Proc. ASME ISPS Conference,
Santa Clara, CA, USA, 2000

LOW ORDER CONTROLLER DESIGN FOR DUAL-STAGE HARD DISK DRIVES

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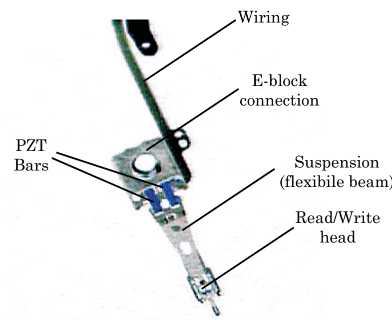
Introduction

The projected track densities for future Hard Disk Drives (HDD) will be on the order of 100,000 tracks per inch. A mechanical solution to the above problem is the introduction of dual-stage actuator designs. Along with the inherent track-following benefits of dual-stage actuators, the servo controller design needs to be updated, as the increased track densities can only achieved with the addition of an accurate dual-stage servo controller. There is therefore a need for methods of designing track following controllers of limited complexity, that can take full advantage of dual-stage actuator designs. The complexity of the servo controller is limited to address costs and implementation issues in a commercial hard disk drive.

The current research in servo design for track following with dual-stage actuators may be divided into a classical approach [1], that involves the shaping of open loop transfer functions, and modern control approaches [2,3], in which optimal control theory and optimization tools are used to compute feedback controllers. This talk presents a systematic approach for the design of a low order servo controller utilizing H_∞ optimization techniques. In this talk we will also compare this design procedure with the one given in [1] for a specific micro-actuator manufactured by Hutchinson Technology Inc (HTI).

Dual-Stage Actuator Case Study



In a dual-stage servo actuator, the first stage is built up from a VCM together with pivot bearing and E-block. In this case study, the second stage is a Magnum 5e suspension, manufactured by HTI, on which two piezoelectric strips are mounted at the base of the suspension. The suspension is mounted to the E-block by means of a base plate. Applying a voltage across the piezoelectric strips produces a displacement of the head relative to the E-block. Figure 1 and Figure 2 below show the discrete time transfer functions P_{vcm} and P_{ma} from VCM and micro-actuator input to head position output respectively, and were supplied by HTI. P_{vcm} is a 8^{th} order transfer function, composed of a VCM mode at 25Hz, an E-block mode at 5kHz, a suspension torsion mode at 5.9kHz and a suspension sway mode at 9kHz. P_{ma} is a 4^{th} order

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transfer function that includes only the suspension modes. The two input one output parallel connection of the two transfer functions gives a 12th order model of the dual-stage actuator.

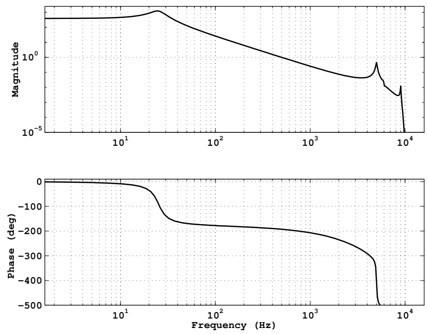

Figure 1: Bode Plot of P_{vcm}

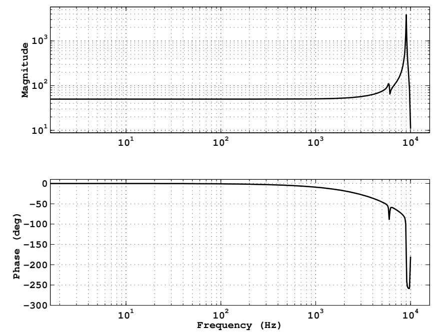

Figure 2: Bode Plot of P_{ma}

Control Design for Dual-Stage Actuators

A low order servo controller design has been developed in this paper by utilizing H_∞ optimization with a choice of specific closed loop weighting functions and additional constraints on the order of the controller. Based on the transfer functions given above a 5th order controller was designed.

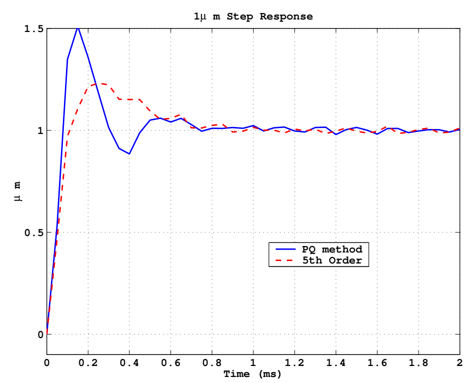

Figure 3: Step Response

Figure 3 shows a step response comparison between the controller designed by the method of this paper and a 10th order controller designed by HTI using the so-called PQ method from [1]. In the table below some of the important control design specifications have been listed. It can be seen from this table that the optimal control design, as proposed in this talk, has designed a controller that has made a good trade off between bandwidth and settling time. The design yields a dual-stage controller with less power consumption and improved performance characteristics compared to a PQ designed controller.

Controller	BandWidth	Gain Margin	Phase Margin	Rise Time	Settling Time	Over-Shoot
PQ [1]	1.5 (kHz)	6.4 (dB)	30 (deg)	0.1 (ms)	0.7 (ms)	51%
Present	1.0 (kHz)	6.6 (dB)	53 (deg)	0.1 (ms)	0.7 (ms)	23%

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