Positioning Improvement for High Speed Performance of a Hard Disk Drive of Computer System

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Abstract**—** *In order to have high speed data processing, storage and retrieval by the central processing unit (CPU) of a computer, it is expected of a hard disk drive (HDD) to operate at a high speed performance and efficient. This has presented positioning improvement for high speed performance of a hard disk drive of a computer system. A dynamic model of read/write (R/W) servo positioning system of an HDD was obtained. A digital compensator was designed using Matlab software. The designed compensator was integrated with servo positioning system. Simulation was performed in Matlab environment. The result obtained showed that the response performance of the compensated system to a unit step input improved significantly. This shows that the digital compensator greatly improved the positioning of the R/W, which invariably reflects the fact that high speed performance has been achieved.*

Keywords**—** *CPU, Digital Compensator, HDD, Positioning system, Read/write.*

I. Introduction

Computers are known to have hard disk drive (HDD) inside them. A hard disk drive is just an integral part of the computer system which is used as a long term storage space for data [1]. It functions to keep data safe regardless of the state of the computer system –whether it is ON or OFF. A typical hard disk drive has the following components parts: platters, the spindle, the read/write (R/W) heads, and actuator.

Platters are circular discs found inside an HDD. The ones (1s) and zeros (0s) that make up the data are stored in the platters. The storage capacity of a hard drive can be increased by using several platters. In order to keep data stored on the platters organized and easier to find, they stored in tracks, sectors and clusters. Each platter is divided into concentric circles known as tracks. Each track is further divided into smaller units called sectors. The R/W heads interface between the magnetic media where the data is stored and electronic components in the HDD. The movement of the R/W heads is actually controlled by the R/W arm. The arm ensures that the heads are well position based on the data that needs to be read or written [2]. Information which are in form of bits are converted to magnetic pulses by the R/W head when it is to be stored on the platter (writing process) and then reverse the process while reading. The platters are kept in position and rotated by the spindle. The head actuator is a small motor which is instructed by the drive’s circuit board to control the R/W arm movement. It operates to ensure that the R/W heads are in exact and right position at all times.

There are basically two main functions carried out by R/W head positioning servo mechanism in HDD. These are: track seeking and track following. Track seeking moves the read/write head from the present track to a specified destination track in minimum time using a bounded control effort. Track following maintains the head as close as possible to the destination track centre while information is being read from or written to the disk [12], [9].

Previous works in literature have been presented on improving the operation of an HDD. The study in [3] presented a servo position control in hard disk drive of a computer using model reference adaptive control integrating proportional integral and derivative (PID) algorithm. Robust track-following controller design in hard disk drives based on parameter dependent Lyapunov functions is presented in [4]. Boettcher et al [5] studied the modelling and control of a dual stage actuator hard disk drive. A hard disk drive mechanism vibration damping using disturbance observer is established in [6]. Design and control of a dual-stage drive servo system with a high-aspect ratio electrostatic microactuator is presented in [7]. Goh et al. [8] presented design and implementation of a hard disk drive servo system using robust and perfect tracking approach. Mbaocha et al. [9] presented compensator for optimum hard disk drive read/write head positioning and control. The research carried out in [10] presented discrete proportional integral and derivative (PID) control scheme for a hard disk drive servomechanism. Design and implementation of a high performance hard disk drive servo controller using genetic algorithm (GA) based two degree of freedom (2DOF) robust controller is presented in [11].

The objective of this paper is to design a digital compensator that will improve the positioning system of the read/write (R/W) head of a hard disk drive (HDD) for high speed performance. In order to have high speed data processing, storage and retrieval by the central processing unit (CPU) of a computer, it is expected of the HDD to be fast (high speed performance) and efficient. To achieve this, the positioning system of an HDD requires a compensator that will enable it operate optimally so as to preserve the integrity of the data/information stored in an HDD.

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II. PERFORMANCE SPECIFICATIONS

The performance specifications expected of a typical hard disk drive servo positioning system considered in this paper are:

i. Percentage overshoot less than or equal to 5% to a unit step input.
ii. Rise time less than 1 seconds to a unit step input.
iii. Settling time less than 5 seconds to a unit step input.

III. DYNAMIC MODELLING AND COMPENSATOR DESIGN

A. Dynamic Modelling

In Fig. 1 a typical hard disk drive is presented. Fig. 2 shows a schematic diagram a hard disk drive read/write (R/W) head positioning system of a computer.

Fig. 1. A typical diagram of a hard disk drive with parts labelled.

The meaning of each labelled parts is as follows:

1. The actuator co-ordinates the movement of the read-write head.
2. Read-write arm swings read-write head back and forth across platter.
3. Central spindle allows platter to rotate at high speed.
4. Magnetic platter stores information in binary form.
5. Plug connections link hard drive to circuit board in personal computer.
6. Read-write head is a tiny magnet on the end of the read-write arm.
7. Circuit board on underside controls the flow of data to and from the platter.
8. Flexible connector carries data from circuit board to read-write head and platter.
9. Small spindle allows read-write arm to swing across platter.

Considering Fig. 2, the R/W head positioning system dynamic model is obtained as follows:

$$J\frac{d^2\theta}{dt^2} + C\frac{d\theta}{dt} + K\theta = K_m i \quad (1)$$

were J = the inertial of head servomechanism, C = the viscous damping coefficient of the bearings, K = the return spring constant, θ = the angular position (or displacement) of the head, K_m = the torque constant of the disk drive motor, and i = the is the supply current.

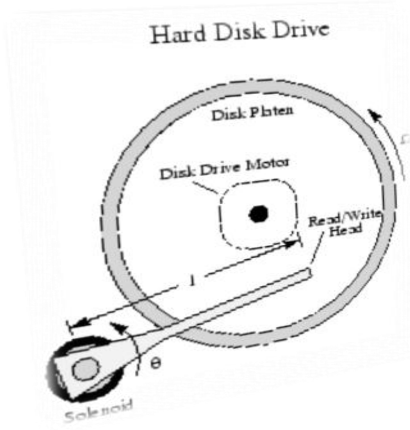

Fig. 2. Schematic diagram of a typical hard disk drive [13].

Taking the Laplace transform of (1) gives:

$$J\theta s^2 + C\theta s + K\theta = K_m I(s) \quad (2)$$

The transfer function of (2) is the ratio of the angular positioning θ of the hard disk drive to supply current, I. This yields:

$$G(s) = \frac{K_m}{Js^2 + Cs + K} \quad (3)$$

The values of the model parameters of a typical hard disk drive (HDD) R/W head servo positioning system are presented in table I below, and are taken from [13].

TABLE I. Values of the parameters of a HDD R/W head model.

Parameter	Unit	Value
J	Kgm^2	0.01
C	Nmrad^{-1}s^{-1}	0.004
K	Nmrad^{-1}	10
K_m	Nmrad^{-1}	0.05

Substituting these values into (3) yields:

$$G(s) = \frac{5}{s^2 + 0.4s + 1000} \quad (4)$$

In discrete time form, (4) becomes:

$$G(z)\frac{0.0001989z - 0.000183}{z^2 - 1.92z + 0.9231} \quad (5)$$

Sampling time of 0.2 s was used for the conversion.

B. Compensator Design

In order to design the digital compensator, a MATLAB software is used. The designed compensator is a discrete time proportional integral and derivative (PID) compensator. The PID tuner of the MATLAB software was used for the design.

$$C(z) = k_p + k_i \frac{T_s}{z-1} + k_d \frac{z-1}{T_s} \quad (6)$$

Table II presents the gain parameters of the PID compensator.

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TABLE II. Compensator gain parameters.

Parameter	Symbol	Value
proportional	k_p	1890
Integral	k_i	403
Derivative	k_d	185
Sampling time	T_s	0.2 s

Substituting the values of the PID compensator into (6) gives the designed digital compensator represented by:

$$C(z) = 1890 + 80.6\frac{1}{z-1} + 925(z-1) \qquad (7)$$

C. Compensated Loop Configuration

The compensated loop is shown in Fig. 3. It can be seen that the loop represents a standard close loop system with the compensator and the servomechanism in the forward path. A unit feedback has been assumed for the implementation.

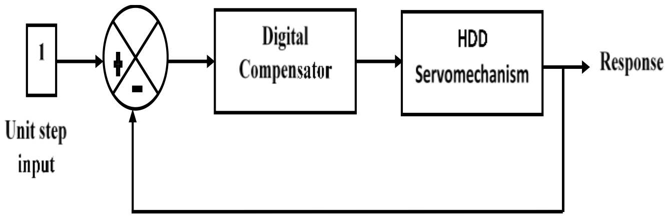

Fig. 3. System configuration.

D. Stability Performance

The stability performance test was analyzed using the Root Locus plot of the MATLAB software. The plot is shown in Fig. 4.

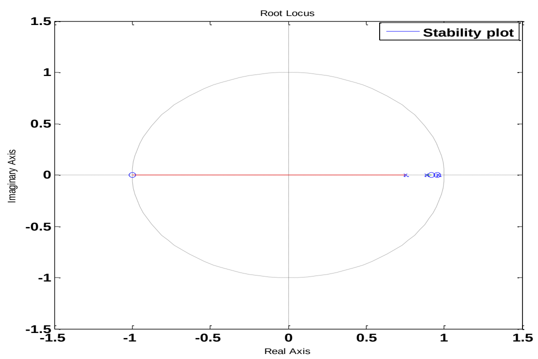

Fig. 4. Stability performance plot.

The plot in Fig. 4 shows that the poles of the system lie within the unit circle with the following values -1, 0.961, and 0.908. Since the poles lie within the unit circle, the system is stable.

IV. Simulation Result And Discussion

A. Simulation Result

Simulation is performed in MATLAB environment in this paper. Fig. 5 is the simulation result for the uncompensated positioning system. Fig. 6 is the simulation result for compensated positioning system.

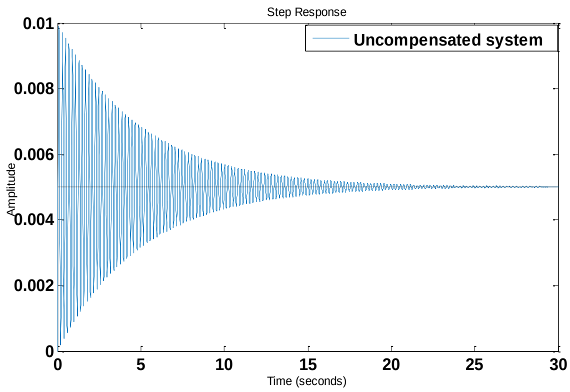

Fig. 5. Step response of uncompensated positioning system.

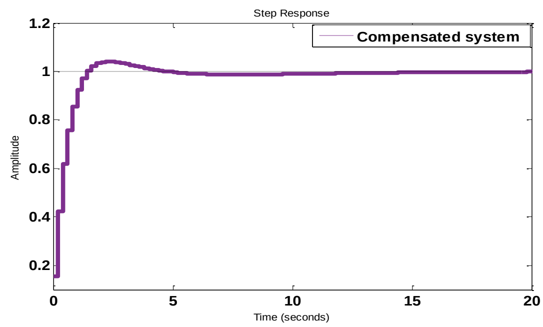

Fig. 6. Step response of compensated positioning system.

B. Discussion

The simulation results presented in Fig. 1 and 2 show the performance characteristics of servo positioning system of a typical hard disk drive (HDD) considered in this paper. In Fig. 1, it can be seen that the uncompensated positioning system show high oscillation to a unit step input. This indicates in-stability, with the following performance characteristics. Overshoot of 98 %, rise time of 0.031 s and a settling time of 19.5 s. In Fig. 6, the system response to a unit step input indicates that the oscillation has been taken care of and the system performance improved. The performance characteristics of the system is: overshoot of 4.12 %, rise time of 0.8 s and settling time of 3.8 s. This shows that with improved response time performance characteristic of the compensated system, a fast and efficient servo positioning is guaranteed.

V. Conclusion

This paper has presented positioning improvement for high speed performance of a hard disk drive (HDD) of computer system. The dynamic model of a typical HDD has been obtained. The designed digital compensated is integrated with the positioning system. Simulation result shows that the response performance of the system to a unit step input has been significantly improved.

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