Position Error Analysis

Histograms Measure Servo Runout and On-Track Percent

On Track percentile is a crucial performance measurement for disk drive servo systems.

As a drive is tracking at a particular location, the servo demodulator (Figure 1) performs an analog peak detect of the servo bursts (commonly referred to as A, B, C, D). The demodulator output is digitized by an A/D converter. The servo decoder looks for common elements such as AGC, sync, cylinder number, and sector ID to determine position. The outputs of the servo demodulator A/D and the servo decoder are then fed to the Servo microprocessor. The Servo microprocessor converts this information to a digital number representing the position of the head over the track.

Most disk drives have a spare digital to analog converter which can be used to scale and display the position error on a LeCroy digital scope (Figure 1). The measured position is compared to the desired (reference) position in order to obtain the **Position Error Signal (PES)** (Figure 2, Trace 2)**.** The PES signal is used to calculate the current necessary to move the voice coil motor to center the head over the appropriate recorded track.

Since tracks are never perfectly circular, the PES is sampled many times per revolution and used to keep the heads centered above the track. The PES is often used as a relative figure of merit as to the on-track performance of the servo system.

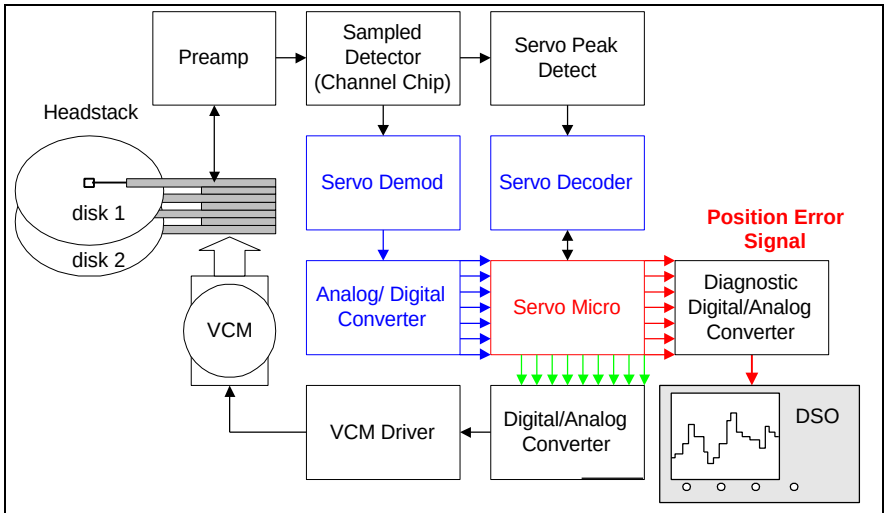

Figure 1: Generic Disk Drive Servo Circuit

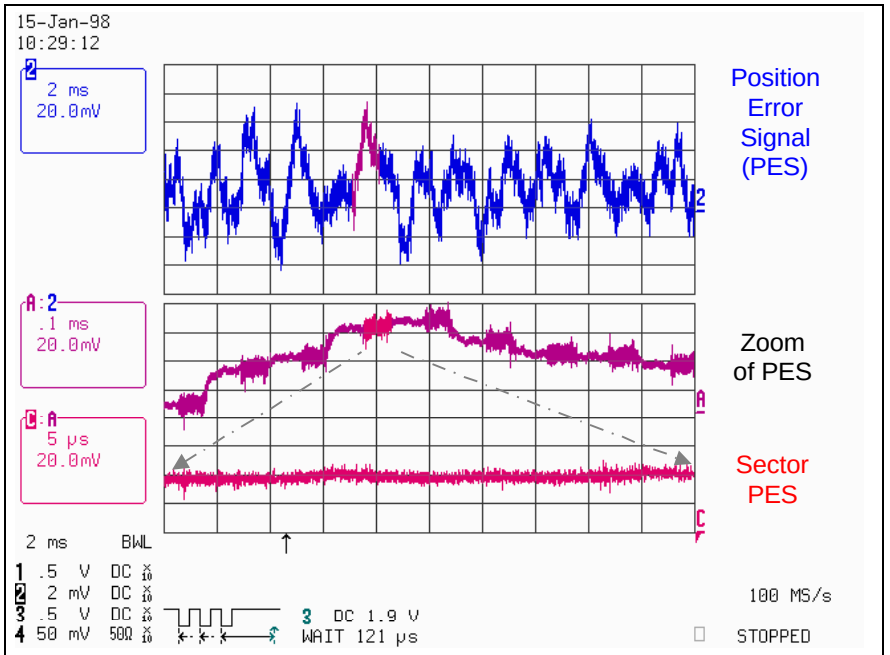

Figure 2: Position Error Signal

Runout is the term used to describe system position error sources. There are four useful measurements:

Instantaneous Runout, Repeatable Runout, Non-Repeatable Runout, and Total Runout.

Instantaneous Runout for a sector is the mean of the PES.

Repeatable Runout is the result of 1st order effects such as error in the servo track writer or disk shift (eccentricity).

Non-Repeatable Runout can be caused by bearing defects, noise, spindle motor imperfections, and servo loop response errors.

Total Runout is the sum of all effects and its 6 sigma value is a measurement of the overall tracking performance (in % of a track).

Figure 3 shows how LeCroy scopes can measure Runout. Total Runout (R_t) is PES (Trace 2) for a revolution of the disk. Repeatable Runout (RR) is the averaged PES signal (Trace A). Non-Repeatable Runout (NRR) is RR minus R_t (Trace C).

The frequency spectrum of NRR (Figure 3, Trace D) can be used to determine the cause of problems such as actuator 'rocking', bearing defects and servo system noise.

Figure 4 shows Runout measurement capability of LeCroy Scopes. Trace 2 is random data for any sector on a track around many revolutions of the disk. Trace B is the histogram of the mean. The histogram parameter values measure each kind of Runout.

Instantaneous Runout is the mean (6.90 mV). Repeatable Runout is histogram range of the mean (1.9 mV). Non Repeatable Runout is the average of the mean (76 mV). Total Runout is the sum of the range of the mean and the average of the mean (77.9 mV).

Tracking error can be computed directly from sigma of the mean. The diagnostic D/A converter produces 1.25 volts/ track or 80 microinches/ volt based on the track width.

Tracking error % =
100% times (6*sigma)/1.25V

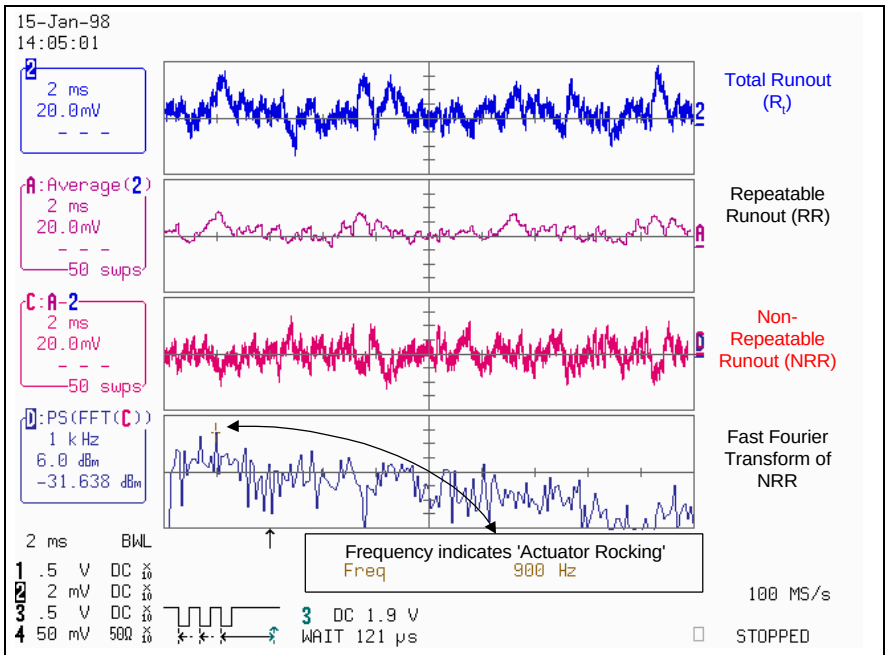

Figure 3

Trace 2: Total Runout for ~2 revolutions (PES),
Trace A: Repeatable Runout, (Average of 50 PES Waveforms)
Trace C: Non-Repeatable Runout, (Total minus Repeatable)
Trace D: FFT of NRR highlights actuator defects

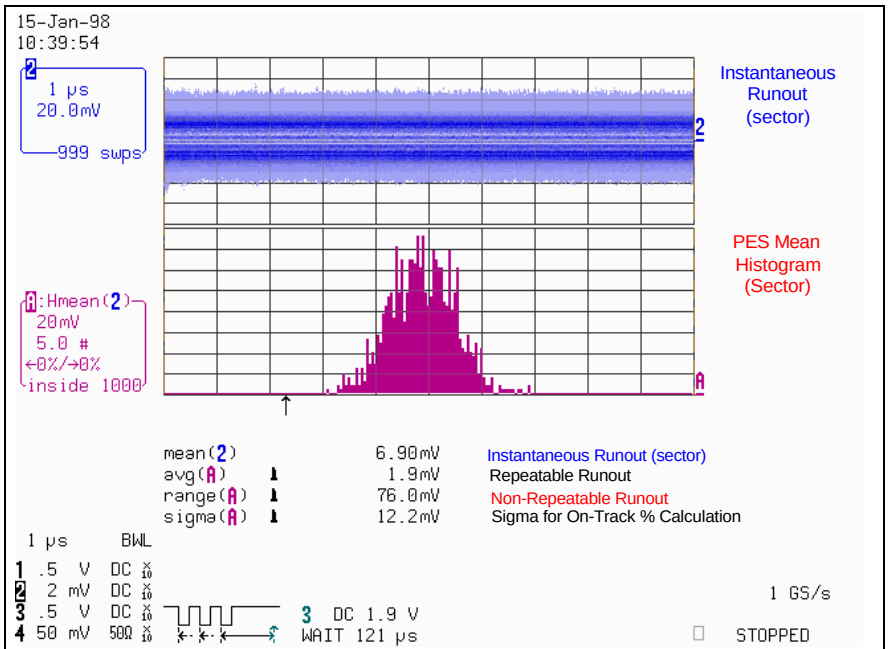

Figure 4:

Trace 2: Instantaneous Runout over 1 Sector
Trace A: Histogram Gives Instantaneous Runout (mean), Repeatable Runout (Avg) and Non-Repeatable Runout (Range) Values, Total Runout is RR + NRR

(Figure 4: sigma =12.2 mV)

Tracking error (% of a track) = 5.86%