a Western Digital brand

HGST Micro Actuator

Second-generation Micro Actuator for Better Head-positioning Accuracy

To increase hard disk drive (HDD) data density, the size of bits – the 1s and 0s that represent the information stored on the disk – decreases and the spacing between their concentric tracks shrinks. As these dimensions shrink, it becomes more difficult to position the read-write head's transducer element over the center of the data track.

Outside disturbances, such as vibrations in the rack in the data center, can cause head-track misalignment.

Dual-stage actuators (DSA) have already been implemented to position the read-write head with greater accuracy. HGST is now implementing HGST Micro Actuator (HMA), a second-generation dual-stage actuator (DSA). HMA enables even better head-positioning accuracy. HGST first implemented HMA in the Ultrastar® He10 hard drive and has included HMA in the mechanical design of subsequent products because better head-positioning accuracy delivers better performance, data integrity and overall drive reliability.

How it Works

HMA structure and actuation are shown in Figure 1. Small multi-layer piezos are attached to the flexure. When differential voltage is applied to the HMA, one piezo element expands as the other contracts. This action causes a slight rotational motion of the read-write head. Since the HMA's moving portion is so small with lighter mass compared with Mlli Actuator (Milli), first-generation DSA, the HMA element's vibrational resonance frequency is much higher than that of Milli. As a result, the HMA can rapidly and accurately position the head element over the correct data track.

The HMA's transfer function from the drive voltage to the head displacement compared with Milli is shown in Figure 2. Main resonance frequency of HMA is much higher than that of Milli. This function increases servo bandwidth to a higher frequency range and improves head positioning accuracy.

Figure 3 shows the schematic dual-stage servo block diagram with Voice Coil Motor (VCM) and Micro Actuator (MA). The block diagram consists of VCM, MA, VCM controller and MA controller. "Pv" and "Pm" are the plant of VCM and MA, respectively. The MA controller consists of compensator "Cm" and MA model "Pm0". The signal "pes" represents the position-error signal, and "r" represents track runout. The "vpe" and "mpe" are respectively the position of VCM and MA. Then the overall position "pe" is the sum of "vpe" and "mpe."

The total dual-stage open loop transfer function from "pes" to "pe" is:

$$G_{ol} = P_m C_m + (1+P_{m0} C_m)\, P_v C_v$$

And the error rejection closed loop transfer function from "r" to "pes" is:

$$Gerr = 1/(1+G_{ol}) = 1/(1+P_m C_m)(1+P_v C_v) = G_{snsvcm} G_{snsma}, \text{ where } P_{m0} = P_m$$

The total error rejection closed loop "Gerr" of the dual-stage servo system is the product of the VCM and MA loop sensitivities, "Gsnsvcm" and "Gsnsma", respectively. Thus, the dual-stage servo control design can be decoupled into two independent controller designs: the VCM loop and the MA loop. Usually, the VCM open loop gain-crossover frequency is limited by the head-stack assembly and suspension resonance modes, and the dual-stage compensator is defined by the design of the MA compensators that attains additional attenuation of "Gsnsma".

Figure 1. HMA structure and actuation

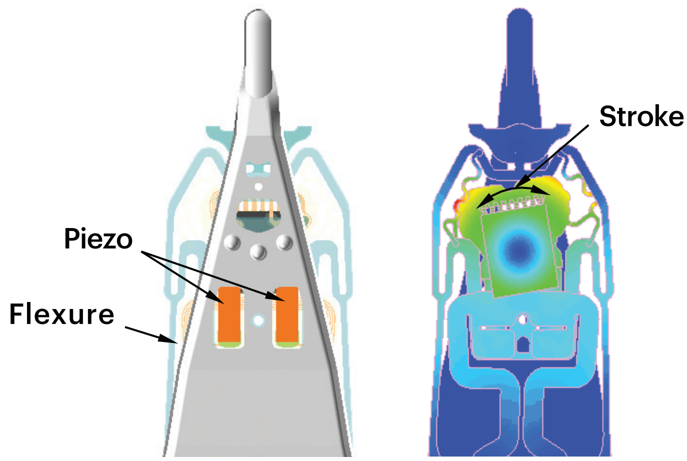


Figure 2. DSA plant transfer function comparison

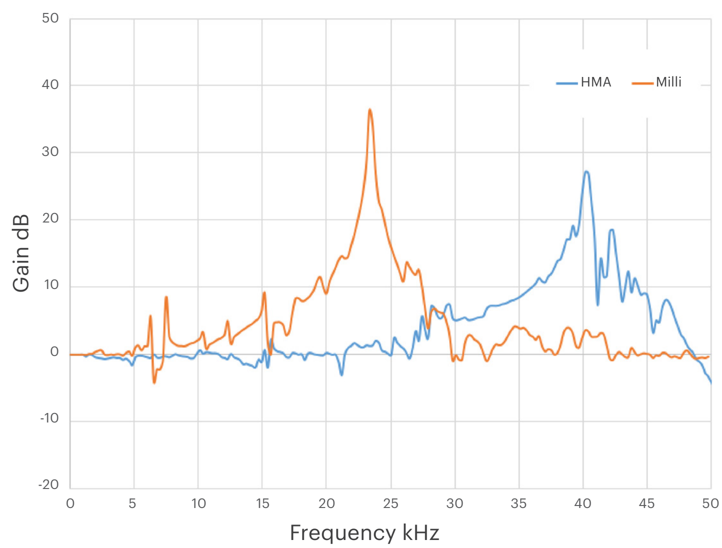
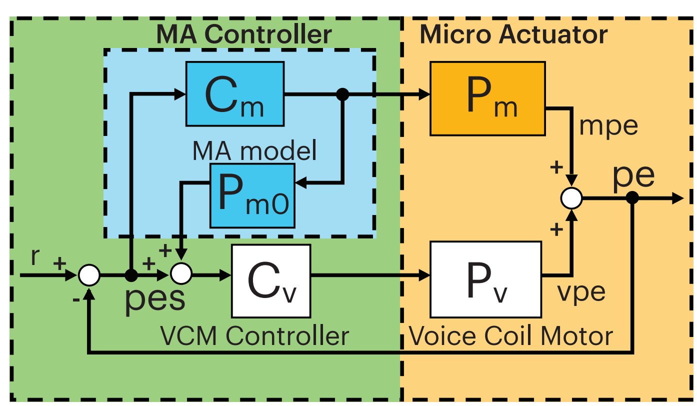


Figure 3. Schematic DSA servo block diagram with VCM and MA



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Figures 4 and 5 show the position-error signal (pes) comparison between the conventional Milli Actuator (blue) and HMA (green) DSA systems under an external vibration condition. The green line shows how significantly the HMA DSA system can reduce the head-positioning error caused by external vibration compared to Milli Actuator DSA system.

Figure 4. Position-error signal of HMA DSA compared to Milli DSA

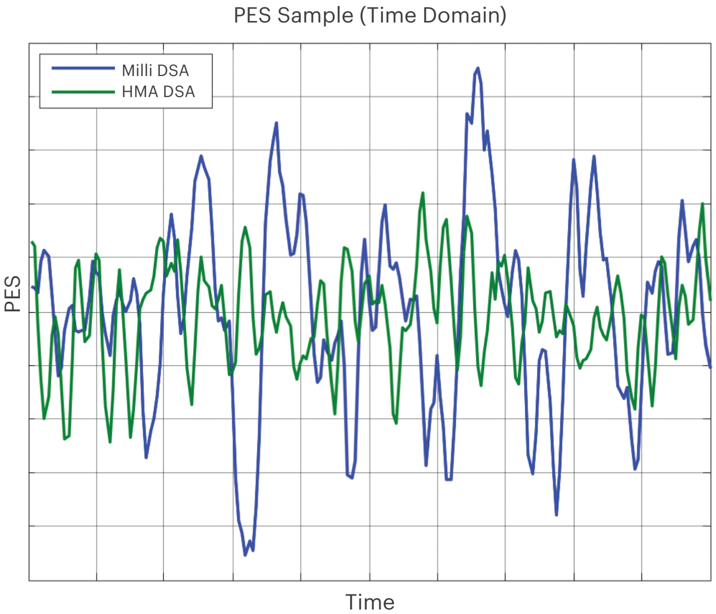
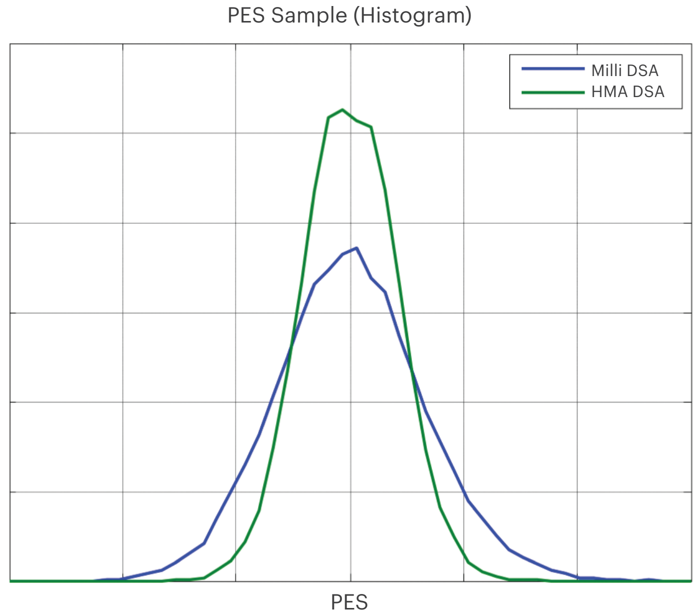


Figure 5. Position-error signal distribution of HMA DSA compared to Milli DSA



Conclusion

The better HMA mechanical dynamics enlarges the DSA servo bandwidth and also improves the loop-shaping capability, which lead to a noticeable operational vibration robustness. Being able to keep the head over the data with better accuracy, especially in multi-drive systems where operational vibration is present, ultimately results in better performance, data integrity and overall drive reliability.

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