VIBRATION
ENGINEERING
CONSULTANTS

Active Vibration Isolation Systems

Daeil Systems Solutions for Electron Microscopy and Semiconductor/Display Manufacturing

Daeil Systems and Vibration Engineering Consultants

Sophisticated Active Vibration Isolation and Unprecedented Customer Support

Electron microscopes, analytical instruments, and semiconductor processing, metrology and inspection tools are extremely sensitive to vibration. In facilities with high levels of vibration, these instruments require active vibration isolation to achieve their performance specifications.

With over 35 years of experience, Daeil Systems is a global leader in building innovative vibration isolation solutions across a wide range of applications with exceptional performance. Their products undergo continuous improvement to keep pace with the increasingly stringent resolution and accuracy demands.

All of us at VEC are very enthusiastic about our partnership with Daeil Systems because of their dedication to customer satisfaction and unparalleled commitment to quality and performance. All Daeil Systems are TUV and CE certified.

Customization for Your Tools and Facility

Each customer's requirements are unique, based on the measured vibration in a facility, the weight and footprint of a tool, the center of mass, the internal operations of the tool, and budgetary considerations. VEC and Daeil Systems will work with you to review the data and design a custom solution based on your facility and your tool's unique requirements.

Daeil Systems Advantages

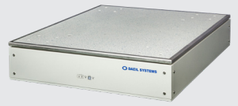
- *Integrated active and passive systems enable excellent vibration isolation across a broad frequency range; mitigates both low-frequency ground resonances and vibration from mechanical equipment*
- *Ten-year warranty on all DVIA-MB and DVIA-UB systems*
- *No generic bases for SEM; VEC and Daeil Systems customize each system based on the unique requirements of your tool or microscope*
- *The built-in controller does not require an external control box for active control*
- *Daeil's extensive product line enables both VEC and Daeil Systems to design a system based on the vibration in your facility, the weight and footprint of your microscope, and your budgetary considerations*

DVIA-MB Series

Ultra High Resolution Imaging and Analytical Instruments (<6000 kg)

- Scanning Electron Microscopes (SEM)
- Focused Ion Beam Microscopes (FIB & FIB/SEM)
- Transmission Electron Microscopes (TEM & STEM)
- Analytical Instruments

10 Year Limited Warranty

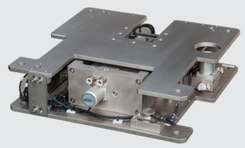


DVIA-P Modular System

Semiconductor & Display Manufacturing Tools

- Process Tools
- Metrology Tools
- Inspection Tools

1 Year Limited Warranty



DVIA-UB Platform

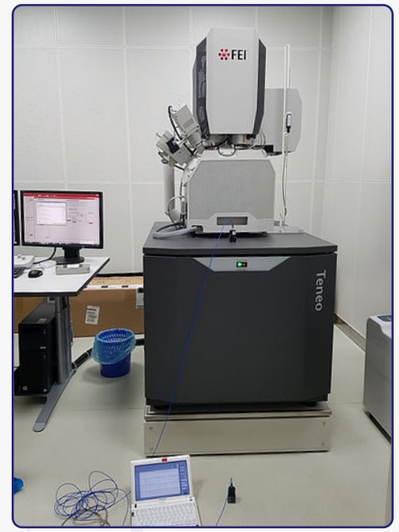
Conventional High Resolution Imaging and Analytical Instruments (<700 kg)

- Scanning Electron Microscopes (SEM)
- Focused Ion Beam Microscopes (FIB & FIB/SEM)
- Analytical Instruments

10 Year Limited Warranty

Vibration Engineering Consultants (VEC) Advantages

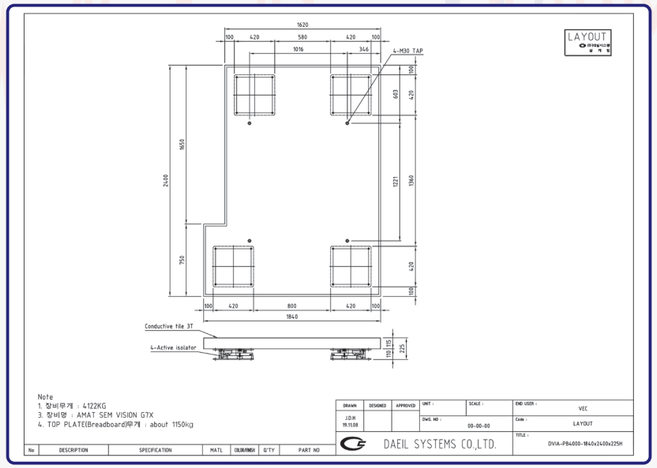
- ***Expertise in vibration.*** *We are the vibration experts and we understand that not all vibration is the same. Vibration from machinery, ground resonance excitations and onboard sources impact tool performance differently and require unique solutions. We will help you understand the data and the vibration sources in your facility.*
- ***Understanding of microscope and tool operating requirements.*** *We have deep expertise in the operating conditions for high-resolution imaging and device processing tools. We understand how they respond to vibration and will tailor a solution based on your unique requirements.*
- ***Integration into onboard vibration isolation systems.*** *Most electron microscopes and precision analytical and semiconductor process tools have built-in passive isolation systems. We will help select and design an active vibration isolation system that integrates with your onboard passive system and is based on your systems' resonances and unique performance characteristics.*
- ***Dedication to quality and performance****. We stand behind the quality of our solutions and offer performance guarantees and a limited warranty, up to 10-years, on most systems.*
- ***Commitment to customer satisfaction.*** *We strive to provide customers with the best outcome possible while being respectful of limited resources. At VEC, we will not recommend a product or solution that we don't believe will noticeably improve performance.*



VEC works directly with the end user to define the requirements for the active vibration isolation system. VEC then works with Daeil Systems to design the solution. VEC provides the installation and on-site tuning to optimize performance.

On-site Tuning for Better Performance

Vibration levels vary depending on the environment, location, vibration sources and other factors. Therefore, VEC will always perform on-site tuning to optimize the performance of your systems. To tune your active vibration isolation system, our engineer first conducts a site survey to measure vibration data. VEC then analyzes and uses this data to tune the feedback and feed-forward control systems to maximize vibration isolation performance.

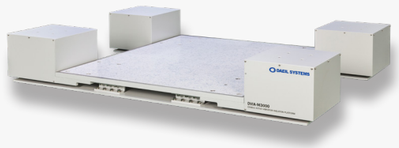


Using site evaluation data from VEC, Daeil Systems designs the specific vibration isolation system required for a particular instrument.

DVIA-MB Series

Ultimate Platform for Ultra High-Resolution SEM, TEM, FIB, FIB/SEM and Other Analytical Instruments

The DVIA-MB platform is the best solution for instruments designed to achieve nanoscale imaging and instruments weighing up to 6000 kg.



The DVIA-MB reduces vibrations in the critical range of 1–5 Hz, where electron microscopes are highly susceptible to low-frequency vibration, providing the optimal environment for achieving high- and ultra-high-resolution imaging and analysis.

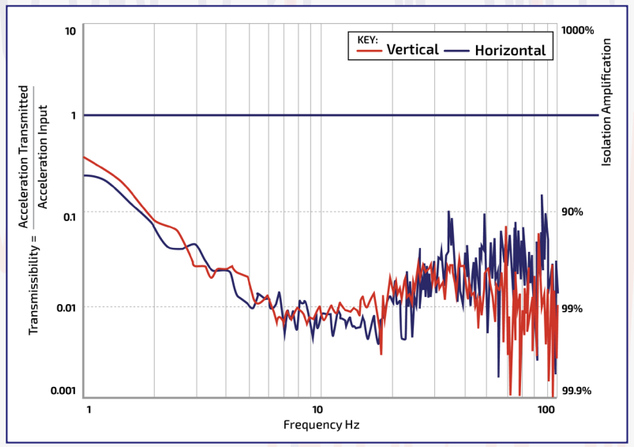
DVIA-MB cradle (top) and front (bottom) views.

Superior Active Vibration Isolation

DVIA-MB achieves its outstanding performance by using four active vibration isolators that utilize both air springs and active isolation technology. The integrated sensors and actuators effectively reduce the low-frequency vibrations and start to isolate vibrations from 0.5 Hz, achieving 90% vibration isolation at 2 Hz. Simultaneously the air springs support payloads from 500 kg to 6000 kg and effectively reduce high-frequency vibrations and, moreover, lower the natural frequency.

Unbeatable Vibration Isolation Performance

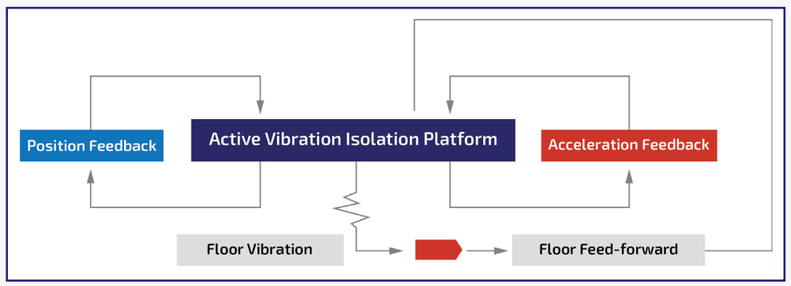
The resonant frequency of active isolation systems is much lower than that of passive isolation systems. The active component of the DVIA-MB excels in controlling vibrations in the 1–10 Hz range. Typical passive systems amplify the low-frequency vibrations rather than filtering them. DVIA-MB is highly effective in isolating ultra-precision instruments from the low-frequency vibrations that cause disruptions and instability. Active vibration isolation starts at 0.5 Hz, with DVIA-MB delivering 90% at 2 Hz and 99% at 10 Hz.



DVIA-MB active vibration isolation performance.

Feedback and Feed-Forward Algorithms

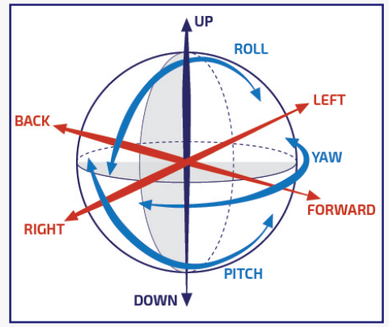
As illustrated on the next page, the DVIA-MB uses the feedback control system to continuously detect vibrations disturbing an isolated payload base and instantaneously react to minimize the vibrations in real-time. The feed-forward system is employed in the DVIA-MB to filter out floor vibrations in a predefined way.



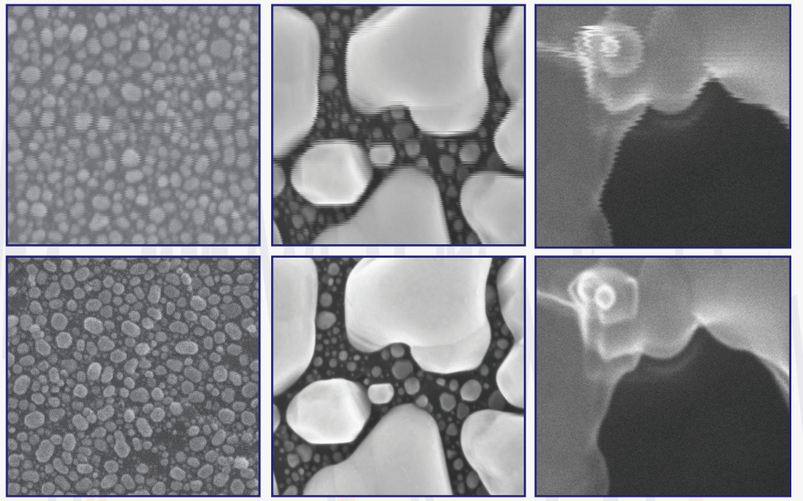
Principles of active vibration isolation.

Controlling Vibrations in all Six Degrees of Motion

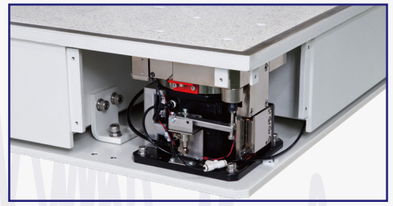
Inertial sensors and electromagnetic actuators installed in the DVIA-MB active vibration isolation systems detect and control vibrations in three translational degrees of motions (X, Y, and Z), and three rotational degrees of motions (pitch, roll, and yaw).



The DVIA-MB provides vibration cancellation along all six degrees of freedom.



These before (top) and after (bottom) images clearly illustrate that when low frequency vibrations disturb electron microscopes, it is critical to reduce these vibrations in order to obtain nanoscale resolution images.



Cutaway of a Daeil DVIA-MB shows the vibration isolator with integrated sensors and actuators.

Specifications

Model No.		DVIA-MB1000	DVIA-MB3000	DVIA-MB6000
Dimensions (W x D x H)	Isolator Unit	180 x 180 x 180 mm	232 x 232 x 180 mm	308 x 308 x 180 mm
	Platform	Custom-made		
Maximum Load Capacity		500 - 1700 kg	1500- 3500 kg	3000 - 6000 kg
Actuator		Electromagnetic Actuator		
Maximum Actuator Force		Vertical : 40 N, Horizontal : 20 N		Vertical : 80 N Horizontal : 40 N
Active Isolation Range		0.5 - 100 Hz		
Degrees of Freedom		6 degrees		
Vibration Isolation Performance		≥90% at 2 Hz / 99% at 10 Hz		
Settling Time		≤0.3 sec*		
Input Voltage (V)		AC 80 - 260 V / 50 - 60 Hz		
Power Consumption (W)		Maximum 110 W, Below 50 W in normal operation		
Operating Range	Temperature (°C)	5 - 50 °C		
	Humidity (%)	20 - 90%		
Required Air Pressure		≥5 kg/cm²		

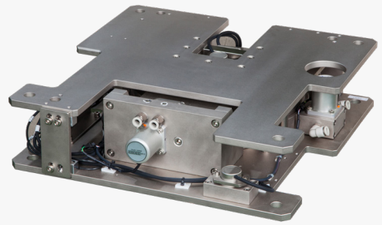
*0.3 sec settling time is measured after 90% reduction of input. (The settling time varies with several conditons, such as payload, force, natural frequecy, etc.)

At installation, VEC custom tunes the DVIA-M control systems based on the data recorded during the site survey.

DVIA-P Modular System

Active Vibration Isolation for Semiconductor and Display Manufacturing Process, Metrology and Inspection Tools

The DVIA-P series is an active pneumatic vibration isolation system that uses integrated, ultra-precise, motorized linear stages to control vibration for advanced processing tools that require both low-frequency vibration isolation and ultra-fast settling time.



Pneumatic vibration isolation platform for semiconductor applications with dynamic operations.

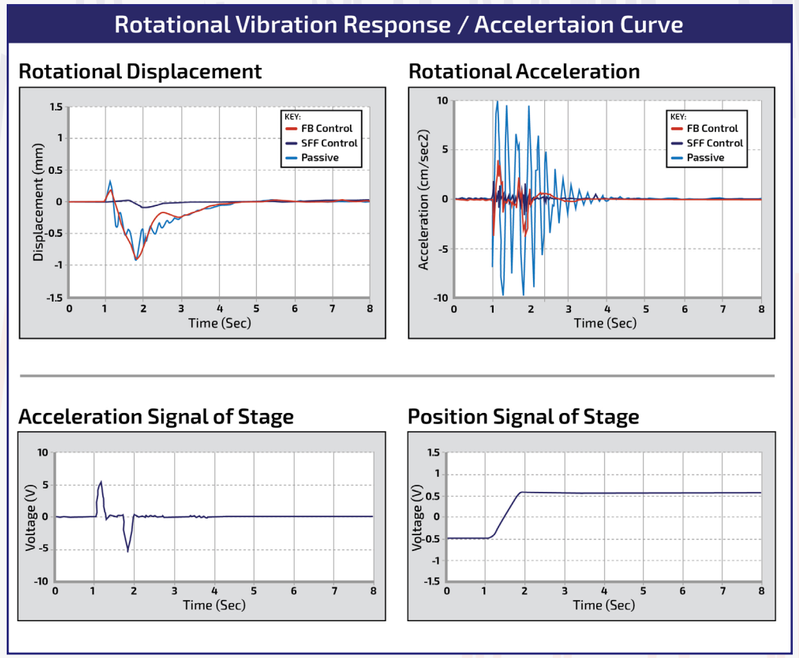
Optimal Vibration Solution for Metrology Tools with Integrated Linear Stages

DVIA-P isolators incorporate extremely sensitive sensors and powerful pneumatic actuators that generate the needed force to counteract incoming vibrations from floors or other tools. Based on real-time analog input and acceleration data, the DVIA-P Series stage feedforward control system effectively compensates residual vibrations caused by motorized linear stages.

When linear stages travel with significant acceleration and mass, large displacement occurs. The acceleration feedback control of the DVIA-P Series minimizes the displacement to reduce the settling time, and improve the position accuracy of the system. Furthermore, the DVIA-P can employ the stage feed-forward (SFF) system if VEC connects the analog outputs measuring displacement and acceleration of the stage position to the controller. The SFF system generates a force that is proportional to the stage rotational moment and the stage vibration force, which can reduce the position displacement of the linear stage drastically.

Ultra-Fast Settling Time and Excellent Position Accuracy

The position sensors continuously measure the position of the isolation system and then maintain its position through a digital signal processor. As a result, the sensors significantly improve the position accuracy of the system. Furthermore, accelerometers instantly detect vibrations originating from the floor or the moving stages, then transmit the digital signals to operate pneumatic actuators to cancel out the detected vibration.



DVIA-P rotational vibration response curves demonstrate outstanding settling time.

Powerful Pneumatic Actuators to Support Moving Stage Applications

The DVIA-P Series is inherently stiffer than a passive vibration isolation system due to the enormous force generated by the pneumatic actuators. The integrated pneumatic actuators in the DVIA-P Series create enough force to support semiconductor and display metrology tools with integrated motorized linear stages.

Superior Vibration Isolation Performance at Low-Frequency

DVIA-P isolators incorporate pneumatic actuators and extremely sensitive sensors with feed-forward and feedback control systems to maximize vibration isolation performance within 1–10 Hz.

Feedback and Feed-forward Algorithms

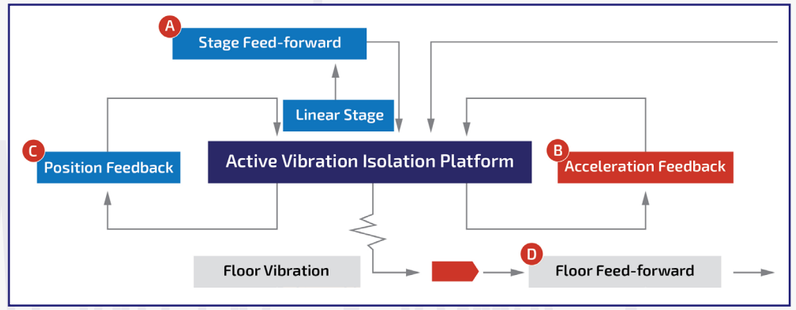
The DVIA-P Series uses feedback and feed-forward algorithms to maximize vibration isolation performance:

(A) Stage Feed-forward: By collecting information about motorized linear stages in advance, the system can produce a force of equal size to the dynamic linear stage in the opposite direction. As a result, the DVIA-P minimizes the external force caused by the motorized linear stage.

(B) Acceleration Feedback: This feedback control system employs sensors and actuators to continuously detect vibrations which disturb the isolated payload, then reacts to minimize vibrations. The acceleration feedback system not only reduces vibrations from the floor but also effectively minimizes vibrations from the motorized linear stages.

(C) Position Feedback: When the isolated base is disturbed by vibrations, the position feedback measures displacement through position sensors that transmit signals into the digital controller. After receiving the signals from the sensors, the digital controller drives actuators to return its original position, improving the position accuracy.

(D) Floor Feed-forward: The floor feed-forward system filters the floor vibrations in a predefined way. The DVIA-P utilizes the feed-forward control system when there are known factors such as a force applied to the isolated base, the data of ambient vibrations and information about equipment that needs to be isolated. Unlike the feedback control system, the feed-forward system analyzes dynamic characteristics of the equipment and tunes the feed-forward gains by the trial and error method to operate the actuators.



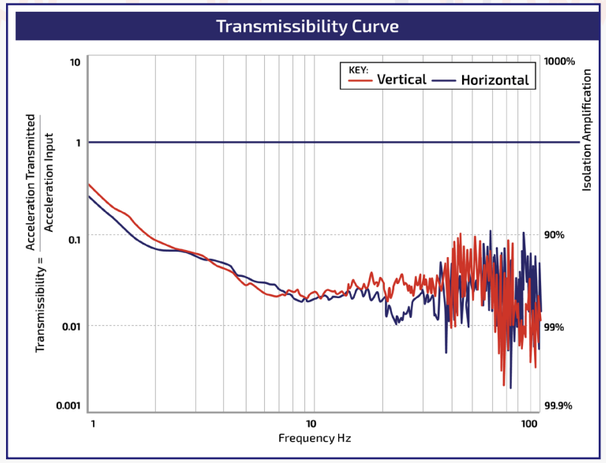
Principles of active vibration isolation.

Compatibility

For compatibility with other devices, the DVIA-P Series has LED indicators, a power switch, two control switches, a serial interface for adjustment and two analog outputs on the front panel of the controller. The rear panel of the controller has four actuator connectors, analog output connectors and digital input and output connectors (16 bit).

Vibration Site Survey and Installation

VEC's experienced engineers measure all sources of environmental disturbance, then analyze the vibration data to design the optimal vibration isolation system for a customer's particular environment. Because the DVIA-P Series is installed under raised floors in semiconductor fabs, technical expertise is required. Our engineers take care of installation and tuning of the isolation system until customer specifications are met.



The DVIA-P provides outstanding vibration isolation performance across a wide frequency band.

DVIA-UB Platform

Cost-Effective Platform for Conventional High Resolution SEM, FIB, FIB/SEM and Other Analytical Instruments

The DVIA-UB is for instruments weighing up to 700 kg. This cost-effective, low-profile platform is installed directly under the vacuum stand or console requiring stabilization. Each DVIA-UB is backed by a 10-year limited warranty.

Back panel (top image) of DVIA-UB platform and view of the front panel.

Active Isolation Technology

DVIA-UB series incorporates sensors and actuators within the feedback and feed-forward control systems to reduce vibration in 1–10 Hz range, with fast settling time.

Low-profile

Daeil Systems has integrated both the isolators and the controller into the DVIA-UB base to create a more streamlined design. DVIA-UB platforms are low-profile, with a height of only 96mm (2.78 in), making them an option for microscopes in an enclosure or at facilities with height constraints.

No Compressed Air Required

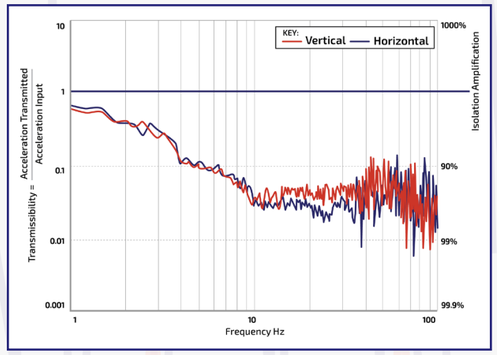
DVIA-UB series does not require air supplies to operate the system. Metal springs in the isolator units both support heavy payloads and provide outstanding passive vibration isolation for high-frequency vibrations.

Integrated Controller

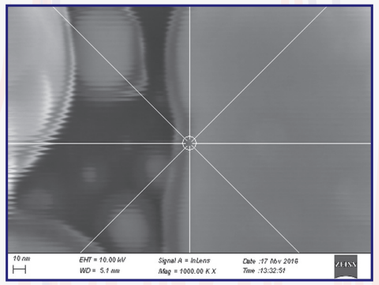
The feedback controls of the isolator in the base mean that no external controller is required.

High-quality Sensors with a Digital Controller

Unlike other competitors with low-cost solutions, DVIA-UB systems employ 12 velocity sensors and a digital controller that uses feed-forward algorithms to enable better vibration isolation performance at lower frequencies. This is not possible with analog systems.



The DVIA-UB performs well at low-frequencies



Top image shows imaging performance before installing the DVIA-UB platform; bottom image shows after platform installation.

Specifications

Model No.		Modular Platform		Desk Platform	Base Platform
		DVIA-U350	DVIA-U700	DVIA-UD350	DVIA-UB700
Dimensions (W x D x H)	Isolator Unit	783 x 205 x 96 mm	818 x 220 x 96 mm	783 x 205 x 96 mm	818 x 220 x 96 mm
	Platform	n/a		Custom / made	
Maximum Load Capacity		150 - 350 kg	350 - 700 kg	150 - 350 kg	350 - 700 kg
Actuator		Electromagnetic Actuator			
Maximum Actuator Force		Vertical ; 6 N Horizontal : 3 N	Vertical ; 12 N Horizontal : 6 N	Vertical ; 6 N Horizontal : 3 N	Vertical ; 12 N Horizontal : 6 N
Active Isolation Range		0.5 - 100 Hz			
Degrees of Freedom		6 degrees			
Vibration Isolation Performance		≥90% at 4 Hz / 97% at 10 Hz			
Settling Time		≤0.3 sec*			
Input Voltage (V)		AC 80 - 260 V / 50 - 60 Hz			
Power Consumption (W)		Maximum 65 W <20 W in normal	Maximum 195 W <60 W in normal	Maximum 65 W <20 W in normal	Maximum 195 W <60 W in normal
Operating Range	Temperature (°C)	5 - 50 °C			
	Humidity (%)	20 - 90%			

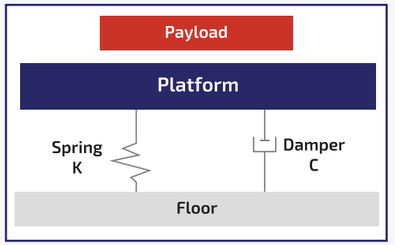
*0.3 sec settling time is measured after 90% reduction of input. (The settling time varies with several conditons, such as payload, force, natural frequecy, etc.)

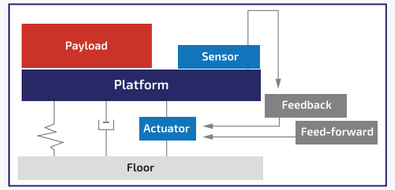
Active vs. Passive Vibration Isolation

Understanding the Differences in Performance and Application

Understanding the difference between active and passive vibration is critical to mitigating their impact on equipment performance. Passive isolation systems use the natural properties of a spring and a dampener to reduce vibration. Active vibration isolation systems use a control system with integrated sensors and actuators to improve low-frequency performance.

Engineers use vibration isolation systems for many different applications in electron microscopy and semiconductor/display manufacturing. Passive vibration isolation systems are widespread and have a diverse range of applications. They can be simple, such as the rubber feet underneath a vibrating pump, or more complicated like shocks and struts on a car. Active vibration isolation systems, however, are intricate systems with highly specialized applications. Understanding the differences in both the implementation and performance of these two systems is critical to making sound decisions regarding your capital equipment.





Principles of passive vibration isolation (top) and active vibration isolation (bottom).

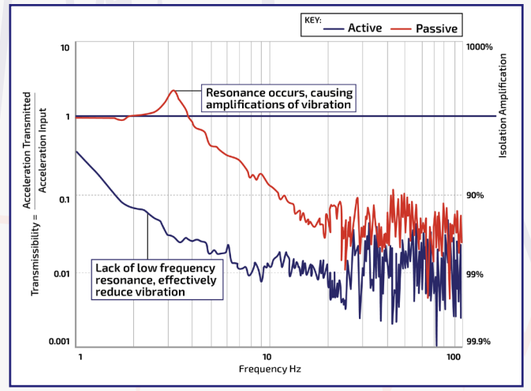
Passive Vibration Isolation System

A passive vibration isolation system consists of three components: an isolated mass (payload), a spring (K), and a damper (C); these work as a harmonic oscillator. The payload and spring stiffness define the natural frequency of the isolation system. While the spring (isolator) reduces the transmission of floor vibrations to the isolated payload, the damper eliminates the oscillation amplified within the isolation system. Often, passive vibration isolation systems employ a pneumatic spring due to its low resonant frequency characteristics. Pneumatic systems provide outstanding vibration isolation and damping for many applications.

Passive isolation systems are relatively inexpensive and are excellent at mitigating high-frequency vibration. However, their natural resonance is problematic in some applications where low-frequency vibration is problematic. Besides the low-frequency resonance, passive vibration isolation systems have a longer settling time and are difficult to control.

Active Vibration Isolation System

Active vibration isolation systems consist of feedback and feed-forward control systems with integrated sensors and actuators. These systems isolate the most sensitive equipment from the extremely low-frequency vibration that passive isolation systems amplify at resonant frequencies. The sensors detect incoming vibration in all six degrees of freedom, and a digital controller processes the measured vibration data into digital signals. The controller then sends the signals to the actuators that cancel the vibrations by generating an equal and opposite force. High-resolution electron microscopes and precision manufacturing tools require active vibration isolation systems when low-frequency vibration is problematic.



Performance comparison between active and passive vibration isolation systems.

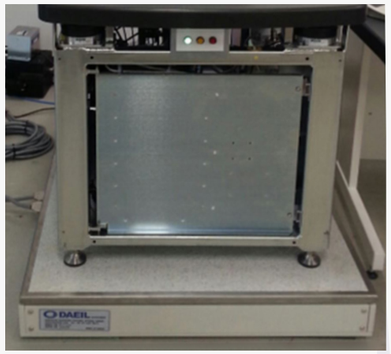
Categories	Active	Passive
Natural frequency	0.5 Hz	1.5-lOHz
Stiffness	Hard	Soft
Vibration Isolation Performance in 10-100 Hz	YES	YES
Vibration Isolation Performance in 1-10 Hz	No resonance, sub-hertz vibration isolation performance	Resonance occurs (amplifications of vibration)
Instantaneous Response	YES	NO
Controllability	Control the system precisely and delicately	Lack of controllability
Center of gravity	Stable	Unstable
Position accuracy	Around 1 μm	Around 0.05 mm-lmm
Degrees of freedom	6 DOF	3 DOF
Settling time	10 – 20 ms	2 – 10 s

Comparison of passive vibration isolation systems and active vibration isolation systems.

Understanding and Mitigating Vibration in Your Facility

Low-frequency and High-frequency Vibration Require Different Strategies for Remediation

Low-frequency and high-frequency vibration both have a significant impact on electron microscopy laboratories and high-tech manufacturing facilities. Because these two types of vibration stem from different causes, the strategy for mitigating each is different. VEC can help you quantify and identify the vibration in your facility and work with you to develop remediation strategies based on your requirements.



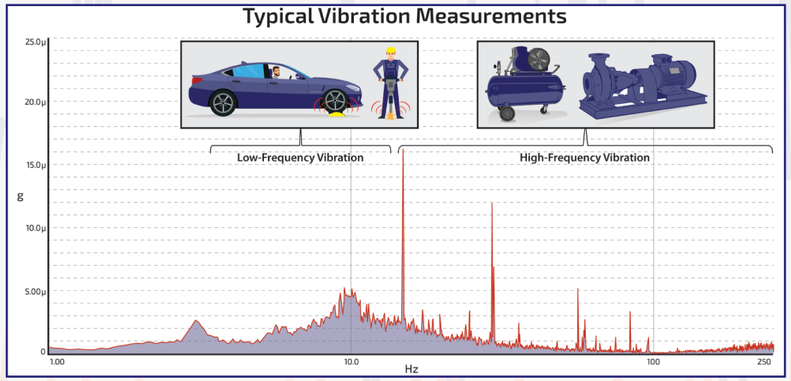
DVIA-UB platform positioned under SEM vacuum stand.

About Low-frequency Vibration

Sources outside your facility typically cause low-frequency vibration. Large impulses excite low-frequency ground resonances that are dependent on the soil conditions within your area. These resonances are usually from 3–20 Hz. Some examples of sources include traffic, speed bumps, construction or trains. Building movement on higher floors is also a source of low-frequency vibration.

Sources of low-frequency vibrations are typically stable over time unless some dramatic change in the infrastructure occurs, or a construction project begins immediately next door. These impulses travel farther and have more energy than high-frequency vibration sources.

Vibration will most severely impact your equipment if it corresponds with the resonance of the tool itself. Think of a child on a swing. If you're pushing at the same frequency that the swing naturally oscillates, the amplitude increases. The natural oscillation frequency depends on the length of the swing from the pivot point to the child and is called the natural frequency. Pushing the swing at the natural frequency may be fun for the child, but for a machine in the lab, exciting the machine's natural resonances often degrades its performance.



Low-frequency and high-frequency vibration are caused by different categorical sources and require different approaches for mitigation.

Mitigating Low-Frequency Vibrations

A lab or high-tech manufacturing facility only has one option to reduce this type of vibration: an active isolation system. In these systems, feedback and feed-forward control systems use integrated sensors and actuators to isolate equipment from vibration. Sensors detect incoming vibration, and a controller sends signals to the actuators that generate equal and opposite force to negate the impact of outside vibration on your equipment.

Although the best systems are very effective at mitigating vibration, they can be costly. Installing active isolation systems in an entire lab can often add hundreds of thousands or even millions of dollars to the cost of your facility.

In an ideal situation, it is best to test and monitor vibration before moving into a new facility. Conducting a thorough site evaluation or installing vibration monitors can prevent expensive mistakes. It's similar to inspecting for mold or other dangerous chemicals in a home before you move in. Sometimes the cost of the repairs can sway the decision to purchase. However, moving facilities is often not an option. In these situations, there is no way other than an active isolation system to mitigate the low-frequency problem, particularly for vibration source located off of your property. Selecting a facility site that does not have a low-frequency vibration problem will pay off in the long term.

This problem will be more prevalent, especially as instrument resolution increases, critical dimensions shrink, and as microscopes and high-tech lab equipment become increasingly sensitive to low-frequency vibration.

About High-frequency Vibrations

The impacts and the vibration mitigation are quite different with high-frequency vibrations. High-frequency vibration sources usually originate inside your facility. Some examples might include pumps, chillers, fans or HVAC systems. The rotating frequencies of these objects may result in vibrations that disrupt tool performance. High-frequency vibrations often change and intensify over time. Because these sources are typically internal to your facility, they are in closer proximity to the tool location and often occur between 20 and 200 Hz.

Mitigating High-frequency Vibrations

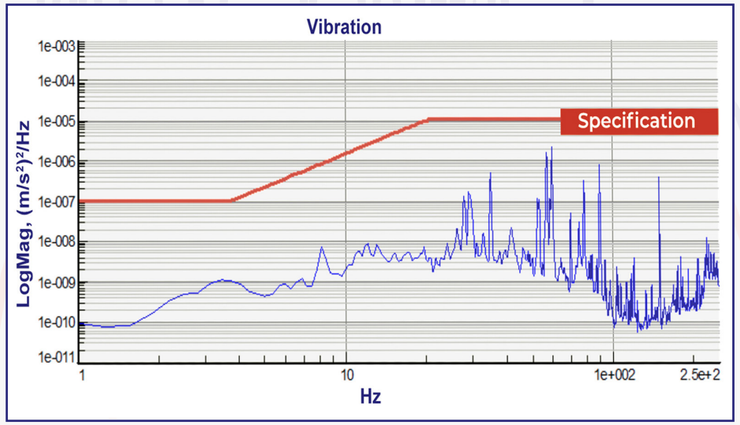
High-frequency vibrations often can be mitigated with low-cost isolators, thoughtful equipment placement, and by keeping machinery in good working order. These solutions are often more effective than active vibration isolation systems, which are designed to mitigate low-frequency vibrations. Many active vibration isolation systems do not mitigate vibration at higher frequencies starting at ~50 Hz. Most sources of mechanical vibration operate within this elevated range.

Since high-frequency vibrations typically change and increase over time, vibration monitoring is an effective and cost-efficient way to prevent vibration problems. The ability to mitigate vibration is strengthened by data and your ability to understand the problem. Monitoring can give you the data that you need to relocate affected equipment, or initially place it in an area that's not impacted by vibration. Your facility is likely evolving and accumulating new pieces of equipment over time. Understanding the environment can help you get the most out of your investment. By deploying custom-designed vibration monitors in your facility, such as our Quantridge platform, you can anticipate problems before they ever impact your equipment.

Use Data in Mitigating Vibration

Because not all vibrations are the same, the way they influence your equipment will differ as well. Hiring an expert like VEC can help you to quantify the data within your facility so you can make more informed decisions:

Vibration testing. Our site evaluations can help you determine where to place equipment and evaluate potential sites before move-in or purchase. These serve as a snapshot of current vibration levels at your facility or a proposed site.



Sample vibration data shows readings collected during the site survey as compared to the tool's vibration specification.

Vibration monitoring. Our Quantridge platform is specifically designed to monitor vibration for high-tech and microscopy facilities. It can help with site evaluations as well as preventing vibration from reaching problematic levels over time.

Assessing vibration mitigation options. We can help you determine which strategy for mitigating vibration is right for you and your facility.

Vibration can be costly and overwhelming when it is discovered nearby or inside your building. VEC will help your organization develop a practical strategy for mitigating vibration, and making sure it does not interfere with your current operations or future plans.

All Daeil systems are TUV and CE certified. Daeil and VEC provide a ten-year warranty on all DVIA-UB and DVIA-MB products.

Daeil Vibration Isolation systems are TUV certified.

Daeil Active Vibration Isolation Systems are CE Certified.

Site Evaluations • Design Consulting • Remediation • Monitoring

DAEIL SYSTEMS

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