# Adapting Feedforward for Active Vibration Isolation Systems

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Vibration isolation systems have been crucial to semiconductor manufacturing equipment for many years. As geometries become smaller, and the need for higher machine throughputs increases, the demands on the isolation systems have become severe. This has been frustrated by the advent of 300mm wafers, which require heavier moving stages with longer travels. These factors have caused force impulses on payloads to become enormous, while the need to settle payloads to quieter levels, in less time, has become critical.

Active vibration isolation systems have the ability to address many of the issues generated by these changes. Both feedforward and feedback techniques can be employed to reduce payload settling times and noise levels. In pneumatic-based active vibration isolation systems, feedback can be strongly limited by structural resonances which limit servo bandwidth. Even if high bandwidths could be achieved, they may not be desirable: Though high bandwidths can give a system exceptionally good settling time for accelerations, the settling time for position in such servos is long. This makes any process which requires precise alignment with off-payload machinery very difficult (such as wafer loading/unloading and optics alignment).

Although some feedback should be used to *damp* the isolators' passive resonance to a suitable level, it should not be used to achieve active *isolation* or improve settling time. Instead, feedforward should be used to improve settling time. This is motivated by the fact that most machines do not require better isolation – they function perfectly well after the payload settles after a stage motion.

Feedforward can improve settling time be reducing the net force a payload sees from a stage motion. If the amplitude of force can be suppressed by a factor of 10, so is the required settling time. More than a factor of 10 is not considered realistic considering the non-ideal aspects of such systems. To obtain this level of suppression, the system must use an adaptive algorithm for finding the feedforward parameters.

Such systems have two feedforward inputs: the X and Y stage position. In addition, sensors mounted to the payload can determine the payload's motion in all six DOFs. Feedforward is accomplished by using servo valves for controlling isolator pressure, and electromagnetic actuators for applying short force pulses to the payload. There are a minimum of 12 parameters required to implement such a feedforward scheme, with several of the terms being nonlinear. One problem is to adapt these 12 parameters with only 8 inputs in a stable way. Pneumatic-only feedforward can avoid much cost and complexity, while maintaining significant benefit.

Pneumatic only feedforward still requires a minimum of 4 parameters to be adaptively set. This algorithm is complicated by the relatively slow response time of the isolators to valving compared with the time scales for typical stage motions. The talk will focus on the type of algorithms being developed at TMC for this problem, and types of issues that come up.