Demystifying Serial vs. Parallel Active Systems

a Technical Review by Dr. John Sandercock of Table Stable / JRS Instruments

Introduction

Active vibration isolation systems (active systems) range in terms of hardware, software, and overall technological capabilities. Properly understanding these differences is important for instrument users and manufacturers to decide on the correct system to support their instrument within their respective environment.

One recent distinction made is the difference between *Serial* and *Parallel* active systems, with the AVI and TS Series falling into the Parallel active systems category. This technical review discusses how these two unique active systems (Serial v. Parallel) are often compared and helps demystify the factual from the fictional differences.

Myth vs. Fact

MYTH: *Serial > Parallel Active Systems for Low Frequency Vibration Isolation Performance*

FACT: *Parallel > Serial Active Systems for Low Frequency Vibration Isolation Performance*

The most prominent and effective isolation mechanism within active systems is a feedback loop system, which dynamically attenuates ambient vibration noise by utilizing a series of inertial sensors, actuators, and control electronics. All feedback systems using inertial sensors have a low-frequency cut-off determined by the low-frequency noise of the sensor. The extent of this noise is defined primarily by the mass of the inertial sensor, which varies between respective active systems.

With respect to small form factor active systems (i.e. AVI and TS Series), a balance is struck between size and low-frequency response. The mass is kept small to allow a compact construction, best suited for precise compact microscopes. As a result of the compact size, the available isolation between 0 – 1 Hz is limited compared to active systems utilizing larger-mass inertial sensors.

To bridge the gap of performance for the AVI Series, the LFS System (Low-Frequency Sensor) was developed, offering a larger-mass inertial sensor working in tandem with the AVI Series to deliver **best-in-class low-frequency vibration isolation**. When paired with the LFS System, the AVI Series offers greater low-frequency isolation performance than any high-mass feedback systems, parallel or serial.

MYTH: *All Parallel Active Systems Need to Be Tuned to the Payload*

FACT: *Parallel Active Systems with High Quality Feedback Loops Do Not Require Payload Tuning*

There is an argument that parallel active systems need to be specifically tuned to the payload being supported, limiting the overall isolation of the platform. While it is true some parallel active systems in the market need to be tuned to the payload being supported, it is not a universal feature of parallel active systems and is typically a function of the quality of feedback loop being developed for the active system. The quality of feedback loop for active systems is determined by the range of frequencies it can accommodate and how well it can damp resonances in the payload. Undamped resonances in the payload cause phase changes, which drive the feedback loops into oscillation (see Appendix A). If the feedback loops are designed well with a high frequency response (several KHz), the payload resonances will not oscillate within the feedback loop, but will instead be damped. This is true for the AVI and TS Series platforms. In addition to the AVI and TS Series platforms having a broad-frequency feedback loop, they **never need to be tuned to specific payload resonances**, which has remained true throughout its entire production history.

MYTH: *Decoupling Serial Active Systems from the Payload Offers an Advantage*

FACT: *Decoupling Serial Active Systems from the Payload Offers a Disadvantage*

Serial active systems utilizing a larger mass can be susceptible to having a poor feedback response, as many manufacturers publish data to 100 Hz. Due to this limitation, serial active systems decouple itself from the payload at approximately 20 Hz, allowing passive isolation mechanisms to mitigate the higher frequencies. While this decoupling removes higher frequency payload resonances, it does not account for external vibration sources from directly being coupled to the payload itself. Decoupling the payload then becomes a disadvantage because the feedback loop of the active system no longer applies to the vibration noise imparted to the payload directly (i.e. vibration noise not imparted through the floor).

While it is clear a payload supported by an inertial platform and decoupled at 20 Hz as a "serial" system will have reasonable isolation from floor vibrations, the level of performance degrades as more external connections are made to the payload. A typical payload (i.e. electron microscopes) will be coupled via electrical cables, conduit, pump lines to the surroundings, and therefore indirectly to the floor. While many of these lines and cables can be stiff, the sum of the cable stiffness can in fact come close to or exceed the stiffness of the 20 Hz decoupler, causing the cable and pump lines to form a mechanical bypass to the active system itself, introducing significant vibrations into the payload directly.

The issue of an instrument having indirect vibration sources be ignored by an active system is non-existent for parallel active systems such as the AVI and TS Series. These systems are stiffly coupled to the payload and are directly combatting the forces entering the payload from the surroundings as well as the floor, which serves as a unique differentiating benefit over serial active systems. *It is important to note* that all active systems will decouple from the payload at a sufficiently high frequency, be it due to internal resonances in the payload or due to rubber feet under the payload. This frequency, however, will typically be in the range of a few hundred Hz, far removed from the 20 Hz range of serial active systems.

Conclusion

Understanding the factual differences between unique active isolation technologies is important, as it can result in whether an instrument is receiving optimal vibration isolation performance for the conditions of their laboratory. The only practical difference between serial and parallel active systems is that parallel active systems are more stiffly coupled to the payload and therefore more effective at isolating the payload from forces coming directly from the surroundings. Knowing these differences and planning accordingly can help save time and money, while enabling the end user to focus on their research and not their isolation platform.

About Dr. John Sandercock

Dr. John Sandercock is the Founder and Director of JRS Scientific Instruments, the parent company of Table Stable and a manufacturer of precision Fabry Perot interferometers. John Sandercock initially developed the active vibration isolation platform in 1987 while working in the RCA research laboratories in Zürich, creating the first successful active feedback system. Since then, several iterations of the active feedback system have developed and refined (EVIS > MOD-2 > MOD-1 > AVI Series > TS Series). JRS Scientific Instruments and Table Stable reside in Mettmenstetten, Switzerland.

Appendix A

Using inertial feedback, the gain in the feedback loop can be high at mid-range frequencies. High gain is needed for example around 10 - 20 Hz, where most buildings have strong vertical vibrations. The gain must fall off to higher and lower frequencies with the phase remaining correct until the gain has fallen to below unity. For stability, the phase must always remain between +/- 90°. This limits the attenuation to be proportional to f at low frequencies and 1/f at high frequencies.

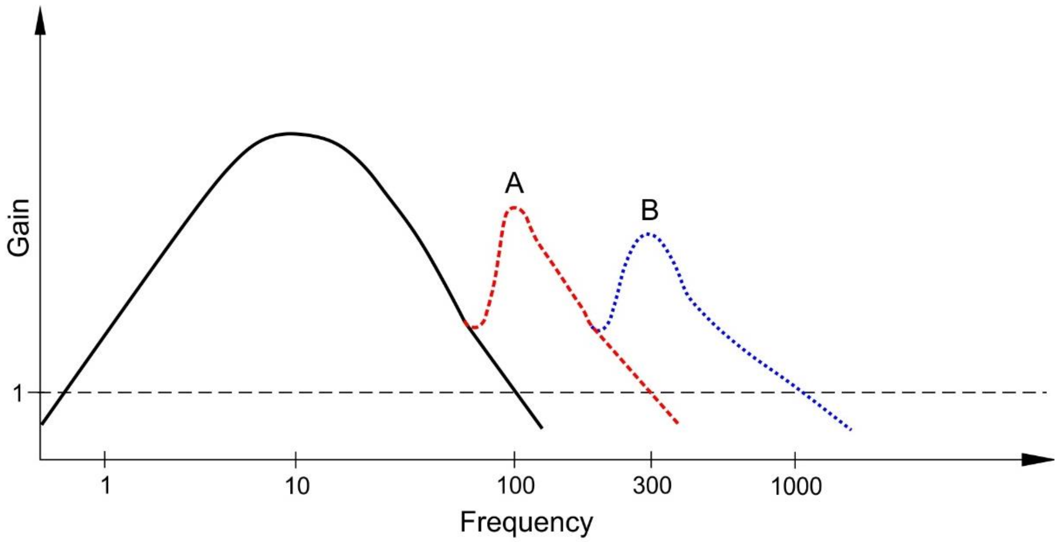

Figure 1: Gain Graph

In the Figure 1, the solid line shows a typical gain curve assuming direct contact to a non-resonant payload. The gain falls below one at 1 Hz and 100Hz in this example. In real life the payload will not be non-resonant. The curve A shows decoupling from the payload at approximately 100 Hz. Since the feedback loop sees only part of the payload's mass, there is a second order increase in the effective gain corresponding to the smaller effective mass. The gain now falls below one at approximately 300 Hz in this example and the phase must remain correct out to this frequency. A further payload resonance at 300 Hz, as shown in curve B, means the gain now remains above unity until 1,000 Hz and again the phase must remain within the limits of +/- 90°.

This diagram demonstrates why it is essential to maintain the correct phase out to several KHz. If the feedback loop is poorly designed and the correct phase is not maintained, the feedback loops will oscillate. This is why some parallel active systems require tuning to the payload resonances, as they are trying to compensate for the limited feedback loop of the active system.