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High-Gain Servo Controller for Optical Disk Drives and the Initial Value Compensation

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Abstract: As optical disks are removable and have some distortions, servo systems of optical disk drives must be robust, especially at low frequency. We proposed the high-gain servo controller with complex zeros, which is the same 2nd order controller as conventional controllers, and realizes a much higher gain at low frequency. Decrease of servo error was confirmed, but the controller increased overshoot of initial value responses. We also proposed applying the initial value compensation to suppress the overshoot.

1. INTRODUCTION

As optical disks are removable and have some distortions, servo systems must be made robust. Various control technologies have been studied (Miyazaki *et al*., 2003) (Takahashi *et al*., 2003), but they require large circuits or high power. We proposed the high-gain servo controller with complex zeros (Urakawa *et al*., 2004), which is the same 2nd order controller as conventional controllers. It realizes a much higher gain with the same bandwidth. We confirmed decrease of servo error and improvement of a resistance to vibration. But the controller also increased overshoot of initial responses. We applied the initial value compensation (Yamaguchi *et al*., 1993) to suppress the overshoot.

2. HIGH-GAIN SERVO CONTROLLER

2.1 Theoretical Background

Figure 1 shows a servo system. If we use a conventional controller shown in fig.2 by the thin line, poles of the system are -628, -38989+6794j , -38989-6794j and -34680 [rad/sec].

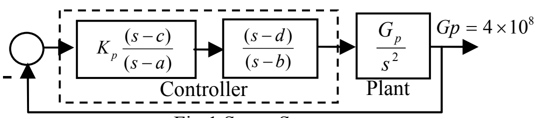


Fig.1 Servo System

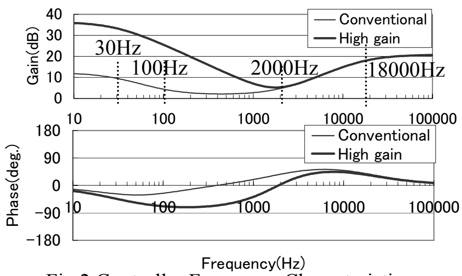


Fig.2 Controller Frequency Characteristics

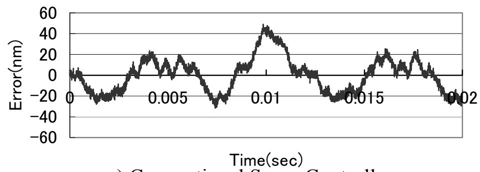
We tried to place the slowest pole at -628[rad/sec] to a faster position, and set the four poles at -27000[rad/sec] using the pole assignment method. Parameters of the high-gain servo controller were obtained as Kp=10.9, b=-107880, c=-9048 +6353j and d=-9048-6353j [rad/s]. Frequency characteristics of the controller are shown in fig.2 by the thick lines. The high-gain servo controller has a much higher gain by 25dB than that of the conventional controller at a low frequency. The values of c,d show it has complex zeros, and they allow the higher gain with a small loss of the phase margin.

2.2 Effects of the High-Gain Servo Controller

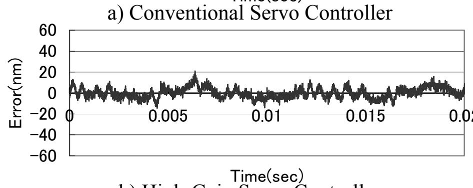
We applied the high-gain servo controller to a Blu-ray disk drive. Focus Error signals at 4.8X speed (r=49mm) are shown in fig. 3. Error signal of the high-gain servo controller (fig.3 b) is well suppressed to 36nm$_{p-p}$, while that of the conventional controller (fig.3 a) is 81nm$_{p-p}$.

We added a random vibration of 0.7Grms (5-120Hz) to the Blu-ray disk drive. Focus error signal of the conventional controller (fig.4 a) is 37nm$_{p-p}$, and that of the high gain servo controller (fig.4 b) is suppressed to 17nm$_{p-p}$. The high gain servo controller shows a much better resistance to vibration.

We also show initial value responses at servo switching in fig.5. The response of the high gain servo controller (fig.5 b) has larger overshoot than that of the conventional servo controller (fig.5 a). This overshoot makes fault rates of servo switching worse as shown in Table I.

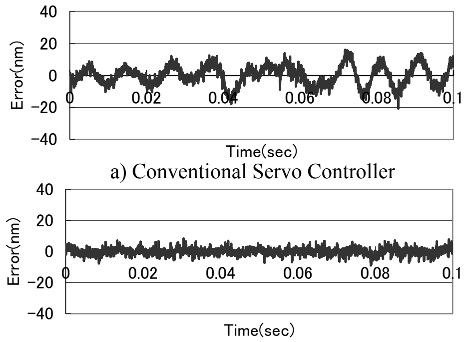


a) Conventional Servo Controller



b) High-Gain Servo Controller

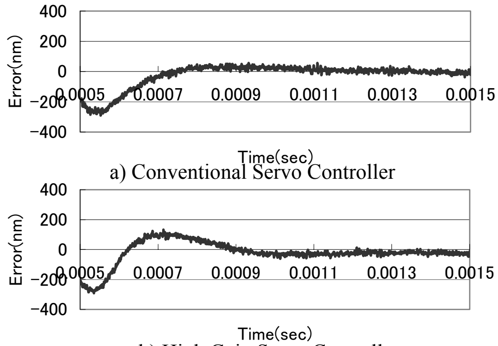
Fig.3 Focus Error (4.8X)



a) Conventional Servo Controller

b) High Gain Servo Controller

Fig.4 Focus Error (Vibrated: 1X)



a) Conventional Servo Controller

b) High Gain Servo Controller

Fig.5 Initial Responses of the Focus Servo System (Rotated Disk)

3. INITIAL VALUE COMPENSATION

We applied the initial value compensation method to a focus servo system shown in fig.6, to make the overshoot small. According to the method, we set the initial values as (1) to change zeros of the initial responses, where $x_{c1}(0)$ was a initial value of a low pass filter, $x_{c2}(0)$ was a initial value of a lead-lag filter, y(0) was a position of the plant and v(0) was a velocity of the plant.

$$\begin{pmatrix} x_{c1}(0) \\ x_{c2}(0) \end{pmatrix} = \alpha \begin{pmatrix} y(0) \\ v(0) \end{pmatrix} \qquad (1)$$

We set the α matrix as (2) to assign zeros 0.96416 and 0.95975. An initial value response without compensation is shown in fig.7 a), and compensated response is shown in fig.7 b). The overshoot is suppressed as simulated data.

$$\alpha = \begin{pmatrix} 1.6940\times10^{4} & 1.0276\times10^{-1} \\ 3.1543\times10^{5} & -8.4265 \end{pmatrix} \qquad (2)$$

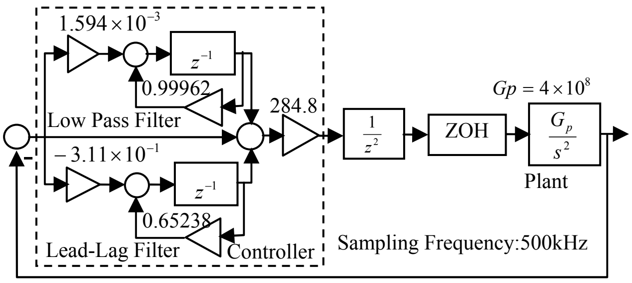
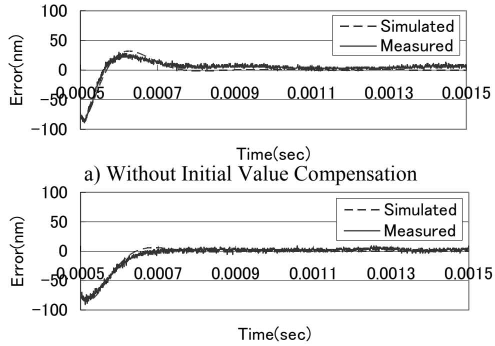


Fig.6 Digital Servo System

Table I shows that the initial value compensation method is effective to the fault rate of servo switching. The rate using the method is recovered to the original rate. The initial value compensation can recover the demerit of the high gain servo controller.



a) Without Initial Value Compensation

b) With Initial Value Compensation

Fig.7 Effect of Initial Value Compensation (Stopped Disk)

Table I. Fault Rate of Servo Switching

	Conven -tional	High-Gain	High-Gain with IVC
Inner track	1.2%	12.0%	0.9%
Middle Track	0.6%	6.0%	0.0%
Outer Track	0.0%	0.0%	0.0%

4. CONCLUSIONS

We proposed the high-gain servo controller with complex zeros, and applied to Blu-ray disc drives. We confirmed decrease of servo error and improvement of a resistance to vibration. We also observed the controller increased the overshoot of the initial value response, and confirmed the initial value compensation could suppress the overshoot of the high-gain servo controller.

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