti-vibration tables to reduce the structural vibrations of the tabletop. Typically, the broadband damping involves energy absorption materials such as foam, rubber or elastomers. It may also involve mass blocks/plates and rubbers installed along the side of the table to absorb moderate amounts of vibrations for a broad frequency range that covers the resonances of a standard size optical table. Broadband damping does not target any specific table resonance or any specific set of frequencies; instead it absorbs and dissipates vibration energies uniformly across the frequency range. It is usually affordable and good for applications that do not require high damping performance. Newport's RPR Reliance™ Series broadband damped optical tables represented the state-of-the-art optical table tops before the advent of tuned damping, and they still offer good value for many less stringent applications.



Tuned Mass Damping (TMD)

A tuned mass damper is a device consisting of a mass, spring and damper that is attached to a structure in order to reduce the dynamic response of the structure. It is tuned to a particular structural frequency so that when the table resonance is excited, the damper will resonate out of phase with the structural motion of the structure. Vibration energy is then dissipated by the damper inertia force acting on the structure. TMD is the most effective method among all known passive damping methods, as it concentrates damping efforts where it's needed at the frequencies of dominant resonance modes. It is widely used in various industries for its efficiency and effectiveness of damping, such as the famous Grand Canyon Skywalk, Taipei 101 Building, and NASA's Ares I rocket. Compared to broadband damping which absorbs a moderate amount of vibration energy equally over the broad band, TMD targets resonances and as a result is much more effective.

Newport's patented precision tuned dampers (US patent 8857585) are specially designed with precise tuning capabilities and immunity to load changes of up to several hundred pounds. With each damper targeting one major resonance mode of the table, a standard optical table's resonance amplitudes are effectively reduced within a broad range of frequencies. Our RS4000 Series features 6 precision tuned dampers and delivers the best passive damping performance for applications requiring a critical level of damping, such as live cell imaging, high resolution imaging and interferometry. The RS2000 Series features 2 precision tuned dampers to selectively eliminate two fundamental structural table modes and



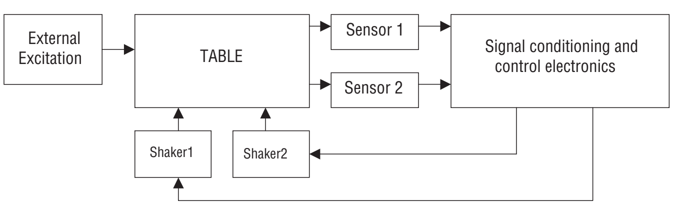
their entire harmonics and is ideal for applications such as biomedical imaging, scanning microscopy, spectroscopy and electrophysiology.

Moreover, because our tuned mass dampers can be tuned to very low frequencies, even Newport's doubled table tops that have low resonance frequencies can be damped –broadband damping, by contrast, could not achieve as good of a result in such a scenario.

For more information about TMD, see our technical note Narrowband Damping with Tuned Vibration Absorbers on page 42.

Active and Hybrid Damping

Newport introduced the first commercially available actively damped optical tables in 2005. Different from the passive methods of broadband or tuned mass damping, active damping is the most advanced

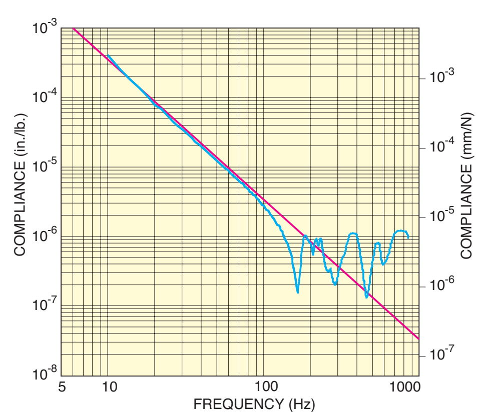


damping technique. Instead of absorbing vibrations passively, an active damping system senses vibration in real time and immediately sends out signals to actuators to counteract and cancel the vibrations. It effectively addresses the resonances of optical tables by incorporating two pairs of sensor and actuator in the optical table design and uses an external controller to coordinate the signal processing, enabling the fast and accurate damping response for optical tables. Active damping systems have a much shorter settling time than passive systems and reduce all table resonances within the entire active bandwidth. Hybrid damping incorporates both active and passive damping techniques into the optical table.

Newport's SmartTable® line of optical tables featuring active and hybrid damping with patented IQ technology (US patents 7320455, 8196891, 8807515, 9086112, 8276873, 8231098, 8651447 and 8857585) deliver the quietest table top available with a 10x improvement in vibration damping (up to 22dB) and up to 6x faster settling times. They are ideal for the most demanding applications such as nanostructure studies and fabrication; long exposure holography, spectroscopy and microscopy; ultrafast studies; live cell imaging; and any application that involves constant load changes. For more information about active damping, see our technical note Active Vibration Damping on page 32.

Understanding the Compliance Curve

No actual structure is a perfectly rigid body – all structures vibrate by flexing and twisting. The response of structures to random vibrations can be quite complicated because they vibrate with complex deformations and have more than one resonant frequency. A useful tool for evaluating the basic dynamics of a vibrating structure is the compliance curve, and knowing how to interpret it is vital when choosing the most appropriate table top for your application. For more information, please see our tutorial Understanding the Compliance Curve on page 101.



Optical Table Guide

Optical Table Supports

If the optical table will be in an environment subject to seismic floor vibrations – for example, from foot and vehicle traffic and building vibrations – then the type of optical table supports should be the next consideration. Newport offers pneumatic vibration isolators, passive air mounts and rigid legs to support optical tables. For the most demanding applications or challenging environments, our S-2000A Stabilizer™ Series pneumatic vibration isolators with automatic re-leveling are the industry's highest performing table supports. For experiments needing lower levels of vibration isolation, SL Series LabLegs™ also provide pneumatic vibration isolation at a very affordable price when automatic re-leveling is not required. And if vibration isolation is not required, RL Series LabLegs™ offer rigid high load support of optical table tops. For more information about vibration isolation, please see our Vibration Isolator Selection Guide on page 54.

Separate or Combined System

Table tops and supports can be selected and ordered separately as stand-alone items, or they can be ordered as combined systems. This should be the next consideration.

* Table and legs sold separately

Advantages of choosing separate table tops and supports include more customization – and thus, constructing the optimal system for your application and environment – higher payloads per isolator and maximum storage capacity. Disadvantages of separate table tops and supports include more difficult setup, less mobility than combined systems, difficulty in adding casters and potentially higher prices.

On the other hand, combined optical table systems (OTS) are easier to set up, more mobile, easier to add accessories to (such as casters and shelves) and may be more economical. Newport offers a wide variety of active damped, tuned mass damped and broadband damped tables integrated into a robust frame system with either pneumatic isolation or rigid supports. Disadvantages of combined systems include lower payloads per isolator and possible resonances introduced by the frame structure.

SmartTable OTS

SmartTable OTS was designed specifically for advanced applications such as live cell imaging, semiconductor metrology and precision optical alignment and testing. The integrated accessories and ergonomic designs available with the SmartTable OTS deliver exceptional performance, flexibility and upgradability. This is the only optical table system that is field-upgradable with three levels of table damping performance and two levels of isolation performance, which could satisfy current requirements but also allow the flexibility needed for future performance improvement.

Integrity VCS

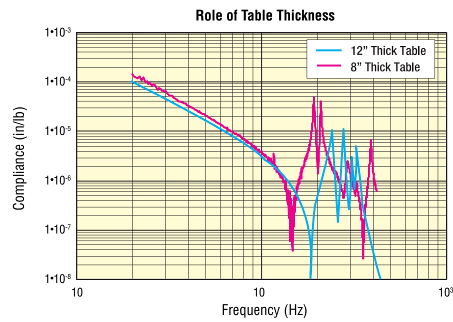
Integrity VCS is the best value table system to support basic optical research and development applications at universities, corporate labs and manufacturing floors. These systems deliver comparable damping and isolation performance to other optical platforms at a more affordable price, while also offering accessories to improve platform requirements.

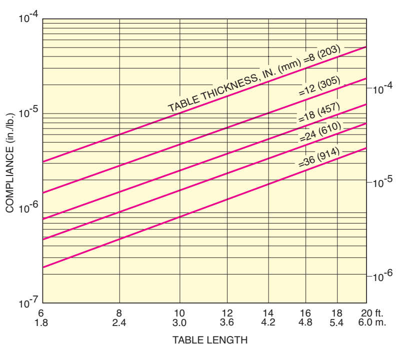
Size, Thickness and Additional Options

The last considerations will include the dimensions of the table top – including thickness – and other options such as English or metric mounting holes, height of table supports, casters, shelves, earthquake restraints, enclosures, air regulator, compressor, and many other accessories. Newport offers a comprehensive set of optical table accessories for a complete product experience.

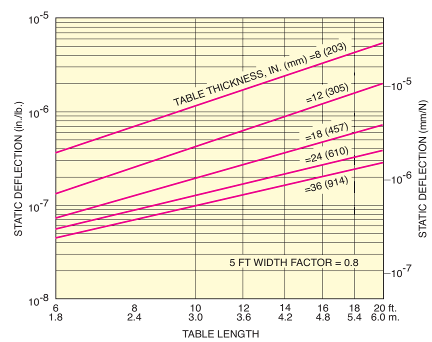
The Importance of Optical Table Thickness

Thickness is considered as structural mass of a structure and thus contributes to the overall stiffness of an optical table. A thicker optical table provides better stiffness and smaller static deflection under the load. Dynamic deflection is also reduced, as thicker optical tables require taller honeycomb structures inside without increasing the overall mass significantly. Therefore, the stiffness-to-mass ratio is improved and the rigid body frequency zone of the table is expanded. The most popular thickness choices are 8” (203 mm) and 12” (305 mm). For increased stiffness and minimized deflection, choose 18” (457 mm) and above. For cost effective and less demanding applications choose.

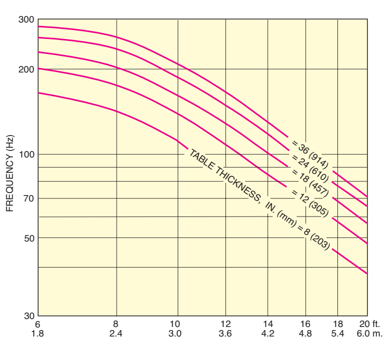




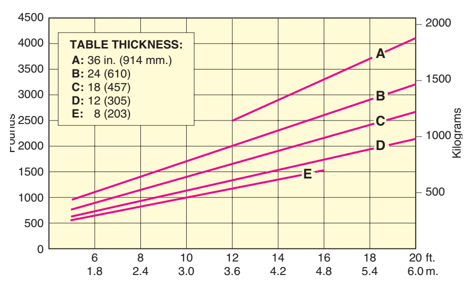
Maximum compliance guide for Newport tables.
Values plotted are for the R4000



Static deflection guide for Newport tables. Maximum deflection values are plitted for the 4 ft (1.2 m) wide tables.
Multiply values by 0.8 for 5 ft (1.5 m) wide tables.



Minimum frequency guide for any vibrational mode of Newport tables.



Approximate net weights (±10%) for 4 ft (1.2 m) wide steel tables. For 5 ft (1.5 m) wide models add 20%, for 3 ft (0.9 m) models, subtract 25%. Shipping weights can be estimated by adding 100-200 lbs (45-90 kg) for crate weight.

Optical Table Guide

Table Top Series	Hybrid SmartTable	Active SmartTable	Upgradable SmartTable	Passive RS4000	Passive RS2000	Broadband RPR
Active IQ Dampers	2	2	0	0	0	0
Precision Tuned Dampers	2	0	2	6	2	0
Broadband Damping	Constrained Layer Core. Damped Working Surface. Composite Edge Finish					
Damping Perfomance	★★★★	★★★	★★	★★★	★★	★
Cost	$$$$	$$$$	$$	$$$	$$	$
Working Surface	4.8 mm Thick 430 Ferromagnetic Stainless Steel					
Bottom Skin	4.8 mm Thick Carbon Steel					
Core Design	Vertically Bonded Trussed Honeycomb					
Side Panels	Highly Damped Composite Wood					
Mounting Holes	Individually Sealed					
Mounting Threads	1/4-20 (M6) on 1 inc. (25 mm) Grid					
Standard Tabletops	SST	ST	ST-UT2	RS4000	RS2000	RPR
Other Standard Versions	N/A	N/A	N/A	Cleanroom	Double Density	Non-Magnetic
Table Support Systems	OTS-SST Isolated	OTS-ST Isolated Rigid	OTS-UT2 Isolated Rigid	N/A	INT4 Isolated Rigid	INT2 Isolated Rigid

1. Upgradable SmartTable can be field upgraded to Hybrid SmartTable by installing two active IQ dampers.
2. Table system is offered with pneumatic isolation support or rigid support. The table top in table system has different leg mounting holes than standalone table tops.

Active and Hybrid Damped Optical Tables and Systems

Different from broadband or tuned mass damping which are passive damping methods, Newport's SmartTable line of products feature active damping with patented IQ technology (US patent 7320455, 8196891, 8807515, 9086112, 8276873, 8231098, 8651447 and 8857585). Instead of absorbing vibrations passively, the active damping system senses vibration in real time and immediately sends out signals to actuators to counteract and cancel the vibrations. It effectively addresses the resonances of optical tables by incorporating two pairs of sensor and actuator in the optical table design and uses an external controller to coordinate the signal processing, enabling the fast and accurate damping response for optical tables. Active damping system is the most advanced damping technique for optical tables. It has a much shorter settling time than passive system and reduces all table resonances within the entire active bandwidth.

Hybrid damping combines the advantages of both active damping and tuned mass damping and provides the best performance optical tables ever in the market. Active system is able to further reduce vibrations on top of a good foundation created by precision tuned dampers, delivering optical tables and systems with the minimum resonance peaks.

Active and Hybrid Damped Optical Tables and Systems

Optical Table Series | **Technical Description**

Top Performance Hybrid Damped SmartTables®

IQ Active damping plus precision tuned damping, top performance table

Applications:

- Super resolution microscopy
- Ultra precision nanostructure studies and fabrication
- Applications that involves constant load changes
- Super long exposure holography, spectroscopy and microscopy
- Any application that requires the best vibration control platform

Actively Damped SmartTables®

IQ Active Damping

Applications:

- Live cell imaging
- Precision nanostructure studies and fabrication
- High resolution spectroscopy
- Applications that involves constant load changes
- Long exposure holography, spectroscopy and microscopy
- Ultrafast studies
- Any application that requires long term stability and sub micron precision

Top Performance SmartTables® Table Systems with Hybrid Damping

Optical table system with IQ Active damping plus precision tuned damping, top performance table system

Applications:

- Super resolution microscopy
- Ultra precision nanostructure studies and fabrication
- Applications that involves constant load changes
- Super long exposure holography, spectroscopy and microscopy
- Any application that requires the best vibration control platform

Actively Damped SmartTable® Table Systems

Optical table system with IQ Active damping

Applications:

- Live cell imaging
- Precision nanostructure studies and fabrication
- High resolution spectroscopy
- Applications that involves constant load changes
- Long exposure holography, spectroscopy and microscopy
- Ultrafast studies
- Any application that requires long term stability and sub micron precision

Optical Table Guide

Precision Tuned Damped Optical Tables & Systems

	Optical Table Series	Technical Description
 * Table and legs sold separately	**RS4000 Precision Tuned Damped Top Performance Optical Tables**	Highest level of tuned damping with 6 precision tuned dampers. **Applications**: • Super resolution microscopy • Ultra precision nanostructure studies and fabrication • Applications that involves constant load changes • Super long exposure holography, spectroscopy and microscopy • Any application that requires the best vibration control platform
 * Table and legs sold separately	**RS2000 Precision Tuned Damped Research Optical Tables**	Meets competitor's top performance models, featuring 2 precision tuned dampers. **Applications**: • Microscopy, spectroscopy and other demanding applications
	**Upgradable SmartTable® Table Systems with Passive Precision Tuned Dampers**	Optical table system with frame - Meets competitor's top performance models, featuring 2 precision tuned dampers. Casters included and tabletop could be bolted to frame using provided safety clips. Field upgradable to SmartTable active damping using IQ upgrade kits. **Applications**: • Microscopy, spectroscopy and other demanding applications
	**Integrity 4 VCS Table Systems with 2 Precision Tuned Dampers**	Optical table system with frame - Meets competitor's top performance models, featuring 2 precision tuned dampers. **Applications**: • Microscopy, spectroscopy and other demanding applications
	**Integrity 3 VCS Table Systems with 1 Precision Tuned Damper**	Optical table system with frame - Meets competitor's top performance models, featuring 2 precision tuned dampers. **Applications**: • Microscopy, spectroscopy and other demanding applications

Broadband Damped Optical Tables and Systems

	Optical Table Series	Technical Description
 * Table and legs sold separately	**RPR Series Industrial and Educational Optical Tables**	Fully sealed holes, 8 - 24 in. thick, up to 5 ft wide by 20 ft long **Applications**: • Manufacturing fiber optics assembly • Teaching labs • Non-interferometric applications, etc.
	**Integrity 2 VCS 4.8 mm Skin Table Systems**	Optical table system with frame - same damping performance with RPR Series Industrial and Educational Optical Tables **Applications**: • Basic spectroscopy • Multi-mode fiber • Micro-positioning, etc.
	**Integrity 1 VCS 3.4 mm Skin Table Systems**	Optical table system with frame – most affordable optical table system with broadband damping **Applications**: • Manufacturing fiber optics assembly • Teaching labs • Non-interferometric applications

Custom Solutions

If our standard optical tables and isolation systems do not quite meet the requirements for your application or environment, please contact Newport to discuss a custom solution. For over 50 years our extensive design and manufacturing capabilities have delivered customized, damped platforms used in applications ranging from laser research to microscope workstations to optical platforms and much more. Our capabilities include custom shaped granite, honeycomb or Invar structures, non-magnetic honeycomb tables, cleanroom and vacuum compatible structures with either broadband or tuned dampers for optimal stability and vibration reduction. Newport is the first source for many of the world's leading optical scientists who require complex honeycomb structures for applications including optical tables, high power laser platforms, rigid assembly and test fixtures or space-based vacuum platforms. For more information, please see Custom Vibration Isolation Solutions on page 51.

Optical Tables Frequently Asked Questions

Q: What is the difference between vibration damping and isolation? Why do I need isolators when I already have an optical table top?

A: Vibrations transmitted from the floor to the tabletop is handled by isolators. Those floating legs provide isolation to your experiment and eliminate surrounding floor vibrations like building sway, street traffic or even people walking nearby. Damping, on the other hand, targets the tabletop and minimizes its resonances caused by the rest of your experiments or environment. Combined together, they eliminate vibrations and make your optical table the cornerstone of your experiment.

Q: For optical tables, is the heavier the better? Why not use granite as an optical table top?

A: Surprisingly, we don't want our tables to be too heavy. What matters is the stiffness-to-mass ratio, and we want this ratio to be as large as possible so that the table has a higher stiffness and expanded rigid body zone. Granite is very flat, but it is also very heavy. The mass in granite does not contribute to its structural stiffness; therefore, granite is not the ideal candidate for optical table top. Instead, honeycomb structure provides less mass and better stiffness and delivers the best vibration control performance.

Q: Why use composite wood for side panels? Isn't wood more vulnerable compared to steel in terms of environmental instability?

A: Side panels and edge finish for optical tables do more than just covers. They should contribute to the overall damping performance of the table. The advantage of steel is that it is stiff and provides good environmental stability. The drawbacks are: Like many other hard metals with high elasticity and high density, steel tends to allow vibration or ringing and would resonate with very little natural damping. The wood, on the other hand, is very good at natural damping and eliminating vibrations. This is why ringing bells are always made out of steel/metal and high end hi-fi speakers that require acoustic damping are almost all enclosed by composite wood. But wood also has its drawbacks: It tends to be more vulnerable than steel under difficult environmental factors. Considering the pros and cons from each side and the fact that optical tables are generally used in house and under controlled environment, Newport decides to use composite wood with moisture-protective paint layers, which provides superior damping and prevents the side panels from introducing vibrations to the tabletop.

Q: What is the proper way to compare the performances of different optical tables?

A: Optical tables are not complex structures. Modes of rectangular plate-like structures like optical tables have been discussed and depicted in numerous handbooks and textbooks. The most direct way is to compare the compliance curves. Compliance test is the vibration control industry standard to test the vibration damping characteristics of a structure; it is well documented and has been used for decades. The test is done on all corners of the table, as those tend to have the highest level of vibration. For more information, please see our tutorial Understanding the Compliance Curve on page 101.

SST Series

Top Performance Hybrid Damped SmartTables® with IQ Damping Technology®

*Table and legs sold seperately

Key Features

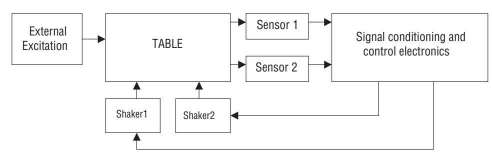
- Active IQ damping combined with precision tuned damping technology
- Active damping provides a work surface auto-tuned to your specific application – independent of load, one table for any application
- Passive precision tuned damping provides additional damping with robust patented design
- Ideal for demanding applications that require the highest level of damping

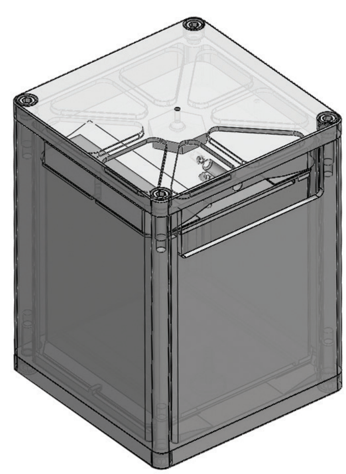
What makes SmartTable HD the best performance optical table is the unique combination of SmartTable active IQ dampers and the well-known patented passive precision tuned dampers. The passive dampers from Newport delivers unmatched performance compared to competitors, and gives the HD table a good foundation to start with. IQ active dampers built on top of this foundation further eliminates all the resonance peaks in range, delivering the quietest tabletop for your application.

The core of the SmartTable is an advanced damping technology called Intelligent Damping (IQ). It effectively addresses the medium frequency resonances of optical tables by incorporating two pairs of sensor and actuator in the optical table design and use an external controller to coordinate the signal processing, enabling the fast and accurate damping response for optical tables. Each sensor-actuator pair is controlled by a separate control channel. The sensor senses the vibrations and the actuator outputs signal to compensate for the vibrations. The pre-amplifiers and band-pass filters condition the sensor output signal before feeding it to the digital controller. The digital controller implements recursive filters that compensate for the dynamic response of the shaker and correct the phase to bring the phase difference between the displacement and force close to ($-\pi/2$) in the desired frequency range.

SmartTable HD optical tables also include passive tunable mass dampers and our damper designs have evolved over the years. The latest version of the design eliminates the use of oil, and use a proprietary mass-spring mechanism to allow for better damping performance, and more precise and easier tuning to the exact frequency needed to damp the resonance. This patented design (US patent 8857585) further improves damping performance by 3x to

Intelligence Q (IQ) Active Damping Technology



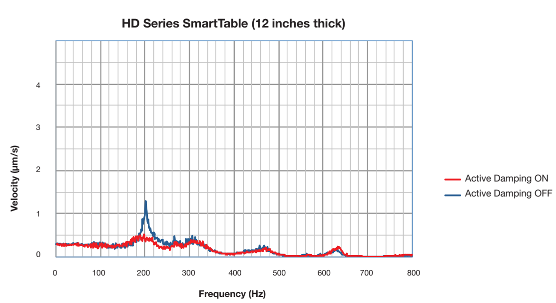


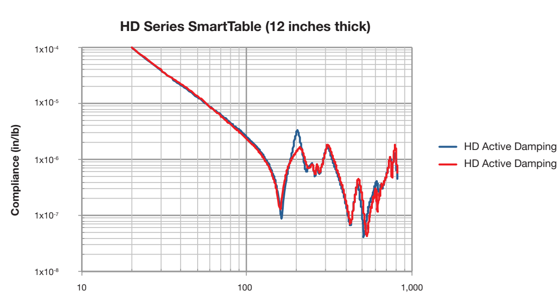
SST Series

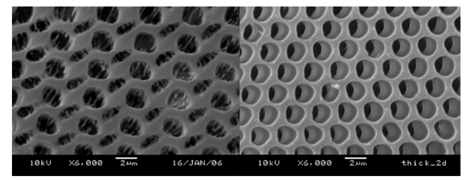
5x compared to the previous generation design, which was already superior than competitor's broadband dampers. The precisely tuned dampers work from as low as 25 Hz and go all the way up to 525 Hz, creating opportunity for optimum damping on larger optical tables, the resonances of which often fall outside of competitor's broadband frequency range. Once tuned at factory the dampers are locked securely and the frequency would not shift during shipping of the table.

Many applications can benefit from a SmartTable HD Platform. Compared to traditional optical tables, SmartTables detect and damp vibration real-time over a broad frequency range, and accurately and precisely damp multiple resonance peaks to provide a quiet platform for your application. SmartTable HD adds two active IQ dampers to an already passively damped platform with Newport's precision tunable passive dampers to provide the quietest platform in the industry.

- Super resolution microscopy
- Ultra precision nanostructure studies and fabrication
- Application that involve constant load changes
- Super long exposure holography, spectroscopy and microscopy
- Any application that requires the best vibration control platform







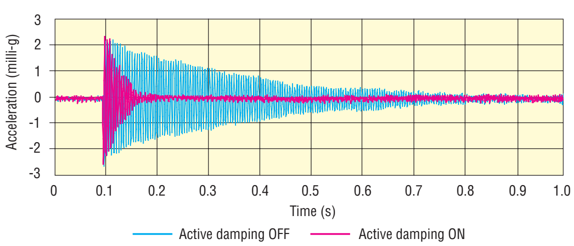
The Nanostructures shown in the images above were built on and imaged with a SmartTable. The image on the left was built with SmartTable damping disabled. The image on the right was built with SmartTable damping enabled. Source for images: Steven E. Kooi, Ph.D. Research Engineer, Institute for Solder Nanotechnologies, MIT

Specifications

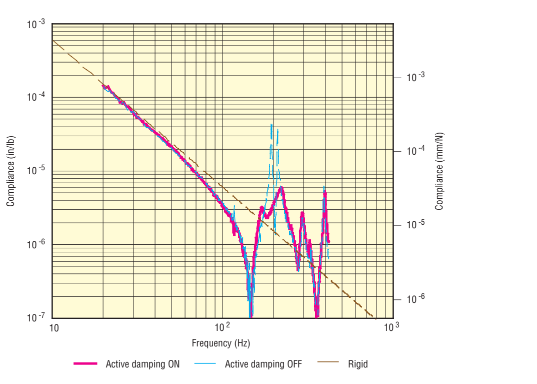
- **Mounting Holes**
  1/4-20 (M6)
- **Surface Flatness**
  ± 0.004 in. (0.1 mm) over 2 ft. (600 mm) square
- **Broadband Damping**
  Constrained layer core, damped working surface and composite edge finish
- **Tuned Damping**
  2 IQ active and 2 precision tuned dampers
- **Mounting Hole Pattern**
  1 in. (25 mm) grid
- **Mounting Hole Borders**
  0.5 in. (12.5 mm)
- **Working Surface**
  400 series ferromagnetic stainless steel
- **Top and Bottom Skins**
  3/16 in. (4.8 mm) thick with integrated damping layer
- **Hole Sealing Type**
  Easy clean conical cup, 0.75 in. (19 mm) deep, non-corrosive high impact polymer material

Order Information

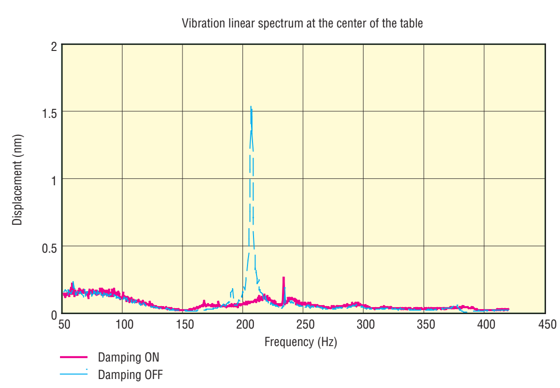
Model (Metric)	Width [ft. (mm2)]	Length [ft. (mm2)]	Thickness [in. (mm)]
ST-46-8 (M-ST-46-8)	4 (1200)	6 (1800)	8 (203)
ST-46-12 (M-ST-46-12)	4 (1200)	6 (1800)	12 (305)
ST-48-8 (M-ST-48-8)	4 (1200)	8 (2400)	8 (203)
ST-48-12 (M-ST-48-12)	4 (1200)	8 (2400)	12 (305)
ST-410-8 (M-ST-410-8)	4 (1200)	10 (3000)	8 (203)
ST-410-12 (M-ST-410-12)	4 (1200)	10 (3000)	12 (305)
ST-410-18 (M-ST-410-18)	4 (1200)	10 (3000)	18 (457)
ST-412-18 (M-ST-412-18	4 (1200)	12 (3600)	18 (457)
ST-414-18 (M-ST-414-18)	4 (1200)	14 (4200)	18 (457)
ST-56-8 (M-ST-56-8)	5 (1500)	6 (1800)	8 (203)
ST-56-12 (M-ST-56-12)	5 (1500)	6 (1800)	12 (305)
ST-58-8 (M-ST-58-8)	5 (1500)	8 (2400)	8 (203)
ST-58-12 (M-ST-58-12)	5 (1500)	8 (2400)	12 (305)
ST-510-8 (M-ST-510-12)	5 (1500)	10 (3000)	8 (203)
ST-510-12 (M-ST-510-12)	5 (1500)	10 (3000)	12 (305)
ST-510-18 (M-ST-510-18)	5 (1500)	10 (3000)	18 (457)
ST-512-18 (M-ST-512-18)	5 (1500)	12 (3600)	18 (457)
ST-514-18 (M-ST-514-18)	5 (1500)	14 (4200)	18 (457)



Compared with passive damping technologies, IQ damping provides much more accurate and timely compensation across the entire working ranges of the actuator sensor pairs, delivering a quiet tabletop surface for any challenging applications.



Dynamic compliances near the corner of the table. Red line: damping on; Blue line: damping off, dots: rigid body line. Table size: 8ft x 4ft x 12 in.



Linear spectra of vibration near the corner of the table. Red line: damping on; Blue line: damping off. Table size: 8ft x 4ft x 12in.

ST Series

Actively Damped SmartTables®
with IQ Damping Technology®

*Table and legs sold seperately

Key Features

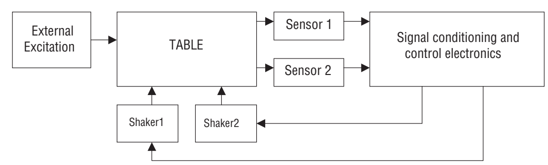
- Improve vibration damping 10x (up to 22dB) with the push of a button – improve settling time, stability and throughput
- Provide a work surface auto-tuned to your specific application – independent of load, one table for any application
- Use the BNC interface to monitor ambient vibrations or trigger events
- USB interface for adjusting damping performance and collecting data
- ST Series is available in Doubled configurations

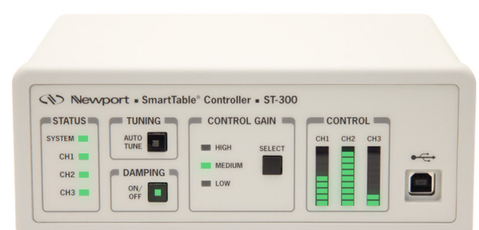
The ST Series SmartTable incorporates Newport's patent pending intelligent Q (IQ) damping Technology to actively monitor, report, and adjust table-damping performance over a wide frequency band. This provides a dramatically quieter table surface, resulting in high quality imaging, improved long term stability, faster settling times and the ability to make measurements that previously required the quietest lab environments. SmartTable also allows users to monitor tabletop vibrations through built in vibration sensors that provide real time feedback on the vibration state of the table. Compare to the SST Series Smart HD Table, the ST Series includes 2 same active dampers, except without the 2 passive dampers.

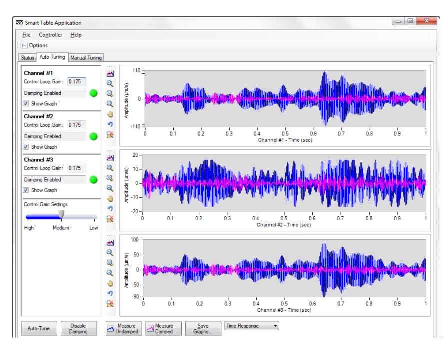
Many applications can benefit from SmartTable platforms. Compared to traditional optical tables, SmartTables detect and damp vibration in real time in a broad frequency range, accurately and precisely damping multiple resonance peaks to provide a quiet platform for your application. Typical applications include:

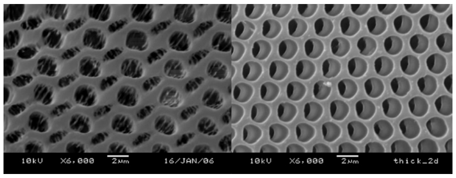
Live cell imaging
Precision nanostructure studies and fabrication
High resolution spectroscopy
Applications that involves constant load changes
Long exposure holography, spectroscopy and microscopy
Ultrafast studies Any application that requires long term stability and sub micron precision

Intelligence Q (IQ) Active Damping Technology









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Specifications

- **Mounting Holes**
  1/4-20 (M6)
- **Surface Flatness**
  ± 0.004 in. (0.1 mm)
  over 2 ft. (600 mm) square
- **Broadband Damping**
  Constrained layer core, damped working surface and composite edge finish
- **Tuned Damping**
  2 IQ active dampers
- **Mounting Hole Pattern**
  1 in. (25 mm) grid
- **Mounting Hole Borders**
  0.5 in. (12.5 mm)
- **Working Surface**
  400 series ferromagnetic stainless steel
- **Top and Bottom Skins**
  3/16 in. (4.8 mm) thick with integrated damping layer
- **Hole Sealing Type**
  Easy clean conical cup, 0.75 in. (19 mm) deep, non-corrosive high impact polymer material

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ST-512-18 (M-ST-512-18)	5 (1500)	12 (3600)	18 (457)
ST-514-18 (M-ST-514-18)	5 (1500)	14 (4200)	18 (457)

Optical Tables

ST-UT2 Series

Upgradable SmartTables®
with Passive Precision Tuned Dampers

*Table and legs sold seperately

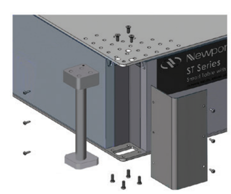
Key Features

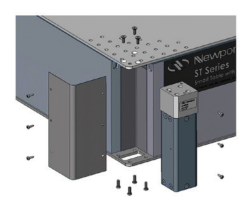
- Field upgradeable to hybrid SmartTable performance
- Precision tuned passive dampers
- Ideal for challenging applications that require standard damping levels
- Honeycomb cells for a lighter, stiffer table with better dynamic rigidity
- Triple core interface increases point loading capability

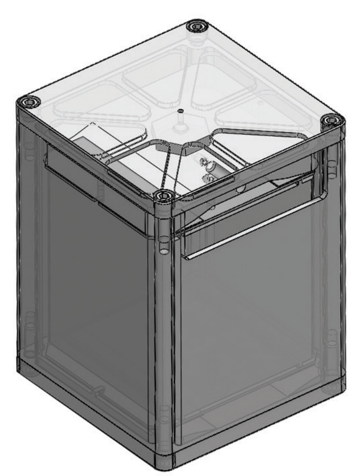
The fully integrated ST Series SmartTable incorporates factory installed IQ dampers. But if you are not sure how much damping your application requires or to prepare for potential changes to your experimental requirements or lab environment, the upgradeable ST-UT2 Series combines Newport's precision tuned damping with IQ damping. ST-UT2 Series SmartTables tables are field upgradeable to ST Series performance. When the IQ dampers are not installed, the ST-UT2 table provides performance equivalent to the RS2000 Series table.

As your application requirements become more stringent, the Upgradeable SmartTable can be field upgraded to Hybrid Damped Top Performance SmartTable performance levels by installing an IQ-300-UG upgrade kit. Each upgrade kit includes two active IQ dampers, ST-300 controller and instruction manuals to easily convert your passively damped optical table into the best performance optical table in the market. There is no need to dismantle your experiment in order to upgrade the table. Once upgraded, the table will provide a dramatically quieter table surface, resulting in high quality imaging, improved long term stability, faster settling times and the ability to make measurements that previously required the quietest lab environments.

ST-UT2 feature RS-2000 equivalent performance with precision tuned mass dampers installed. Our optical tables have been using tunable mass dampers for decades and our damper designs have evolved over the years. The latest version of the design eliminates the use of oil, and use a proprietary mass-spring mechanism to allow for better damping performance, and more precise and easier tuning to the exact frequency needed to damp the resonance. This patented design (US patent 8857585) further improves damping performance by 3x to 5x







compared to the previous generation design, which was already superior than competitor's broadband dampers. The precisely tuned dampers work from as low as 25 Hz and go all the way up to 525 Hz, creating opportunity for optimum damping on larger optical tables, the resonances of which often fall outside of competitor's broadband frequency range. Once tuned at factory the dampers are locked securely and the frequency would not shift during shipping of the table.frequency needed to damp the resonance. This patented design (US patent 8857585) further improves damping performance by 3x to 5x compared to the previous generation design, which was already superior than competitor's broadband dampers. The precisely tuned dampers work from as low as 25 Hz and go all the way up to 525 Hz, creating opportunity for optimum damping on larger optical tables, the resonances of which often fall outside of competitor's broadband frequency range. Once tuned at factory the dampers are locked securely and the frequency would not shift during shipping of the table.

Specifications

- **Mounting Holes**
  1/4-20 (M6)
- **Surface Flatness**
  ± 0.004 in. (0.1 mm)
  over 2 ft. (600 mm) square
- **Broadband Damping**
  Constrained layer core, damped working surface and composite edge finish
- **Tuned Damping**
  2 precision tuned dampers (upgradable)
- **Mounting Hole Pattern**
  1 in. (25 mm) grid
- **Mounting Hole Borders**
  0.5 in. (12.5 mm)
- **Working Surface**
  400 series ferromagnetic stainless steel
- **Top and Bottom Skins**
  3/16 in. (4.8 mm) thick with integrated damping layer
- **Hole Sealing Type**
  Easy clean conical cup, 0.75 in. (19 mm deep, non-corrosive high impact polymer material

Model (Metric)	Width [ft. (mm)]	Length [ft. (mm)]	Thickness [in. (mm)]
ST-UT2-46-8 (M-ST-UT2-46-8)	4 (1200)	6 (1800)	8 (203)
ST-UT2-46-12 (M-ST-UT2-46-12)	4 (1200)	6 (1800)	12 (305)
ST-UT2-48-8 (M-ST-UT2-48-8)	4 (1200)	8 (2400)	8 (203)
ST-UT2-48-12 (M-ST-UT2-48-12)	4 (1200)	8 (2400)	12 (305)
ST-UT2-410-8 (M-ST-UT2-410-8)	4 (1200)	10 (3000)	8 (203)
ST-UT2-410-12 (M-ST-UT2-410-12)	4 (1200)	10 (3000)	12 (305)
ST-UT2-410-18 (M-ST-UT2-410-18)	4 (1200)	10 (3000)	18 (457)
ST-UT2-412-18 (M-ST-UT2-412-18)	4 (1200)	12 (3600)	18 (457)
ST-UT2-414-18 (M-ST-UT2-414-18)	4 (1200)	14 (4200)	18 (457)
ST-UT2-56-8 (M-ST-UT2-56-8)	5 (1500)	6 (1800)	8 (203)
ST-UT2-56-12 (M-ST-UT2-56-12)	5 (1500)	6 (1800)	12 (305)
ST-UT2-58-8 (M-ST-UT2-58-8)	5 (1500)	8 (2400)	8 (203)
ST-UT2-58-12 (M-ST-UT2-58-12)	5 (1500)	8 (2400)	12 (305)
ST-UT2-510-8 (M-ST-UT2-58-12)	5 (1500)	10 (3000)	8 (203)
ST-UT2-510-12 (M-ST-UT2-510-12)	5 (1500)	10 (3000)	12 (305)
ST-UT2-510-18 (M-ST-UT2-510-18)	5 (1500)	10 (3000)	18 (457)
ST-UT2-512-18 (M-ST-UT2-512-18)	5 (1500)	12 (3600)	18 (457)
ST-UT2-514-18 (M-ST-UT2-514-18)	5 (1500)	14 (4200)	18 (457)

Bolt-on Dampers

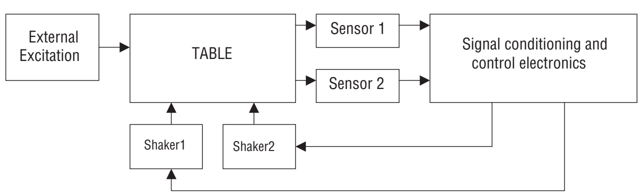
with IQ Damping Technology®

Key Features

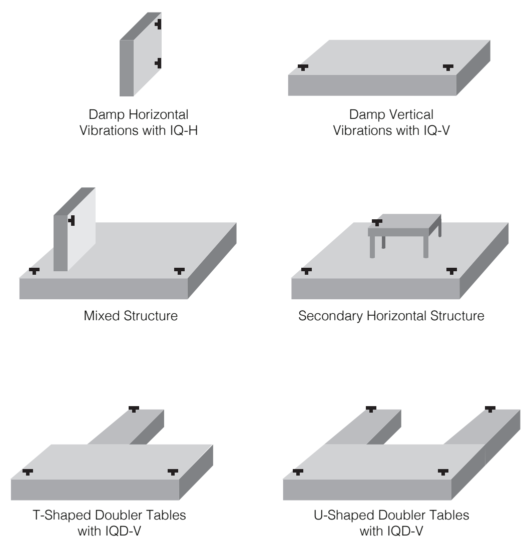
- Attach to virtually any optical table or structure
- Improve table performance using IQ active damping
- Easy installation - just bolt on and auto tune table
- Enable actove damping on complex structures
- Optimized damping enhancement for Newport optical tables

The stand-alone design of the SmartTable ADD dampers are revolutionary as they open up new opportunities to actively damp existing tables or complex structures. Simply attach to optical table or structure and perform auto-tune on the ST-300 controller, those dampers will start damping vibrations immediately.

Intelligence Q (IQ) Active Damping Technology



The core of the SmartTable is an advanced damping technology called Intelligent Damping (IQ). It effectively addresses the medium frequency resonances of optical tables by incorporating two pairs of sensor and actuator in the optical table design and use an external controller to coordinate the signal processing, enabling the fast and accurate damping response for optical tables. Each sensor-actuator pair is controlled by a separate control channel. The sensor senses the vibrations and the actuator outputs signal to compensate for the vibrations. The pre-amplifiers and band-pass filters condition the sensor output



signal before feeding it to the digital controller. The digital controller implements recursive filters that compensate for the dynamic response of the shaker and correct the phase to bring the phase difference between the displacement and force close to ($-\pi/2$) in the desired frequency range.

Thanks to the 3 channel capability of the ST-300 controller, one could mix and match IQ-H and IQ-V bolt-on active dampers to damp out vibrations in complex structures including those shown in the picture. Contact Newport for a three-dampers kit.

SmartTable ADD dampers come with vertical and horizontal versions to damp out vibrations in those directions. It has never been easier to damp out the vibrations on vertical or secondary level horizontal shelve or structure in your experiments.

Optical Tables

Ordering Information

IQ-H-10	Active Damper Kit, SmartTable ADD Bolt-on,, Horizontal
IQ-H-5	Active Damper Kit, SmartTable ADD Bolt-on, Horizontal Vibration, 5 m Cable
IQ-V-10	Active Damper Kit, SmartTable ADD Bolt-on, Vertical Vibration, 10 m
IQ-V-5	Active Damper Kit, SmartTable ADD Bolt-on, Horizontal Vibration, 5 m Cable
IQD-H-10	Active Damper Kit, SmartTable ADD Bolt-on, Doublers, Horizontal, 10 m
IQD-V-10	Active Damper Kit, SmartTable ADD Bolt-on, Doublers, Vertical, 10 m

Bolt-on Dampers

Technical Note

Active Vibration Damping

Overview

An optical table is a stiff platform supporting vibration–sensitive equipment. A typical optical table is a sandwich structure consisting of two faceplates and a lightweight honeycomb core. Due to high stiffness-to-weight ratio, these platforms are used in a wide variety of applications in optical research and high-precision manufacturing, usually in conjunction with soft pneumatic vibration isolators. Although good isolation from floor vibration can be achieved in these systems, the platform deviates from the ideal rigid-body behavior at natural frequencies of its flexural vibrations. These higher frequency flexural vibrations cause misalignment of optical equipment installed on the table, which leads to deterioration of the optical performance.

Dynamic properties of optical tables are usually characterized by their dynamic compliances. Dynamic compliance is a ratio of dynamic deflection to dynamic force, as a function of frequency. For a free absolute rigid body, dynamic compliance is inversely proportional to frequency squared, represented by a straight line on a logarithmic scale. Plots of dynamic compliances provide a convenient way to estimate deviations from a rigid body behavior. Figure 1 shows a typical plot of the absolute value of compliance for an optical table measured near a corner. The graph clearly shows three different areas: (1) low-frequency zone below the first resonance frequency of flexural vibration (but above the isolation frequency) where the behavior of the table is close to that of a rigid body, (2) a medium-frequency zone containing main resonances and (3) a high-frequency zone of non-resonant behavior characterized by a “background” impedance. To reduce flexural vibration of the table, it is necessary to reduce the main resonance peaks, which are usually clustered between 100 Hz and 500 Hz for the most frequently used sizes of optical tables.

Various known passive means of reducing these unwanted vibrations, such as structural damping and “wide-band” damping by auxiliary mass coupled to the table by visco-elastic compounds, have only limited effect. Dynamic vibration absorbers (tuned mass dampers) as used in high-end tables such as Newport Corporation’s RS series suppress flexural resonance vibration of the table efficiently. These tuned mass dampers can only be tuned to the tables particular resonant frequencies and can not be adjusted for significant changes to table loading.

Methods of active vibration control offer a promise of high efficiency without the restrictions of passive methods. Active vibration control involves monitoring vibrations of a structure and utilizing the vibration signal to generate a force with the proper phase and amplitude to attenuate the vibration. An additional advantage of an active approach is the ability to supply a vibration signal that can be used independently for monitoring the vibration environment.

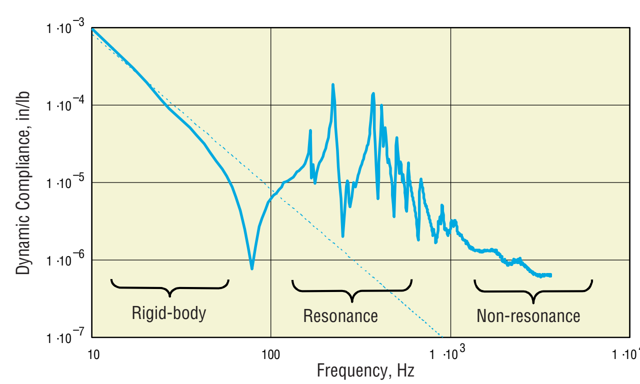


Figure 1: Typical corner compliance of an optical table without any special means of damping

Theoretical Background

Active vibration control of multi-degree-of-freedom systems has been a subject of extensive research since the early 1990’s. For a general active multi-degree-of-freedom system, dynamic deflection at an arbitrary point, un, caused by an external excitation force, fm, can be represented in the frequency domain by

Optical Tables

$$u_n = G_{nm}(\omega) \bullet f_m + \sum_{l=1}^{L} G_{nl}(\omega) \bullet f_m^{act},$$

(1)
where flact are active forces created by control loops, and Gnm(ω) are dynamic compliances. It is well known that collocated sensor-actuator pairs offer a robust active feedback control system. Accordingly, consider a linear feedback system producing active forces at certain locations from the motion signals at the same locations:

$$f_l^{act} = C_l(\omega) \bullet u_l,$$

(2)
where Cl(ω) are complex-valued control functions. Equations (1) and (2) form a closed system of linear equations governing the motion of the system. Dynamic compliances can be represented by the familiar modal expansion:

$$G_{nm}(\omega) = \sum_k \frac{\phi_{nk}\phi_{mk}}{\omega_k^2(1+i\eta_k(\omega))\text{-}\omega^2}.$$

(3)
Here, ϕnk are components of the normal modes that are, for sake of simplicity, assumed real for a low-damped primary system, ωk are "undamped" natural frequencies and ηk are associated loss factors. As mentioned above, main resonance peaks present the main concern in reducing flexural vibration of optical tables. Suppose the "open-loop" dynamic response is dominated by the kth normal mode in the vicinity of its resonance frequency. Then the compliance can be approximately represented by a single member of the series (3) in the vicinity of ωk:
(4)

$$G_{mn}(\omega) \approx \frac{\phi_{nk}\phi_{mk}}{\omega_k^2(1+i\eta_k(\omega))\text{-}\omega^2}, \omega \approx \omega_k.$$

The linear system (1), (2) with the approximate expressions (4) substituted for dynamic compliances can be solved explicitly in the following form:

$$\frac{u_n}{u_n^{\text{passive}}} = \frac{1}{1+\frac{i}{\eta_k\omega_k^2} \bullet \sum_{l=1}^{L} \phi_{lk}^2 \bullet C_l(\omega)} \omega \approx \omega_k,$$

(5)
where unpassive represents the solution in absence of active forces. The equation (5) leads to two important conclusions. First, the optimal phase of the complex-valued control functions Cl(ω) is (-π/2) in the frequency range of interest. This has to be expected, because damping is known to be the most efficient way of reducing resonance vibrations. Second, the right hand side of (5) does not depend on n or m. This shows that a small number of collocated sensor-actuator pairs can damp resonance vibration throughout the structure created by any source. Based on the analysis of the typical resonance modes of anisotropic plates known in the literature, as well as archival data of Newport Corporation, it was confirmed by testing proof-of-concept prototypes that two active dampers placed at two corners of the table would effectively reduce a few first dominant resonance modes a factor of 10.

System Architecture

Figure 2 shows the general layout of the SmartTable. Two sensor-actuator assemblies are integrated into the structure of the optical table at two corners. The design ensures rigid coupling of the sensor and the actuator, and includes a stiff tubular structure coupling the damper to both top and bottom facesheets and serving as a shield to internal electronic circuit boards. Since both actuator and sensor are electromagnetic devices, they are also shielded securely from each other. Two cables connect the dampers to the controller unit. The controller unit can communicate, over USB interface, with a PC. The software supplied with the product allows users to change the controller settings, and also collect, display and store vibration data in both time and frequency formats.

Bolt-on Dampers

Technical Note

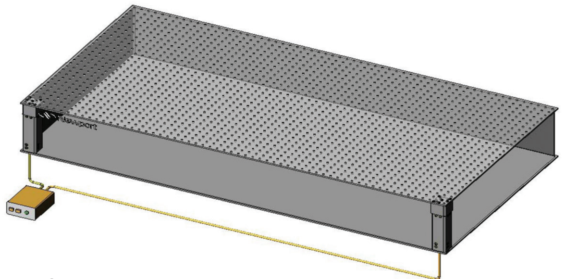


Figure 2: SmartTable system layout.

Figure 3 shows, in general terms, the feedback schematics. Each sensor-actuator pair is controlled by a separate control channel. These control channels are shown in more detail in Figure 4.

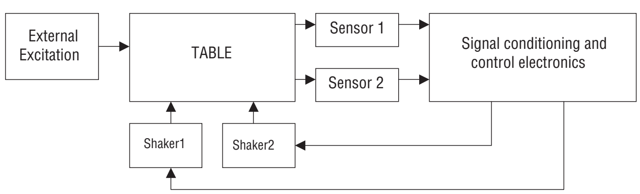


Figure 3: Feedback schematics.

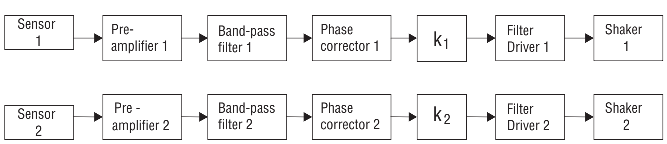


Figure 4: Control channels.

The pre-amplifiers and band-pass filters condition the sensor output signal before feeding it to the digital controller. The digital controller implements recursive filters that compensate for the dynamic response of the shaker and correct the phase to bring the phase difference between the displacement and force close to ($-\pi/2$) in the desired frequency range. This, in effect, emulates the action of a viscous damper in the frequency range of interest. The control functions include gain factors k1 and k2 that define the tradeoffs between damping performance and system stability. It is desirable to make these gains as high as possible for increasing the damping and thereby decreasing the vibration level. Nevertheless, the feedback system would become unstable if the gains were too high. The optimal gains will depend on the payload configuration. To determine the optimal gains for a given safety margin, one should know the full model of the plant (table and payload) and control circuitry, which is not practical. Even if such models were available, the optimum tuning of k1 and k2 would change because of variation in motor constants and sensitivities of sensors and actuators, in addition to variations in the parameters of electronic components. To circumvent this problem, a simple method was used for adaptive tuning the control loop gains. This method is illustrated in Figure 5. The procedure consists of the following steps.

- Initially, the first control channel is enabled and the second one is disabled.
- The first channel gain is ramped up until the onset of instability is detected by the sensor.
- After that, the gain is scaled back to stay in the stability domain.
- A converging search by bisection is used to make the procedure more precise.
- The value of the gain is stored.
- The procedure is then repeated for the second channel.
- Finally, both channels are enabled and the gains are ramped up proportionally to the stored values until instability is detected by at least one channel.
- After that, all the gains are scaled back in small proportional steps to stay in the stability domain. Again, bisection is used to make the procedure more precise.
- A safety factor is applied to the resulting gain values.

In order to maintain high signal-to-noise ratio, the Smart table control system employs auto-ranging based on the mean-square value of the feedback signal. The switching of ranges is accomplished by driving a signal that sets up the preamplifier at a desired level. Range switch is accomplished such that the signal parameters (noise, phase, bandwidth) are unmodified and only

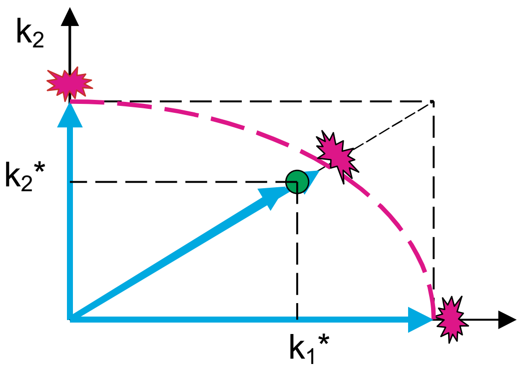


Figure 5: Auto-tuning process.

the gain is changed. The low noise preamplifier is, of course, essential for ensuring high signal quality.

If the feedback signal is at the lowest range and it still violates the desired constraints, the system is said to be in a "Vibration Overload" condition. The overload condition is also detected using an error signal generated by the signal clipping detectors in the preamplifier. The overload condition is reported to the user; the system is, however, capable of operating in overload condition, although maybe not with the same efficiency.

Test Results

The SmartTable product has endured extensive testing in the Newport vibration control and quality assurance laboratories. The performance was verified under various vibration environments, created either by on-board sources of vibration or by ambient environmental vibration sources in an adjacent production shop. Figure 6 compares the vibration spectra created by random excitation. The main resonance vibration peaks are reduced by about ten times. Figure 7 shows the dynamic compliances of the Smart table obtained by applying random excitation (about 0.25 lb RMS) through a force sensor. The damping performance is on par with that of top-of-the-line tables containing tuned vibration absorbers. Nevertheless, if the table is loaded by a weight comparable to the weight of the table, the passive vibration absorbers can become "mistuned", whereas the SmartTable dampers work equally well after auto-tuning.

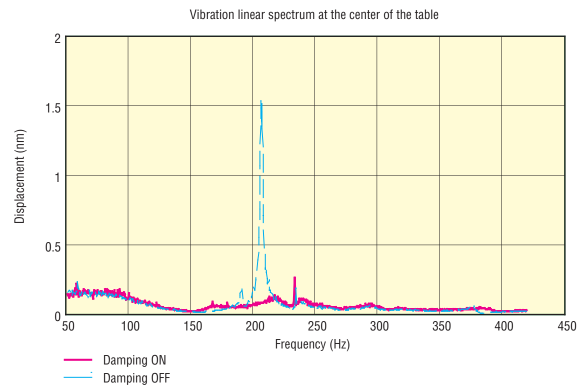


Figure 6: Linear spectra of vibration near the corner of the table Red line: damping on; Blue line: damping off. Table size: 8 ft x 4 ft x 12 in.

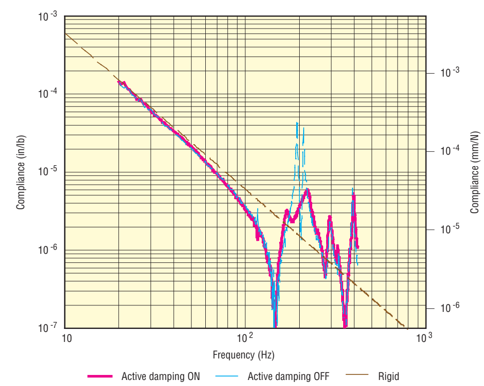


Figure 7: Dynamic compliances near the corner of the table. Red line: damping on; Blue line: damping off, dots: rigid body line. Table size: 8 ft x 4 ft x 12 in.

Finally, Figure 8 illustrates the effect of damping in the time domain. It shows attenuation of vibration caused by a short load pulse. The shock was applied near a corner about 10 inches from the edges of the table; the resulting vibration was monitored by an accelerometer near the center of the table.

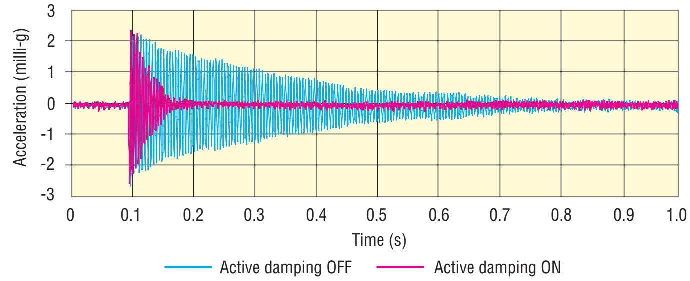


Figure 8: Transient attenuation near the corner of the table. Red line: damping on; Blue line: damping off. Table size: 8 ft x 4 ft x 12 in.

RS4000 Series

Precision Tuned Damped Optical Tables

* Table and legs sold separately

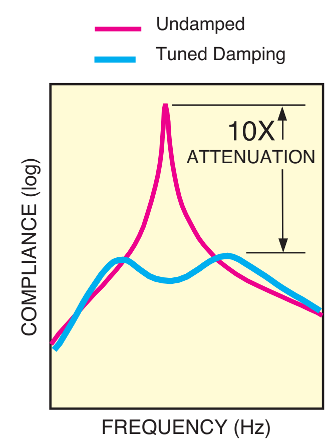
Key Features

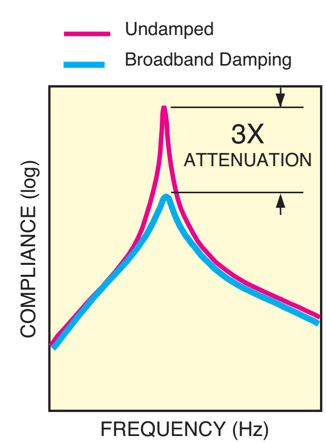
Precision Tuned Damped Optical Tables

- **6 Precision tunable dampers concentrate damping where it's needed**
- **Trussed honeycomb core improves table stiffness**
- **Unmatched vibration immunity for a passive table top**
- **Triple core interface increases point loading capability**
- **Mounting holes individually sealed with conical polymeric cup**
- **Compatible with S-2000A isolators and LabLegs**

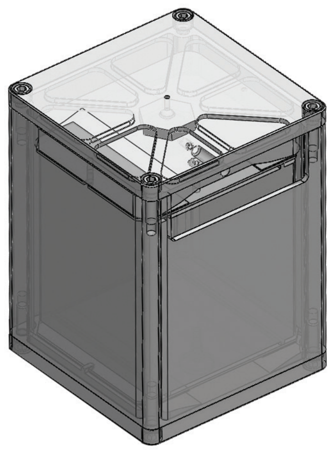
RS4000 Series optical tables use Tuned Mass Damping (TMD) technology to eliminate table resonances. TMD is the most effective method among all known passive damping methods, as it concentrates damping efforts where it's needed at the frequencies of dominant resonance modes. It is widely used in various industries for its efficiency and effectiveness of damping, such as the famous Grand Canyon Skywalk, Taipei 101 Building, and NASA's Ares I rocket. Compared to our top competitor's broadband damping methods which absorbs a moderate amount of vibration energy equally over the broad band, Newport's tuned mass damping method targets at resonances and as a result is much more effective.

Our optical tables have been using tunable mass dampers for decades and our damper designs have evolved over the years. The latest version of the design eliminates the use of oil, and use a proprietary mass-spring mechanism to allow for better damping performance, and more precise and easier tuning to the exact frequency needed to damp the resonance. This patented design (US patent 8857585) further improves damping performance by 3x to 5x compared to the previous generation design, which was already superior than competitor's broadband dampers. The precisely tuned dampers work from as low as 25 Hz and go all the way up to 525 Hz, creating opportunity for optimum damping on larger optical tables, the resonances of which often fall outside of competitor's broadband frequency range. Once tuned at factory the dampers are locked securely and the frequency would not shift during shipping of the table.

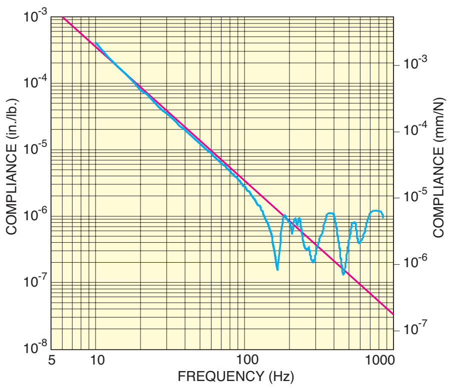




Featuring 6 precision tunable dampers, RS4000 brings the best passive damping performance to your applications that require critical level of damping. The 6 dampers are designed specifically to target majority of the resonances of the table. The result is an ultra quiet tabletop that's ideal for critical applications such as live cell imaging, high resolution imaging, interferometry, experiments with long exposure time and so on.



Newport also offers cleanroom version (UCS Series) of the RS4000 optical tables.

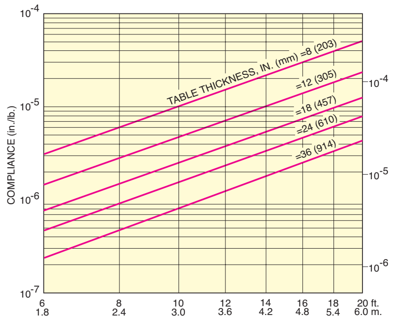


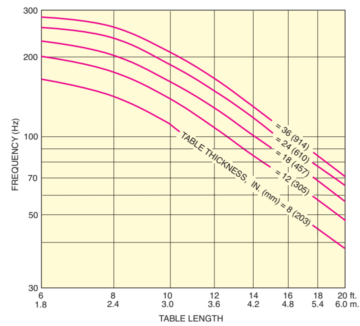
Specifications

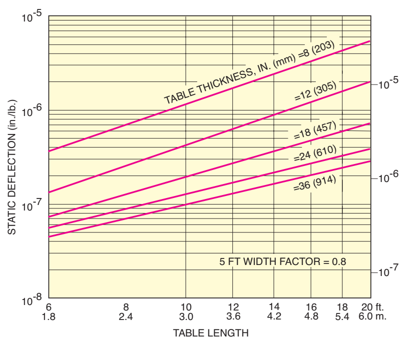
- **Mounting Holes**
  1/4-20 (M6)
- **Surface Flatness**
  ± 0.004 in. (0.1 mm) over 2 ft. (600 mm) square
- **Broadband Damping**
  Constrained layer core, damped working surface and composite edge finish
- **Tuned Damping**
  6 Precision Tuned Dampers
- **Mounting Hole Pattern**
  1 in. (25 mm) grid
- **Mounting Hole Borders**
  0.5 in. (12.5 mm)
- **Working Surface**
  400 series ferromagnetic stainless steel
- **Top and Bottom Skins**
  3/16 in. (4.8 mm) thick with integrated damping layer
- **Hole Sealing Type**
  Easy clean conical cup, 0.75 in. (19 mm) deep, non-corrosive high impact polymer material
- **Maximum Dynamic Deflection Coefficient**
  0.4 x 10-3
- **Maximum Relative Motion Value**
  3.0 x 10-9 in. (7.6 x 10-8 mm)
- **Deflection Under Load**
  5.0 x 10-5 in. (1.3 x 10-3 mm)
- **Non-Magnetic Surface**
  No
- **Alpha-Numeric Grid Labels**
  Yes

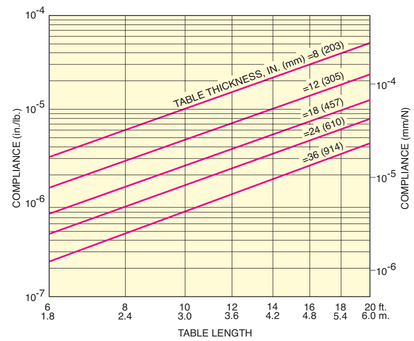
Optical Tables

RS4000 Series









Ordering Information

Model (Metric)*	Width [ft. (mm2)]	Length [ft. (mm2)]	Thickness [in. (mm)]
RS4000-36-8 (M-RS4000-36-8)	3 (900)	6 (1800)	8 (203)
RS4000-36-12 (M-RS4000-36-12)	3 (900)	6 (1800)	12 (305)
RS4000-36-18 (M-RS4000-36-18)	3 (900)	6 (1800)	18 (457)
RS4000-38-8 (M-RS4000-38-8)	3 (900)	8 (2400)	8 (203)
RS4000-38-12 (M-RS4000-38-12)	3 (900)	8 (2400)	12 (305)
RS4000-38-18 (M-RS4000-38-18)	3 (900)	8 (2400)	18 (457)
RS4000-38-24 (M-RS4000-38-24)	3 (900)	8 (2400)	24 (610)
RS4000-310-8 (M-RS4000-310-8)	3 (900)	10 (3000)	8 (203)
RS4000-310-12 (M-RS4000-310-12)	3 (900)	10 (3000)	12 (305)
RS4000-310-18 (M-RS4000-310-18)	3 (900)	10 (3000)	18 (457)
RS4000-310-24 (M-RS4000-310-24)	3 (900)	10 (3000)	24 (610)
RS4000-46-8 (M-RS4000-46-8)	4 (1200)	6 (1800)	8 (203)
RS4000-46-12 (M-RS4000-46-12)	4 (1200)	6 (1800)	12 (305)
RS4000-46-18 (M-RS4000-46-18)	4 (1200)	6 (1800)	18 (457)
RS4000-46-24 (M-RS4000-46-24)	4 (1200)	6 (1800)	24 (610)
RS4000-48-8 (M-RS4000-48-8)	4 (1200)	8 (2400)	8 (203)
RS4000-48-12 (M-RS4000-48-12)	4 (1200)	8 (2400)	12 (305)
RS4000-48-18 (M-RS4000-48-12)	4 (1200)	8 (2400)	18 (457)
RS4000-48-24 (M-RS4000-48-24)	4 (1200)	8 (3600)	24 (610)
RS4000-410-8 (M-RS4000-410-8)	4 (1200)	10 (3000)	8 (203)
RS4000-410-12 (M-RS4000-410-12)	4 (1200)	10 (3000)	12 (305)

RS4000-410-18 (M-RS4000-410-18)	4 (1200)	10 (3000)	18 (457)
RS4000-410-24 (M-RS4000-410-24)	4 (1200)	10 (3000)	24 (610)
RS4000-412-8 (M-RS4000-412-8)	4 (1200)	12 (3600)	8 (203)
RS4000-412-12 (M-RS4000-412-12)	4 (1200)	12 (3600)	12 (305)
RS4000-412-18 (M-RS4000-412-18)	4 (1200)	12 (3600)	18 (457)
RS4000-412-24 (M-RS4000-412-24)	4 (1200)	12 (3600)	24 (610)
RS4000-414-8 (M-RS4000-414-8)	4 (1200)	14 (4200)	8 (203)
RS4000-414-12 (M-RS4000-414-12)	4 (1200)	14 (4200)	12 (305)
RS4000-414-18 (M-RS4000-414-18)	4 (1200)	14 (4200)	18 (457)
RS4000-414-24 (M-RS4000-414-24)	4 (1200)	14 (4200)	24 (610)
RS4000-416-8 (M-RS4000-416-12)	4 (1200)	16 (4800)	8 (203)
RS4000-416-12 (M-RS4000-416-12)	4 (1200)	16 (4800)	18 (457)
RS4000-416-18 (M-RS4000-416-18)	4 (1200)	16 (4800)	18 (457)
RS4000-416-24 (M-RS4000-416-24)	4 (1200)	16 (4800)	24 (610)
RS4000-418-8 (M-RS4000-418-8)	4 (1200)	18 (5400)	8 (203)
RS4000-418-12 (M-RS4000-418-12)	4 (1200)	18 (5400)	12 (305)
RS4000-418-18 (M-RS4000-418-18)	4 (1200)	18 (5400)	18 (457)
RS4000-418-24 (M-RS4000-418-24)	4 (1200)	18 (5400)	24 (610)
RS4000-420-8 (M-RS4000-420-8)	4 (1200)	20 (6000)	8 (203)
RS4000-420-12 (M-RS4000-420-12)	4 (1200)	20 (6000)	12 (305)
RS4000-420-18 (M-RS4000-420-18)	4 (1200)	20 (6000)	18 (457)
RS4000-420-24 (M-RS4000-420-24)	4 (1200)	20 (6000)	24 (610)
RS4000-56-8 (M-RS4000-56-8)	5 (1500)	6 (1800)	8 (203)
RS4000-56-12 (M-RS4000-56-8)	5 (1500)	6 (1800)	12 (305)
RS4000-56-18 (M-RS4000-56-18)	5 (1500)	6 (1800)	18 (457)
RS4000-56-24 (M-RS4000-56-24)	5 (1500)	6 (1800)	24 (610)
RS4000-58-8 (M-RS4000-58-8)	5 (1500)	8 (2400)	8 (203)
RS4000-58-12 (M-RS4000-58-12)	5 (1500)	8 (2400)	12 (305)
RS4000-58-18 (M-RS4000-58-18)	5 (1500)	8 (2400)	18 (457)
RS4000-58-24 (M-RS4000-58-24)	5 (1500)	8 (2400)	24 (610)
RS4000-510-8 (M-RS4000-510-8)	5 (1500)	10 (3000)	8 (203)
RS4000-510-12 (M-RS4000-510-12)	5 (1500)	10 (3000)	12 (305)
RS4000-510-18 (M-RS4000-510-18)	5 (1500)	10 (3000)	18 (457)
RS4000-510-24 (M-RS4000-510-24)	5 (1500)	10 (3000)	24 (610)
RS4000-512-8 (M-RS4000-512-8)	5 (1500)	12 (3600)	8 (203)
RS4000-512-12 (M-RS4000-512-12)	5 (1500)	12 (3600)	12 (305)
RS4000-512-18 (M-RS4000-512-18)	5 (1500)	12 (3600)	18 (457)
RS4000-512-24 (M-RS4000-512-24)	5 (1500)	12 (3600)	24 (610)
RS4000-514-8 (M-RS4000-514-8)	5 (1500)	14 (4200)	8 (203)
RS4000-514-12 (M-RS4000-514-12)	5 (1500)	14 (4200)	12 (305)
RS4000-514-18 (M-RS4000-514-18)	5 (1500)	14 (4200)	18 (457)
RS4000-514-24 (M-RS4000-514-24)	5 (1500)	14 (4200)	24 (610)
RS4000-516-8 (M-RS4000-516-8)	5 (1500)	16 (4800)	8 (203)
RS4000-516-12 (M-RS4000-516-12)	5 (1500)	16 (4800)	12 (305)
RS4000-516-18 (M-RS4000-516-18)	5 (1500)	16 (4800)	18 (457)
RS4000-516-24 (M-RS4000-516-24)	5 (1500)	16 (4800)	24 (610)

* For Metric verion, add M- to part number when ordering.

RS2000 Series

*Table and legs sold seperately

Key Features

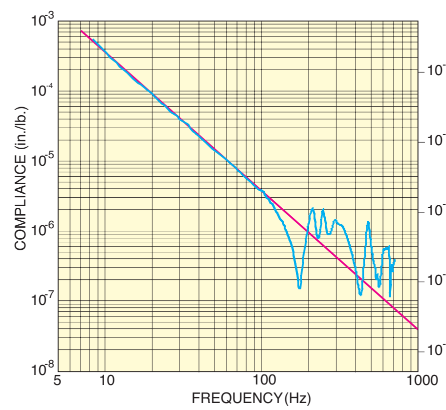
Precision Tuned Damped Optical Tables

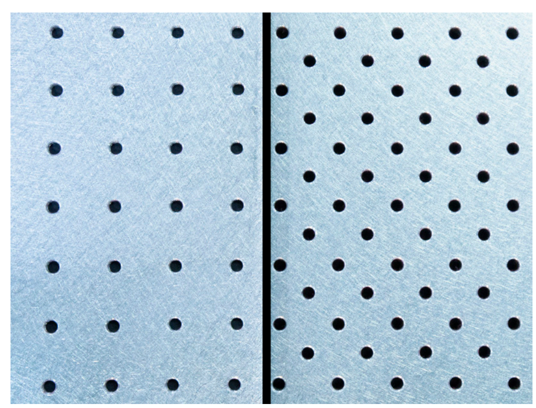
- **2 Precision tunable dampers concentrate damping where it's needed**
- **Trussed honeycomb core improves table stiffness**
- **Excellent vibration immunity for a passive table top**
- **Triple core interface increases point loading capability**
- **Mounting holes individually sealed with conical polymeric cup**
- **Compatible with S-2000A isolators and LabLegs**

RS2000 Series optical tables use Tuned Mass Damping (TMD) technology to eliminate table resonances. The RS2000 Series features 2 precision tunable dampers, compare to 6 tuned dampers for RS4000 Series.

The RS2000 Series is a culmination of many years of experience, innovation and attention to detail leading to unmatched vibration immunity. It combines Newport's uniquely rigid trussed honeycomb core with tuned damping. Originally designed for high end interferometric research, these optical tables are the best choice for extremely sensitive measurements requiring the utmost in vibration control.

Newport also offers RS2000D series double density optical tables. The unique double-density hole pattern on these tables provides more mounting locations than standard 1-inch (25-mm) hole patterns. It is ideal for applications that require a dense mounting surface, such as laser cooling, atomic physics, and spectroscopy.

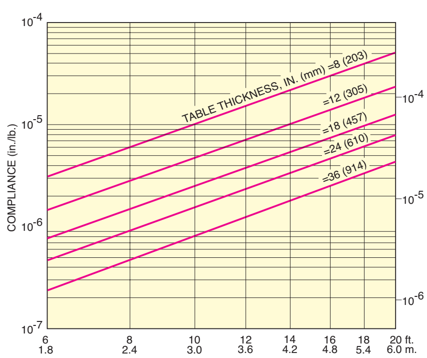


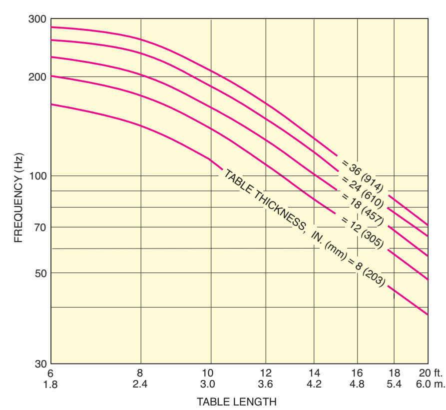


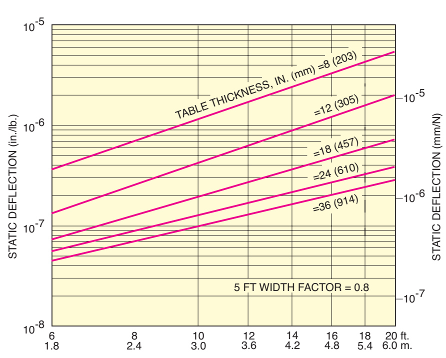
Standard 1-inch (25 mm) grid (Left) Double Density 1-inch (25 mm) grid (Right)

SPECIFICATIONS

- **Mounting Holes**
  1/4-20 (M6)
- **Surface Flatness**
  ± 0.004 in. (0.1 mm) over 2 ft. (600 mm) square
- **Broadband Damping**
  Constrained layer core, damped working surface and composite edge finish
- **Tuned Damping**
  2 Precision Tuned Dampers
- **Mounting Hole Pattern**
  1 in. (25 mm) grid
- **Mounting Hole Borders**
  0.5 in. (12.5 mm)
- **Working Surface**
  400 series ferromagnetic stainless steel
- **Top and Bottom Skins**
  3/16 in. (4.8 mm) thick with integrated damping layer
- **Hole Sealing Type**
  Easy clean conical cup, 0.75 in. (19 mm) deep, non-corrosive high impact polymer material
- **Maximum Dynamic Deflection Coefficient**
  0.8 x 10_{-3}
- **Maximum Relative Motion Value**
  8.0 x 10-9 in. (2.0 x 10-7 mm)
- **Deflection Under Load**
  5.0 x 10-5 in. (1.3 x 10-3 mm)
- **Non-Magnetic Surface**
  No
- **Alpha-Numeric Grid Labels**
  Yes







RS2000 Series

Technical Note

Narrowband Damping with Tuned Vibration Absorbers

The primary reason why Newport RS Series Passive Damped Optical Tables are superior to all other products is their use of tuned vibration absorbers for narrowband damping. Commonly called "Tuned Dampers", these devices selectively eliminate a fundamental structural table mode and its entire harmonics. Multiple tuned dampers can be selected to eliminate multiple modes along with the resulting mode harmonics. Tuned damping is the most effective means of reducing relative motion across the table surface.

Narrowband "Tuned" Dampers vs. "Broadband" Dampers

Tuned damping techniques use individual mode selected vibration absorbers to eliminate a particular vibration mode of the table. On the other hand, "broadband" damping techniques use one design for all modes to indiscriminately absorb moderate amounts of vibration over the broadband. Using a single design damper is less expensive than specifically selected tuned dampers but not as effective in reducing the amplitude of resonance modes. A popular version of "broadband" damping is using several heavy steel plates positioned around the periphery of the table and supported at the edges by small rubber support pieces, hoping that several resonance frequencies of these tables will somehow interact with the resonance frequencies of the table. This "hit or miss" strategy is seldom effective. This is especially true for the lower frequency resonances found on large tables. In contrast, Newport stocks tuned dampers for large tables down to 10 Hz. For smaller tables, dampers up to 500 Hz are also stocked. Figure 1 compares the typical effects of narrow-band vs. broadband damping on an individual mode.

Newport Tuned Damping - Broadband Damping

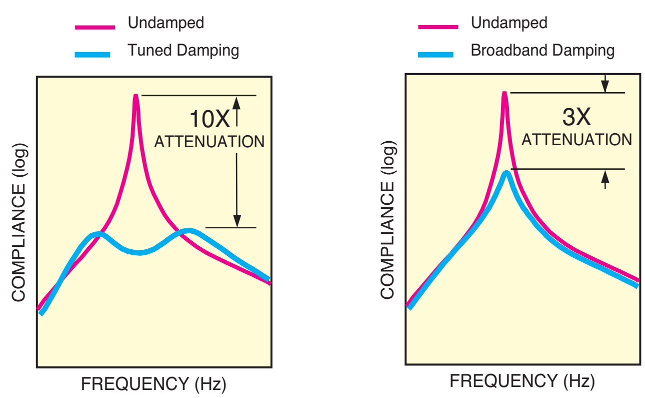


Figure 1: Newport tuned dampers (left) concentrate damping where it's needed most, at the frequencies of dominant resonance modes. Since broad-band dampers (right) are designed to provide moderate damping over a wide range of frequencies, they are not as effective at damping the dominant modes of table vibration.

Another problem with broadband dampers is their weight. Since such dampers are not selective, they must be quite heavy to be effective. Unfortunately, this additional weight is added to the edges of the table and can significantly degrade the bending mode performance. The heavy edges and poor bending mode performance greatly increase unwanted relative motion in the center of the table where most experiments are built. Newport tuned dampers are much lighter and produce minimal mass loading impact on the fundamental table modes. Finally, "broadband" techniques use rubber support element that can change over time under load resulting in a degradation of their damping effects and change in stiffness; besides, their properties are strongly temperature-dependent.

Newport "Tuned Dampers" use a rugged, bolted construction that will not degrade over time. They feature a compact inertial mass supported on two sides by steel leaf springs; damping is provided by thin layers of specially engineered highly damped polyurethane elastomer molded with the plate and working in the conditions guaranteeing longevity and stability of properties. More information on design and application of tuned mass dampers can be found in the recent paper[i]

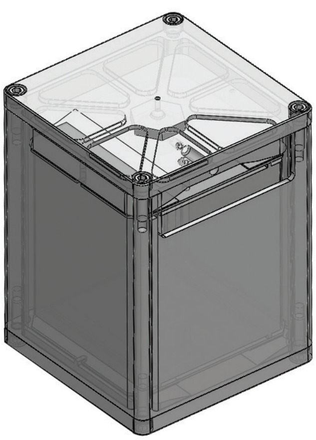


Figure 2: Schematic of Newport vibration absorber used in tuned damping table systems US patents 8,857,585 et al.modes of table vibration.

Unlike competitive offerings that can only offer several table tops with obscure names such as "nominal" damping, Newport tables can be tuned damped into thousands of configurations depending on the table geometry and individual experimental need. Most of these configurations fall into two product offerings: RS4000™ and RS2000™. However, custom tuned tables are available to account for special geometries and heavily loaded surfaces.

How an RS Series table is "Tuned"

A vibration engineer trained in structural analysis tunes each RS Series table design. The table is built with provisions for adding the dampers. After construction, the table is tested using modal analysis techniques to experimentally determine the actual resonance frequencies or modes. Then the tuning frequencies of dampers are determined using known optimization techniques. Different table sizes will exhibit different natural frequencies and modes. Even tables that are close in size can have dramatically different modal signatures. This is a primary reason why the "one size fits all" approach to damping is a poor choice.

For example: Newport's RPR Series Industrial and Educational Grade Optical Tables are the mechanical equivalent of the RS Series Passive Damped Optical Tables but without the tuned dampers. The RPR-38-8 (3 ft wide, 8 ft long, 8 in. thick) exhibits a fundamental "bending" mode at 223 Hz. The most effective location for the damper to absorb the bending mode is in each end of the table. In contrast, the RPR-48-8 (4 ft wide) exhibits a fundamental "torsion" mode at 217 Hz. The most effective location for the damper to absorb the torsion mode is in the corners of the table. The plots in Figure 3 show the FEAs for these tables.

RS2000 Series

Technical Note

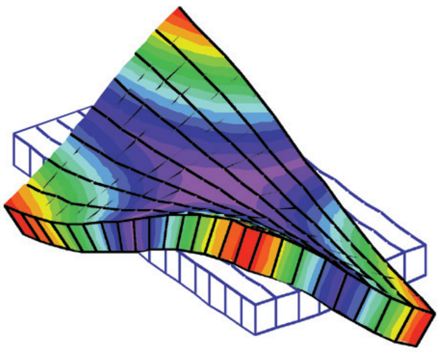
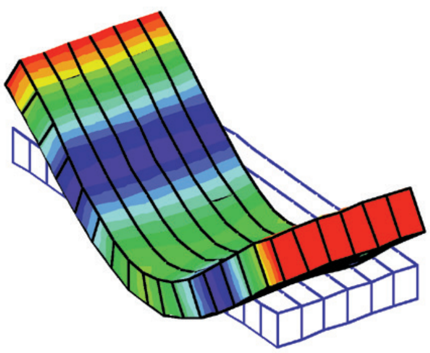


Figure 3



The example above shows the basic process used for determining the proper damper and location to eliminate the fundamental mode. Once the dampers are built into the table to attenuate this mode, the table is transformed from an RPR to an RS2000 with two dampers, or to RS4000 with six dampers.

Specialized Tuning

Newport's tuned damping techniques allow the table construction to be tuned for specific applications.

Doubled Tables: Modular Doubled Tables are multiple tables that are doubled together into complex monolithic structures that can exhibit very low frequency fundamental modes. When building these large structures, Newport assembles the doubled tables into their final configuration and tunes them as a monolithic system. Multiple dampers placed in selected locations (usually up to six dampers per section) can be used. Broadband techniques are very ineffective for such complex low frequency structures.

Large Table Loads: Tuned dampers are heavily damped, and their tuning is not "sharp" so that they stay effective in a frequency range centered around the tuning frequency. The performance is not significantly affected unless the equipment load exceeds 30% of the table weight. For example, an RS4000-48-12 weighs close to 1200 lbs - if the table load starts to exceed 360 lbs, the tuned dampers will be slightly less effective. In these cases, Newport will simulate the positional load and specially damp the table to the application requirement. Fortunately, most optical table experiments rarely exceed 30% of the table mass.

Special Shapes: Table structures with special shapes, cutouts, multiple levels and other custom features are modeled and tuned using the same process described above.

On-site tuning: Newport tuned mass dampers can be tuned or adjusted on-site. All it takes is to provide special removable corner pieces of the table.

Advantages of Tuned Dampers

- Eliminate fundamental mode resonances
- Offer much better vibration absorption at low frequencies
- Lighter weight does not mass load table construction
- Rugged bolted design with the damper mass supported by leaf steel springs is thermally stable and does not deteriorate in time
- Can be adjusted or re-tuned in the field (with special table corner covers providing accessibility)

Problems with “Broadband Dampers”

- Less effective in reducing vibration amplitudes
- Does not work well for large tables with low frequency modes
- Heavy weight reduces table stiffness-to-weight ratio
- Rubber support pieces can degrade with time and change properties with temperature

[i] V.M. Ryaboy, Practical aspects of design, tuning and application of dynamic vibration absorbers, Proceedings of Meetings on Acoustics, 26, 065006 (2016); https://doi.org/10.1121/2.0000231 .

RS2000 Series

Ordering Information

Model (Metric)*	Width [ft. (mm²)]	Length [ft. (mm)]	Thickness [in. (mm)]
RS2000-36-8 (M-RS2000-36-8)	3 (900)	6 (1800)	8 (203)
RS2000-36-12 (M-RS2000-36-12)	3 (900)	6 (1800)	12 (305)
RS2000-36-18 (M-RS2000-36-18)	3 (900)	6 (1800)	18 (457)
RS2000-38-8 (M-RS2000-38-8)	3 (900)	8 (2400)	8 (203)
RS2000-38-12 (M-RS2000-38-12)	3 (900)	8 (2400)	12 (305)
RS2000-38-18 (M-RS2000-38-18)	3 (900)	8 (2400)	18 (457)
RS2000-38-24 (M-RS2000-38-24)	3 (900)	8 (2400)	24 (610)
RS2000-310-8 (M-RS2000-310-8)	3 (900)	10 (3000)	8 (203)
RS2000-310-12 (M-RS2000-310-12)	3 (900)	10 (3000)	12 (305)
RS2000-310-18 (M-RS2000-310-18)	3 (900)	10 (3000)	18 (457)
RS2000-310-24 (M-RS2000-310-24)	3 (900)	10 (3000)	24 (610)
RS2000-46-8 (M-RS2000-46-8)	4 (1200)	6 (1800)	8 (203)
RS2000-46-12 (M-RS2000-46-12)	4 (1200)	6 (1800)	12 (305)
RS2000-46-18 (M-RS2000-46-18)	4 (1200)	6 (1800)	18 (457)
RS2000-46-24 (M-RS2000-46-24)	4 (1200)	6 (1800)	24 (610)
RS2000-48-8 (M-RS2000-48-8)	4 (1200)	8 (2400)	8 (203)
RS2000-48-12 (M-RS2000-48-12)	4 (1200)	8 (2400)	12 (305)
RS2000-48-18 (M-RS2000-48-18)	4 (1200)	8 (2400)	18 (457)
RS2000-48-24 (M-RS2000-48-24)	4 (1200)	8 (2400)	24 (610)
RS2000-410-8 (M-RS2000-410-8)	4 (1200)	10 (3000)	8 (203)
RS2000-410-12 (M-RS2000-410-12)	4 (1200)	10 (3000)	12 (305)
RS2000-410-18 (M-RS2000-410-18)	4 (1200)	10 (3000)	18 (457)
RS2000-410-24 (M-RS2000-410-24)	4 (1200)	10 (3000)	24 (610)
RS2000-412-8 (M-RS2000-412-8)	4 (1200)	12 (3600)	8 (203)
RS2000-412-12 (M-RS2000-412-12)	4 (1200)	12 (3600)	12 (305)
RS2000-412-18 (M-RS2000-412-18)	4 (1200)	12 (3600)	18 (457)
RS2000-412-24 (M-RS2000-412-24)	4 (1200)	12 (3600)	24 (610)
RS2000-414-8 (M-RS2000-414-8)	4 (1200)	14 (4200)	8 (203)
RS2000-414-12 (M-RS2000-414-12)	4 (1200)	14 (4200)	12 (305)
RS2000-414-18 (M-RS2000-414-18)	4 (1200)	14 (4200)	18 (457)
RS2000-414-24 (M-RS2000-414-24)	4 (1200)	14 (4200)	24 (610)
RS2000-416-8 (M-RS2000-416-8)	4 (1200)	16 (4800)	8 (203)
RS2000-416-12 (M-RS2000-416-12)	4 (1200)	16 (4800)	12 (305)
RS2000-416-18 (M-RS2000-416-18)	4 (1200)	16 (4800)	18 (457)
RS2000-416-24 (M-RS2000-416-24)	4 (1200)	16 (4800)	24 (610)
RS2000-418-8 (M-RS2000-418-8)	4 (1200)	18 (5400)	8 (203)
RS2000-418-12 (M-RS2000-418-12)	4 (1200)	18 (5400)	12 (305)
RS2000-418-18 (M-RS2000-418-18)	4 (1200)	18 (5400)	18 (457)

RS2000-418-24 (M-RS2000-418-24)	4 (1200)	18 (5400)	24 (610)
RS2000-420-8 (M-RS2000-420-8)	4 (1200)	20 (6000)	8 (203)
RS2000-420-12 (M-RS2000-420-12)	4 (1200)	20 (6000)	12 (305)
RS2000-420-18 (M-RS2000-420-18)	4 (1200)	20 (6000)	18 (457)
RS2000-420-24 (M-RS2000-420-24)	4 (1200)	20 (6000)	24 (610)
RS2000-56-8 (M-RS2000-56-8)	5 (1500)	6 (1800)	8 (203)
RS2000-56-12 (M-RS2000-56-12)	5 (1500)	6 (1800)	12 (305)
RS2000-56-18 (M-RS2000-56-18)	5 (1500)	6 (1800)	18 (457)
RS2000-56-24 (M-RS2000-56-24)	5 (1500)	6 (1800)	24 (610)
RS2000-58-8 (M-RS2000-58-8)	5 (1500)	8 (2400)	8 (203)
RS2000-58-12 (M-RS2000-58-12)	5 (1500)	8 (2400)	12 (305)
RS2000-58-18 (M-RS2000-58-18)	5 (1500)	8 (2400)	18 (457)
RS2000-58-24 (M-RS2000-58-24)	5 (1500)	8 (2400)	24 (610)
RS2000-510-8 (M-RS2000-510-8)	5 (1500)	10 (3000)	8 (203)
RS2000-510-12 (M-RS2000-510-12)	5 (1500)	10 (3000)	12 (305)
RS2000-510-18 (M-RS2000-510-18)	5 (1500)	10 (3000)	18 (457)
RS2000-510-24 (M-RS2000-510-24)	5 (1500)	10 (3000)	24 (610)
RS2000-512-8 (M-RS2000-512-8)	5 (1500)	12 (3600)	8 (203)
RS2000-512-12 (M-RS2000-512-12)	5 (1500)	12 (3600)	12 (305)
RS2000-512-18 (M-RS2000-512-18)	5 (1500)	12 (3600)	18 (457)
RS2000-512-24 (M-RS2000-512-24)	5 (1500)	12 (3600)	24 (610)
RS2000-514-8 (M-RS2000-514-8)	5 (1500)	14 (4200)	8 (203)
RS2000-514-12 (M-RS2000-514-12)	5 (1500)	14 (4200)	12 (305)
RS2000-514-18 (M-RS2000-514-18)	5 (1500)	14 (4200)	18 (457)
RS2000-514-24 (M-RS2000-514-24)	5 (1500)	14 (4200)	24 (610)
RS2000-516-8 (M-RS2000-516-8)	5 (1500)	16 (4800)	8 (203)
RS2000-516-12 (M-RS2000-516-12)	5 (1500)	16 (4800)	12 (305)
RS2000-516-18 (M-RS2000-516-18)	5 (1500)	16 (4800)	18 (457)
RS2000-516-24 (M-RS2000-516-24)	5 (1500)	16 (4800)	24 (610)

RPR Series

*Table and legs sold seperately

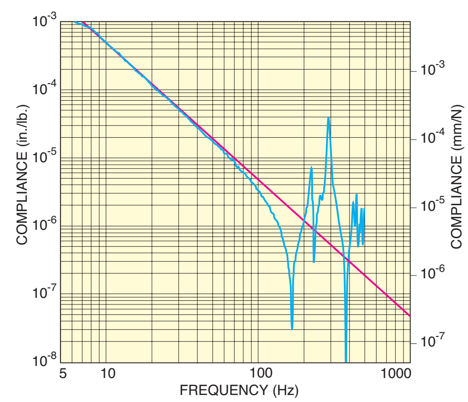
Key Features

Broadband Damped RPR Series Industrial and Educational Optical Tables

- **Damped worksurface eliminates skin resonance**
- **Damped composite edge finish eliminates sidewall resonance**
- **Constrained layer core damping attenuates broadband vibration**

The RPR Series broadband damped tables represented the state of the art before the advent of tuned damping found in the RS Series. Indeed, the RPR set the standard that younger companies still imitate. Today they still offer good value for many less stringent applications. The RPR Series tables offer Newport performance and quality at an affordable price.

Newport also offers RPR grade non-magnetic optical tables (RPR-N Series).



SPECIFICATIONS

- **Mounting Holes**
  1/4-20 (M6)
- **Surface Flatness**
  ± 0.004 in. (0.1 mm) over 2 ft. (600 mm) square
- **Broadband Damping**
  Constrained layer core, damped working surface and composite edge finish
- **Mounting Hole Pattern**
  1 in. (25 mm) grid
- **Mounting Hole Borders**
  0.5 in. (12.5 mm)
- **Working Surface**
  400 series ferromagnetic stainless steel
- **Top and Bottom Skins**
  3/16 in. (4.8 mm) thick with integrated damping layer
- **Hole Sealing Type**
  Easy clean conical cup, 0.75 in. (19 mm) deep, non-corrosive high impact polymer material
- **Maximum Dynamic Deflection Coefficient**
  2.0 x 10-3
- **Maximum Relative Motion Value**
  12.0 x 10-9 in. (3.0 x 10-7 mm)
- **Deflection Under Load**
  5.0 x 10_{-5} in. (1.3 x 10-3 mm)
- **Non-Magnetic Surface**
  No
- **Alpha-Numeric Grid Labels**
  Yes

RPR Series

Ordering Information

Model (Metric)	Width [ft. (mm2)]	Length [ft. (mm2)]	Thickness [in. (mm)]
RPR-36-8 (M-RPR-36-8)	3 (900)	6 (1800)	8 (203)
RPR-36-12 (M-RPR-36-12)	3 (900)	6 (1800)	12 (305)
RPR-36-18 (M-RPR-36-18)	3 (900)	6 (1800)	18 (457)
RPR-38-8 (M-RPR-38-8)	3 (900)	8 (2400)	8 (203)
RPR-38-12 (M-RPR-38-12)	3 (900)	8 (2400)	12 (305)
RPR-38-18 (M-RPR-38-18)	3 (900)	8 (2400)	18 (457)
RPR-38-24 (M-RPR-38-24)	3 (900)	8 (2400)	24 (610)
RPR-310-8 (M-RPR-310-8)	3 (900)	10 (3000)	8 (203)
RPR-310-12 (M-RPR-310-12)	3 (900)	10 (3000)	12 (305)
RPR-310-18 (M-RPR-310-18)	3 (900)	10 (3000)	18 (457)
RPR-310-24 (M-RPR-310-24)	3 (900)	10 (3000)	24 (610)
RPR-46-8 (M-RPR-46-8)	4 (1200)	6 (1800)	8 (203)
RPR-46-12 (M-RPR-46-12)	4 (1200)	6 (1800)	12 (305)
RPR-46-18 (M-RPR-46-18)	4 (1200)	6 (1800)	18 (457)
RPR-46-24 (M-RPR-46-24)	4 (1200)	6 (1800)	24 (610)
RPR-48-8 (M-RPR-48-8)	4 (1200)	8 (2400)	8 (203)
RPR-48-12 (M-RPR-48-12)	4 (1200)	8 (2400)	12 (305)
RPR-48-18 (M-RPR-48-18)	4 (1200)	8 (2400)	18 (457)
RPR-48-24 (M-RPR-48-24)	4 (1200)	8 (2400)	24 (610)
RPR-410-8 (M-RPR-410-8)	4 (1200)	10 (3000)	8 (203)
RPR-410-12 (M-RPR-410-12)	4 (1200)	10 (3000)	12 (305)
RPR-410-18 (M-RPR-410-18)	4 (1200)	10 (3000)	18 (457)
RPR-410-24 (M-RPR-410-24)	4 (1200)	10 (3000)	24 (610)
RPR-412-8 (M-RPR-412-8)	4 (1200)	12 (3600)	8 (203)
RPR-412-12 (M-RPR-412-12)	4 (1200)	12 (3600)	12 (305)
RPR-412-18 (M-RPR-412-18)	4 (1200)	12 (3600)	18 (457)
RPR-412-24 (M-RPR-412-24)	4 (1200)	12 (3600)	24 (610)
RPR-414-8 (M-RPR-414-8)	4 (1200)	14 (4200)	8 (203)
RPR-414-12 (M-RPR-414-12)	4 (1200)	14 (4200)	12 (305)
RPR-414-18 (M-RPR-414-18)	4 (1200)	14 (4200)	18 (457)
RPR-414-24 (M-RPR-414-24)	4 (1200)	14 (4200)	24 (610)
RPR-416-8 (M-RPR-416-8)	4 (1200)	16 (4800)	8 (203)
RPR-416-12 (M-RPR-416-12)	4 (1200)	16 (4800)	12 (305)
RPR-416-18 (M-RPR-416-18)	4 (1200)	16 (4800)	18 (457)
RPR-416-24 (M-RPR-416-24)	4 (1200)	16 (4800)	24 (610)
RPR-418-8 (M-RPR-418-8)	4 (1200)	18 (5400)	8 (203)
RPR-418-12 (M-RPR-418-12)	4 (1200)	18 (5400)	12 (305)
RPR-418-18 (M-RPR-418-18)	4 (1200)	18 (5400)	18 (457)

RPR

Ordering Information

RPR-418-24 (M-RPR-418-24)	4 (1200)	18 (5400)	24 (610)
RPR-420-8 (M-RPR-420-8)	4 (1200)	20 (6000)	8 (203)
RPR-420-12 (M-RPR-420-12)	4 (1200)	20 (6000)	12 (305)
RPR-420-18 (M-RPR-420-18)	4 (1200)	20 (6000)	18 (457)
RPR-420-24 (M-RPR-420-24)	4 (1200)	20 (6000)	24 (610)
RPR-56-8 (M-RPR-56-8)	5 (1500)	6 (1800)	8 (203)
RPR-56-12 (M-RPR-56-12)	5 (1500)	6 (1800)	12 (305)
RPR-56-18 (M-RPR-56-18)	5 (1500)	6 (1800)	18 (457)
RPR-56-24 (M-RPR-56-24)	5 (1500)	6 (1800)	24 (610)
RPR-58-8 (M-RPR-58-8)	5 (1500)	8 (2400)	8 (203)
RPR-58-12 (M-RPR-58-12)	5 (1500)	8 (2400)	12 (305)
RPR-58-18 (M-RPR-58-18)	5 (1500)	8 (2400)	18 (457)
RPR-58-24 (M-RPR-58-24)	5 (1500)	8 (2400)	24 (610)
RPR-510-8 (M-RPR-510-8)	5 (1500)	10 (3000)	8 (203)
RPR-510-12 (M-RPR-510-12)	5 (1500)	10 (3000)	12 (305)
RPR-510-18 (M-RPR-510-18)	5 (1500)	10 (3000)	18 (457)
RPR-510-24 (M-RPR-510-24)	5 (1500)	10 (3000)	24 (610)
RPR-512-8 (M-RPR-512-8)	5 (1500)	12 (3600)	8 (203)
RPR-512-12 (M-RPR-512-12)	5 (1500)	12 (3600)	12 (305)
RPR-512-18 (M-RPR-512-18)	5 (1500)	12 (3600)	18 (457)
RPR-512-24 (M-RPR-512-24)	5 (1500)	12 (3600)	24 (610)
RPR-514-8 (M-RPR-514-8)	5 (1500)	14 (4200)	8 (203)
RPR-514-12 (M-RPR-514-12)	5 (1500)	14 (4200)	12 (305)
RPR-514-18 (M-RPR-514-18)	5 (1500)	14 (4200)	18 (457)
RPR-514-24 (M-RPR-514-24)	5 (1500)	14 (4200)	24 (610)
RPR-516-8 (M-RPR-516-8)	5 (1500)	16 (4800)	8 (203)
RPR-516-12 (M-RPR-516-12)	5 (1500)	16 (4800)	12 (305)
RPR-516-18 (M-RPR-516-18)	5 (1500)	16 (4800)	18 (457)
RPR-516-24 (M-RPR-516-24)	5 (1500)	16 (4800)	24 (610)

Custom Vibration Isolation Solutions

Newport's extensive manufacturing capabilities to deliver customized, damped platforms used for laser research, microscope workstations and optical platforms spans over 40 years. Our capabilities include custom shaped granite, honeycomb or Invar structures, nonmagnetic honeycomb tables, cleanroom and vacuum compatible structures with either broadband or tuned dampers for optimal stability and vibration reduction. Newport is the first source for many of the world's leading optical scientists who require complex honeycomb structures for applications including optical tables, high power laser platforms, rigid assembly and test fixtures or space-based vacuum platforms.

Custom Capabilities

Doubled Table Tops

- Broad selection of table section sizes, quantities, materials, shapes and operating condition
- Modular options for adding new applications later
- Over 45 years of experience in making the most rigid doubler tables

Doubled Table Tops

- Provide virtually nonmagnetic tables with nonmagnetic 316 stainless steel
- Significantly less magnetic 304 stainless steel material available
- Optional Nonmagnetic aluminum wrought or cast ground & stress relieved plate facesheets with or without anodize
- Optional 3003 commercial grade aluminum honeycomb
- Optional 5052 or 5056 military grade aluminum honeycomb

Less Magnetic Table Tops

- Provide virtually nonmagnetic tables with nonmagnetic 31 stainless steel
- Significantly less magnetic 304 stainless steel material available
- Optional Nonmagnetic aluminum wrought or cast ground & stress relieved plate facesheets with or without anodize
- Optional 3003 commercial grade aluminum honeycomb
- Optional 5052 or 5056 military grade aluminum honeycomb

Custom Vibration Isolation Solutions

Cradle Systems

- Ideal way to isolate high center of gravity systems
- Wide variety of payload isolator selections
- Electropolished stainless steel, electrodeless nickel and other finishes available
- Finite element analysis and modal test services

Vibration Isolator Selection Guide

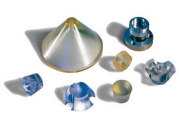
Newport's broad offering of vibration isolation solutions includes active, passive, and elastomeric Vibration Isolators. Our S-2000 series pneumatic vibration isolator is the industry standard for vibration isolator performance and our broad offering of OEM vibration isolators are preferred by the world's leading semiconductor equipment, microscope and diagnostic instrument manufacturers. Our elastomeric vibration isolator solutions are preferred by the leading photovoltaic (PV) system integrators and metrology instrument manufacturers for their excellent balance of high load capacity, damping and vibration isolation performance.

We provide three application types for S-2000 Stabilizer™ Series vibration isolators: standard, cleanroom and non-magnetic to suit your various needs. With hybrid chamber design and laminar flow disks, the S-2000 vibration isolator provides you with industry leading vibration isolation performance, and is currently the one and only vibration isolator in the market that has an integrated, mechanical height adjustment system to allow improved table leveling, height control and compensation for non-level floors. For all S-2000 series vibration isolators we have also integrated built-in leveling indicators providing visual feedback ensuring the table is properly floating at the correct level.

Among our broad offerings of pneumatic vibration isolators there are economic LabLegs™ Air Mount Vibration Isolators and many others. Those vibration isolators use sealed air chamber to provide outstanding performance for your vibration isolation application.

Apart from pneumatic vibration isolator option, we provide mechanical, elastomeric vibration isolator and rigid table legs products.

Vibration Isolator Selection Guide

	Series	Resonant Frequency Vertical/Horizontal	Load Range (Per 4 Isolators)	Applications
	**S-2000 Stabilizer™ Series** Vibration Isolator with Automatic Re-Leveling, Standard Version	1 Hz / 1.5 Hz	660–8000 lb (300–3636 kg)	• High-resolution experiments and processes • Electro-optical experiments and systems • Interferometry, spectroscopy applications
	**S-2000 Stabilizer™ Series** Vibration Isolator with Automatic Re-Leveling, Cleanroom Version	1 Hz / 1.5 Hz	660–8000 lb (300–3636 kg)	• High-resolution experiments and processes • Electro-optical experiments and systems • Interferometry, spectroscopy applications
	**S-2000 Stabilizer™ Series** Vibration Isolator with Automatic Re-Leveling, Non-magnetic Version	1 Hz / 1.5 Hz	660–8000 lb (300–3636 kg)	• High-resolution experiments and processes • Electro-optical experiments and systems • Interferometry, spectroscopy applications
	**SL Series LabLegs™ Air Mount Vibration Isolators**	3.2 Hz / 1.5 Hz	600–4800 lb (300–2180 kg)	Experiments requiring lower levels of vibration isolation with total loads less than 4800 lbs on a four leg system
	**CM-225 Compact Pneumatic Vibration Isolator with Self-Leveling**	3.5 Hz / 3.5 Hz	50–225 lb (22–100 kg)	Very low profile requirements
	**SLM Series Compact Air Mount without Self Leveling**	3.5 Hz (Vertical)	100–19,200 lb (45–8727 kg)	Support equipment frames and breadboards
	**VIBe™ VIB320 Series Mechanical Vibration Isolators**	6.7 Hz / 6.3 Hz	8–720 lb (4–326 kg)	Ideal for isolating microscopes and other sensitive lab instruments
	**NewDamp™ Series Constant Natural Frequency Elastomeric Vibration Isolators**	9 Hz / 4 Hz	52–1800 lb (24–800 kg)	• Fast response, fast settling time • Excellent for moving loads
	**RL Series LabLegs™ Rigid Optical Table Supports**	55 Hz / 45 Hz	100–8000 lbs (45–3636 kg)	• Equipment requiring non-isolated, high rigidity platforms • Experiments requiring table to table beam pointing

Vibration Isolator Accessoris

	Series	Features
	Air Compression Systems & Accessories for Pneumatic Isolators	Air compressors and leveling valves for optical table system
	LabLegs™ Upgrade Kits	• Modular support bases • Interchangeable spacer bases of different heights allow convenient cost-effective ad justment of working surface height or retrofitting of caster.

Learn More About Newport Vibration Isolators

When you choose Newport Vibration Control solutions, you have chosen not only high quality and performance products, but also our committed product support. Newport's experienced support engineers will be glad to help you determine which product suits your needs. Simply call 877-227-8766, or contact us online to forward your feedback or questions.

S-2000 Stabilizer™

Pneumatic Isolators with Automatic Re-Leveling

Key Features

- **Hybrid chamber design maximizes isolation bandwidth and stability**
- **Laminar flow damping minimizes amplification at resonance**
- **Highly accurate leveling improves repositioning after disturbance**
- **Built in leveling indicators provide visual feedback ensuring the table is properly floating at the correct level.**
- **Cleanroom and non-magnetic versions available**

The S-2000 isolator incorporates many features of its highly successful predicessor the I-2000, including a patented self-centering pendulum design, laminar flow damping system and precision auto-leveling valves to deliver unmatched vibration isolation performance. Additionally, the new S-2000 design incorporates additional features and benefits including enhanced leveling indicators, recessed lifting channels and a significantly lower magnetic permeability design which greatly improves the ease of use, functionality and overall value for customers. The S-2000, with a 2000lb load capacity per isolator, is an ideal solution for isolating optical tables, large inspection equipment, heavy machinery and large area sub-floors. S-2000 isolators are availbale in standard, cleanroom and non-magnetic versions.

Exclusive laminar flow damping is the heart of the Stabilizer's unparalleled performance. Unlike single damping orifices, the Stabilizer employs thousands of tiny orifices, resulting in greater damping efficiency overall. Combined with the hybrid chamber design to minimize air volume between piston motion and damper airflow, the Stabilizer protects applications like no other.

Numerous performance advantages include:

- Faster settling time for large and small magnitude disturbance
- Aluminum casting construction provides low permiability for non magnetic applications. Non-magnetic versions are constructed from aluminum and 316 stainless steel

S-2000A isolator with Tie-Bar compatability.

Tie Bar System

- Lower natural frequency for superior protection against hard-to-control low frequencies below 5 Hz
- Minimized amplification at resonance, thereby maximizing the system's overall stability
- Built in leveling indicators provide visual feedback ensuring the table is properly floating at the correct level.
- Integrated mechanical height adjustment system allows improved table leveling and compensated for non-level floors without using shims or leveling putty

Installation is fast and easy with patented, self-centering pistons. They automatically center the piston at the top and bottom of its vertical stroke, guaranteeing unrestricted movement for optimal performance. SafeLock™ mounting brackets eliminate the need to precisely align isolators and table holes when attaching the isolator to the table. Mechanical height adjustment allows quick and easy table leveling and compensates for non-level floors. Built in leveling indicators provide visual feedback ensuring the table is properly floating at the correct level.

The S-2000 series is available in three versions, the S-2000A, S-2000AC and S-2000AN. The S-2000A version is the standard isolator with leveling valves. The S-2000AC is a cleanroom isolator with leveling valves and the S-2000AN is a non-magnetic version with leveling valves constructed from aluminum and non-magnetic 316 stainless steel.

Specifications

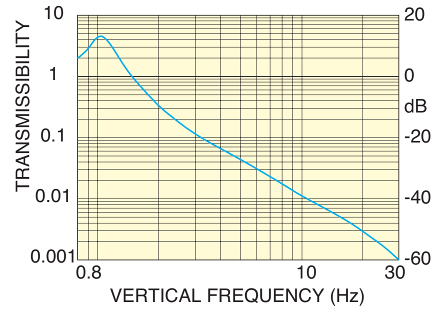
Isolation Specifications

Because of the large size and weight of the total table systems,

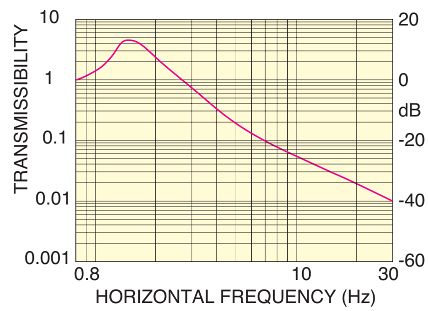
Model	Vertical Isolation*			Horizontal Isolation*			Amplification at Resonance				
	Res (Hz)	5Hz (%)	10Hz (%)	Res (Hz)	5Hz (%)	10Hz (%)	Vert (dB)	Horz (dB)	Damping Element Airflow	Horz. Damping	Load per Isolator [lb (kg)]
S-2000A Series	1	94	98	1.5	85	95	10	9	Normal	Oil	2000 (900)
S-2000AC Series	1	94	98	1.5	85	95	10	9	Normal	Oil	2000 (900)
S-2000-AN Series	1	94	98	1.5	85	95	10	9	Normal	Oil	2000 (900)

*Isolation at full load

Vertical



Horizontal



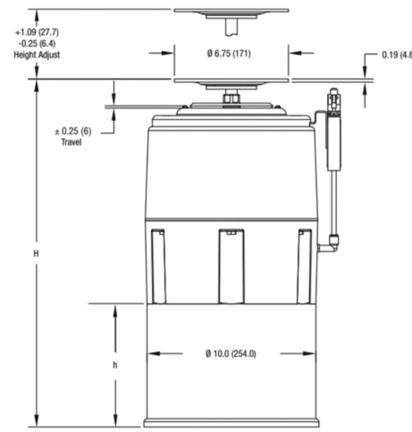
S-2000-AC Cleanroom version

S-2000AN Non-magnetic version constructed from aluminum castings and 316 series non-magnetic stainless steel.

Vibration Isolator Accessories

Physical Specifications

Height [in. (mm)]	16 (406), 19.5 (495), 22 (559), 23.5 (597), 28 (711)
Height Adjustment [in. (mm)]	1.3 (33)
Valve	IPV-S1
Re-leveling Accuracy [in. (mm)]	±0.010 (±.250)
Settling Time	1.5 sec. (typical)
Max. Air Pressure [psi (kg/cm2)] (1.4-6.0)	20–85 (1.4 - 6.0)
Self Centering	YES
Floating height indicator	YES



Other heights available upon request

Order Information

Isolator Ordering Options

Model	Number of Isolators	Load Capacity[lb (kg)]
S-2000A-4H, S-2000-AC-4H, S-2000-AN-4H	4	660 (330)–8000 (3600)
S-2000A-6H, S-2000-AC-6H, S-2000-AN-6H	6	990 (500)–12000 (5400)
S-2000A-8H, S-2000-AC-8H, S-2000-AN-8H	8	1320 (660)–16000 (7200)

	Dimensions	[in. (mm)]
Model	**H**	**h**
S-2000A-N16, S-2000-AC-N16, S-2000-AN-N16	16.0 (406)	3.8 (96.5)
S-2000A-N19.5, S-2000-ACN19.5, S-2000-AN-N19.5	19.5 (495)	7.3 (185.4)
S-2000A-N22, S-2000-AC-N22, S-2000-AN-N22	22.0 (559)	9.8 (248.9)
S-2000A-N23.5, S-2000-ACN23.5, S-2000-AN-N23.5	23.5 (597)	11.3 (287.0)
S-2000A-N28, S-2000-AC-N28, S-2000-AN-N28	28.0 (711)	15.8 (401.3)

Other heights available upon request

Order using this general format:

Example: S-2000A-428 designates a system with four 28 in. isolators and leveling valves. To add a tiebar caster system for a 4 ft x 8 ft table, add -TC after the Model number and order tie-bars and/or casters as below:

1) S-2000A-428-TC

2) TBC-48

S-2000XX-NH

Isolator type:
A - Automatic Leveling
AC - Automatic Leveling Cleanroom
AN - Automatic leveling non-magnetic

Isolator height (inches)
16
19.5
22
23.5
28

Number of Isolators per set
1
4
6
8

S-2000A Series (Standard version with leveling valves)

Model (Metric)	Description
S-2000A-116	One S-2000 Series 16 in. tall, standard isolator with automatic leveling
S-2000A-119.5	One S-2000 Series 19.5 in. tall, standard isolator with automatic leveling
S-2000A-122	One S-2000 Series 22 in. tall, standard isolator with automatic leveling
S-2000A-123.5	One S-2000 Series 23.5 in. tall, standard isolator with automatic leveling
S-2000A-128	One S-2000 Series 28 in. tall, standard isolator with automatic leveling
S-2000A-416	Set of four S-2000 Series 16 in. tall, standard isolators, automatic leveling
S-2000A-419.5	Set of four S-2000 Series 19.5 in. tall, standard isolators, automatic leveling
S-2000A-422	Set of four S-2000 Series 22 in. tall, standard isolators, automatic leveling
S-2000A-423.5	Set of four S-2000 Series 23.5 in. tall, standard isolators, automatic leveling
S-2000A-428	Set of Four S-2000 Series 28 inch Standard Isolators With Automatic Leveling
S-2000A-616	Set of six S-2000 Series 16 in. tall, standard isolators with automatic leveling
S-2000A-619.5	Set of six S-2000 Series 19.5 in. tall, standard isolators, automatic leveling
S-2000A-622	Set of six S-2000 Series 22 in. tall, standard isolators with automatic leveling
S-2000A-623.5	Set of six S-2000 Series 23.5 in. tall, standard isolators, automatic leveling
S-2000A-628	Set of six S-2000 Series 28 in. tall, standard isolators with automatic leveling
S-2000A-816	Set of eight S-2000 Series 16 in. tall, standard isolators, automatic leveling
S-2000A-819.5	Set of eight S-2000 Series 19.5 in. tall, standard isolators, automatic leveling
S-2000A-822	Set of eight S-2000 Series 22 in. tall, standard isolators, automatic leveling
S-2000A-823.5	Set of eight S-2000 Series 23.5 in. tall, standard isolators, automatic leveling
S-2000A-828	Set of Eight S-2000 Series 28 inch Standard Isolators With Automatic Leveling
S-2000A-119.5-TC	One S-2000 Series 19.5 in. tall, standard isolator with automatic leveling and tie-bar option
S-2000A-122-TC	One S-2000 Series 22 in. tall, standard isolator with automatic leveling and tie-bar option
S-2000A-123.5-TC	One S-2000 Series 23.5 in. tall, standard isolator with automatic leveling and tie-bar option
S-2000A-128-TC	One S-2000 Series 28 in. tall, standard isolator with automatic leveling and tie-bar option
S-2000A-419.5-TC	Four S-2000 Series 19.5 in. tall, standard isolator with automatic leveling and tie-bar option
S-2000A-422-TC	Four S-2000 Series 22 in. tall, standard isolator with automatic leveling and tie-bar option
S-2000A-423.5-TC	Four S-2000 Series 23.5 in. tall, standard isolator with automatic leveling and tie-bar option
S-2000A-428-TC	Four S-2000 Series 28 in. tall, standard isolator with automatic leveling and tie-bar option

S-2000AC Series (Cleaning version with leveling valves)

S-2000AC-116	One S-2000 Series 16 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-119.5	One S-2000 Series 19.5 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-122	One S-2000 Series 22 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-123.5	One S-2000 Series 23.5 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-128	One S-2000 Series 28 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-416	Set of four S-2000 Series 16 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-419.5	Set of four S-2000 Series 19.5 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-422	Set of four S-2000 Series 22 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-423.5	Set of four S-2000 Series 23.5 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-428	Set of four S-2000 Series 28 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-616	Set of six S-2000 Series 16 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-619.5	Set of six S-2000 Series 19.5 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-622	Set of six S-2000 Series 22 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-623.5	Set of six S-2000 Series 23.5 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-628	Set of six S-2000 Series 28 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-816	Set of eight S-2000 Series 16 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-819.5	Set of eight S-2000 Series 19.5 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-822	Set of eight S-2000 Series 22 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-823.5	Set of eight S-2000 Series 23.5 in. tall, cleanroom compatible isolators with automatic leveling
S-2000AC-828	Set of eight S-2000 Series 28 in. tall, cleanroom compatible isolators with automatic level

S-2000AN Series (Non-magnetic version with leveling valves)

S-2000AN-116	One S-2000 Series 16 in. tall, non-magnetic isolator with automatic leveling
S-2000AN-119.5	One S-2000 Series 19.5 in. tall, non-magnetic isolator with automatic leveling
S-2000AN-122	One S-2000 Series 22 in. tall, non-magnetic isolator with automatic leveling
S-2000AN-123.5	One S-2000 Series 23.5 in. tall, non-magnetic isolator with automatic leveling
S-2000AN-128	One S-2000 Series 28 in. tall, non-magnetic isolator with automatic leveling
S-2000AN-416	Set of four S-2000 Series 16 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-419.5	Set of four S-2000 Series 19.5 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-422	Set of four S-2000 Series 22 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-423.5	Set of four S-2000 Series 23.5 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-428	Set of four S-2000 Series 28 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-616	Set of six S-2000 Series 16 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-619.5	Set of six S-2000 Series 19.5 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-622	Set of six S-2000 Series 22 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-623.5	Set of six S-2000 Series 23.5 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-628	Set of six S-2000 Series 28 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-816	Set of eight S-2000 Series 16 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-819.5	Set of eight S-2000 Series 19.5 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-822	Set of eight S-2000 Series 22 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-823.5	Set of eight S-2000 Series 23.5 in. tall, non-magnetic isolators with automatic leveling
S-2000AN-828	Set of eight S-2000 Series 28 in. tall, non-magnetic isolators with automatic leveling

Tie-Bar/Caster System Options

Standard tie-bar/caster systems are available for the table sizes listed below. Select from the Model numbers below to add a standard load tie-bar system — with or without casters — to your table. For other table sizes, please contact Newport for price and delivery.

Tie Bars with Casters

Tables [ft. (m)	Model (Metric)
4 (1.2) x 6 (1.8)	TBC-46 (M-TBC-46)
4 (1.2) x 8 (2.4)	TBC-48 (M-TBC-48)
4 (1.2) x 10 (3.0)	TBC-410 (M-TBC-410)
4 (1.2) x 12 (3.6)	TBC-412 (M-TBC-412)
5 (1.5) x 6 (1.8)	TBC-56 (M-TBC-56)
5 (1.5) x 8 (2.4)	TBC-58 (M-TBC-58)
5 (1.5) x 10 (3.0)	TBC-510 (M-TBC-510)
5 (1.5) x 12 (3.6)	TBC-512 (M-TBC-512)

Tie Bars only

Tables [ft. (m)]	Model (Metric)
4 (1.2) x 6 (1.8)	TB-46 (M-TB-46)
4 (1.2) x 8 (2.4)	TB-48 (M-TB-48)
4 (1.2) x 10 (3.0)	TB-410 (M-TB-410)
4 (1.2) x 12 (3.6)	TB-412 (M-TB-412)
5 (1.5) x 6 (1.8)	TB-56 (M-TB-56)
5 (1.5) x 8 (2.4)	TBC-58 (M-TBC-58)
5 (1.5) x 10 (3.0)	TB-510 (M-TB-510)
5 (1.5) x 12 (3.6)	TB-512 (M-TB-512)

Newport Optical Bench Isolation Systems - The Most Effective Vibration Filtering Available

Overview

Newport invented the Stabilizer™ isolator and introduced a new level of vibration isolation to the scientific industry. The Stabilizer™ features Newport's proprietary hybrid chamber and laminar flow damping system to provide isolation from even the lowest amplitude vibrations. When used with extremely rigid tuned damped tables, Newport optical bench systems offer unmatched performance.

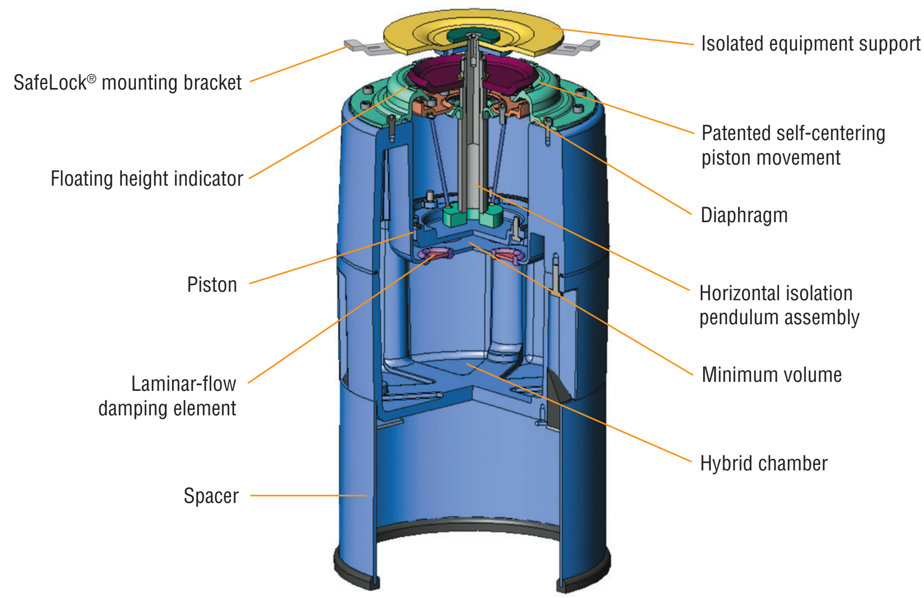


Figure 16: Section view of a Stabilizer S-2000 Isolator.

Pneumatic Isolators

Pneumatic isolators filter vibration before the mechanical noise can reach the optical bench work surface. Improved vibration isolation reduces errors caused by relative motion between optical components in the beam path. Pneumatic isolators combine with the optical table and payload to form a mass/spring/damper system. Pneumatic systems are used instead of mechanical springs, since they offer self-leveling and minimize the effect of varying mass on isolation. The isolator's performance is defined by its natural frequency and damping characteristics:

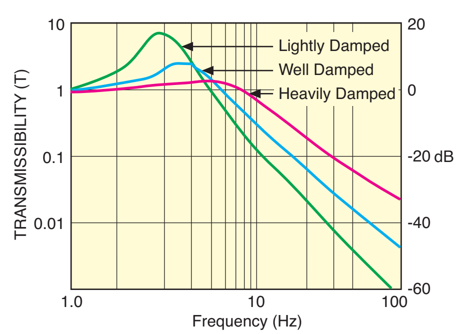


Figure 17: Transmissibility plot shows damping effects.

- **Natural Frequency** (Natural Mode, Resonance) - The pneumatic isolator is essentially a simple harmonic oscillator that uses the "fast roll-off" at higher frequencies to act as a low pass mechanical filter. Below the natural frequency of the harmonic oscillator, the isolator is essentially rigid and vibration is passed directly to the platform. At the natural frequency, vibration is actually amplified. Taking these into consideration, a primary goal is to lower the natural frequency, since this improves low frequency isolation and overall isolation bandwidth.

- **Damping** - Another primary goal is to damp the harmonic oscillator amplitude at resonance. This lowers the magnification of vibration at low frequencies and improves system stability. Unfortunately, there is a compromise between the natural frequency and damping. As damping is increased, the isolator's natural frequency moves slightly higher, and higher frequency isolation is decreased.

Conventional Isolators

Conventional isolators use a compliance chamber to act as an air spring and a damping chamber to increase system stability. The two chambers are connected through a thin tube or orifice.

- **Compliance Chamber** - The compliance chamber is sealed with a flexible diaphragm to form a piston and support the optical table on compressed air. If the piston is pushed further into the compliance chamber, the pressure of the gas increases and provides a restoring force - somewhat like a soft spring. The isolation performance is primarily related to the volume of the compliance chamber. As the compliance chamber volume is increased, the natural frequency is decreased.

- **Damping Chamber** - After the compliance chamber, air is pumped to the damping chamber through a flow restrictor - usually a thin tube or orifice. The flow restrictor dissipates energy into the air and essentially damps the system. The design of both chambers and the restrictor must be optimized to minimize the natural frequency/damping trade-off. When added together, the volume of these chambers is relatively large and unresponsive because of the amount of air that must pass between them.

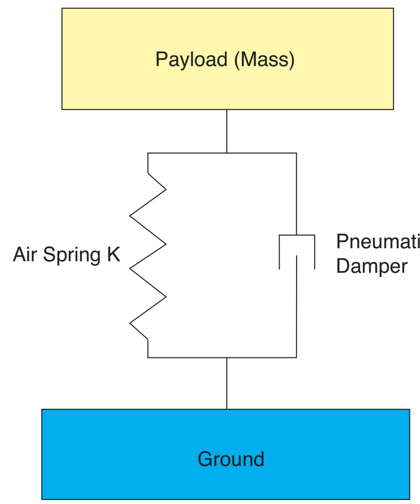


Figure 18

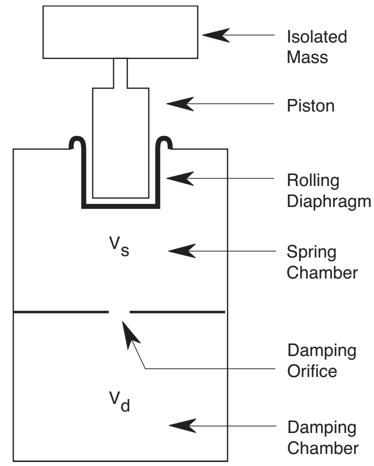


Figure 19: A conventional pneumatic isolator with damping.

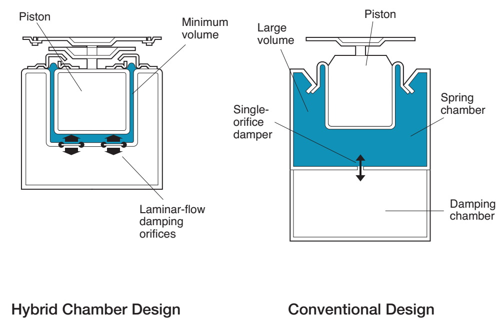


Figure 20: Damping chamber

Damping efficiency is proportional to the air flow and pressure drop through the damper. As the hybrid-chamber design minimizes air volume between the piston and damper, there is a better linkage between piston motion and damper air flow. This generates a higher damping force for a given piston displacement for faster, more efficient damping of vertical motion.

Stabilizer™ Isolator Design

Newport's proprietary Stabilizer™ design offers an innovative and greatly improved approach to isolator design. The Stabilizer™ provides significantly more damping of the natural frequency amplitude from the closer coupling of the piston and damping element. The result is improved isolation and better stability, when compared to conventional isolators.

- **Hybrid Chamber** - The primary innovation of the Stabilizer isolator is the Hybrid chamber system. The hybrid chamber configuration maximizes damping efficiency by minimizing air volume between the piston and the damping elements. Rather than the conventional design that features two equivalently sized chambers, where the first volume is the compliance chamber and the second the damping chamber, the hybrid chamber uses the entire isolator volume for compliance. The initial chamber is reduced dramatically in size. This forces the isolator to use the second chamber as part of the compliance volume. The hybrid chamber offers much larger compliance volume for a given package size. The larger compliance volume lowers the frequency of the natural mode and improves isolation.

The natural frequency of a pneumatic isolator decreases as the compliance volume increases, thereby improving the isolation performance. The hybrid chamber design maximizes the compliance volume; Ultra-soft diaphragms reduce the stiffness limitation.

- **Laminar Flow Damping** - Connecting the hybrid chamber volume is a laminar flow element made of porous metal. The laminar flow element adds resistance to the airflow as it is forced between the hybrid chamber volumes. The resistance added to the airflow significantly damps the amplitude of the natural mode with minimal effect of the isolation bandwidth. The laminar flow element also improves isolator settling time and responsiveness. The airflow volume can be reduced in the factory to add higher levels of damping.

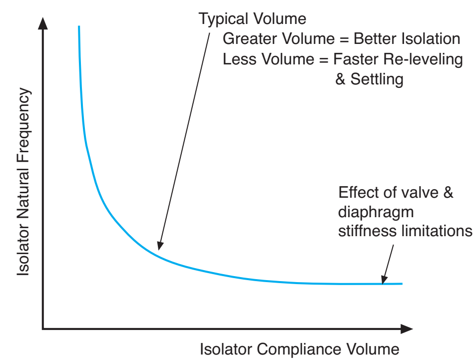


Figure 21: Isolator natural frequency vs. compliance chamber volume.

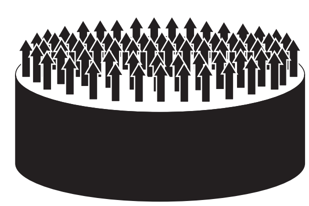


Figure 22: Laminar-flow damping orifice

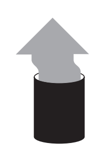


Figure 23: Ordinary single orifice

Damping efficiency is enhanced by a laminar flow damping orifice. Instead of a single orifice, the damper element design contains thousands of tiny orifices that help maintain laminar flow for excellent damping efficiency over a wide range of operating conditions.

- **Ultra-Soft Diaphragms** - One of the limitations on pneumatic systems is the diaphragm stiffness. The diaphragm's stiffness limits the isolation improvements when using a larger compliance volume. Newport uses custom molded ultra-soft diaphragms to maximize the benefits of the hybrid chamber design.

High Accuracy Leveling Valve Systems

The automatic re-leveling capabilities on our S-2000 pneumatic vibration isolators set them apart from other pneumatic isolation solutions by providing precise and fast re-leveling of the entire optical table system. IPV series leveling valves offer a wide variety of valve options including the most popular IPV-S1 coming standard with repeatability of ±0.010 in. (0.25 mm), as well as low gain versions for better higher frequency isolation and high gain version for shorter re-leveling time at a slight decrease in high frequency isolation. Newport also offers high-precision version for an improved re-leveling accuracy to better than ±0.002 in. Individual isolators do not include the leveling valve.

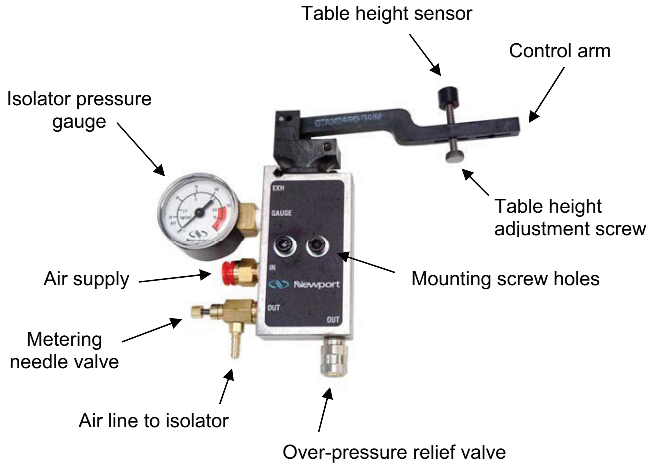


Figure 24: Newport valves are designed specifically for optical table systems.

- **Airflow Control Valves** - Newport provides needle valves to control the airflow from the leveling valve to the hybrid chamber. This system offers a much higher level of user control and allows the system response to be optimized for any specific optical table system.

- **EAR Lever Arm Connection** - Newport uses a specifically designed EAR damping material to connect the lever arm to the optical table. This material prevents high frequency vibrations from traveling through the arm to the table. Other manufacturers use common foam for this purpose. However, the foam increases releveling errors and degrades over time.

- **Pressure Gauges** - Pressure gauges are included on the leveling valves to monitor the pressure inside the isolator.

Very Low Amplitude Horizontal Isolation

The pneumatic isolator offers isolation in the vertical direction; horizontal isolation is achieved through a mechanical filter system. Many manufacturers use some form of a bearing surface to provide a pivot or rolling surface for vibration filtering. However, these contacting systems always have mechanical defects and surface roughness between the bearing surfaces. The bearing surface introduces frictional noise and limits the isolation of very low-level vibrations that commonly disturb high accuracy systems.

- **Trifilar Pendulum** - Newport uses a frictionless trifilar pendulum system for horizontal vibration isolation. The natural mode of the pendulum is very low in frequency, typically 1 to 2 Hz depending on the length of the pendulum. Above the natural frequency, the pendulum isolates vibration. Since the system operates by flexing, it offers no frictional resistance to motion and can isolate very low amplitude mechanical vibration.

● **Viscous Damping** - The natural frequency of the pendulum is damped using low vapor pressure oil. This system offers a significant decrease in the amplitude of the natural mode without adding higher frequency frictional noise.

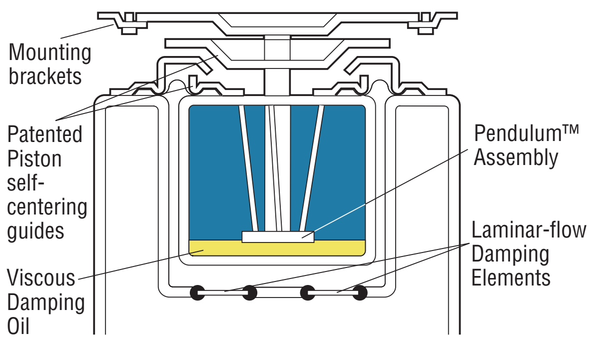


Figure 25: Diagram of Newport's patented horizontal isolation piston.

Superior Mechanical Design

Newport has refined our laboratory grade pneumatic isolator for many years and offers a variety of features not found in competing products.

● **Self-Centering** - (US Patent 5,071,108) - Only Newport offers a self-centering device to ensure unrestricted piston motion. This patented feature eliminates problems caused by shorting out the vibration isolator during table set-up.

● **Height Adjustment** - Apart from its superior isolation design, S-2000 pneumatic vibration isolators also features robust and user friendly mechanical design for better user experience. Newport is the only manufacturer that provides 1.3 inches of height adjustment compensation in the isolator to allow for easy leveling of the entire system or alignment of separate tables. Compared to competitor's solution of using shims or putty before installation, Newport's design brings ease to fine-tuning the isolator height.

● **Modular Support Bases** - our S-2000A optical table supports are built on modular support bases. Interchangeable spacer bases of different heights allow convenient cost-effective adjustment of working surface height or retrofitting of caster systems. Simply order LLS-S2000 series support bases to change your isolator to a new height. For example, if you currently have 28 in. legs and would like to change your leg height to 23.5 in., you would order LLS-S2000-423.5 to change 4 legs to 23.5 in. leg height.

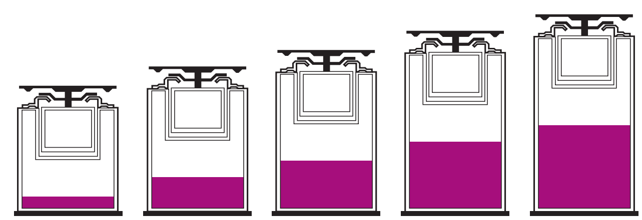


Figure 26: Interchangeable spacer bases of different heights permit convenient, cost-effective adjustment of working surface height or retrofitting of caster systems.

● **Freestanding Design** - Newport legs come standard without any mechanical connection between them. Freestanding legs are preferred for uneven floors, that are not level, and these legs produce better decoupling from vibrations. Tie-bar systems can introduce significant structural resonances in the 25–100 Hz frequency range. Newport only recommends tie-bar systems if the table will be moved frequently and requires a caster wheel system.

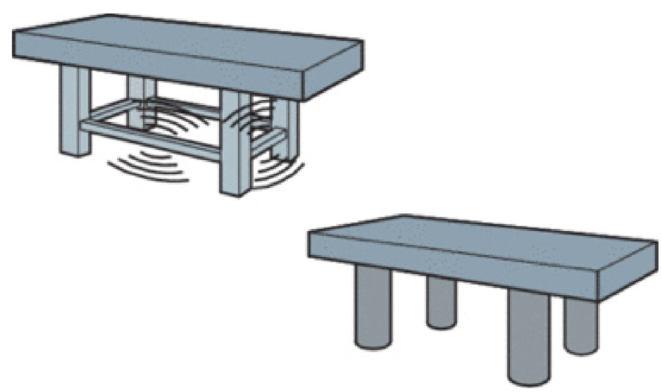


Figure 27: The tie-bars on ordinary tables can actually amplify floor vibrations.

- **S-2000 Isolator Safety Features and Accessories** - S-2000 pneumatic vibration isolators integrate our exclusive SafeLock™ optical table mounting clips to provide a safe and reliable connection of the isolator to the optical table. SafeLock™ mounting clips feature a slot for easy installation. Numerous SafeLock™ secured systems have survived earthquakes throughout California and Japan.

We also offer optical table earthquake restraints as a table accessory. Our earthquake restraints are designed to withstand the earthquake loads corresponding to, or lower than, the 2012 IBC seismic accelerations Ss=2.011, S1=0.786 (for example, Hayward, CA). The design of the Restraint is in compliance with 2012 International Building Code (IBC) and 2013 California Building Code (CBC).

Features	Benefits
Hybrid chamber design	Lowest natural frequency offers maximized isolation bandwidth Optimized damping capability Compact design is 30% smaller than conventional isolators Improved isolator responsiveness Improved high center of mass stability
Laminar flow damping	Less amplification at resonance Improved setting time Very little effect on isolation bandwidth Adjustable damping for special applications
Ultra-soft diaphragms	Improved low frequency isolation Improved isolation of low amplitude vibrations
High accuracy leveling valves	More accurate leveling of table Improved repositioning of table after disturbance Allows table-to-table beam pointing applications
Airflow control valves	Allows optimization of pneumatic control
EAR gain arm interface	Decouples sensor arm vibration from table Better leveling accuracy Does not degrade like foam pads
Trifilar pendulum horizontal isolation	Zero-friction design enables isolation to much lower vibration levels Improved re-positioning after table disturbances
Self-centering	Ensures isolator alignment Eliminates horizontal shorting
Height adjustment	Adaptable to uneven floors Allows alignment of separate tables
Modular support bases	Allows system height to be field modified Allows field integration of tie-bar caster system
Free standing design	Better isolation performance Eliminates structural resonances found on tie-bar systems Adaptable to uneven floors

Air Compression Systems & Accessories for Pneumatic Isolators

ACGP

Key Features

- **Clean, compressed air**
- **Quiet operation - just 30 dB(A) at 1 ft.**
- **Super-precise vertical adjustment down to better than ±0.010 in. (0.25 mm)**
- **ARF air filter regulator removes contaminants from the air and guarantees maintenance free operation**

Model ACGP Silent Air Compressor is ultra quiet (just 30 dB(A) at 1 ft), clean, portable and more convenient than bottled air supplies. The ACGP will supply air to any Newport pneumatic isolator, optical table system or workstation. The supply tanks are large enough to run multiple workstations or table systems simultaneously.

The ACWS Silent Air Compressor is clean, ultra quiet (30dB(A) at 1 ft.), portable, and more convenient than bottled air supplies. The fast filling and economical ACWS can supply air to any workstation or OTS system. The supply tank is large enough to run multiple workstations. The compressor operates intermittently based on air usage; monitored by a sensor that maintains the reserve tank's preset minimum pressure. All required hardware—safety valve, gauges, outlet cocks, fittings and drain—comes standard. Even a high-grade air filter/ regulator is included. There's nothing more to purchase.

ACWS

ARF

IPV Series Isolation Pressure Valve

Specifications

	ACCP	ACWS
Operating Sound Level (1ft) (dB)	30	30
Release Value Sound Level (dB)	62	62
Flow Rate (20–80 psi) [CFM(dm^3/mm)]	0.80 (22.7) – 0.68 (19.3)	0.68 (19.3)
Tank Capacity (liters)	3.5	1.0
Max. Air Pressure [psi (kg/cm^2)]	100 (7.0)	87 (6.17)
Weight (kg)	37 (17)	32 (16)
Regulator Filter	Yes	Yes
Air Intake Filter	Yes	Yes
Automatic Turn Off Switch	Yes	Yes
Leveling Valve Options		
IPV-S1 IPV-S2	Standard IPV	Best compromise of isolation and response Standard IPV without pressure gauge
IPV-HG1 IPV-HG2	High Gain IPV	Faster recovery, reduced high frequency isolation HG without pressure gauge
IPV-LG1 IPV-LG2	Low Gain IPV	Better high frequency isolation, slower recovery LG without pressure gauge
IPV-HP1 IPV-HP2	High-Precision IPV	Increased releveling accuracy (±0.002 in.) HP without pressure gauge

Model (Metric)	Descriptioin
ACGP	Air Compressor, Low Noise. 110V
ACGP-02	Air Compressor, Low Noise, 220V
ACWS	Air Compressor, Low Noise. 110V
ACWS-02	Air Compressor, Low Noise. 220V
ARF	Air Regulator and Filter, 0 to 120 psi
IPV-HG1	High Gain Leveling Valve, Guage, Faster Recovery, Reduced High Freq. Isolation
IPV-HG1-KT	High Gain Leveling Valves, Pressure Guage, 3 Valve Kit
IPV-HG2	High Gain Leveling Valve, No Guage, Faster Recovery, Reduced High Freq Isolation
IPV-HG2-KT	High Gain Leveling Valves, No Pressure Guage, 3 Valve Kit
IPV-HP1	High Precision Leveling Valve, Pressure Guage, ±0.002 inch Releveling Accuracy
IPV-HP1-KT	High Precision Leveling Valves, Pressure Guage, 3 Valve Kit
IPV-HP2	High Precision Leveling Valve, No Pressure Guage, ±0.002in Releveling Accuracy
IPV-HP2-KT	High Precision Leveling Valves No Pressure Guage, 3 Valve Kit
IPV-LG1	Low Gain Leveling Valve, Inc Guage, Better High Freq. Isolation, Slower Recovery
IPV-LG1-KT	Low Gain Leveling Valves, No Pressure Guage, 3 Valve Kit
IPV-LG2	Low Gain Leveling Valve, No Guage, Better High Freq Isolation, Slower Recovery
IPV-LG2-KT	Low Gain Leveling Valves No Pressure Guage, 3 Valve Kit
IPV-S1	Standard Leveling Valve, Pressure Guage, Best Compromise of Isolation & Response
IPV-S1-KT	Standard Leveling Valve, Pressure Guage, 3 Valve Kit
IPV-S2	Standard Leveling Valve, No Guage, Best Compromise of Isolation & Response
IPV-S2-KT	Standard Leveling Valves, No Pressure Guage, 3 Valves Kit

SL Air Mount Isolators

SL Series LabLegs™

Key Features

- **Will not bottom out like conventional air mounts**
- **No air lines or supply required**
- **No filters or gauges needed**

SL Series LabLegs™ Vibration Isolators offer vibration isolation at a very affordable price. The isolators remove floor vibrations in the 10 Hz to 50 Hz range and support a wide variety of less rigorous research and production applications. A foot operated air pump is included.

Specifications

Isolation Specifications

	Vertical Isolation*		Horizontal Isolation*		Amplification at Resonance		Load per Isolator [lb (kg)]
Model	Res (Hz)	10Hz (%)	Res (Hz)	10Hz (%)	Vert (dB)	Horz (dB)	
S-600 Series	3.5	86	1.5	98	9	13	600 (275)
S-1200 Series	3.2	86	1.5	98	9	13	1200 (500)

*Isolation at full load

Physical Specifications

Height [in. (mm)]	10 (254), 13.5 (343), 16 (406), 19.5 (495), 22 (559), 23.5 (597), 28 (711)
Air Valve	Schrader
Foot Pump	Included
Max. Air Pressure (kg/cm2)	6

Ordering Information

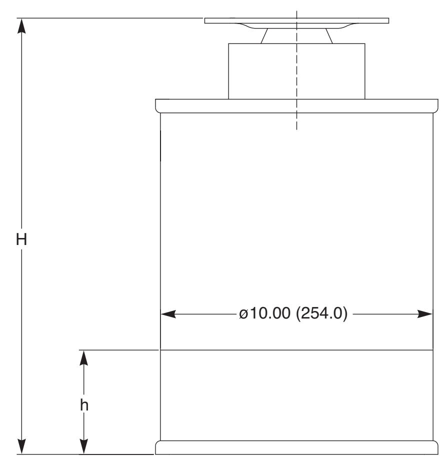
SL-1200-NH

Number of Isolators per set — Isolator height (inches)

Example: SL-1200-428 designates a system with four 28 in. isolators. To add a tiebar caster system for a 4 ft x 8 ft table, add -TC after the Model number and order tie-bars and/or casters as below:

1) SL-1200-428TC

2) TBC-48



Dimensions [in. (mm)]

Model	H	h
SL-600-N10	10.0 (254)	N/A
SL-600-N13.5	13.5 (343)	1.7 (43.2)
SL-600-N16	16.0 (406)	3.8 (96.5)
SL-600-N19.5	19.5 (495)	7.3 (185.4)
SL-600-N23.5	23.5 (597)	11.3 (287.0)
SL-600-N28	28.0 (711)	15.8 (401.3)
SL-1200-N10	10.0 (254)	N/A
SL-1200-N13.5	13.5 (343)	1.7 (43.2)
SL-1200-N16	16.0 (406)	3.8 (96.5)
SL-1200-N19.5	19.5 (495)	7.3 (185.4)
SL-1200-N22	22.0 (559)	9.8 (248.9)
SL-1200-N23.5	23.5 (597)	11.3 (287.0)
SL-1200-N28	28.0 (711)	15.8 (401.3)

Other heights are available upon request.

Non-Isolating Rigid Legs

RL Series LabLegs™

Key Features

- High Load Rigid Construction
- Rigid construction eliminates low frequency support resonance
- High horizontal stability
- Retrofit tie-bar caster systems

RL Series Non-Isolating LabLegs™ vibration isolators offer rigid support where vibration isolation is not required. Unlike cross member support systems, the freestanding design does not amplify low frequency floor vibrations. The height adjustable RL Series is an excellent choice for off table target pointing applications.

Specifications

Isolation Specifications

Model	Vertical Resonance (Hz)	Horizontal Resonance (Hz)	Load per Isoator [lb (kg)]
S-2000 Series	55	45	2000 (900)

Ordering Information

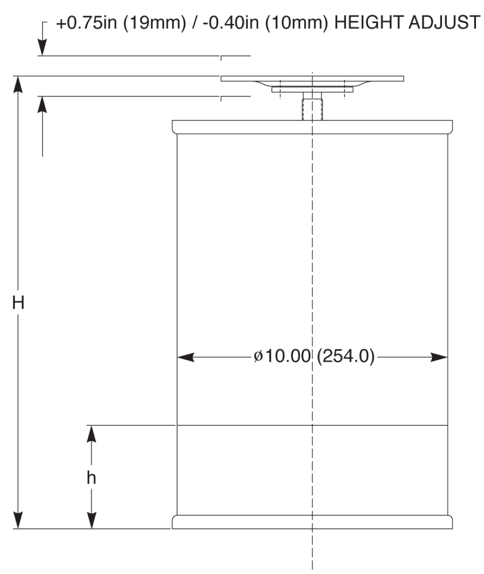
SL-2000-NH

Number of Isolators per set — Isolator height (inches)

Example: RL-2000-428 designates a system with four 28 in. isolators. To add a tiebar caster system for a 4 ft x 8 ft table, add TC after the Model number and order tie-bars and/or casters as below:

1) RL-2000-428TC
2) TBC-48

RL Series



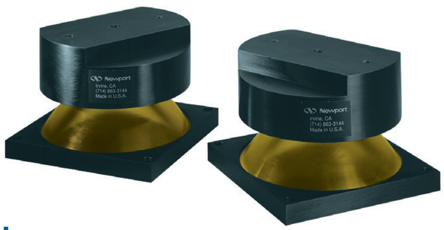
Dimensions [in. (mm)]

Model	H	h
RL-2000-N10	10.0 (254)	N/A
RL-2000-N13.5	13.5 (343)	1.7 (43.2)
RL-2000-N16	16.0 (406)	3.8 (96.5)
RL-2000-N19.5	19.5 (495)	7.3 (185.4)
RL-2000-N22	22.0 (559)	9.8 (248.9)
RL-2000-N23.5	23.5 (597)	11.3 (287.0)
RL-2000-N28	28.0 (711)	15.8 (401.3)

Other heights are available upon request

Technical Note

NewDamp™ Elastomers



Overview

Newport's NewDamp Elastomer products offer a great alternative to pneumatic, air spring and other isolation mount technologies. Available in a variety of standard and custom designs, these mounts do not require electronic circuitry, air hoses or supporting hardware. NewDamp is an excellent value for applications that do not require the wider, low frequency isolation bandwidth of pneumatic or active isolation systems.

NewDamp Elastomers exhibit far higher damping than standard commercial elastomers and are cleanroom compatible. The high damping provides excellent structural stability and short settling time for high throughput machinery. Many NewDamp products offer Constant Natural Frequency (CNF) during load changes to further improve system performance.

Standard interfaces are available to integrate NewDamp products with breadboard and optical table grid arrays, Newport's Microlock™ Breadboard Mounting Systems and Newport's X95 Profiled Rail Systems. Interfaces are also available for use with Newport VH and LW Workstations. Custom OEM designs can be tuned to specific machinery needs.

Super High Damping Material

NewDamp products exhibit a remarkably high damping with loss factors around 0.5 to 0.8 at room temperatures in the 10–100 Hz frequency range — this is two to five times better than other commercial elastomers. The high damping factor makes them ideal for supporting and damping the high acceleration amplitudes produced by very high throughput stages used in wafer positioning and electronic manufacturing applications. NewDamp elastomers can be built into equipment isolation supports and even custom machinery feet.

Cleanroom Compatible

NewDamp is made from a highly engineered polyurethane U-16 compound that is fully cleanroom compatible. These products have been used in Class 100 Fabs to support wafer inspection and positioning systems. NewDamp polymers meet NASA spacecraft use outgassing requirements with a Total Mass Loss (TML) of only 0.72%; and Collected Volatile Condensable Material (CVCM) of only 0.01% (testing per the American Society of Testing and Materials standard E-595-77/84/90).

CNF Designs

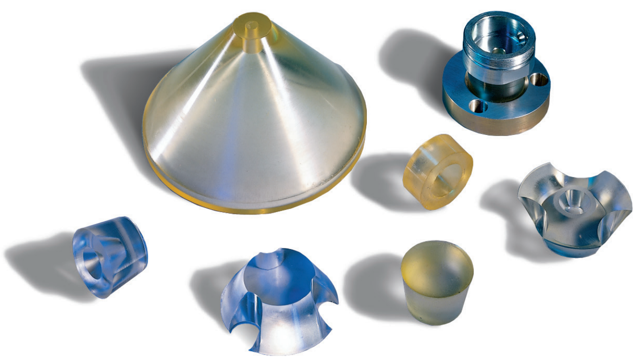
CNF (Constant Natural Frequency) is a complex property that reduces sensitivity to load deviations and offers a high degree of modal decoupling. The natural frequency of most elastomeric mounts lowers with increasing mass or increases with decreasing mass. This means that the vibration isolation characteristics will vary with load. NewDamp CNF products use special geometry profiled elastomers and mounting fixtures. These isolators accommodate changes in load with changes in stiffness — thus the stiffness to mass ratio is held constant. As a result, the CNF isolators deliver much better isolation than even softer conventional isolators do.

Custom Design Capabilities

NewDamp Elastomers are available as elastic elements, to be incorporated into the customer's vibration isolation system, with Newport standard interfaces (Microlock; X95; breadboard) as standard vibration isolators, and with Newport custom interface plates, as custom vibration isolators. Moreover, the Newport vibration control engineering group has developed proprietary software and test systems to customize elastomers for specific machinery needs. Once provided with primary machinery characteristics such as load, shock response, and resonance modes, Newport can develop a tuned solution. First articles can be produced quickly in our rapid prototype shops. Contact Newport Custom Products Group for your complete solution.

NewDamp™ Series

Constant Natural Frequency Elastomeric Isolators



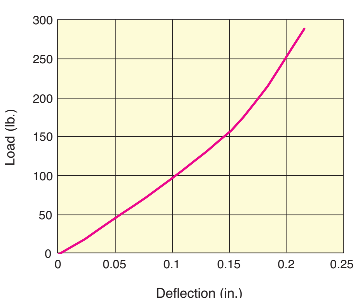
NewDamp™ ND01 Series

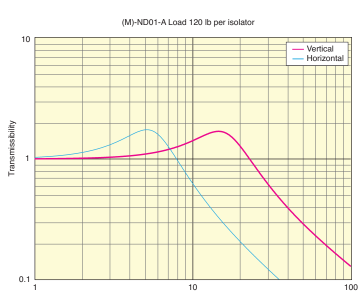
ND01-A supports up to 250 lbs. and provides excellent CNF (constant natural frequency) characteristics: the vertical natural frequency is virtually constant at approximately 22 Hz for loads above 70 lbs. per isolator. This compact size isolator ensures excellent horizontal isolation with natural frequencies of 5 to 7 Hz and minimum resonance amplification. The typical isolation characteristics are shown.

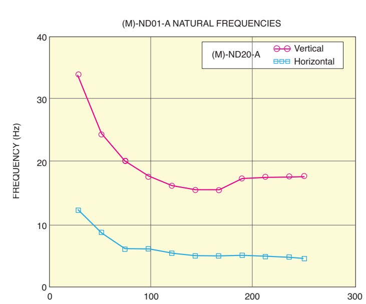
Specifications

Model	Load per Isolator [lb (kg)]	Load Range (set of 4) [lb (kg)]	Natural Frequency Hz, Vertical	Natural Frequency Hz, Horizontal	Height, Isolator [in. (cm)]	Base Dimension [in. (cm)]	Interface Compatability
ND01-A (M-ND01-A)	70 (30)–250 (115)	280 (120)–1000 (460)	15–21	4.5–7	1.36 (3.5)	2.5 x 1.5 (6.4 x 3.8)	Breadboard, Microlock
ND20-A (M-ND20-A)	45 (20)–250 (115)	180 (80)–1000 (460)	6–16	4.5–11	3.28 (8.3)	4.5 x 4.5 (11.4 x 11.4)	Breadboard, Microlock
ND30-A (M-ND30-A)	70 (30)–300 (135)	280 (120)–1200 (540)	6.4–14	4.5–9.5	3.28 (8.3)	4.5 x 4.5 (11.4 x 11.4)	Breadboard, Microlock
ND41-A (M-ND41-A)	70 (30)–225 (100)	280 (120)–900 (400)	9–22	2.5–8	2.25 (5.7)	3.0 x 3.0 (7.6 x 7.6)	Breadboard, Microlock X95 Rail
ND41-B (M-ND41-B)	70 (30)–225 (100)	280 (120)–900 (400)	9–22	2.5–8	2.25 (5.7)	2.5 x 2.5 (6.4 x 6.4)	Breadboard, Microlock
ND40-A (M-ND40-A)	100 (45)–450 (200)	400 (180)–1800 (800)	10–23	3–7	2.63 (6.7)	3.0 x 3.0 (7.6 x 7.6)	Breadboard, Microlock X95 Rail
ND50-A (M-ND50-A)	17 (8)–28 (13)	68 (32)–112 (50)	8-12	7.5–11	1.3 (3.3)	2.4 x 2.4 (6.4 x 6.4)	Breadboard, Microlock
ND60-A (M-ND60-A)	13 (6)–17 (8)	52 (24)–68 (32)	9.5–18	10–16	1.3 (3.3)	2.4 x 2.4 (6.4 x 6.4)	Breadboard, Microlock (universal mounting plate)

NewDamp™ ND01





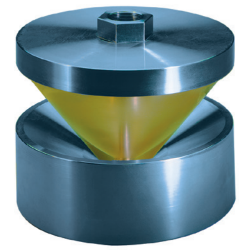


ND01-A NewDamp elastomere isolator

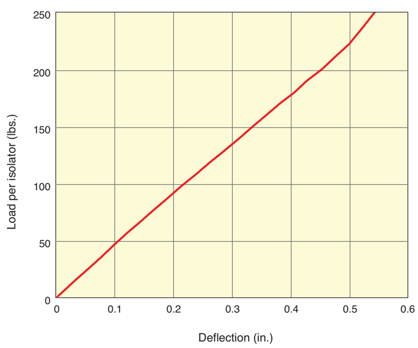
NewDamp™ Series

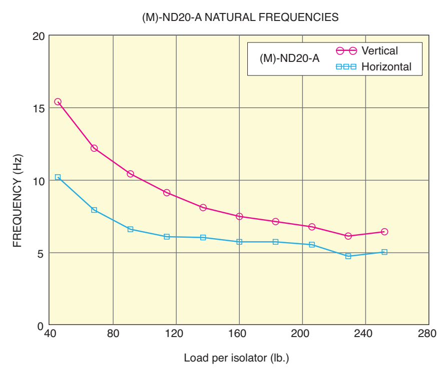
ND20 Series

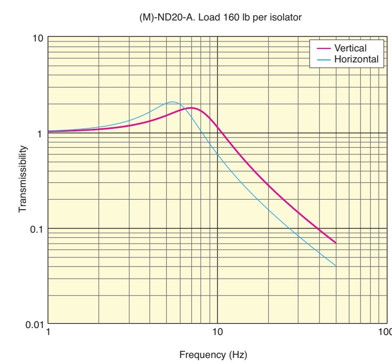
These isolators are based on conical elastic elements. They provide almost equal isolation in vertical and horizontal directions. Within the same design envelope, they provide stiffer, higher load (ND30-A); and softer, lower load (ND20-A) options. By using custom profiled upper supports, these isolators can be easily tuned to particular load/frequency requirements.



Customized ND20 NewDamp™ Elastomeric Isolator.

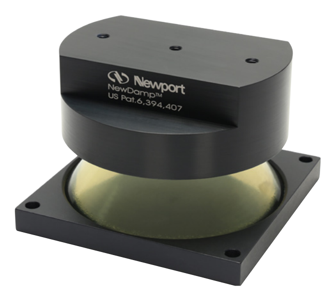


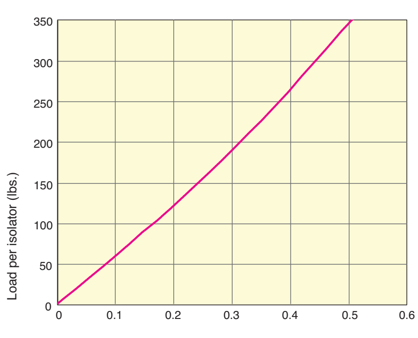


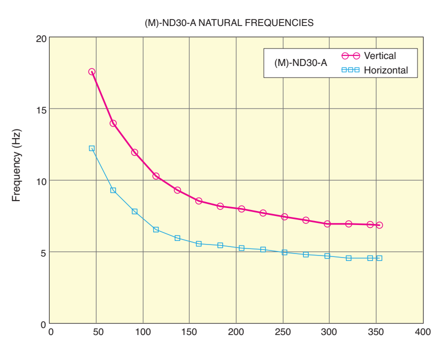


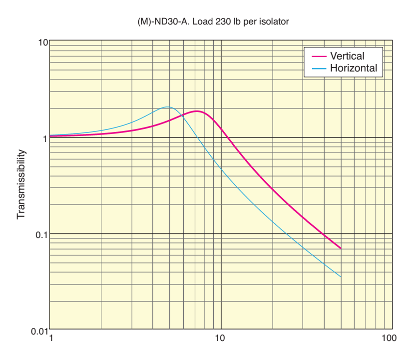
ND30 Series

These isolators are based on conical elastic elements. They provide almost equal isolation in vertical and horizontal directions. Within the same design envelope, they provide stiffer, higher load (ND30-A); and softer, lower load (ND20-A) options. By using custom profiled upper supports, these isolators can be easily tuned to particular load/frequency requirements.





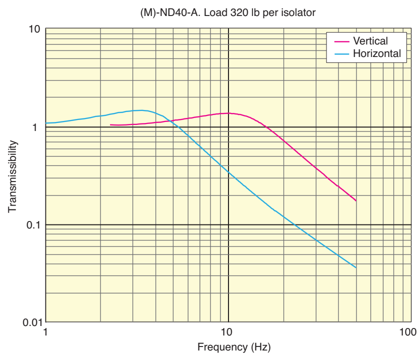


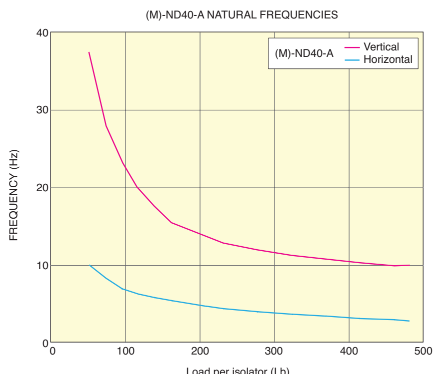


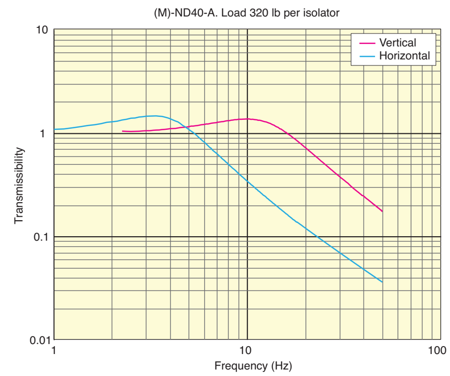
ND40 and ND41 Series

These isolators are based on cylindrical elements. They are the best option for applications requiring good isolation and short settling time with respect to horizontal motions while maintaining low tilt due to moving loads.

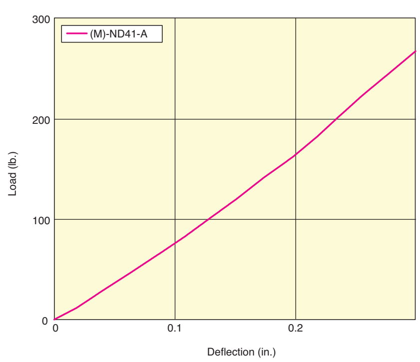
ND40

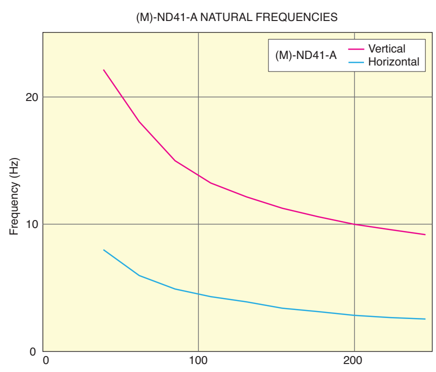


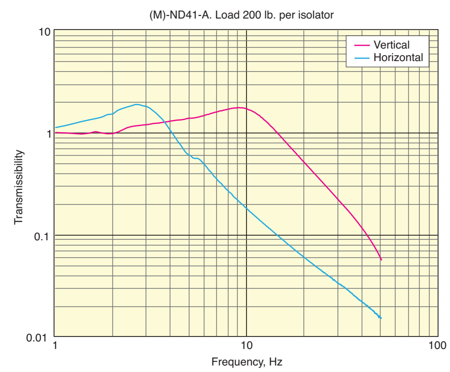




ND41

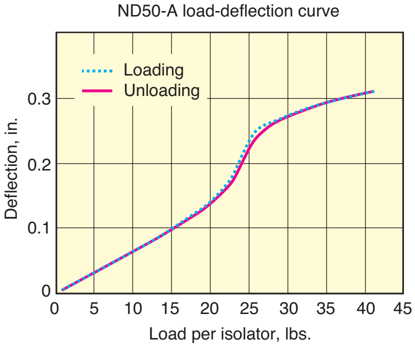


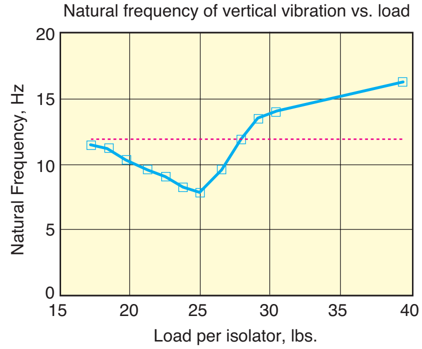


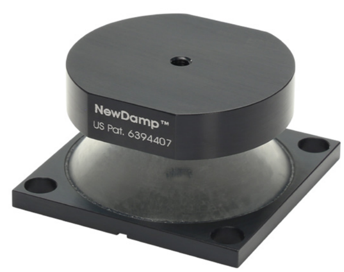


ND50 Series

These isolators are based on conical elastic elements designed for low load applications. The ND50 supports loads up to 40 lbs.

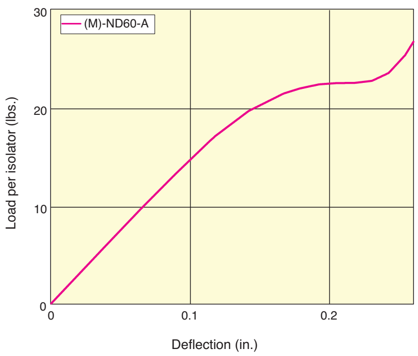


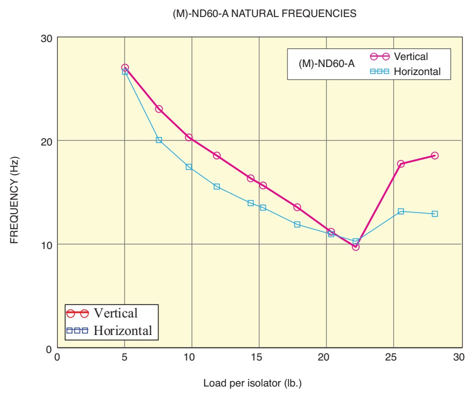


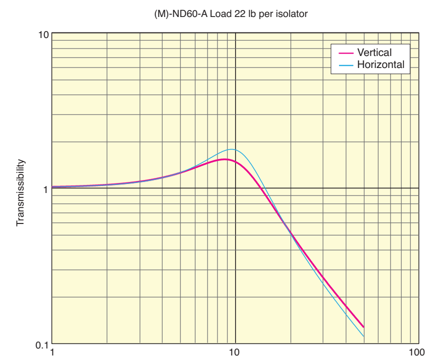


NewDamp™ ND60 Series

The ND60-A NewDamp Elastomeric Isolator supports 13-17 lb. loads and is based on conical elastic elements designed for low load applications. The ND60-A has a 1.3 inch height and a 2.4 x 2.4 inch base. By using custom profiled upper supports, these isolators can be easily tuned to particular load/frequency requirements. Breadboard microlock compatible.



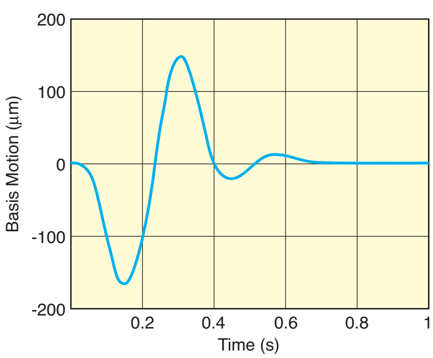




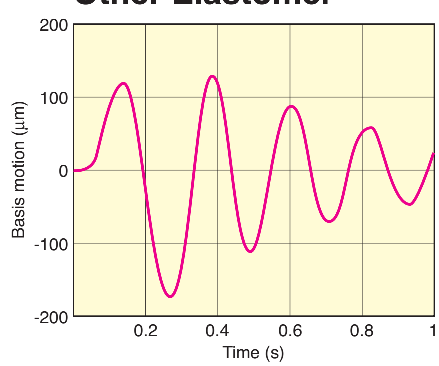
ND Settling Time vs. Other Isolators

A remarkable property of NewDamp™ isolators is their ability to quickly attenuate the transient motions, thereby reducing the settling time of the equipment after the stage movements or other disturbances. The following comparison was made for a dual-axis air bearing stage mounted on a granite basis (total weight: 800 kg) and supported by four NewDamp™ ND40 isolators.

ND40



Other Elastomer

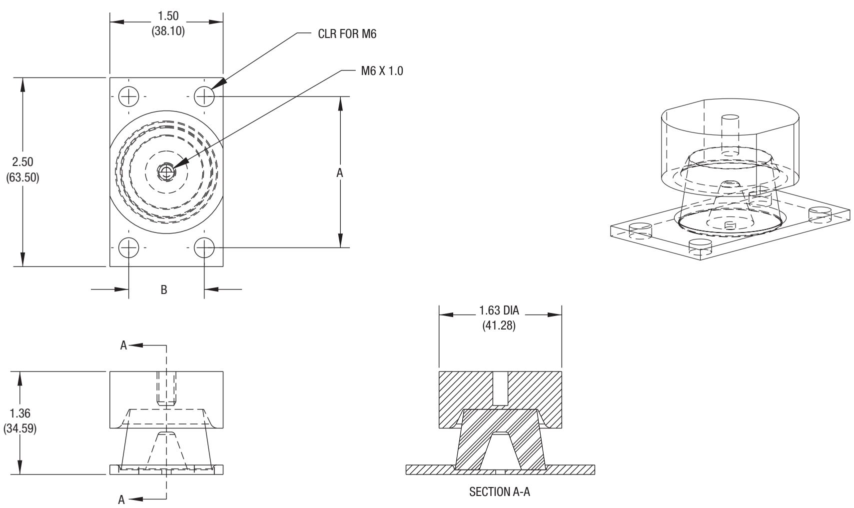


Order Information

Model	Description
ND01-A (M-ND01-A)	70-250 lb load, X95 Rail Compatible
ND20-A (M-ND20-A)	45-250 lb load, X95 Rail Compatible
ND30-A (M-ND30-A)	70-300 lb load, X95 Rail Compatible
ND40-A (M-ND40-A)	100-450 lb load, X95 Rail Compatible
ND40-B (M-ND40-B)	100-450 lb load, BB Microlock Compatible
ND41-A (M-ND41-A)	70-225 lb load, X95 Rail Compatible
ND41-B (M-ND41-B)	70-225 lb load, BB Microlock Compatible
ND50-A (M-ND50-A)	17-28 lb load, BB Microlock Compatible
ND60-A (M-ND60-A)	13-17 lb load, BB Microlock Compatible

Dimensions

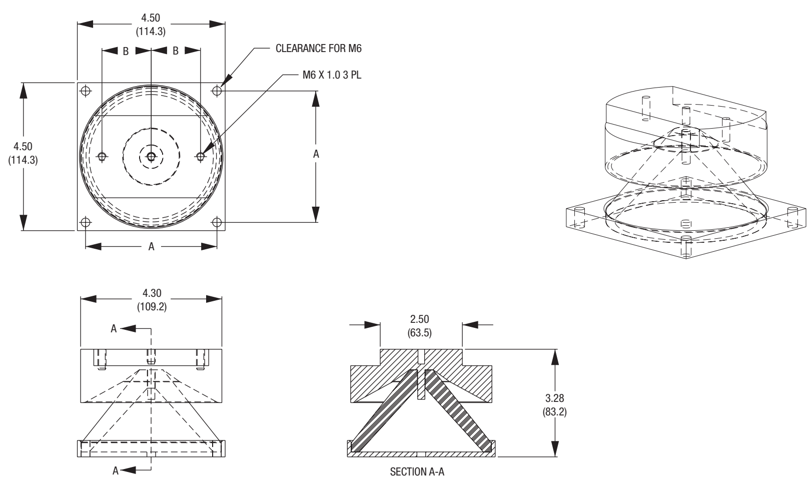
ND01-A



Dimensions [in.(mm)]

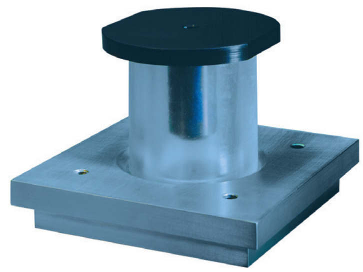
Model (Metric)	A	B
ND01-A (M-ND01-A)	2.00 (50.0)	1.00 (25.0)

ND20 and ND30 Series

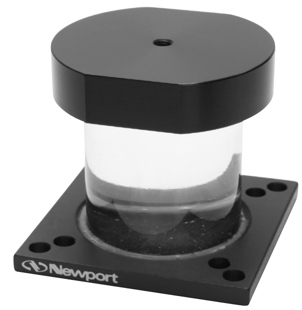


Dimensions [in.(mm)]

Model (Metric)	A	B
ND20-A (M-ND20-A)	4.00 (100.0)	1.50 (37.5)
ND30-A (M-ND30-A)	4.00 (100.0)	1.50 (37.5)

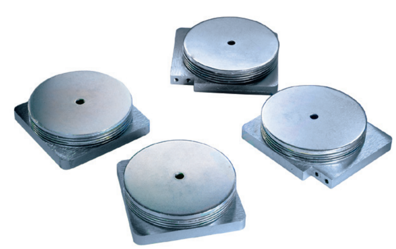


Customized ND41 NewDamp™ Elastomeric Isolator.



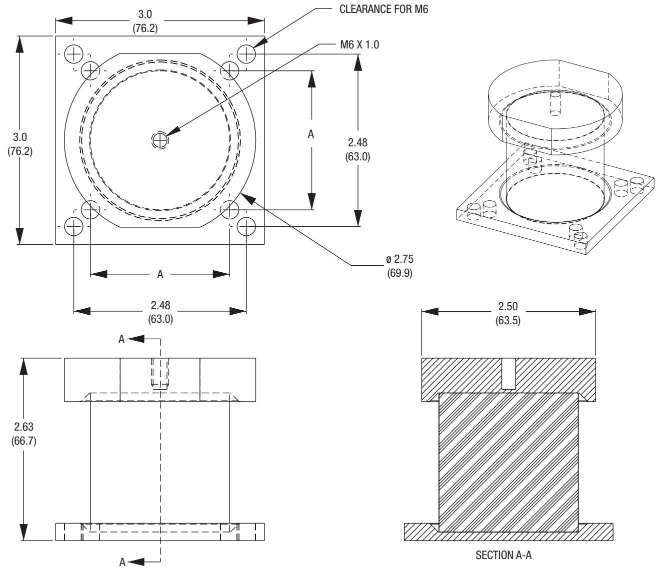
ND40-A NewDamp elastomere isolator

Custom machine isolators.

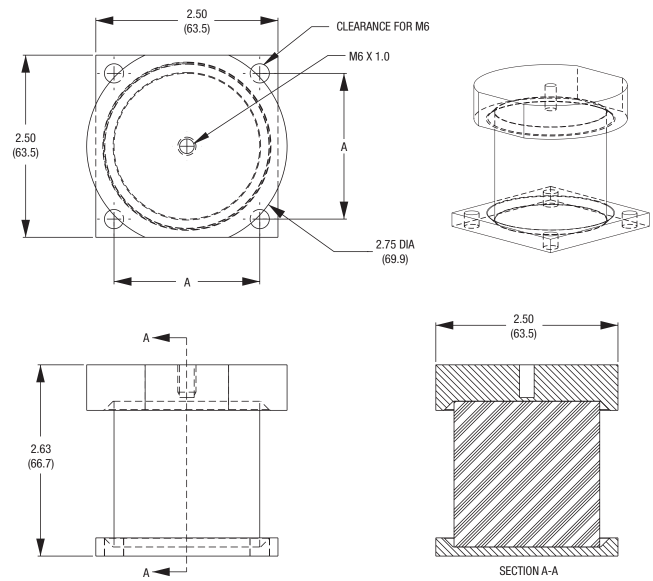


Custom machinery feet offer high horizontal damping with vertical stiffness.

Model ND40-A

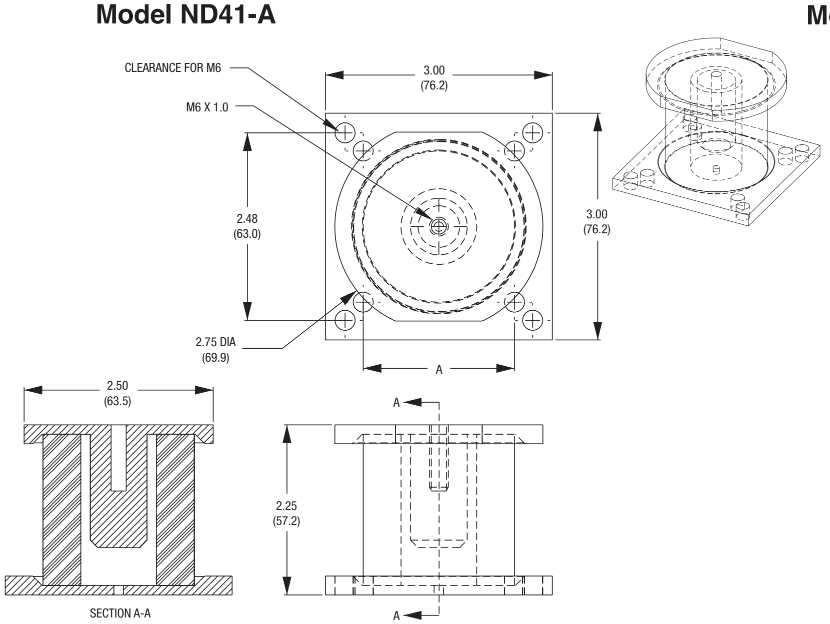


Model ND40-B

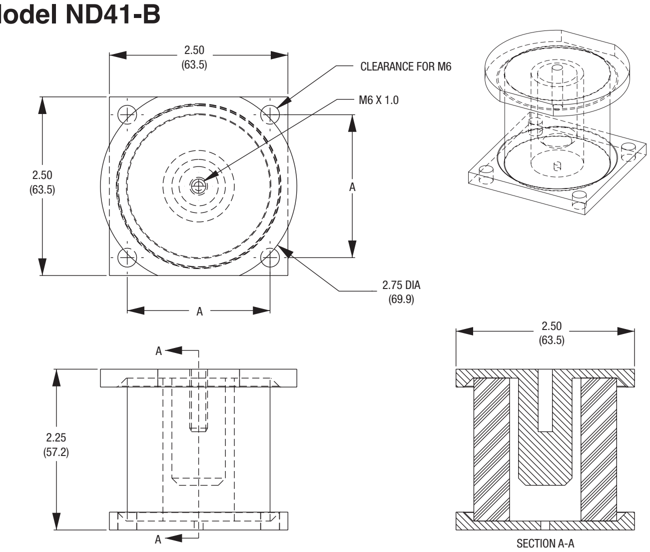


	Dimensions [in. (mm)]
Model (Metric)	A
ND40-A (M-ND40-A)	2.00 (50.0)
ND40-B (M-ND40-B)	2.00 (50.0)

Model ND41-A

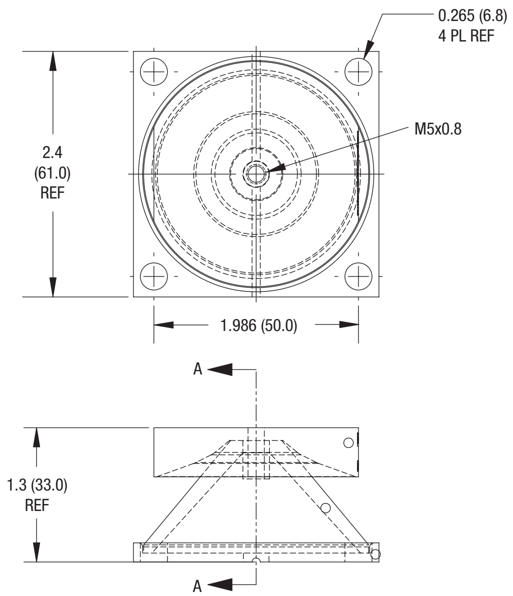


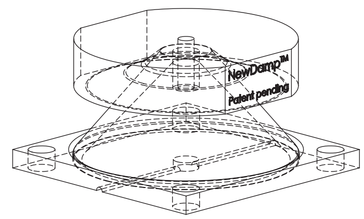
Model ND41-B

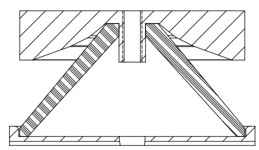


	Dimensions [in. (mm)]
Model (Metric)	A
ND41-A (M-ND41-A)	2.00 (50.0)
ND41-B (M-ND41-B)	2.00 (50.0)

Model ND40-B






SECTION A-A

	Dimensions [in. (mm)]		Thread
Model (Metric)	A	B	Thd A
ND50-A (M-ND50-A)	2.00 (50.0)	0.22 (5.5)	10-24 NC-2A (M5-08)

Vibration Isolators

Application Note

Matching Isolators to OEM Industrial Applications

Basics of Pneumatic Isolator Design

Micro-vibration isolation first became necessary in laser research laboratories. Newport Research Corporation, beginning in 1969, satisfied this need with a series of isolation legs to support optical tables in laboratory applications. These isolators were designed to provide the best transmissibility, or ratio of isolated body motion to floor motion, over the widest possible bandwidth.

Pneumatic isolators consist primarily of an air chamber that is sealed with a flexible diaphragm. This air chamber supports the payload on a cushion of air. Self-leveling designs incorporate leveling valves to control air into and out of the air chamber. The purpose of the leveling valve is to make the isolator performance relatively independent of load and to return the platform to the proper position after changes in load distribution.

Basic

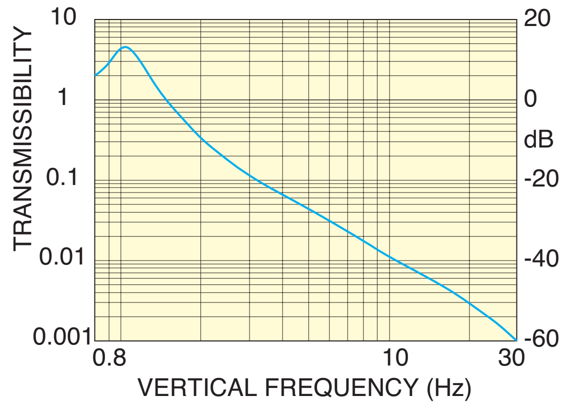
The isolator becomes part of a payload mass/spring/damper system. Essentially, pneumatic isolators act as a mechanical filter. Before they begin isolating, floor motion is amplified at their natural frequency. The natural frequency is given as:

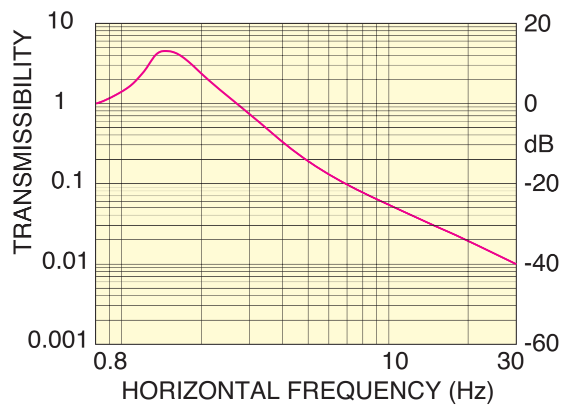
$$f_n = (1/2\pi) * \sqrt{(k/m)}$$

where "k" is the system stiffness and "m" its mass.

Thus, the requirement for best isolation and maximum bandwidth implies that the natural frequency be as low as possible; normally 1–2 Hz. At floor vibration frequencies below the isolated system natural frequency, the isolator transmissibility is one and the payload motion is the same as the floor motion. At the system's natural frequency, the passive isolator amplifies floor motion by a factor of about 3–10, depending on damping. Heavily damped systems amplify less than lightly damped systems. At 1.41 times the natural frequency, transmissibility is again one.

Isolation begins above the 1.41 x fn frequency point. As the vibration frequency increases, the transmissibility rolls off with a slope of -40 dB/decade. This means the isolation improves by a factor of 100 for every factor of 10 increase in frequency.





For example, given a system with a 2 Hz natural frequency; and thus a transmissibility of one at 2.8 Hz (1.41 x 2); the transmissibility at 28 Hz would be –40 dB, or 0.01. Horizontal isolation in a Newport isolator is achieved by use of a pendulum system. The behavior of the pendulum horizontal isolator is basically the same as that of the vertical pneumatic isolator. In this case, the pendulum natural frequency is given by:

$$f_n\ 1/(2\pi)^* \sqrt{(L/g)}$$

where "L" is the pendulum length and "g" is the acceleration due to gravity. The horizontal natural frequency is generally about 1.5 Hz. The passive vibration isolator then provides vibration attenuation starting at about 2–3 Hz and improving as the vibration frequency increases. The measure of quality in passive isolation systems for research applications was low natural frequency for better isolation — the lower the better. The downside of passive mass/spring/damper isolators is that they are a very soft suspension system. Further, the better the isolation, the softer they are. The slightest disturbance of the payload can result in significant payload motion and settling times of up to ten seconds. This is generally acceptable in the research world. However, as the research projects filtered down into the manufacturing and inspection environment, long settling times in automated systems became unacceptable due to cycle time cost. Further, many precision manufacturing and measurement operations cannot tolerate base motion or tilt. The measure of quality for a manufacturing isolation system has taken on a broader meaning that is application dependent. No longer is "lowest natural frequency" the only criteria by which passive isolation systems are judged.

Isolator Performance Criteria

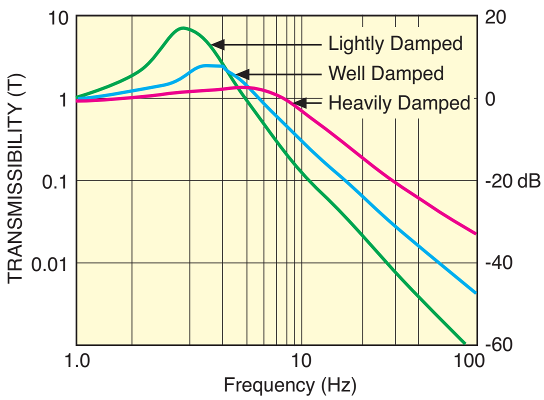
Performance criteria for evaluating pneumatic isolators include the following:

- Isolation (low natural frequency)
- Settling time (vertical and horizontal after an agreed upon disturbance)
- Leveling accuracy
- Ability to remain level during load changes such as stage movement
- Amount of horizontal motion acceptable as a result of stage reaction forces

The isolator's overall performance is a compromise between each of the criteria.

Newport's Stabilizer™ Hybrid Chamber System vs. Conventional Designs

For a given load, the isolation performance is primarily a function of the isolator compliance volume. Reduced diaphragm and leveling valve stiffness also improves isolation. All pneumatic isolators must also incorporate some vertical pneumatic damping or the isolator would be unstable. Thus, conventional isolators consist of a spring (compliance) chamber that is connected to a damping chamber. The primary design compromise is between isolation and damping. Improved damping results in a sacrifice of isolation — as damping is increased so is the natural frequency and thus the isolation bandwidth is decreased. Conventional isolators with these properties are available from a number of manufacturers.



All Newport isolators designed since about 1991 have incorporated the patented Stabilizer™ approach. The Stabilizer "hybrid" chamber concept uses the compliance of the total isolator volume (both "chambers"). The unique Newport design incorporates a laminar flow damping element in a barrier that fits closely about the isolator piston within the overall isolator air volume. This approach allows a wide range of damping, from light for research applications to very heavy for industrial moving stage applications. Minimal natural frequency increase (isolation efficiency reduction) is seen in the heavily damped versions.

Vibration Isolators

Other manufacturers offer only the conventional two-chamber design with a small orifice connecting the chambers. The chamber adjacent to the diaphragm provides the compliance, or spring, of the isolator. The orifice and second chamber provide the system damping as air is forced through the orifice between the chambers. The orifice size is very critical. If it is optimized for floor vibration isolation, it will be too small to optimally damp large motion resulting from load changes or stage travel. In the conventional two chamber design used by other manufacturers, it is impossible to greatly increase vertical damping for seismic-level floor disturbances without raising the isolator natural frequency, impacting high frequency isolation, and decreasing damping for large disturbances.

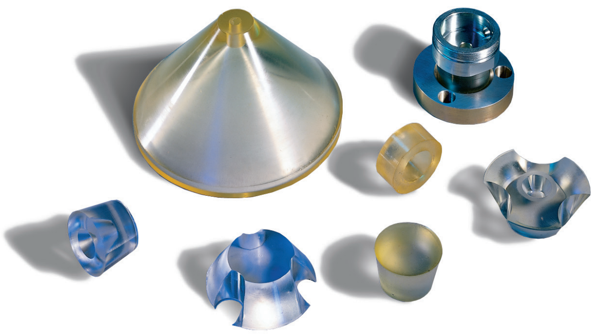
Damping for Manufacturing Systems

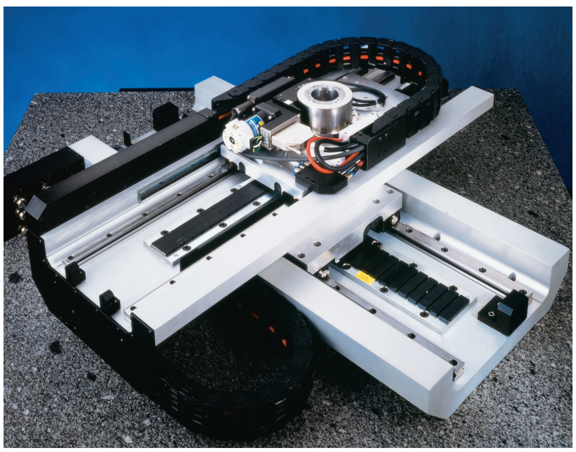
Damping is generally set to give transmissibility amplification of about 3 (9.5 dB) at the isolator/payload vertical resonance. This damping provides a good balance of low amplification at resonance and good isolation at higher frequencies. However, this is not enough damping for rapid settling after a stage move or other payload disturbance. There are two types of payload disturbance — those that do not change the isolator loading and those that do:

- Disturbances that do not change the isolator loading include bumping the isolated payload by accident and touching the system to make adjustments. To improve settling time in these applications, part of the Newport laminar flow elements can be blocked (or specially designed in custom isolators) to limit amplification at resonance to about 2. This higher damping enables settling times of better than 3 seconds after a significant payload disturbance.
- Disturbances that do change the isolator loading include loading or unloading parts in work or moving stage applications. In these applications, higher isolator damping enables the use of higher leveling valve gain (the ratio of valve air flow to payload height error). It is then possible to let in air to or exhaust air from the isolators more quickly without the system oscillating. Faster airflow makes it possible for the payload to remain more level during stage moves or parts loading and unloading.

Damping Pneumatic Isolation Systems

Building on the high isolation Stabilizer technology, Damping was developed in 1997 to offer improved damping for moving payload applications. Damping isolation systems use constricted laminar flow orifice and high gain valve systems. Standard Damping configurations constrict the laminar flow by 50% and greatly improve system stability on moving loads. Custom designs can be further tuned to machinery needs by adjusting laminar flow, valve gain and even the diaphragm stiffness.





NewDamp™ Elastomer

Very high throughput systems may not tolerate pneumatic systems due to the high accelerations produced. NewDamp elastomers were developed in 1997 to support Newport's high throughput MAT350 and DynamYX wafer positioning systems. These custom elastomers offer much higher damping properties than other materials. They also overcome a traditional disadvantage of elastomers caused by changes in natural frequency due to changes in load. CNF (constant natural frequency) designs offer much more flexibility than previously found with elastomeric isolation systems. Newport has invested in the engineering and modeling expertise to custom design the elastomers for specific machinery requirements.

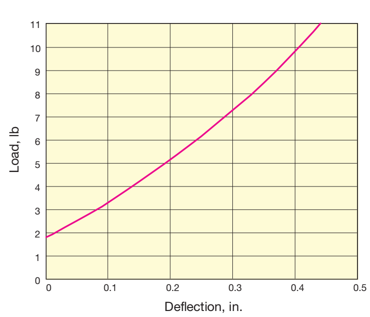
VIBe™ VIB320X Mechanical Vibration Isolators

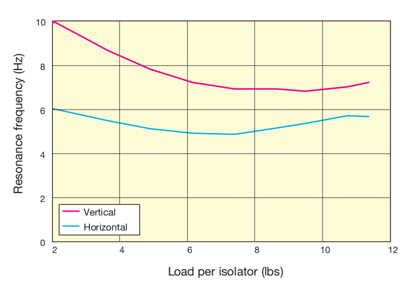
VIB320X mechanical isolators use patented VIBe™ technology for maintenance-free operation. They offer robustness for tough environments, quicker settling time than pneumatic isolators, and solid vibration isolation performance.

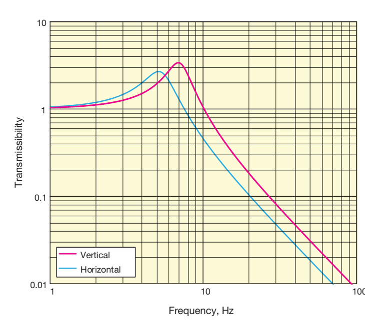
- 2.7 in. diameter design with up to 180 lb load capacity
- Mechanical isolation without the need for air hoses or compressor
- Easy to mount and design into applications
- Economical and maintenance free microscope vibration isolation

VIB320X-0211
Vibration Isolator, Mechanical, 2 lb (0.9 kg) to 11 lb (5.0 kg)

VIB320X mechanical isolators use patented VIBe™ technology for maintenance-free operation. They offer robustness for tough environments, quicker settling time than pneumatic isolators, and solid vibration isolation performance.



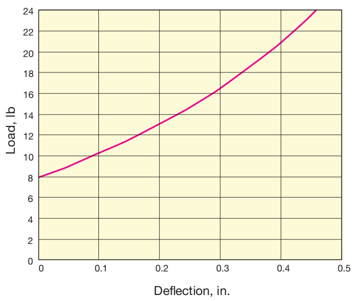


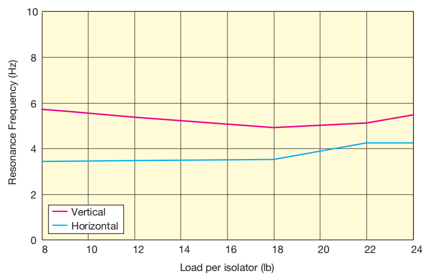


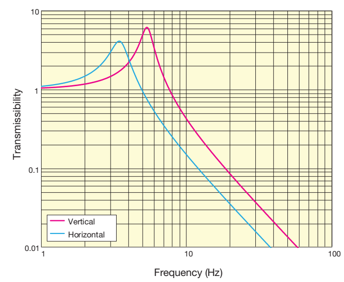
VIB320X-0824

Vibration Isolator, Mechanical, 8 lb (3.6 kg) to 24 lb (10.8 kg)

The VIB320X-0824 bearing is a self-contained unit that provides both vertical and horizontal isolation from 8 lbs (3.6 kg) to 24 lbs (10.8 kg). The isolators feature a 4.75 Hz vertical resonance frequency and a horizontal resonance of 3.25 Hz. This is sufficient performance to eliminate 85% of vibration noise seen within typical laboratories. The VIB320X bearings attach to the VIBe base plate via specially designed brackets that feature a threaded aperture to allow leveling adjustment of the platform.



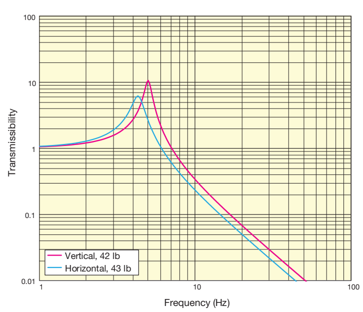


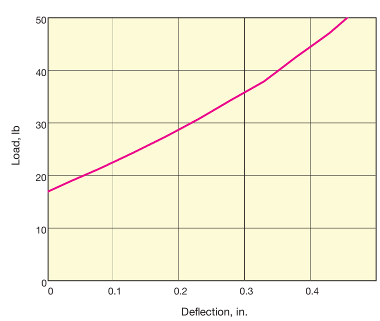


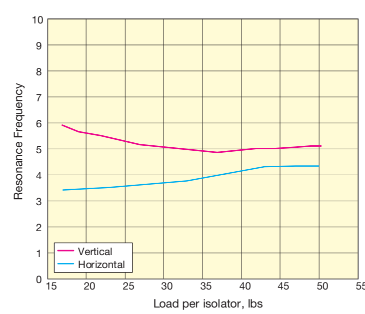
VIB320X-1750

Vibration Isolator, Mechanical, 17 lb (7.6 kg) to 50 lb (22.5 kg)

The VIB320X-1750 bearing is a self-contained unit that provides both vertical and horizontal isolation from 17 lbs (7.6 kg) to 50 lbs (22.5 kg). The isolators feature a 4.75 Hz vertical resonance frequency and a horizontal resonance of 3.25 Hz. This is sufficient performance to eliminate 85% of vibration noise seen within typical laboratories. The VIB320X bearings attach to the VIBe base plate via specially designed brackets that feature a threaded aperture to allow leveling adjustment of the platform.



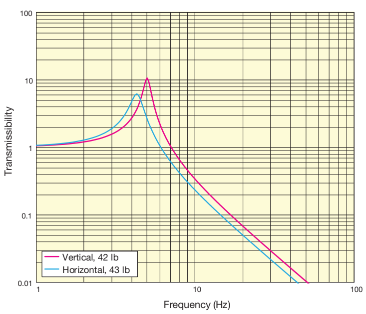


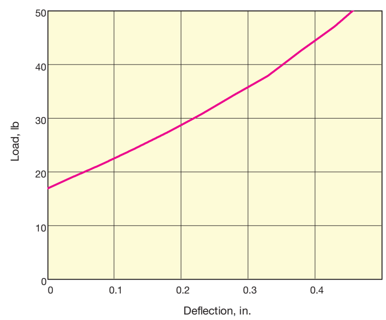


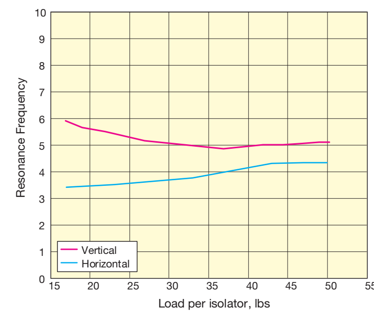
VIB320X-35100

Vibration Isolator, Mechanical, 35 lb (15.8 kg) to 100 lb (45 kg)

The VIB320X-35100 bearing is a self-contained unit that provides both vertical and horizontal isolation from 35 lbs (15.8 kg) to 100 lbs (45 kg). The isolators feature a 5.25 Hz vertical resonance frequency and a horizontal resonance of 3.5 Hz. This is sufficient performance to eliminate 85% of vibration noise seen within typical laboratories. The VIB320X bearings attach to the VIBe base plate via specially designed brackets that feature a threaded aperture to allow leveling adjustment of the platform.



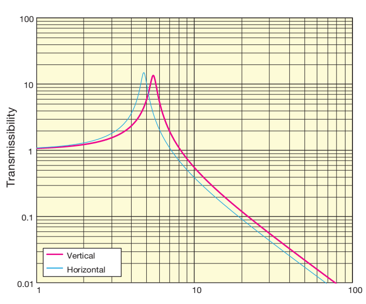


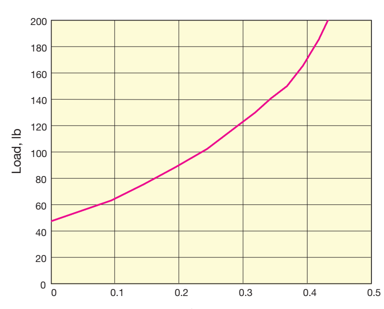


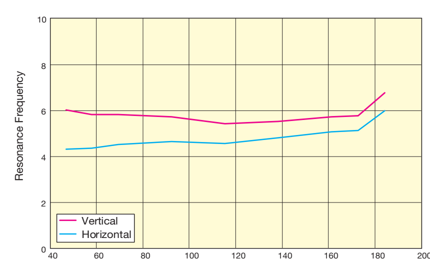
VIB320X-50180

Vibration Isolator, Mechanical, 50 lb (22.5 kg) to 180 lb (81.2 kg)

The VIB320X-50180 bearing is a self-contained unit that provides both vertical and horizontal isolation from 50 lbs (22.5 kg) to 180 lbs (81.2 kg). The isolators feature a 5.25 Hz vertical resonance frequency and a horizontal resonance of 4.25 Hz. This is sufficient performance to eliminate 85% of vibration noise seen within typical laboratories. The VIB320X bearings attach to the VIBe base plate via specially designed brackets that feature a threaded aperture to allow leveling adjustment of the platform.







Vibration Isolators

Optical Table and Support Systems

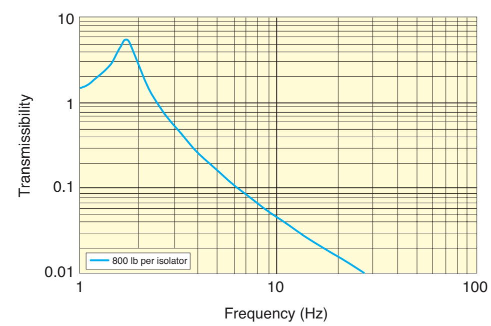
Optical Table Systems consist of an optical table top and matching table supports. They are available with rigid or isolated table supports, and various levels of vibration damping for tabletops. We also offer flexible accessories for completing your optical table system. Integrity VCS is best value entry level table systems while SmartTable OTS embraces more features and higher performance.

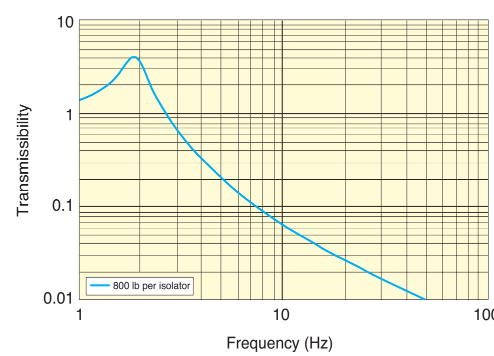
Robust and Flexible Pneumatic Isolated Frame Support

The Integrity VCS optical table system features a sturdy and multi-functional support frame that is designed to maximize utility, minimize space occupied and optimize structural rigidity. The support legs feature pneumatic isolators to passively absorb vibrations from the optical table's environment. The frame features leveling feet, and optional INT-C casters can be added for easy transportation of the system. A wide variety of accessories are compatible with the Integrity VCS frame and can be used to customize your optical table system.

High Performance Pneumatic Vibration Isolators

The pneumatic vibration isolators in the supporting frame feature our patented Stabilizer™ hybrid chamber design which consists of a small size initial chamber and a second damping chamber connected by a laminar flow disk. Because the initial chamber is reduced dramatically in size, it forces the isolator to use the second chamber as part of the compliance volume, which greatly increases the compliance volume for a given package size, and greatly lowers the natural frequency. Besides, our exclusive incorporation of the laminar flow damping element creates better linkage between piston motion and damping chamber air flow, which generates a higher damping force for a given piston displacement for faster, more efficient damping. It also lowers the amplification at resonance and improves isolation bandwidth and settling time. The vibration isolation performance is characterized by transmissibility curve which shows the mechanical filtering properties for the isolator leg - how much floor vibration will be transmitted through the leg to the table top.





SmartTable® OTS™
Optical Tables

Key Features

- **Field upgradeable table and platform options**
- **Integrated accessories to improve lab space utilization, organization and safety**
- **Four levels of damping and isolation performance to address any performance and budgetary needs**

Newport's new patent pending SmartTable® OTS™ optical table system combines the unmatched performance and value of our patented SmartTable® optical table with a new, innovative isolation platform that features integrated accessories to optimize laboratory space, organization and safety.

The new OTS™ platform integrates Newport's I-800 pneumatic isolator design with a new rigid frame design to deliver an economical isolation platform with superior isolation performance and unmatched accessories.

The SmartTable OTS optical table system is available in the most popular sizes and performance levels to fit any budget and with the exceptional offering of accessories and upgrade options will support any lab's growing needs. All OTS systems come with casters as a standard feature for easy mobility.

Upgradeability

No other optical table system delivers the performance and field upgradeability like the SmartTable OTS optical table system. As system requirements and budgets change users can easily upgrade their system in their lab to improve performance, organization and safety to optimize laboratory space and productivity. As an example, users can initially select an 4'x8'x8" thick ST-UT2 damped upgradeable table surface with a rigid leg frame and high load casters (OTS-UT2-48-8-N) and field upgrade both the damping and isolation performance to the highest performance level available.

The SmartTable OTS is available with four levels of table performance and two frame options (isolated or rigid).

Model shown includes auto-leveling I-1250 isolators, ST Series SmartTable optical table, high load casters, optional front hip bar, optional overhead shelf and optional lower shelf.

SmartTable® OTS™ Optical Tables

The SmartTable OTS is available with three levels of table performance and two frame options (isolated or rigid).

Table options below are in order of increasing performance

ST-UT2 Series upgradeable optical table with tuned mass dampers

ST Series SmartTable optical table with IQ active damping technology

SST Series hybrid SmartTable optical table top with two IQ active dampers and two precision tuned passive dampers

Standard Table Sizes

4' x 6' x 8"

4' x 8' x 8"

4' x 10' x 8"

5' x 10' x 8"*

5' x 10' x 12"*

*Note: Actual width measurement for 5 ft. wide tables is 59.06 in. (1.5 m)

Standard Features Include:

- Leveling Feet
- SafeLock™ Mounting Brackets
- Alpha-Numeric Grid Markings
- Heavy load casters

Integrity VCS™ Series Vibration Control System

Key Features

- **Available in 6,8 and 12 inch thickness**
- **Athermalized Design for Excellent Thermal Stability**
- **Surface Flatness of ±015 mm (±0.006") over any 1 m²**
- **Proprietary constrained layer damping attenuates broadband vibrations**
- **Non-corrosive sealing of holes and honeycomb cells**
- **Field upgradable pneumatic isolation with automatic leveling valves**
- **Integrated leveling feet**

Newport's new Integrity VCS™ vibration control system combines the performance and value of our patented optical tables with a new, innovative isolation platform that features integrated shelf and mobility accessories to optimize laboratory space, organization and safety.

Integrity Series Vibration Control Systems (VCS) are composed of two components: a damped stainless steel work surface and either rigid or pneumatic isolators with automatic leveling valves integrated into a new frame design to deliver an economical isolation platform with superior isolation performance.

The vibration sources in the environment surrounding the optical table principally determine the level of isolation required in the isolator while the application and sources of vibration on the optical table surface are the determining factors in choosing an optical table. Integrity Vibration Control Systems are available in the most popular sizes and several performance levels to fit any budget. An optional overhead shelf is available to improve lab space utilization, organization and safety. Integrity VCS systems are available in 4 performance levels: Integrity 1, Integrity 2, Integrity 3 and Integrity 4 Series. All performance levels comes with either rigid or pneumatic isolators. The rigid Integrity system is field upgradeable to pneumatic isolation. Casters can be added to provide increased mobilitycomes with either rigid or pneumatic isolators. The rigid Integrity system is field upgradeable to pneumatic isolation. Casters can be added to provide increased mobility.

Workstations and Table Systems

Integrity VCS™ Series Vibration Control System

Integrity 1

The Integrity 1 Series VCS is designed to provide a superior mounting surface for general purpose photonics applications that are not extremely sensitive to vibrations. Integrity 1 VCS systems are often used in spectroscopy, multimode fiber, micro positioning, and non-interferometric applications.

Integrity 2

The Integrity 2 Series VCS is designed to provide a superior mounting surface for general purpose photonics applications that are not extremely sensitive to vibrations. Integrity 2 VCS systems are often used in spectroscopy, multimode fiber, micro positioning, and non-interferometric applications.

Integrity 3

The Integrity 3 Series VCS is designed to provide a superior mounting surface for vibrationally sensitive photonics applications due to trussed honeycomb core design with proprietary tuned and broadband damping systems. Integrity 3 Series Vibration Control Systems are often used in imaging, single mode fiber launch and micro positioning, applications.

Integrity 4

The Integrity 4 Series VCS is an integrated platform designed for challenging applications with its built-in precision tunable damping technology used in RS2000 Series optical tabletops. Integrity 4 Series VCS Systems are often used in imaging, spectroscopy and optical characterization applications.

Vision IsoStation™ Optical Workstations

Key Features

- **Field upgradeable table and platform options**
- **Integrated accessories to improve lab space utilization, organization and safety**
- **Four levels of damping and isolation performance to address any performance and budgetary needs**

The Vision IsoStation provides industry leading performance and more user friendly features and accessories than any other vibration isolation workstation. All of the features and accessories have been designed specifically to improve ease–of–installation, set-up and lab space utilization.

Better Performance - More Options

The Vision IsoStation is offered with platform sizes from 24”x24” up to 36”x72” to accommodate the widest range of applications from small bio-instrumentation isolation up to medium size optical investigations that may have previously needed a full sized optical table. The Vision IsoStation will be available in two load capacities, 500lb gross and 1,300lb gross, delivered by Newport’s high-performance I-125 and I-325 Series pneumatic isolators. Both versions reduce transmitted vertical and horizontal vibrations by 85% or more after 5Hz and by more than 95% after 10Hz.

Easier to Use

The Vision IsoStation features a unique platform interface that acts as a docking surface, an accessory mount and a restraint to keep the breadboard atop the frame. The interface also features float height indicators and frame bubble levels to make set-up and installation easier than ever. These same features are also useful when the system is relocated to another lab or if system performance needs to be verified. With these new features and integrated leveling feet and casters standard on all versions the system is much easier and safer to transport and install. Another unique feature of the Vision IsoStation is a new shipping package that not only reduces packaging materials but also allows users to simply roll their system off into their lab, it’s as plug-and-play as can be! Since the breadboard is shipped pre-installed on the frame customers no longer need to lift the heavy breadboard during installation.

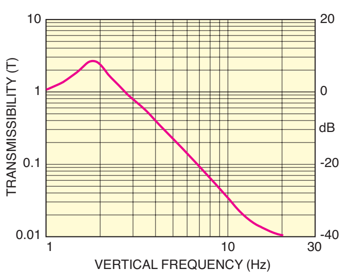
New Accessories

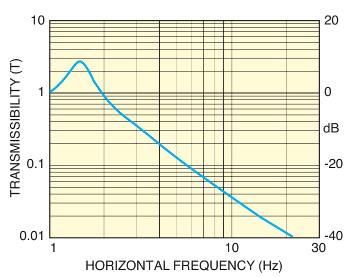
The Vision IsoStation family also includes a new offering of accessories designed specifically for modern scientific and biological investigations. This includes several new instrumentation and accessory storage options.

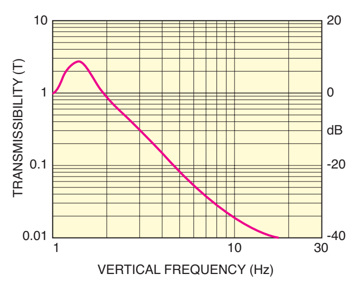
Performance

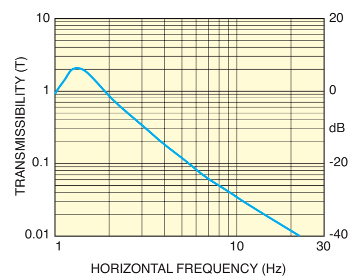
Isolation

The Vision IsoStation is available in two isolated load capacities, 500lb gross and 1,300lb gross, provided by Newport's highperformance I-125 and I-325 Series pneumatic isolators. Both versions reduce transmitted vertical and horizontal vibrations by 85% or more after 5Hz and by more than 95% after 10Hz. Both isolator models incorporate hybrid chamber designs, laminar flow damping and horizontal pendulum isolation to provide a quiet and stable isolation platform. Unisolated versions are also available and can be field upgraded to provide isolated performance in the future.









Model	Vertical Isolation, Res* (Hz)	Vertical Isolation, 5Hz* (%)	Vertical Isolation 10Hz* (%)	Horizontal Isolation Res* (Hz)	Horizontal Isolation, 5Hz* (%)	Horizontal Isolation, 10Hz*	Amplification at Resonance, Vert. (dB)	Amplification at Resonance, Horz. (dB)	Valve	Load per Isolator [lb (kg)]
125A Series	1.8	85	95	1.8	86	96	9	6	IPV-S2	125 (60)
325A Series	1.5	90	98	1.2	90	98	6	4	IPV-S2	325 (150)

Platforms

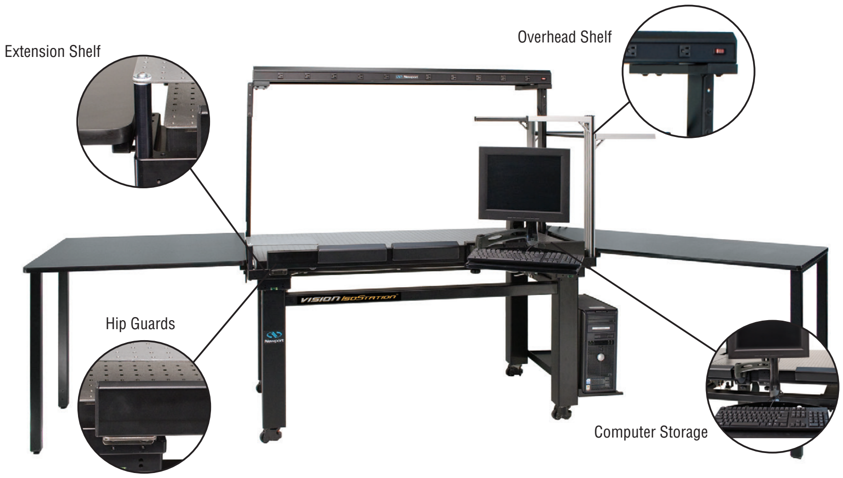
The Vision IsoStation is available in multiple platform sizes from 24"x24" up to 36"x72" to accommodate the widest range of applications from small bio-instrumentation isolation up to medium size optical investigations that may have previouslyrequired a full sized optical table. Two standard worksurface thicknesses are available. A 2" thick industrial grade or IG breadboard provides a 34 inch working height and the 4" thick SG and PG breadboard provides a 36 inch working height. Custom worksurfaces are also available including special materials, thru holes and custom shapes to provide OEM's and multi-user facilities with a more customized solution.

PG Series 4 in. Breadboards

IG and PG Series 2 in. Breadboards

Applications	Precision Grade (PG)	Scientific Grade (SG)	Industrial Grade (IG)
	Interferometry and critical high resolution experiments	Electro-optical experiments & processes	Industrial equipment platforms and less critical experiments
Damping Performance	★★★★★	★★★★	★★★
Working Surface	4.8 mm Thick 430 Stainless Steel		3.4 mm Thick 430 Stainless Steel
Bottom Skin	3.4 mm thick Carbon Steel		
Total Thickness [in. (mm)]	2.3 (59), 4.3 (110)		2.3 (58)
Core Design	Vertically Bonded Trussed Honeycomb		
Side Panels	Modal Dampers	Highly Damped Composite Wood	
Mounting Holes	Tapped and Individually Sealed		
Mounting Threads	1/4-20 (M6) on 1 in. (25 mm) Grid		

Accessories



Optical Work Station Accessories

Our optical workstation accessories feature quality design and ease of use features. We have the accessories needed to customize you optical workstation. They are designed specifically to improve ease of installation while minimizing lab space requirements. Available accessories includes

- Overhead shelf
- Sliding shelf
- Under table shelf
- Extension shelf
- Keyboard/monitor mount
- Hip guard
- Faraday cage

Order Information

(M-)* VIS ❑ ❑ ❑ ❑ - IG2-125 ❑

BREADBOARD SIZE:

2424 - 24 x 24 inches	600 x 600 mm
2436 - 24 x 36 inches	600 x 900 mm
3030 - 30 x 30 inches	750 x 750 mm
3036 - 30 x 36 inches	750 x 900 mm
3048 - 30 x 48 inches	750 x 1200 mm

THICKNESS: IG2-125

FRAME:
A – Isolated
N – Rigid

*The M- prefix designates metric threads

(M-)* VIS ❑ ❑ ❑ ❑ - ❑ ❑ -325 ❑

BREADBOARD SIZE:

3048**-	30 x 48 inches	750 x 1200 mm
3636 -	36 x 36 inches	900 x 900 mm
3648 -	36 x 48 inches	900 x 1200 mm
3660 -	36 x 60 inches	900 x 1500 mm
3672 -	36 x 72 inches	900 x 1800 mm

THICKNESS:
SG
PG

2 – 2″
4 – 4″

FRAME:
A – Isolated
N – Rigid

*The M- prefix designates metric threads
**3048 is only available in 2″ thickness

Guardian™ Series
Active Isolation Workstations

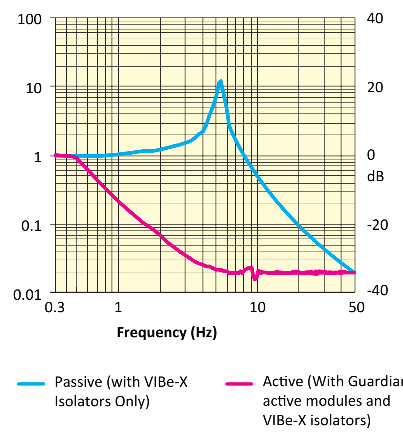
Key Features

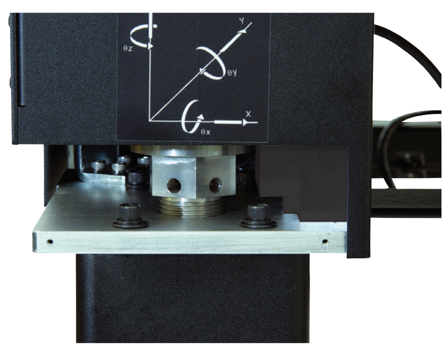
- **Provides sub-hertz vibration isolation in 6 DOF starting at 0.5 Hz**
- **Reaches 20 dB attenuation (10X) at 1.5 Hz**
- **Active and passive isolation elements guard your results even during a power outage**
- **Integrated all-in-one solution with minimal installation and maintenance effort**
- **30x36 in. (750x900 mm), 36x48 in. (900x1200 mm) and 36x60 in (900x1500 mm) standard sizes**
- **Custom sizes available**

The Guardian workstation includes two active isolation modules each contains 3 sensors and 3 actuators to actively sense and compensate for vibration in six degree of freedom real-time. It not only removes the resonance response inherent to the passive system, but provides up to 34 dB (50 times) additional isolation. Isolation starts at 0.5 Hz and reaches 20 dB (10 times) at 1.5 Hz. It vastly outperforms not only the passive spring-based systems, but also the best pneumatic workstations.

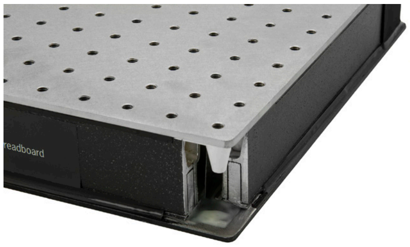
One special feature about Guardian technology is that it combines the powerful active modules with Newport's patented VIBe™ passive mechanical isolator design to achieve the best performance across a wide frequency range. The improved constant natural frequency VIBe isolators starts passive isolation from 8 Hz and provides a solid and quiet foundation for the active modules to further reduce the vibration amplitudes below 50 Hz. The carefully designed leveling mechanism in the modules allow users to easily level their system prior to use.

The Guardian™ Controller features multiple essential functions on the front panel, as well as real time control display for six axes. A full set of control functions are available using software suite provided with the product to achieve even more precise vibration control or 24/7 vibration data monitoring and recording. The sub-hertz, ultra-low noise electronics and advanced DSP control system inside the controller provides the most accurate vibration compensation for sensitive applications.

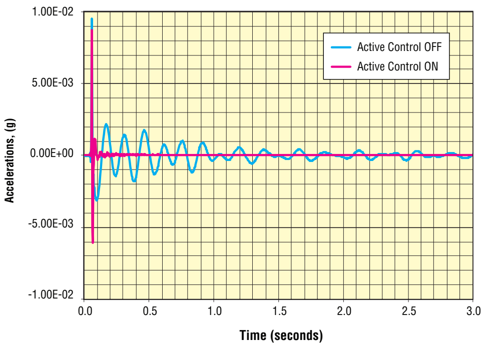




In addition to active and passive vibration isolation, a well damped working surface reduces resonances from top down, which helps tremendously for any high precision applications. Guardian™ workstation embraces modal damping, another world innovation for the most critical applications. Precision Grade optical breadboard serves as tabletop for Guardian™ workstation, bringing damping performance to the next level. The patented modal dampers are installed along the entire perimeter of the tabletop, providing effective and broadband damping for your delicate instruments.



Guardian can reduce the platform's reaction to the disturbances acting directly on the platform, whereas passive systems and some active systems can reduce only the vibration coming from the floor through the isolators. This is illustrated by the test results in the graph. The graphs represent the time histories of acceleration caused by a short (about 0.01 s) triangular pulse with maximum force about 1.5 lbs. created by an instrumented hammer near the corner of the breadboard (6 in. from edges) and measured by the accelerometer placed nearby. The settling time after this disturbance is negligible with active controls, whereas it can be of the order of seconds with passive isolation acting alone.



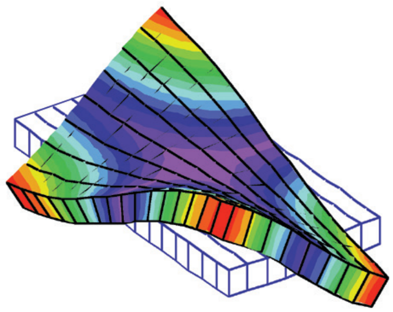
The Guardian™ workstation delivers superior rigidity with its all-in-one design. Carefully designed to provide the maximum mechanical stability, the fully welded frame system firmly supports the active modules as well as the tabletop. It also provides ergonomic workstation environment for the users to perform their applications.

Order Information

Material	Platform	Length	Width	Minimumload	Loadcapacity
GW3036-PG4-H	4.3 in. Precision Grade Breadboard	36 in.	30 in.	110 lb	420 lb
GW3036-PG4-L	4.3 in. Precision Grade Breadboard	36 in.	30 in	0	190 lb
GW3648-PG4-H	4.3 in. Precision Grade Breadboard	48 in.	36 in.	20 lb	320 lb
GW3660-PG4-H	4.3 in. Precision Grade Breadboard	60 in.	36 in.	0	240 lb
M-GW3036-PG4-H	110 mm Precision Grade Breadboard	900 mm	750 mm	50 kg	190.5 kg
M-GW3036-PG4-L	110 mm Precision Grade Breadboard	900 mm	750 mm	0	86.2 kg
M-GW3648-PG4-H	110 mm Precision Grade Breadboard	1200 mm	900 mm	9 kg	145 kg
M-GW3660-PG4-H	110 mm Precision Grade Breadboard	1500 mm	900 mm	0	109 kg

Tutorial

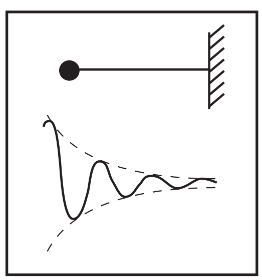
Fundamentals of Vibration

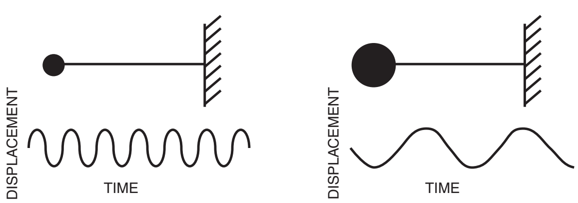


Vibration and vibration isolation are both intimately connected with the phenomenon of resonance and simple harmonic motion.

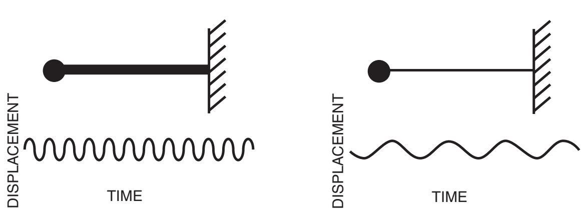
Simple Harmonic Motion

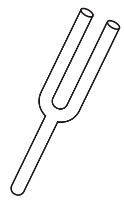
External force, either from a one-time impulse or from a periodic force such as vibration, will cause the system to resonate as the spring alternately stores and imparts energy to the moving mass. A simple example of harmonic motion is a mass connected to a flexible cantilevered beam. The figure below illustrates a simple masson a cantilevered beam resonating under the influence of an external force.





(Above) A lower mass increases natural frequency.
(Below) A higher mass lowers natural frequency.





Another simple example of natural frequency is a tuning fork, which is designed to vibrate at a particular natural frequency. For example, a tuning fork for the musical note “A” vibrates at a frequency of 440 Hz. Just as the natural frequency of the cantilevered beam can be changed with a different spring rate or a change in the mass, the natural frequency of the tuning fork can be altered by adding or reducing mass of the two tines and/or by making the tines longer or shorter.

Damping

In the cantilevered beam and tuning fork models, we considered undamped systems in which there is no mechanism to dissipate mechanical energy. Without damping, these systems will vibrate for quite a long period of time — at least several seconds — before coming to rest.

Damping dissipates mechanical energy from the system and attenuates vibrations more quickly. For example, when the tuning fork’s tips are immersed in water, the vibrations are almost instantly attenuated. Similarly, when a finger touches the resonating mass-beam system lightly, this damping action also rapidly dissipates the vibrational energy.

Model I: The Simple Harmonic Oscillator

The Simple Harmonic Oscillator consists of a rigid mass M connected to an ideal linear spring as shown in Figure 1.

$$M\ddot{x} + k(x - u) = 0$$

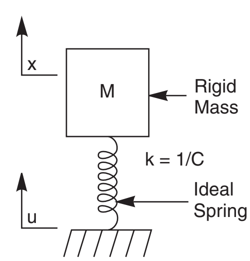


Figure 1. Simple Harmonic Oscillator

The spring has a static compliance C, such that the change in length of the spring Δx that occurs in response to a force F is: Δx = C F

Note that the compliance C is the inverse of the spring stiffness (denoted by k) such that k = 1/C.

If the spring-mass system is driven by a sinusoidal displacement with frequency ω and peak amplitude |u| it will produce a sinusoidal displacement of the mass M with peak amplitude |x| at the same frequency ω. The steady-state ratio of the amplitude of the mass motion |x| to the spring end motion |u| is called the transmissibility T and is given by:

$$T = \frac{|x|}{|u|} = \frac{1}{1 - \frac{\omega^2}{\omega_0^{\,2}}}$$

Where ω0 is the resonant, or natural frequency of the system given by:

$$\omega_0 = \sqrt{\frac{1}{CM}}$$

Note that the natural frequency of the system, ω0, is determined solely by the mass and the spring compliance. It decreases for a larger mass or a more compliant (softer) spring. The transmissibility, T, of the system is plotted as a function of the ratio ω/ω0 (on a log-log plot in Figure 2.)

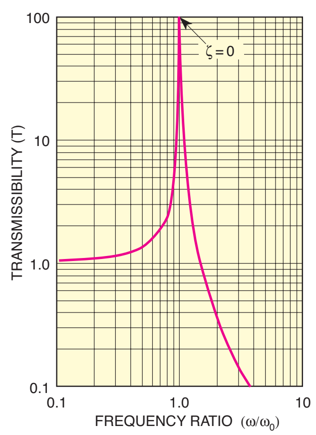


Figure 2. Transmissibility of a Simple Harmonic Oscillator.

The three characteristic features of this system are:

1. For ω « ω0, well below the resonance frequency, the transmissibility T = 1 so the motion of the mass is the same as the motion at the other end of the spring.

2. For ω ≈ ω0, near resonance, the motion of the spring end is amplified, and the motion of the mass |x| is greater than that of |u|. For an undamped system, the motion of the mass becomes theoretically infinite for ω = ω0.

3. For ω » ω0, the resulting displacement |x| decreases in proportion to 1/ω2. In this case, the displacement |u| applied to the system is not transmitted to the mass. In other words, the spring acts as an isolator.

Model II: The Damped Simple Harmonic Oscillator

In the first model, we considered an undamped system in which there is no mechanism to dissipate mechanical energy from the mass-spring system. Damping refers to a mechanism that removes the mechanical energy from the system—very often as heat. A damped Simple Harmonic Oscillator is shown schematically in Figure 3.

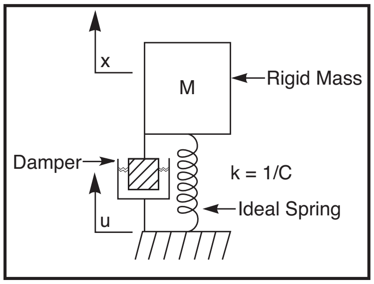


Figure 3. Damped Simple Harmonic Oscillator

$$M\ddot{x} + b\dot{x} + k(x - u) = 0$$

A rigidly connected damper is expressed mathematically by adding a damping term proportional to the velocity of the mass and to the

Tutorial continued

differential equation describing the motion. For an external force that results in a displacement amplitude |u| of the end of the spring as in Model I, the transmissibility, T, of the damped system becomes:

$$T = \frac{|x|}{|u|} = \sqrt{\frac{1 + \left(2\zeta \frac{\omega}{\omega_0}\right)^2}{\left(1 - \frac{\omega^2}{\omega_0^{\,2}}\right)^2 + \left(2\zeta \frac{\omega}{\omega_0}\right)^2}}$$

where ζ is a “damping” coefficient given by:

$$\zeta = \frac{b}{2\sqrt{\frac{M}{C}}}$$

A plot of the transmissibility T is shown in Figure 4 for various values of the damping coefficient ζ. In the limit where ζ approaches zero, the curve becomes exactly the same as in Model I, that is, there is infinite amplification at the resonance frequency ω0. As the damping increases, the amplitude at resonance decreases. However, the “roll-off” at higher frequencies decreases (i.e. the transmissibility declines more slowly as damping increases). For ω/ω0 » 1/ζ, note that the motion of |x| is proportional to 1/ω, as compared to Model I where at high frequencies the motion of |x| decreases as 1/ω2.

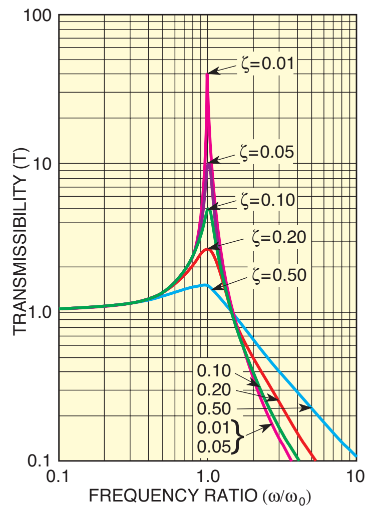
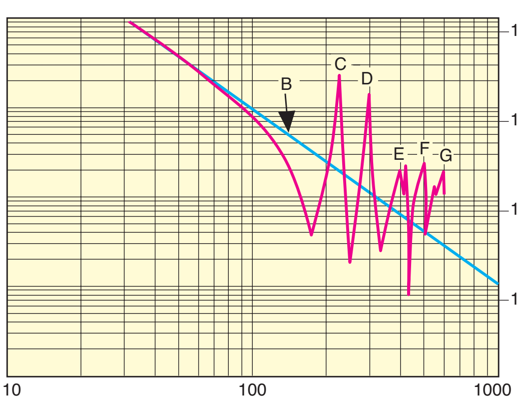


Figure 4. Transmissibility of a damped oscillator system with various values of the damping coefficient (ζ).

Understanding the Compliance Curve

Overview

No actual structure is a perfectly rigid body - all structures vibrate by flexing and twisting. The response of structures to random vibrations can be quite complicated because they vibrate with complex deformations and have more than one resonant frequency. The compliance curve, the classic method of measuring dynamic rigidity, is a useful tool for evaluating the basic dynamics of a vibrating structure. The curve supplies information on the two key parameters that govern dynamic performance - minimum resonant frequency and maximum amplification at resonance, which can be used to calculate the actual relative motion between two points on the structure's surface.



Starting to Quantify Dynamic Rigidity: Compliance

"Compliance" is a measure of the susceptibility of a structure to move as a result of an external force. The greater the compliance (i.e., the lower the stiffness), the more easily the structure moves as a result of an applied force. Compliance curves show the displacement amplitude of a point on a body per unit force applied, as a function of frequency. Expressed as a formula:

$$C = \frac{|x|}{|F|}$$

where:

- C denotes the compliance,
- $|F|$ the magnitude of the applied force, and
- $|x|$ the magnitude of resulting amplitude of the displacement

The units of compliance are displacement force; for example, mm/Newton or inches/pound.

Compliance of a Free Ideal Rigid Body

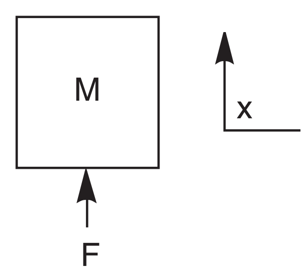


Figure 1. The free ideal rigid body model, $M\ddot{x}=F$

The theoretical model for compliance is the free ideal rigid body. We wish to know what happens when an external force F is applied to a rigid body of mass M, as shown in Figure 1. When a simple harmonic force is applied, the steady-state solution is:

$$x = x_0 \sin(\omega t)$$

$$\text{where} \quad x_0 = -\frac{F}{M\omega^2}$$

This means that the body moves back and forth in a sinusoidal fashion, and the amplitude of the motion is inversely proportional to the square of the input

Tutorial continued

angular frequency, ω. In this example, the compliance C is simply the magnitude of |x0| divided by the magnitude of the force, |F|, or:

$$C = \frac{|x_0|}{|F_0|} = \frac{1}{M\omega^2}$$

The compliance of a rigid body, therefore, is proportional to 1/ω2 and is graphed as a straight line with slope of -2 on a log–log plot. This line, which is called the Ideal Rigid Body line, represents the dynamic performance of a theoretically perfect rigid table.

The Table Top Compliance Curve

The dynamic performance of a table top is usually characterized with a compliance curve, a log–log plot of the table's dynamic response to random vibration. For non-rigid bodies, a compliance curve shows the structure's resonant frequencies and its maximum amplification at resonance. With other information, compliance curves can also furnish a reliable estimate of how a particular system will perform in your application.

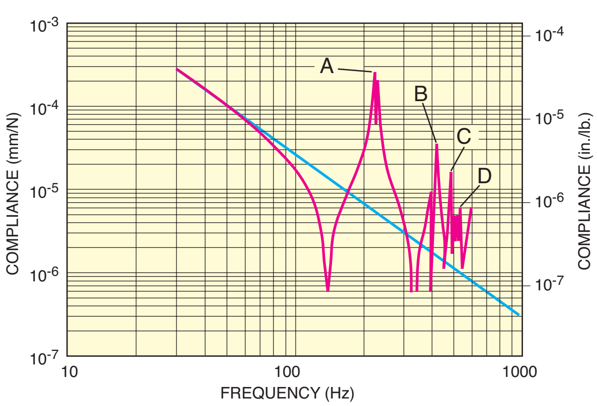


Figure 2. Typical compliance curve of an undamped table top.

Resonances and Minimum Frequency (fn)

Figures 2 and 3 show the relationship between an undamped table top's vibration modes and the peaks on its compliance curve. Each peak in the curve, marked A through D, corresponds to a fundamental vibration mode. Figure 3 shows the associated vibrational modes occurring at the frequencies seen in Figure 2.

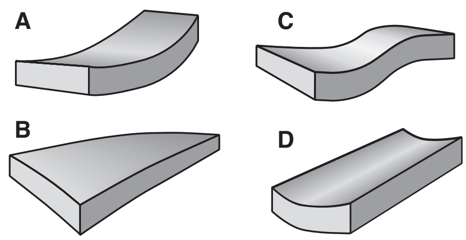


Figure 3. Vibrational modes of table top associated with compliance curve in Figure 2.

A table top's response to vibration depends on the frequency range. Consider the compliance curve shown in Figure 4 for an aluminum honeycomb table top. For low frequencies the compliance decreases inversely proportional to the square of the applied frequency (ω= 2πf). In other words, the structure is behaving as an "ideal rigid body." The Ideal Rigid Body line is included on all Newport compliance curves in order to measure the structural damping of a table top via the dynamic deflection coefficient, and is shown as the straight line (B) in Figure 4.

For frequencies greater than 80 Hz, the compliance curve begins to deviate from this line, and the table can no longer be thought of as an ideal rigid body. Above 80 Hz, structural vibrational modes are excited, and the table begins to deform. Peaks of maximum compliance (C, D, E, F and G) correspond to the table's resonance modes (approximately 220, 290, 420, 495 and 600 Hz).

The rigid body compliance falls off rapidly as frequency increases, so the largest displacements are generally caused by low-frequency resonances. The first peak on the left has usually the highest amplitude and dominates the table's response to vibration. In Figure 4, for example, 220 Hz is the minimum resonant frequency or natural frequency (fn) of the table top. The highest possible minimum resonant frequency is desirable, because the amplitude of table displacements is much smaller at higher frequencies, providing greater stability.

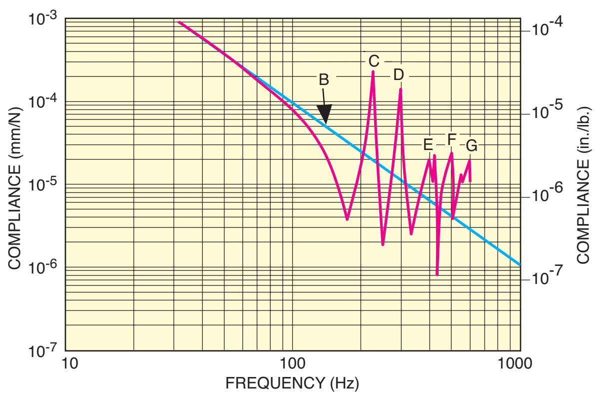


Figure 4. Compliance curve for an aluminum honeycomb core table top.

Maximum Amplification at Resonance (Q)

Damping of table top resonance modes is critical for maximum stability. Effective table top damping reduces compliance (i.e., reduces the height of resonance peaks). The goal is to design a table top whose compliance curve deviates as little as possible from its theoretical ideal rigid body line. Absolute compliance values that are not referenced or compared to the Ideal Rigid Body provide little indication of the table top's structural damping.

A quick glance at a compliance curve can provide a rough estimate of the quality of damping. For example, in Figures 4 and 5, it is intuitively obvious that the damping in the table shown in Figure 5 is superior. But by how much? When comparing curves by eye, logarithmic plots can be quite deceptive. Fortunately, it is very easy to obtain a precise comparison of relative damping efficiency by determining a table top's maximum amplification at resonance.

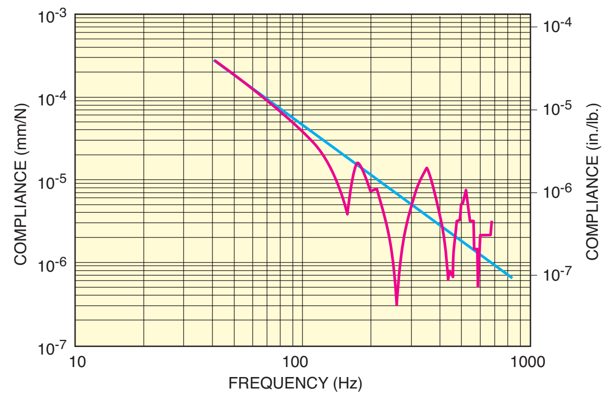


Figure 5. Compliance curve for a steel honeycomb core table top.

Maximum amplification at resonance, or Q, is a measure of how much the compliance curve deviates from the ideal rigid body line. In exact terms, it is defined as the maximum compliance value of the highest peak above the ideal rigid body line (usually, but not always, the first peak on the left) divided by the ideal rigid body response at the same frequency, see Figure 6. The lower the Q a structure has, the better it is damped and the more stable the structure will be. A structure's Q and corresponding resonant frequency together determine its Dynamic Deflection Coefficient.

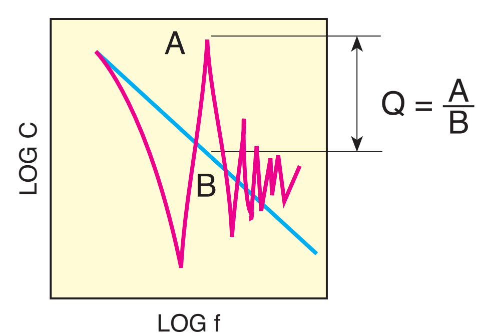


Figure 6. Maximum amplification at resonance (Q).

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Q can be easily calculated from any compliance curve. If a curve does not have a rigid body line, make sure to draw one. The line should be tangent to the “straight” part of the compliance curve, and should have a slope of -2 (a 10-fold increase in frequency corresponds to a 100-fold decrease in compliance). Be wary of compliance curves that have ideal rigid body lines that don’t have slopes of -2.

Example:

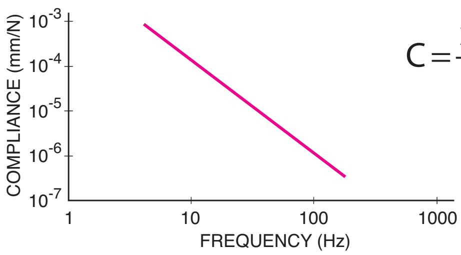
Calculation of the maximum amplification at resonance (Q) for the honeycomb core table tops is shown in Figures 4 and 5, revealing that the steel-core table in Figure 5 damps out about 3 times more effectively than the aluminum-core table in Figure 4. The Q of a typical granite block (compliance curve not shown) is also included for your comparison.

Steel honeycomb core	$Q = \dfrac{1.4\;\;10^{-5}}{3.9\;\;10^{-6}} \cong 4$
Aluminum honeycomb core	$Q = \dfrac{2.2\;\;10^{-4}}{1.9\;\;10^{-5}} \cong 12$
Granite block	$Q = \dfrac{2.3\;\;10^{-4}}{5\;\;10^{-7}} \cong 460$

How to Approximate an Optical Tables "Ideal Rigid Body" Line

About Compliance

The compliance of a body is defined as the displacement amplitude of a point on the table surface per unit of force applied. Under the influence of a time-varying force, the compliance of a free ideal rigid body in one dimension is proportional to the inverse square of the frequency:



$$C = \frac{x_0}{F_0} \cong \frac{1}{M\omega^2}$$

Where:

C = compliance

$\mathbf{x_0}$ = displacement

F = applied force

M = mass

ω = forcing frequency (rad/s) 2πf when f is frequency in Hz

When plotted on a log–log plot, the compliance of a perfectly rigid body is always a straight line with a slope of -2. This line, called the Ideal Rigid Body (IRB) line, is a fundamental feature of a table top's compliance curve and is the starting point for a meaningful evaluation of a table top's dynamic performance.

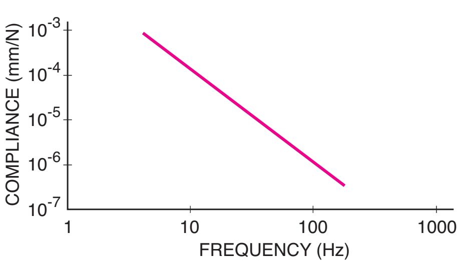


Figure 1. Compliance of an Ideal Rigid Body.

So far, so good. But a few customers have noticed that when they use this formula to approximate an Ideal Rigid Body line for a table top, the result of their calculation is several times lower than the Ideal Rigid Body line shown in the corresponding compliance curves. Is there something wrong with the compliance curve data? Not at all. This technical note explains the "discrepancy" and offers a method for reliably approximating the Ideal Rigid Body line for a table top.

Experimental Procedure Accounts for the Difference

The incongruous results arise from a difference in where the force is applied to a table top and where the response of the structure is measured.

The force was applied and measured at the center of the object (Figure 2). When a table top is measured experimentally using this method, the calculated value for the Ideal Rigid Body line does indeed match the experimental performance of the tables.

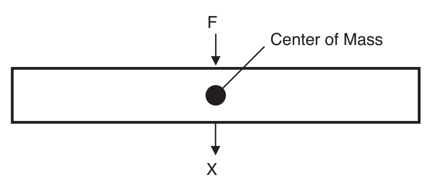


Figure 2. The idealized 1/Mω2 formula assumes the force is applied and measured at the center of the rigid structure.

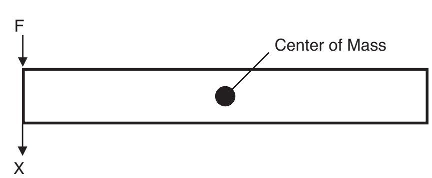


Figure 3. In practice, table top compliance is tested by striking the table edge, and measuring table top response in the same location.

However, it is common knowledge that the compliance of a table top is worst at its edges and therefore all reputable suppliers of vibration-control systems apply the force at the edge and monitor the response of the table at the same location (Figure 3). But when the compliance is measured in this manner, there are

Tutorial continued

actually two components of the rigid body motion in response to the applied force: 1) Center-of-Mass Motion - Identical to the response of the table as if the force were applied at the center of the table

(i.e.

$$\frac{1}{M\omega^2}$$

, and 2) Rotational Motion - Due to the torque exerted on the table when the force is applied.

Quantifying Table Top Rotation

We can approximate the rotational component by modeling the table as a rigid rod. The torque applied to the rod by a force at the end (Figure 4) is:

$$|\tau| = |F\,\Sigma r| = \left|\frac{F\ell}{2}\right| = \left|\frac{dL}{dt}\right| = I\ddot{\theta}$$

Where:

τ = torque

F = applied force

r = radius to the center of mass

l = length of the rod

I = moment of inertia

L = angular momentum

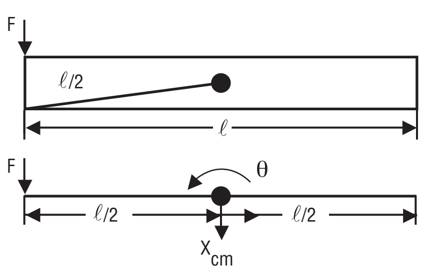


Figure 4. Applying a time-varying force and using r = l/2, we have:.

$$I\ddot{\theta} = F_0 \sin(\omega t)\frac{\ell}{2}$$

Integrating twice, angular displacement is found:

$$\theta(t) = -\frac{F_0\,\ell}{2I\omega^2}\sin(\omega t)$$

For small linear displacements, r sin θ = r θ, so:

$$x_{ROT}(t) = \frac{\ell}{2}\theta(t) = -\frac{F_0\,\ell^2}{4I\omega^2}\sin(\omega t)$$

Now, we need I, the moment of inertia, for a rigid rod:

$$I = \int_{-\frac{\ell}{2}}^{+\frac{\ell}{2}} \rho \bullet r^2 dr \;\; \left(\textit{where } \rho = \frac{M}{\ell} \textit{ is the mass per unit length}\right) = \frac{M}{\ell}\frac{x^3}{3}\Bigg|_{-\frac{\ell}{2}}^{\frac{\ell}{2}} = \frac{1}{3}\frac{M\ell^2}{4}$$

Thus, the rigid-body rotation (torque) component of the motion is:

$$x_{ROT}(t) = -\frac{F_0\ell^2}{4\omega^2}\bullet\frac{3\bullet 4}{M\ell^2}\sin(\omega t) \;= -\frac{3F_0}{M\omega^2}\sin(\omega t)$$

Combined Center-of-Mass and Rigid-Body Displacement

For the force applied and displacement measured, as in Figure 3, the center-of-mass (CM) and rigid-body rotation (ROT) displacements are additive.

$$x_{TOTAL}(t) = x_{CM}(t) + x_{ROT}(t) \quad = -\frac{F_0}{M\omega^2}\sin(\omega t) - 3\frac{F_0}{M\omega^2}\sin(\omega t) \quad = -4\frac{F_0}{M\omega^2}\sin(\omega t)$$

Thus, the total compliance for applying the force to the table edge, as in Figure 3, and measuring the response in the same location is:

$$C_{TOTAL} = \frac{|x_{TOT}|}{|F|} = \frac{4}{M\omega^2}$$

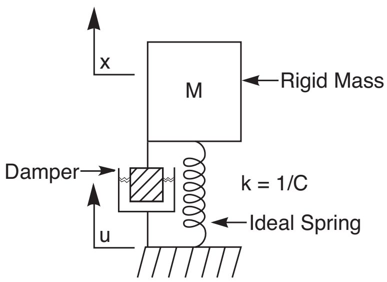
This result is exactly four times the compliance value predicted by the simplified (force applied at center) model. If the force were applied at the table corner, analogous computations for a rigid plate would give:

$$C_{TOTAL} = \frac{7}{M\omega^2}$$

When the Ideal Rigid Body line is approximated with these formulas, the result correlates well with the observed Ideal Rigid Body lines in experimental compliance curves.

Note: We would like to acknowledge the assistance of Dr. John Beckerle at Clemson University in preparing this technical note.

About Optical Table Performance Specifications



The Dynamic Deflection Coefficient and Relative Motion: The Most Meaningful Table Top Specifications

The dynamic rigidity of a table top (its resistance of the top surface movement from vibration) is the single most important measure of vibration control performance. But compliance curves, the classic method of measuring dynamic rigidity, do not go far enough in providing a quantitative measure of table top vibration control capabilities.

The Dynamic Deflection Coefficient, a figure of merit that can be derived from any compliance curve, enables you to compare dynamic performance directly and select an appropriate level of table stability for your application. When the ambient vibration level is known, the Dynamic Deflection Coefficient can also be used to calculate the Relative Motion value, which can then be used in selecting the most appropriate table for your application.

For easier comparison of Newport table tops, the Dynamic Deflection Coefficient and Relative Motion value for a typical lab environment are specified for all full-size tables and breadboards.

Table Top Dynamic Response to Vibration

A table top is subjected to a myriad of different vibration inputs, which taken together, closely approximate random vibration. A table's acceleration response to random vibration is given by:

(1)

$$G_{rms} = \left[\frac{\pi}{2} f_n Q\,(PSD)\right]^{\frac{1}{2}}$$

Where:

G_{rms} is rms acceleration response

f_n is the table's corresponding resonant frequency (Hz)

Q is the maximum amplification at resonance, a measure of damping efficiency (dimensionless), and

PSD is the applied power spectral density (g2/Hz)

The relative displacement response of the table top is given by:

(2)

$$\delta = \frac{G_{rms}\,g}{(2\pi f_n)^2}$$

Where:

G is the displacement response

g is the acceleration due to gravity

Combining equations (1) and (2) yields the displacement response of a table top to random vibration:

(3)

$$\delta = \frac{g}{(2\pi f_n)^2}\left[\frac{\pi}{2} f_n Q\,(PSD)\right]^{\frac{1}{2}}$$

$$\delta = \left(\frac{1}{32\pi^3}\right)^{\frac{1}{2}} g \left(\frac{Q}{f_n^{\,3}}\right)^{\frac{1}{2}} (PSD)^{\frac{1}{2}}$$

The Relative Motion Formula

Equation 3, the basis for the Relative Motion Formula in Figure 1, enables you to calculate the worst-case relative motion between two points on a table at the natural frequency (fn). Calculated results agree closely with measured performance generated by interferometric methods. For your convenience,

Tutorial continued

Newport also provides a calculated Relative Motion value for all tables and breadboards, which accurately reflects performance in a typical quiet laboratory environment.

The second term of the Relative Motion equation, (Q/fn3)1/2, is the Dynamic Deflection Coefficient, a figure of merit derived from the table top's minimum resonant frequency and damping efficiency, which together quantify the table top's dynamic performance. The third term, (PSD)1/2, is the contribution of the applied vibration intensity level, which can be measured directly or estimated using the table (random vibration is assumed). Isolator transmissibility, the fourth term, accounts for the attenuation of ground vibrations at the frequency range of interest through the support structure.

Note that this formula is a worst-case estimate of relative motion, and that the actual relative motion experienced in most typical installations will be less. On the other hand, if the applied vibration includes sharp peaks at certain frequencies (i.e., non-random vibration), the actual relative motion may be considerably higher.

Example:

Calculate the worst-case (or maximum) Relative Motion value (RM) between two points on a 4 ft x 8 ft x 12 in. (1200 x 2400 x 305 mm) RS 2000™ table top installed in a lab near a street. Please see Research Grade Optical Tables for the compliance curve.

First of all, find the maximum Dynamic Deflection Coefficient.

For the resonance peak at:

fn ≈ 190 Hz, Q ≈ 2.7, (Q/fn3)1/2 ≈ 0.6 x 10-3.

For the resonance peak at:

fn ≈ 270 Hz, Q ≈ 22, (Q/fn3)1/2 ≈ 1.1 x 10-3.

Assume

g = 386 in./sec2

PSD = 10-9 g2/Hz

T <0.01 at typical frequency range of interest

Then the relative motion:

$$RM = \frac{1}{32\pi^3}^{\frac{1}{2}} \sum 386 \sum \left(1.1 \sum 10^{-3}\right) \sum \left(10^{-9}\right)^{\frac{1}{2}} \sum 0.01 \sum 2$$

$$RM \cong 0.85 \sum 10^{-8} \text{ inches, or}$$

$$RM \cong 0.2 \text{ nm.}$$

About the Deflection Under Load Specification

After dynamic rigidity, the static rigidity of a table top is the most important performance specification. Static rigidity corresponds to the intuitive concept of stiffness and is measured by static deflection, the amount of downward "sag" of the table top between its support points when a static load is placed on the table top.

A small deflection means that components will remain better aligned on the table, especially when heavy loads are placed on the table or are moved. Static rigidity is also an important factor in the table top's dynamic response to low-frequency vibrations.

Using the formula provided, you can accurately predict the deflection in the center of the table for a given point load. For comparison purposes, Newport provides a Deflection Under Load specification for all full-sized tables and breadboards based on a 250 lb (114 kg) load.

In the case of a table supported by isolators in the recommended location (22% from the table ends) and an incremental point load applied halfway in between, the downward deflection at the center of the table (Figure 2) is given by:

$$\text{Static Deflection} = \frac{PL^3}{24\,EbTH^2} + \frac{PL}{4\,GHb}$$

Where:

P = force exerted by a point load

L = length of span between isolators (length of table x 0.56)

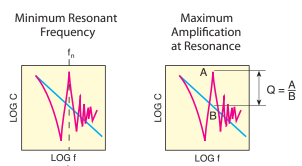
b = width of table

H = thickness of table

T = thickness of skins

E = Young's modulus of the skin material

G = shear modulus of the core



Typical PSD Values*

Relatively Quiet Lab	$<10^{-10}$ g²/Hz
Lab Next to Street	$<10^{-9}$ g²/Hz
Light Manufacturing	$<10^{-8}$ g²/Hz

*Assumes random vibration as found in real world environments

$$\text{Maximum Relative Motion at } f_n = g \left(\frac{1}{32\pi^3}\right)^{\frac{1}{2}} \Sigma \left(\frac{Q}{f_n^3}\right)^{\frac{1}{2}} \Sigma \left(\text{PSD}\right)^{\frac{1}{2}} \Sigma \; T \; \Sigma \; 2$$

Constant [g = 386 in/sec² (9.8 m/sec²)] — Dynamic Deflection Coefficient — Floor Vibration Level (g²/Hz) — Isolator Trans-missibility (<0.01 Above 10 Hz Typical) — Multiplier For Worst-Case Motion Between Two Points

Figure 1. Formula for determining the maximum relative motion between two points on an isolated table top from any compliance curve. Table tops supported by rigid stands (or legs) would have a larger relative motion value.

The first term in the equation is the contribution from bending and is largely a function of the skin properties, while the second term is the contribution due to shear, which is primarily dependent on the properties of the core.

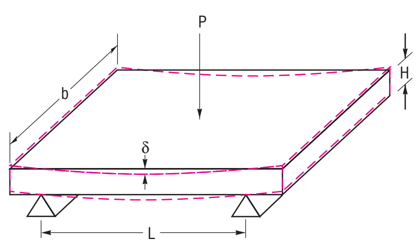


Figure 2. Static deflection for a point load P applied at the center of a panel supported at the recommended isolator locations.

All table and breadboard material constants are readily available in the table and breadboard sections, with the exception of the Young's Moduli, which are supplied in the following table

Young's Moduli of Skin Materials:

Carbon Steel	29.0 x 106 psi (200 GPa)
Stainless Steel	29.0 x 106 psi (200 GPa)
Super Invar 6061-T6	21.5 x 106 psi (148 GPa)
Aluminum	9.9 x 106 psi (69 GPa)
Granite	7.0 x 106 psi (48 GPa)

Example:

P = 250

L = 52 in. span

E = 29,000,000 psi

b = 48 in.

T = 0.1875 in.

H = 12 in.

G = 225,000 psi

Stat Defl Equa 2-S

$$SD = \frac{(250)(52)^3}{(24)(29 \text{ x } 10^6)(48)(.1875)(12^2)} + \frac{(250)(52)}{(4)(225{,}000)(12)(48)}$$

$$= 3.90 \text{ x } 10^{-5} + 2.51 \text{ x } 10^{-5}$$

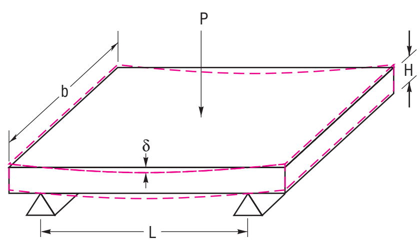
$$SD = 6.41 \text{ x } 10^{-5} \text{ inches}$$

Footnote:We greatly appreciate the assistance of Daniel Vukobratovich of the University of Arizona Optical Sciences Center in preparing this technical note.

Tutorials

Tutorial

Why Honeycomb Structures Deflect Less Than Solid Structures



Sandwich structures for vibration isolation tables are stiffer than solid tables of equal weight. For the same weight, the fundamental frequency of a sandwich table is higher than that of a solid table. Although the bending behavior of a sandwich table is complex, the following simple approximations are useful.

The fundamental frequency of a vibration isolation table acted on by only self-weight is given by:

$$f \cong \frac{C}{2\pi}\left(\frac{g}{\delta}\right)^{\frac{1}{2}}$$

Where:

f = f is the fundamental frequency (Hz)

δ is the self-weight induced deflection

g is the acceleration due to gravity

C is estimated to be 1.13–1.26, depending on the table geometry*

The self-weight induced deflection of a rectangular table with simple supports at its corners is given by:

$$\delta \cong \frac{1}{144} e^{1.267\left(\frac{b}{L}\right)} \frac{P}{D} L^4$$

Where: δ is the self-weight induced deflection

P is the table weight per unit area

L is the table length

b is the table width

D is the static flexural rigidity of the table

The static flexural rigidity of a solid table is given by:

$$D_{SOLID} = \frac{Eh^3}{12\left(1-\upsilon^2\right)}$$

Where: $D_{SANDWICH}$ is the flexural rigidity of the sandwich table

E is the elastic modulus of the face sheets of the sandwich

t_F is the thickness of the face sheets of the sandwich

h is the table thickness.

(The previous equation assumes that the top and bottom face sheets have the same thickness and the shear stiffness of the core is not significant.)

Using the equations for deflection and static flexural rigidity, the ratio of the solid to sandwich deflection for equally thick tables is given by:

$$\frac{\delta_{SANDWICH}}{\delta_{SOLID}} = \frac{P_{SANDWICH}}{\rho \quad h} \quad \frac{D_{SOLID}}{D_{SANDWICH}}$$

Where:

δ_{SOLID} is the deflection of the solid table

$\delta_{SANDWICH}$ is the deflection of the sandwich table

$P_{SANDWICH}$ is the weight per unit area of the sandwich table

ρ is the density of the solid material

An example of the above equation is the performance of an 8 in. thick Newport table compared with a solid 8 in. thick carbon steel table. The properties of the two tables are:

Solid	Sandwich	
1. Elastic modulus	29 x 106 psi	29 x 106 psi
2. Skin density	0.28 lb-in.-3	0.28 lb-in.-3
3. Poisson's ratio	0.33	0.33
4. Face sheet thickness	N/A	0.19 in.
4. Weight per unit area	2.24 lb/in.2	0.17 lb/in.2

The static flexural rigidity of the solid table is:

$$D_{SOLID} = \frac{Eh^3}{12\left(1-\upsilon^2\right)} = \frac{\left(29\times10^6\,psi\right)\left(8in.\right)^3}{12\left[1-\left(0.33\right)^2\right]} = 1.39\times10^9\,lb-in.$$

The static flexural rigidity of the sandwich table is:

$$D_{SANDWICH} = \frac{Et_F h^2}{2\left(1-\upsilon^2\right)} = \frac{\left(29\times10^6\,psi\right)\left(0.19in.\right)\left(8in.\right)^2}{2\left[1-\left(0.33\right)^2\right]} = 198\times10^6\,lb-in.$$

But the ratio of the self-weight deflections is:

$$\frac{\delta_{SANDWICH}}{\delta_{SOLID}} = \frac{P_{SANDWICH}}{\rho\times h}\;\frac{D_{SOLID}}{D_{SANDWICH}} = \frac{\left(0.17psi\right)}{\left(0.28lb-in.^{-3}\right)\left(8in.\right)}\;\frac{1.39\times10^9\,lb-in.}{198\times10^6\,lb-in.} = 0.53$$

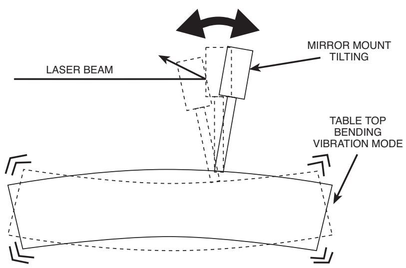
This example shows that the self-weight deflection of a sandwich table is about half that of a solid table< of the same thickness. Indeed, experience has shown that the self-weight deflection of a sandwich table compared with a solid table of equal weight is significantly better than this example.

* See C.W. Bert, Journal of Sound and Vibration, 1993, 162 (3), 547-557.

Note: We greatly appreciate the mathematical treatment supplied by Daniel Vukobratovich of the Optical Sciences Center at the University of Arizona.

Tutorial

Approximating Real-World Beam Deflection



Newport's Maximum Relative Motion formula provides an excellent approximation of maximum (worst-case) table top deflection. This technical note explains and quantifies the relationship between Maximum Relative Motion and actual beam deflection in real-world applications.

A simple setup illustrates the examples that follow: a mirror mount attached to a table top. A laser beam reflected in the mirror will be affected by two types of table top vibrational modes: axial deflection from translational (expanding/contracting) table top motion and angular deflection caused by table top bending motion. The relative contributions of each mode are generalized under two principles, and a quick method for estimating beam deflection directly is included.

Principle 1: Table top deflection is not a problem, as long as the displacement is in translation

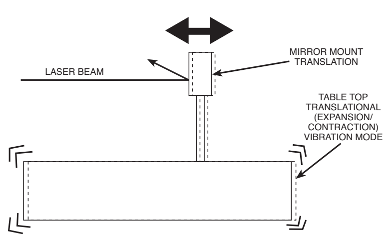


Figure 1: Translational motion of the table top does not affect even sensitive systems.

The maximum deflection of the table top surface is calculated with the Maximum Relative Motion formula:

This formula yields the worst-case deflection for the table top or breadboard where:

$$\delta = \left(\frac{1}{32\,\pi^3}\right)^{\frac{1}{2}} g \left(\frac{Q}{f_n^3}\right)^{\frac{1}{2}} PSD^{\frac{1}{2}}$$

δ = worst-case (maximum) deflection of the table top

g = acceleration due to the Earth's gravity (386 in./sec2)

Q/fn$_3$ = the Dynamic Deflection Coefficient of the table (specified for all Newport tables and breadboards, but can also be derived from any com pliance curve)

PSD = power spectral density at fn

Using this formula, we can see how the table deflection affects a mirror mounted to a table top.

Example:

Consider again the vibrational response of a 4 ft. x 8 ft x 12 in. (1200 x 2400 x 305 mm) Newport RS 2000™ table. Using a realistic PSD of 1 x 10-9g2/Hz, the maximum table deflection is:

$$\delta = \left(\frac{1}{32\pi^3}\right)^{\frac{1}{2}} g \left(\frac{5}{190^3}\right)^{\frac{1}{2}} \left(10^{-9}\right)^{\frac{1}{2}} = 331 \quad 10^{-9}\text{inches}$$

This calculated translational displacement is about one-third of a millionth of an inch, or about 0.013 waves of HeNe laser light. This deflection would not normally be a concern in most experiments or applications.

Principle 2: Table top angular deflection is a far more significant contributor to beam deflection

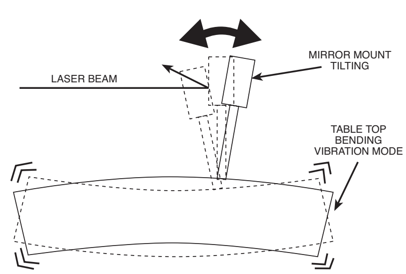


Figure 2: Table top bending is the most significant cause of beam deflection.

A more serious situation arises when the slope of the table top is considered in the calculation. When a table top or breadboard is affected by vibration, it not only exhibits translational modes, it also has bending modes. Table top bending can have serious consequences for optical performance for two reasons:

- When a mirror is rotated, the angle of the reflected beam is twice the tilt angle.
- The “doubled” error also increases linearly with reflected spot distance from the mirror, or:

δtilt = θmirror x ×

Where:

δtilt = spot displacement

θmirror = mirror tilt angle

× = distance from the mirror to spot

For example, a tilt of only one milliradian (1 x 10-3 radian) of a flat mirror at a distance of one meter produces a shift in the reflected beam of 2 mm!

Note: We greatly appreciate the participation of Dr. Daniel Vukobratovich of the Optical Sciences Center at the University of Arizona who supplied this mathematical treatment.

The maximum slope of the table is also quite easy to determine. As an example, consider a 4 ft x 8 ft x 12&in. (1200 x 2400 x 305 mm) Newport RS 2000™ table. The table is supported at each corner and is excited by a PSD of 10-9g2/Hz. In this idealized case the table acts like a simply supported, uniformly loaded beam, and maximum surface slope is related to maximum table deflection by:

$$\theta_{max} = \pi \quad \frac{\delta_{max}}{L}$$

Where:

θmax = maximum surface slope

δmax = maximum surface deflection

L = table length

From the previous example, the maximum table deflection was 331 x 10-9 in. So the maximum table slope is:

$$\theta_{max} = \pi \quad \frac{331 \quad 10^{-9}}{96} = 10.8 \quad 10^{-9}\text{radians}$$

To determine the effect this will have, consider a flat mirror reflecting a beam over 40 in. (~1 m). The shift in spot location is then:

δ = 2 x (10.8 x 10-9) x 40 = 867 x 10-9 in.

The beam deflection is slightly less than one millionth of an inch. This effect, multiplied by the number of mirrors in the system and the total path length, can have a significant effect on experimental results if the table does not provide an adequate level of vibration-control performance. For example, a total relative movement of five millionths of an inch can seriously degrade the image quality of a diffraction-limited optical system with a numerical aperture of 0.25. This level of deflection can also completely ruin the exposure of a hologram.

Calculating Spot Deflection for any Table Top or Breadboard

Combining the equations for reflected spot deflection and table deflection yields an excellent approximation for the displacement of a spot reflected in a mirror for any table top or optical breadboard:

$$\delta = 77 \quad \frac{x}{L} \quad \frac{Q}{f_n^3}^{\frac{1}{2}} \quad PSD^{\frac{1}{2}}$$

Tutorial continued

Where:

δ = motion of the reflected spot in inches

x = distance of the reflected spot from the mirror, in inches

L = table length, in inches

Q/fn3 = dynamic deflection coefficient of table top or breadboard

PSD = power spectral density at table top's natural frequency

Example:

As a check, this equation will be used to calculate spot motion in the last example. The parameters are then:

x = 40 in.

L = 96 in.

Q = 5

f_n = 190 Hz

PSD = 1 x 10-9g2/Hz

Then the deflected spot displacement is:

$$\frac{\delta_{\mathrm{SANDWICH}}}{\delta_{\mathrm{SOLID}}} = \frac{P_{\mathrm{SANDWICH}}}{\rho \times h} \quad \frac{D_{\mathrm{SOLID}}}{D_{\mathrm{SANDWICH}}} = \frac{(0.17\mathrm{psi})}{(0.28\mathrm{lb-in.}^{-3})(8\mathrm{in.})} \quad \frac{1.39\times10^{9}\mathrm{lb-in.}}{198\times10^{6}\mathrm{lb-in.}} = 0.53$$

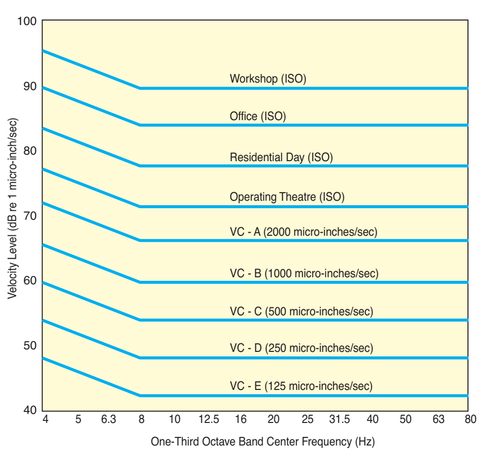
This is essentially the same result that was obtained before.

Environmental Vibration Criteria

Generic Vibration Criteria Curves

These generic criterion curves have been developed on the basis of data from individual systems and measurements made in facilities both before and after vibration problems had been solved. Moreover, they have been used extensively by leading vibration consultants for the semiconductor manufacturing industry for almost 20 years, and have been extended and refined as the industry has moved to narrower line widths.

The curves take into account that equipment used for the most exacting tasks (such as manufacturing semiconductors with smaller device geometries) is stiffer and better-isolated. It is, however, important to note that these criteria are for guidance only. For example, like any useful and general rule of thumb, the criterion curves are reasonably conservative for some specific cases, especially equipment with well-designed built-in vibration control systems. It should also be noted that these criterion curves do not replace high-resolution narrowband spectrum analysis for diagnostic studies. If a comprehensive study is required, both methods should be used.



Generic vibration criterion table

Velocity-Based

The criteria are specified as a set of “1/3-octave-band velocity spectra” that define guidelines for allowable vibration levels for various activities and equipment. One of the major benefits of these criterion curves is that vibration is expressed in terms of root-mean-square velocity instead of units of displacement or acceleration. Various studies have shown that while individual equipment may show unique displacement responses to different frequencies, these points often lie on a curve of constant velocity. Moreover, the threshold constant velocity that affects the performance of equipment within each class tends to be rather uniform. The International Standards Organization (ISO) also uses a velocity-based standard for human exposure to vibration, which is incorporated into the criterion curve chart.

Broadband

Floor vibration in both manufacturing and research environments is typically dominated by random, “broadband” energy, as opposed to pure tone energy consisting of discrete frequencies. Although both broadband and pure tone vibrations will excite system resonances, the degree of their excitation will be different. Because random vibration closely approximates the measured floor vibrations observed in laboratories and manufacturing facilities, a specification based on random vibration more accurately reflects real world applications.

Evaluation of sites and the design goal of many new facilities confirm that “1/3-octave” vibration criteria accurately reflect typical environmental vibration spectra. This means that the bandwidth of the random vibration — the “window” of frequencies which is taken into account — is 23% of the band’s center frequency. A proportional bandwidth is used instead of fixed bandwidth based on a conservative estimate of the system’s ability to damp resonances.

Tutorial continued

Current Semiconductor Industry Requirements

Much of the current design activity for fab construction is setting goals in the VC-D to VC-E (250 µin./sec to 125 µin./sec). This range is believed to be appropriate to production of line widths of 0.3 µm. Older facilities will increasingly need supplemental vibration control systems to achieve the required level of vibration control. Next generation systems seeking line widths of 0.18 µm and below will almost certainly need active vibration isolation to complement even the most thorough fab construction.

Criterion Curve	Max Level(1) micro-in./sec (dB)	Detail Size (2) microns	Description of Use
Workshop (ISO)	32,000 (90)	N/A	Distinctly felt vibration. Appropriate to workshops and non-sensitive areas.
Office (ISO)	16,000 (84)	N/A	Felt vibration. Appropriate to offices and non-sensitive areas.
Residential Day (ISO)	8000 (74)	75	Barely felt vibration. Appropriate to sleep areas in most instances. Probably adequate for computer equipment, probe test equipment and lower-power (to 20X) microscopes.
Operational Theatre (ISO)	4000 (72)	45	Vibration not felt. Suitable for sensitive sleep areas. Suitable in most instances for microscopes to 100X and for other equipment of low sensitivity.
VC-A	2000 (66)	8	Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, etc.
VC-B	1000 (60)	3	An appropriate standard for optical microscopes to 1000X, inspection and lthography equipment (including steppers) to 3 microns line-widths.
VC-C	500 (54)	1	A good standard for most lithography and inspection equipment to 1 micron detail size.
VC-D	250 (48)	0.3	Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operation to the limits of their capacity.
VC-E	125 (42)	0.1	A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems and other systems.

Additional Notes

The information given in this table is for guidance only. In most instances, it is recommended that the advice of someone knowledgeable about applications and vibration requirements of the equipment and process be sought.

1. As measured in one-third octave bands of frequency over the frequency range 8–100 Hz. The dB scale is referenced to 1 micro-in./sec.
2. The detail size refers to the line widths for microelectronics fabrication, the particle (cell) size for medical and pharmaceutical research, etc. The values given take into account the observation that the vibration requirements of many items depend upon the detail size of the process.

Tutorial

Vibration Control Definitions of Characteristics

Absolute: A term applied to calibration (e.g. of an accelerometer) based upon the primary standards of mass, length and time. (See also comparison calibration.)

Absorber: A device capable of soaking up vibration.

Acceleration: Acceleration is rate of change of velocity with time (denoted as dv/dt or d2x/dt2), along a specified axis, usually expressed in g or gravitational units. It may refer to angular motion.

Accelerometer: A sensor or transducer or pickup for converting acceleration to an electrical signal.

Accuracy: The capability of an instrument to indicate the true value. Do not confuse with inaccuracy (sum of hysteresis + non-linearity + temperature effect, etc.) nor with repeatability.

Aliasing: A spectrum analysis problem resulting from sampling data at too low a rate. It causes high-frequency signals to appear in a spectrum at low frequencies.

Amplitude: The magnitude of variation (in a changing quantity) from its zero value. Always modify it with an adjective such as peak, RMS, average, etc. May refer to displacement, velocity, acceleration, voltage, current force of pressure.

Angular Frequency: (Also known as circular frequency.) ω is the torsional vibration frequency in radians per second. Or divide by 2π and express in hertz (Hz) or (obsolete) cycles per second (cps).

Average: Refer to a textbook on electrical engineering. In the exclusive case of a pure sine wave, the average value is 0.636 x peak value.

Averaging: Summing and suitably dividing several like measurements to improve accuracy or to lessen any asynchronous components.

Balancing: (Mechanical) Adjusting the distribution of mass in a rotating element, to reduce vibratory forces generated by rotation.

Broadband: Vibrations (or other signals) which are unfiltered. Signals at all frequencies contribute to the measured value.

Calibration: (As applied to vibration sensors) An orderly procedure for determining sensitivity as a function of frequency, temperature, altitude, etc.

Charge Amplifier: An amplifier which converts a charge input signal (as from an accelerometer) into an output voltage; charge-to-voltage converter.

Coherence: A measure of the similarity of vibration at two locations, giving insight into possible cause and effect relations.

Comparison: A term applied to calibration (e.g. of an accelerometer) in which sensitivity is tested against a standard.

Compliance: The reciprocal of stiffness, i.e., displacement divided by force.

Critical Frequency: The particular resonant frequency (see resonance) at which damage or degradation in performance is likely.

Crossover Frequency: In sinusoidal vibration testing, the unique foreign frequency at which the required displacement yields the desired acceleration and vice versa.

Cycle: The complete sequence of instantaneous values of a periodic event, during one period.

Damping: Dissipation of oscillatory or vibratory energy, with motion or with time. Critical damping CC is that value of damping that provides most rapid response to

Tutorial continued

a step function without overshoot. Damping ratio is a fraction of CC.

Decade: The interval between two frequencies which differ by exactly 10:1.

deciBel: Ratios of identical quantities are expressed in decibel or deciBel or dB units. The number of dB is ratioed against some standard or reference value in terms of base 10 logarithm of the ratio. In measuring acoustic or vibration power, as in PSD or ASD or random vibration, the number of dB = 10 log10P/P0. P0, the reference level, equals 0 dB. In measuring the more common voltage-like quantities such as acceleration, the number of dB = 20 log10E/E0. E0, the reference level, equals 0 dB.

Degrees of Freedom: In mechanics, the total number of directions of motion, of all the points being considered, on a structure being modeled or otherwise evaluated. In statistics, the number of independent variables used in constructing a mathematical model representing some collection of random variables.

Deterministic Vibration: A vibration whose instantaneous value at any future time can be predicted by an exact mathematical expression. Sinusoidal vibration is the classic example. Complex vibration is less simple (two or more sinusoids).

Displacement: Specified change of position, or distance, usually measured from mean position or position of rest. Usually applies to uniaxial, less often to angular motion.

Distortion: In electronic measurements, distortion is any unwanted signal; e.g. amplifiers may generate unwanted signals. This refers to any unwanted motion. If sinusoidal motion was desired at a fundamental frequency, distortion is any motion at harmonics or subharmonics of the frequency, or any mechanical “hash” (perhaps due to parts colliding).

Duration: of a shock pulse is how long it lasts. For “classical” pulses, time is usually measured between instants when the amplitude is greater than 10% of the peak value.

Filter: An electronic device to pass certain frequencies (pass band) but block other frequencies (stop band). Classified as low-pass (high-stop), high-pass (low-stop), band-pass or band-stop.

Forced Vibration: The vibratory motion of a system caused by some mechanical excitation. If the excitation is periodic and continuous, the response motion eventually becomes steady-state.

Forcing Frequency: In sinusoidal vibration testing or resonance searching, the frequency at which a shaker vibrates.

Fragility: The maximum load equipment can stand before failure (malfunction, irreversible loss of performance or structural damage) occurs.

Fragility Test: Expensive but highly useful dynamic tests of several samples (to account for variations in tolerances material properties and manufacturing processes) at potentially destructive frequencies, to determine fragility.

Free Vibration: Free vibration occurs without forcing, similar after a reed is plucked.

Frequency: The reciprocal of the period T in seconds (or a periodic function; 1/T0). Usually given in Hertz (Hz), meaning cycles per second (cps).

Frequency Response: The portion of the frequency spectrum over which a device can be used, within specified limits of amplitude error.

Frequency Spectrum: A description of the resolution of any electrical signal into its frequency components, giving the amplitude (sometimes also phase) of each component.

Fundamental Mode of Vibration: That mode having the lowest natural frequency.

g: The acceleration produced by Earth's gravity. By international agreement, the value for 1 gravitational unit is 9.80665 m/s2= 386.087 in/sec2= 32.1739 ft/sec2.

Harmonic: A sinusoidal quantity having a frequency that is an integral multiple (x2, x3, etc.) of a fundamental (x1) frequency.

Hash: Distortion (usually non-harmonic) on a signal. May be viewed on an oscilloscope trace. (slang).

Impact: A collision between masses.

Impulse: The integral of force over a time interval.

Induced Environments: Conditions generated by operating some equipment, as opposed to natural environments.

Inertance (or Accelerance). The ratio of acceleration to force.

Input: The mechanical motion, force or energy applied to a mechanical system, e.g., the vibratory input from shaker to test item. Or an electrical signal, e.g. from an oscillator to the power amplifier driving a shaker.

Input Control Signal: Originates in a control sensor; sometimes selected between or averaged between several sensors. Used to regulate shaker intensity. (May originate in a force sensor for force-controlled testing.)

Intensity: The severity of a vibration or shock. Nearly the same meaning as Amplitude, defined earlier, but less precise, lacking units.

Isolation: A reduction in motion severity, usually by resilient support. A shock mount or isolator attenuates shock. A vibration mount or isolator attenuates steady-state vibration.

Jerk: The rate of change of acceleration with time.

Linear System: A system is linear if its magnitude of response is directly proportional to its magnitude of excitation, for every part of the system.

Linearity: The closeness of a calibration curve to a specified straight line, preferably passing through zero. Commonly specified as a % of full scale.

Mass: A physical property, dynamically computed as acceleration divided by force. Statically computed as W (which can be measured on a butcher scale) divided by the acceleration due to gravity. Ordinary structures are not pure masses as they contain reactive elements, i.e. springs and damping.

Mean: A value intermediate between quantities under consideration. A shaker's mean acceleration must be zero; no steady-state acceleration. But a vehicle can have steady-state motion.

Mechanical Impedance: The ratio of force to velocity, where the velocity is a result of that force only. Its reciprocal, mobility, is today more favored.

Mode: A characteristic pattern in a vibrating system. All points reach their maximum displacements at the same instant.

Natural Environments: Conditions occurring in nature, not caused by any equipment; effects are observed whether an equipment is at rest or in operation.

Natural Frequency: The frequency of an undamped system's free vibration; also, the frequency of any of the normal modes of vibration. Natural frequency drops when damping is present.

Noise: The total of all interferences in measurement system, independent of the presence of signal.

Notch: Minimum spectral value, at a natural frequency. Also, the deliberate reducing of a portion of a test spectrum (random vibration testing).

Tutorial continued

Octave: The interval between two frequencies differing by exactly 2:1.

Oscillation: Variation with time of a quantity such as force, stress, pressure, displacement, velocity, acceleration or jerk. Usually implies some regularity (as in sinusoidal or complex vibration).

Peak: Extreme value of a varying quantity, measured from the zero or mean value. Also, a maximum spectral value.

Peak-to-Peak Value: The algebraic difference between extreme values (as D = 2X).

Period: The interval of time over which a cyclic vibration repeats itself.

Periodic Vibration: (See also Deterministic Vibration.) An oscillation whose waveform regularly repeats. Compare with probabilistic vibration.

Phase: (Of a periodic quantity), the fractional part of a period between a reference time (such as when displacement = zero) and a particular time of interest; or between two motions or electrical signals having the same fundamental frequency.

Pickup: See Transducer.

Platform: Per MIL-STD-810, any vehicle, surface or medium that carries an equipment. For example, an aircraft is the carrying platform for internally-mounted avionics equipment and externally-mounted stores. The land is the platform for a ground radar set, and a man for a hand-carried radio.

Power Spectral Density or PSD: Describes the power of random vibration intensity, in mean-square acceleration per frequency unit, as g2/Hz or m2/s3. Acceleration spectral density or ASD is preferred abroad.

Precision: The smallest distinguishable increment (almost the same meaning as resolution); deals with a measurement system's possible or design performance.

Probabilistic Vibration: As compared to Deterministic Vibration, one whose magnitude at any future time can only be predicted on a statistical basis.

Quadrature Motion: (Or side or lateral motion or crosstalk), any motion perpendicular to the reference axis. Shakers are supposed to have zero quadrature motion.

Quadrature Sensitivity: (Or side or lateral motion or crosstalk sensitivity) of a vibration sensor is its sensitivity to motion perpendicular to the sensor's principal axis. Commonly expressed in % of principal axis sensitivity.

Random Vibration: (See Probabilistic Vibration.) One whose instantaneous magnitudes cannot be predicted. Adjustive "Gaussian" applies if they follow the Gaussian distribution. May be broadband, covering a wide, continuous frequency range, or narrow band, covering a relatively narrow frequency range. No periodic or deterministic components.

Range: A statement of the upper and lower limits over which an instrument works satisfactorily.

Repeatability: (1) The maximum deviation from the mean of corresponding data points taken under identical conditions. (2) The maximum difference in output for identically-repeated stimuli (no change in other test conditions). Do not confuse with accuracy.

Resolution: The smallest change in input that will produce a detectable change in an instrument's output. Differs from precision in that human capabilities are involved.

Resonance: Forced vibration of a true single degree of freedom system causes resonance when the forcing frequency equals the natural frequency, when any forcing frequency change decreases system response.

Response: The vibratory motion or force that results from some mechanical input.

Response Signal: The signal from a "response sensor" measuring the mechanical response of a mechanical system to an input vibration or shock.

Ringing: Continued oscillation after an external force or excitation is removed, as after a guitar string is plucked.

Rise Time: The time required for the output of a transducer to rise from 10% to 90% of its final value, as it responds to a step change in the measurand.

RMS or Root-Mean-Square Value: The square root of the time-averaged squares of a series of measurements. Refer to a textbook on electrical engineering. In the exclusive case of sine wave, σ, the RMS value, is 0.707 x the peak value.

Self-Induced Vibration: Also called self-excited vibration, results from conversion of non-oscillatory energy into vibration, as wind exciting telephone wires into mechanical vibration.

Sensitivity: Of a mechanical-to-electrical sensor or pickup, the ratio between electrical signal (output) and mechanical quantity (input).

Sensor: (See Transducer.)

Shock Machine: Or shock test machine, a device for subjecting a system to controlled and reproducible mechanical shock pulses.

Shock Pulse: A transmission of kinetic energy into a system in a relatively short interval compared with the system's natural period. A natural decay of oscillatory motion follows. Usually displayed as time history, as on an oscilloscope.

Shock Response Spectrum (or SRS): A plot of maximum response of SDoF systems vs. their natural frequencies, as they responded to an applied shock.

Signal Conditioner: An amplifier following a sensor, which prepares the signal for succeeding amplifiers, transmitters, readout instruments, etc. May also supply sensor power.

Simple Harmonic Motion: Periodic vibration that is a sinusoidal function of time.

Slew Rate: The maximum rate at which an instrument's output can change by some stated amount.

Source Follower: A device for converting a high impedance electrical signal to low impedance. Also referred to as an "impedance converter". Generally has a voltage gain of unity.

Spectrum: See Frequency Spectrum.

Standard Deviation: A statistical term: σ, the square root of the variance σ2, i.e., the square root of the mean of the squares of the measured deviations from the mean value.

Stationarity: A property of probabilistic vibration if the PSD (or ASD) and the probability distribution remain constant.

Steady-State Vibration: Periodic vibration for which the statistical measurement properties (such as the peak, average, RMS and mean values) are constant.

Stiffness: The ratio of force (or torque) to deflection of a spring-like element.

Strain-Gage Transducer: A changing-resistance sensor whose signal depends upon sensitive element deformation. In an unbonded wire strain-gage accelerometer, inertia affects a mass supported by nichrome wires; the wires change resistance in proportion to acceleration. The term may include piezoresistive accelerometers.

Stress Screening: A modern electronics production tool for precipitating latent defects such as poorly soldered connections. Utilizes random vibration + rapid temperature ramping.

Subharmonic: A sinusoidal quantity having a frequency that is an integral submultiple (x1/2, x1/3, etc.) of a fundamental (x1) frequency.

Tutorial continued

Time Constant: The interval needed for an instrument's output to move 63% of its ultimate shift as a result of a change in its input.

Tracking Filter: A narrow bandpass filter whose center frequency follows an external synchronizing signal.

Transducer: (or Pickup or Sensor). A device which converts some mechanical quantity into an electrical signal. Less commonly, the reverse conversion.

Transient Vibration: Short-term vibration of a mechanical system.

Transmissibility: In steady-state vibration, T is the non-dimensional ratio of response motion/input motion: two displacements, two velocities or two accelerations. The maximum T value is the mechanical "Q" of a system. At resonance, T is maximum.

Velocity: Rate of change of displacement with time, usually along a specified axis; it may refer to angular motion as well as to uniaxial motion.

Vibration: Mechanical oscillation or motion about a reference point of equilibrium.

Vibration Machine (or Exciter or Shaker). A device which produces controlled and reproducible mechanical vibration testing of mechanical systems, components and structures.

Vibration Meter: An apparatus (usually an electronic amplifier, detector and readout meter) for measuring electrical signals from vibration sensors. May display displacement, velocity and/or acceleration.

Weight: That property of an object that can be weighted, as on a scale; the gravitational force on an object.

White Random Vibration: That broadband random vibration in which the PSD (ASD) is constant over a broad frequency range.

Notes:

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