Tutorial
Selection of Vibration Isolators

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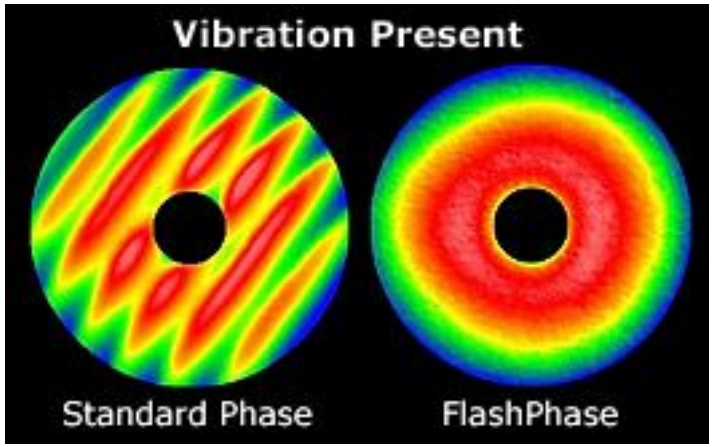
Purpose of this presentation

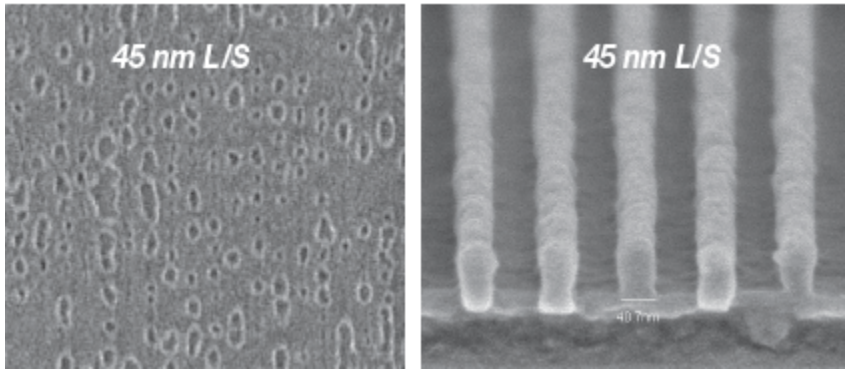
- Let you know
  - how vibration isolation works
  - how to select vibration isolators
  - examples of application

Motivation

- Vibration Isolation is important for
  - Optical measurements
  - Optical fabricatons



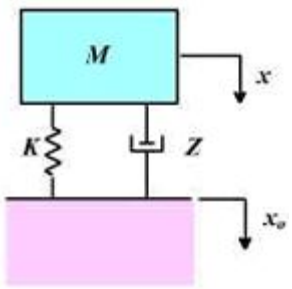
From Zygo, GPI series
http://www.zygo.com/?/met/interferometers/gpi/flashphase/

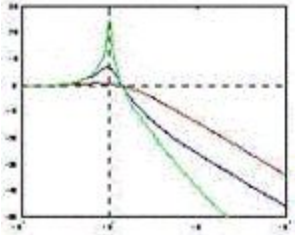


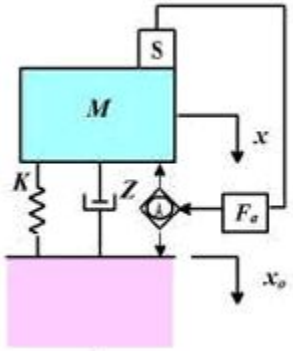
From TMC, STACIS
http://www.techmfg.com/appnotes/SematechAppnote.htm

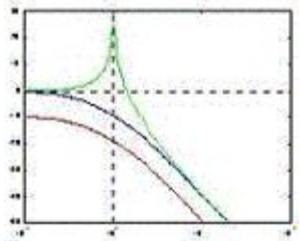
Two types of Vibration Isolation

- Passive Vibration Isolation
  - Mass, Spring, and Damper
  - Can isolate high frequency (5Hz~)
- Active Vibration Isolation
  - Mass, Spring, Damper, and Feedback or Feedforward
  - Can isolate low frequency (~5Hz)+ high frequency









From TOKKYOKIKI
http://www.tokkyokiki.co.jp/technology/technology_a.html

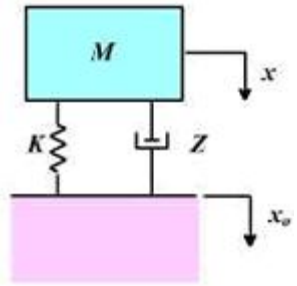
Passive Vibration Isolation

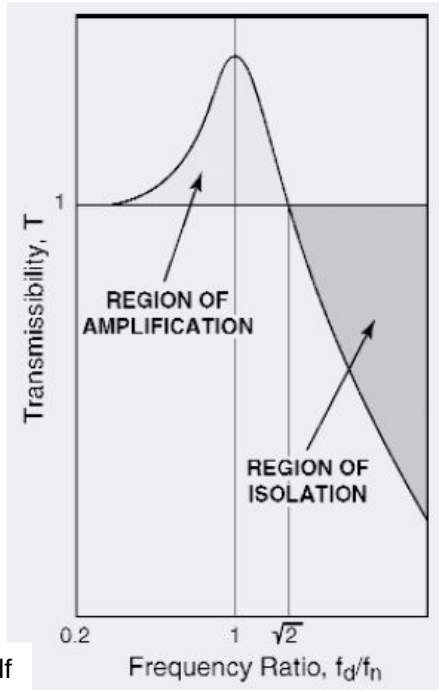
$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}\left(1-\left(\frac{C}{C_C}\right)^2\right)}$$

C/C_C is Critical damping ratio C_R

Material	Approx Damping Factor C/Cc	Tmax (approx.)
Steel Spring	0.005	100
Elastomers:	-	-
Natural Rubber	0.05	10
Neoprene	0.05	10
Butyl	0.12	4.0
Barry Hi Damp	0.15	3.5
Barry LT	0.11	4.5
Barry Universal	0.08	6.0
Friction Damped Springs	0.33	1.5
Metal Mesh	0.12	4.0
Air Damping	0.17	3.0
Felt and Cork	0.06	8.0

Table 1 Damping factors for materials commonly used for isolators





- You want f_d/f_n
- f_d is defined.
- Then fn should
- C/C_C should
- k should
- m should

Advantage
- Low cost

Drawback
- Amplification Region
- Not stable.

From Barry isolators selection guide.pdf

Selection of Passive Vibration Isolator

- Determine f_d (Disturbing frequency)
- and Min. f_n

$$f_n = \frac{f_d}{\sqrt{2}}$$

Use direct measurement or Rule of Thumb

TABLE 2.2
Vibration Power Spectral Densities for Typical Military and Aerospace Environments

Environment	Frequency (f) (Hz)	Power spectral density
Navy warships	1–50	0.001 g^2/Hz
Minimum integrity test	20–1000	0.04 g^2/Hz
per MIL-STD-810E	1000–2000	−6 dB/octave
Typical aircraft	15–100	0.03 g^2/Hz
	100–300	+4 dB/octave
	300–1000	0.17 g^2/Hz
	≥ 1000	−3 dB/octave
Thor-Delta launch vehicle	20–200	0.07 g^2/Hz
Titan launch vehicle	10–30	+6 dB/octave
	30–1500	0.13 g^2/Hz
	1500–2000	−6 dB/octave
Ariane launch vehicle	5–150	+6 dB/octave
	150–700	0.04 g^2/Hz
	700–2000	−3 dB/octave
Space shuttle	15–100	+6 dB/octave
(orbiter keel location)	100–400	0.10 g^2/Hz
	400–2000	−6 dB/octave

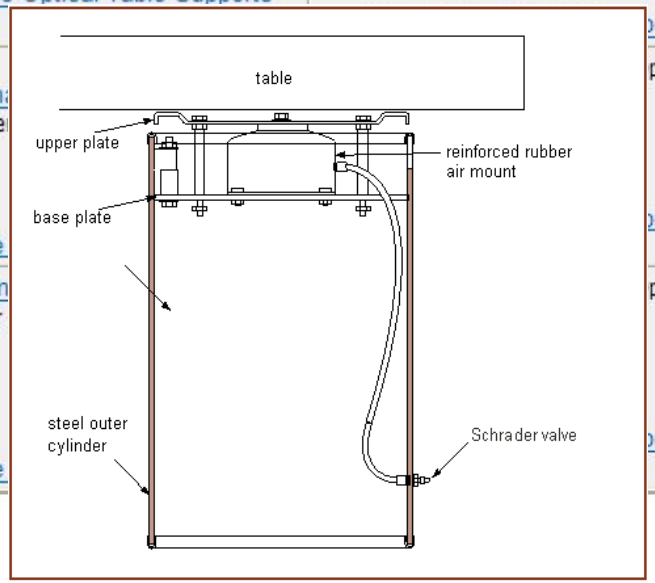
Source: From Vukobratovich, D., in *Handbook of Optomechanical Design*, CRC Press, Boca Raton, FL, 1997, p. 65, chap 2.

Example of Passive Vibration Isolator

Optical Table and Optical Table Supports Selection Guide

	Quite Environment[1] (PSD < 10^{-10} g^2/Hz)	Typical Laboratory Environment[2] (PSD ~10^{-8} to 10^{-9} g^2/Hz)	Noisy Environment[3] (PSD <10^{-7} g^2/Hz)
Less Demanding Applications • Pulsed Laser • General Spectroscopy • Velocimetry • Multimode Fiber Coupling	Standard, StandardPlus, Performance or PerformancePlus Series of Optical Tables with Rigid Optical Table Supports	Performance or PerformancePlus Series of Optical Tables with Passive Optical Table Supports	Performance, PerformancePlus, Ultra, or UltraPlus Series of Optical Tables with …rts
General Applications in Photonics • Bioimaging • Raman Spectroscopy • Micropositioning and Machining	Performance or PerformancePlus Series of Optical Tables with Passive Optical Table Supports	Perform… Se… Active…	…ptical …rts
Demanding Applications • Nanopositioning • Submicron Precision • Phase Related • Holography • Single Mode Fiber Alignment	Performance, PerformancePlus, Ultra, or UltraPlus Series of Optical Tables with Active Optical Table Supports	Perform… Ultra, or… Active…	…ptical …rts

[1]The lab floor consists of a subterranean slab in a remote environment.
[2]The lab is in the basement or ground floor of building.
[3]The lab is on the upper floors of a building or near significant sources of vibrations.

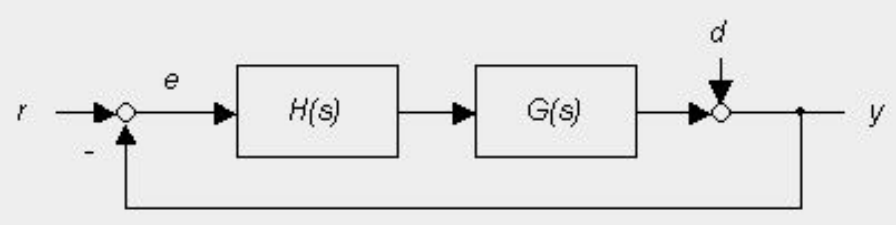


From THORLAB

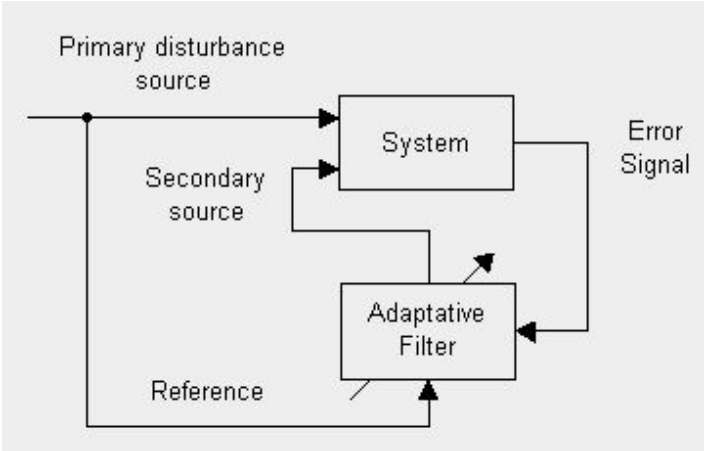
Table 1. A selection matrix for optical tables and optical table supports based on the working environment and application.

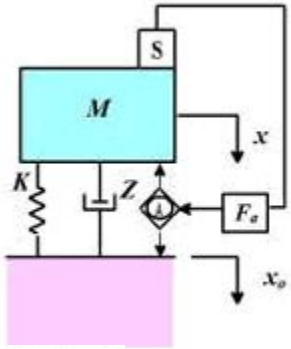
Active Vibration Isolation

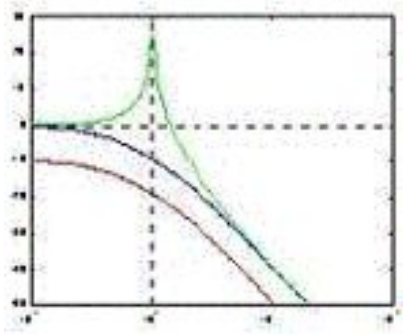
Feedback



Feedback + Feedforward







Advantage
- No Amplification Region

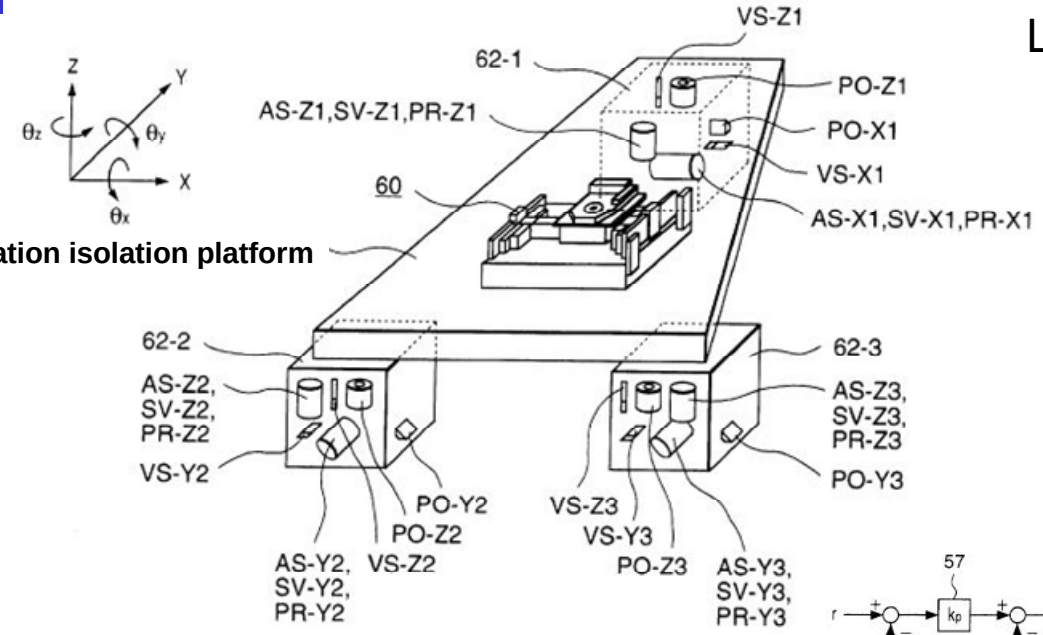
Drawback
- Cost
- algorism
- Need reference

Selection of Active Vibration Isolator

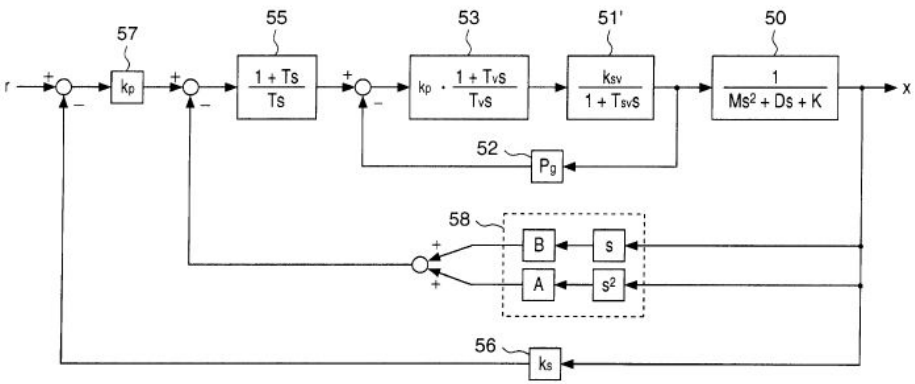
	Advantage	Drawback
Feedback	durable for unexpected disturbance	Slow response
Feedforward + Feedback	Fast response	Need correct reference Need correct model

Example of Active Vibrartion Isolator

Lithography Stage by Canon

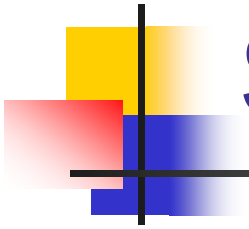


Vibration isolation platform



1. Pressure (Force)
2. Position
3. Velocity

S. Wakui, “Active vibration isolator, exposure apparatus, exposure method and device manufacturing method” United States Patent 6,286,644 B1 (2001)



Summary

- Two types of Vibration Isolation
  - Passive Vibration Isolation
    - Low cost, works for high frequency
    - Have amplification region, Not stable
  - Active Vibration Isolation
    - No amplification region, works for low freq.
    - Need Algorism and reference