TRACKING SERVO APPARATUS

This invention relates to tracking servo apparatus for performing tracking servo with respect to a recording medium having recording tracks.

To perform recording or reproduction of data in a recording track in a non-contact state with respect to a recording medium such as an optical disc, tracking servo must be performed to track a beam spot relative to the recording track.

In a previously proposed tracking servo apparatus, a tracking error signal obtained when a beam spot crosses a track has a waveform such as a signal Vp in Figure 1A of the accompanying drawings. Assuming that the displacement of the beam spot from the track centre is x and a track pitch is p, the signal Vp is given by:

$$Vp = A\sin(2\pi x/p)$$

In this case, tracking servo is performed so that the signal Vp becomes zero.

A track jump for moving a beam spot to an adjacent track or to another track separated by several tracks is performed as follows in the previously proposed tracking servo apparatus. Firstly, the beam spot is moved close to a target track in an open-loop state in which tracking servo is turned off. Then, tracking servo is turned on to track the beam spot to the target track.

However, the signal Vp is a sine wave, and hence cannot be uniquely determined with respect to the displacement x, as is indicated in Figure 1A, wherein the signal Vp is uniquely determined with respect to the displacement x only in the hatched regions. Thus, the beam spot can be stably tracked to the track only when it is located in the hatched regions.

If the displacement x is large, and the beam spot is located outside the hatched regions, tracking servo becomes destabilized or oscillates. Such a state tends to occur especially when the moving speed of the beam spot in a track pitch direction is large, as in a track jump. For example, this occurs when an error is produced in the distance the beam spot is to be moved when a track jump is performed

with tracking servo off, and tracking servo is then turned on outside the hatched regions. It then takes a long time to track the beam spot to the target track, or the beam spot may be tracked to a track other than the target track.

According to the present invention there is provided a tracking servo apparatus for performing tracking servo of a beam spot with respect to recording tracks on a recording medium, the apparatus comprising:

means for deriving a tracking error signal proportional to displacement of the beam spot from a recording track by up to one half of the track pitch of the recording track;

means for processing said tracking error signal and a signal representing a tracking target value to perform tracking servo; and

means for setting said target value to a value proportional to the required displacement when the beam spot is to be jumped from one recording track to another recording track.

In embodiments of tracking servo apparatus according to the present invention, since the error signal for performing tracking servo is proportional to the displacement from the recording track, the error signal can be uniquely determined with respect to the displacement.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references and in which:

Figures 1A to 1D show waveforms of various signals;

Figure 2 is a block diagram of an embodiment of tracking servo apparatus according to the present invention;

Figure 3 is a block diagram of a sample hold device;

Figure 4 is a block diagram of an operator circuit;

Figures 5A and 5B show waveforms of jump signals;

Figure 6 shows waveforms of various signals obtained when tracking servo is off; and

Figure 7 shows waveforms of various signals obtained when a track jump is performed.

Referring to Figure 2, which shows an embodiment applied to an optical disc player, a signal read from an optical disc 11 by an optical pick-up 12 is amplified by an amplifier 13, and is then supplied to a phase locked loop (PLL) 14 and a sample hold device 15.

A clock signal is reproduced from the signal supplied to the PLL 14. On the basis of this clock signal, a timing controller 16 supplies a timing signal required for sampling to the sample hold device 15.

Figure 3 shows an arrangement of the sample hold device 15, which has three sample hold circuits 21 to 23 and an operational amplifier 24.

As shown in Figure 3, the optical disc 11 has tracking pits 11b and 11c offset in opposite directions from the centre of a track 11a by a 1/4 track pitch and sequentially recorded along the track 11a, and a clock pit 11d recorded subsequently to the tracking pits 11b and 11c.

The sample hold circuits 21 and 22 sample-hold signals from the tracking pits 11b and 11c, respectively. Therefore, the operational amplifier 24 supplies a signal Vp shown in Figure 1A in accordance with a tracking error.

The sample hold circuit 23 sample-holds a signal from the clock pit 11d and supplies a signal VQ shown in Figure 1B in accordance with the tracking error.

The signal VQ is represented by:

$$VQ = A\cos(2\pi x/p)+C$$

and has a phase shift of 90° with respect to the signal Vp.

In this case, assuming that:

$$VQ' = VQ-C = A\cos(2\pi x/p),$$

the following equation is obtained:

$$Vp/VQ' = \frac{A\sin(2\pi x/p)}{A\cos(2\pi x/p)}$$

$$= \tan(2\pi x/p)$$

Therefore, assuming that a signal representing a displacement x is VX', the signal VX' is given as follows:

$$VX' = \frac{p}{2\pi} \tan^{-1}(Vp/VQ') \qquad \ldots(1)$$

Figure 1C shows the signal VX'. The signal VX' is proportional to the displacement x in principle in the range $|x| < (p/4)$ but is discontinuous at the position $|x| = (p/4)$. Therefore, if a signal VX shown in Figure 1D is obtained by level-shifting the signal VX' in the range $(p/4) \leq |x| < (p/2)$ as indicated by broken lines and arrows in Figure 1C, this signal VX is proportional to the displacement x in the range $|x| < (p/2)$.

Accordingly, the signal VX is uniquely determined with respect to the displacement x of a beam spot regardless of the magnitude of the displacement x, that is, regardless of a position of the beam spot, except for a position represented by $|x| = (p/2)$, that is a middle position between tracks.

A processing circuit 25 receives the signals Vp and VQ from the sample hold device 15, and supplies the signal VX as described above to a subtractor 26.

Note that in this embodiment, as is apparent from Figure 3, the sample hold circuits 21 to 23 are used because the optical disc 11 is used as a recording medium in which the tracking pits 11b and 11c and the clock pit 11d are preformed, and therefore data can be recorded.

However, when a reproduction-only compact disc or video disc is used, a tracking error signal and a data reproduction signal, both of which are well known to those skilled in the art, can be used as the signal Vp and the signal VQ, respectively. Therefore, the sample hold circuits 21 to 23 need not be used.

Figure 4 shows an arrangement of the processing circuit 25. The

signal Vp is supplied to a programmable read-only memory (PROM) 32 through an analogue-to-digital (A/D) converter 31. A signal VQ' obtained by subtracting a constant C from the signal VQ by a subtractor 33 is supplied to the PROM 32 through an A/D converter 34.

The PROM 32, such as a PROM 2732, stores a look-up table which satisfies a relationship shown in Figure 1D with respect to the digitized signals Vp and VQ', and supplies a signal obtained by looking up the table to a digital-to-analogue (D/A) converter 35. Therefore, the D/A converter 35 supplies an analogue signal VX.

Instead of digital processing as described above, equation (1) may be derived directly by a trigonometric function operator, already on the market as an analogue integrated circuit, and the signal VX' may be corrected to the signal VX.

In this case, if the signal VQ is shifted beforehand in an analogue manner by the amount of the constant C, an operation for subtracting the constant C from the signal VQ to obtain the signal VQ' need not be performed in equation (1). Therefore, the signal VQ can be directly used.

The subtractor 26 receives a signal representing a tracking target value (a value to be displaced from the track 11a) through a switch 36. During normal tracking servo, that is, when a beam spot accurately scans the track 11a, the signal representing the tracking target value is zero.

Therefore, the signal VX which is proportional to the displacement x is supplied from the subtractor 26 to the optical pick-up 12 through a phase compensator 41 and a drive amplifier 42, thereby performing tracking servo.

In order to perform a track jump, the switch 36 is switched to a microcomputer 43 and a D/A converter 44, so that a signal generated by the microcomputer 43 and D/A-converted by the D/A converter 44 is supplied to the subtractor 26.

Figures 5A and 5B show such signals. Figure 5A shows a signal obtained when a beam spot is jumped by one track, that is a beam spot is jumped to an adjacent track, and Figure 5B shows a signal obtained when a beam spot is jumped by two tracks.

As is apparent from Figures 5A and 5B, each signal for a track jump has the same waveform as that of the signal VX obtained from the

processing circuit 25, and has the same number of waves as that of tracks to be jumped over.

Note that such a track jump is performed while tracking servo is kept on, that is in a closed loop state as is apparent from Figure 2. However, as in the previously proposed apparatus, a track jump can be performed while tracking servo is kept off, that is in an open loop state.

In this case, the processing circuit 25 is connected directly to the phase compensator 41 without using the subtractor 26, the switch 36, the microcomputer 43, and the D/A converter 44. In this case, as shown in Figure 2, a switch 45 and a jump signal generator 46 are used.

A beam spot is jumped close to a target track in an open loop state wherein the switch 45 is switched to the jump signal generator 46, and the open loop state is switched to a closed loop state at a position close to this target track.

In this tracking operation, since the range in which tracking servo can be stably performed is also wider than that of the previously proposed apparatus as is apparent from Figure 1, a track jump can be stably performed.

Figure 6 shows the signals VX and Vp obtained before and after a turning point of a beam spot when tracking servo is kept off and the beam spot moves in a zig-zag manner with respect to a plurality of tracks 11a because the optical disc 11 is eccentric, in the embodiment as described above.

As is apparent from Figure 6, when the beam spot moves in the opposite direction, the signal VX is inclined in an opposite direction.

Figure 7 shows the signals VX and Vp obtained when a gain of the jump signal shown in Figure 5A is larger than normal and a beam spot is jumped to an adjacent track. When the gain of the jump signal is normal, the beam spot is immediately tracked to the adjacent track, and the signal VX has a waveform 51 as indicated by an alternate long and short dashed line in Figure 7.

When the signal VX indicated by a solid line in Figure 6 is obtained, the gain of the jump signal is too large. Therefore, as is apparent from a waveform 52, the beam spot passes beyond the target

track. However, as is apparent from a waveform 53, the beam spot falls in the range wherein it can be tracked. As is apparent from a waveform 54, the beam spot is subsequently returned to the target track.

On the contrary, according to the signal Vp, the beam spot falls outside the range wherein it can be tracked. Therefore, if the signal Vp is an error signal, the beam spot may not have returned to the target track.

CLAIMS

1. A tracking servo apparatus for performing tracking servo of a beam spot with respect to recording tracks on a recording medium, the apparatus comprising:
means for deriving a tracking error signal proportional to displacement of the beam spot from a recording track by up to one half of the track pitch of the recording track;
means for processing said tracking error signal and a signal representing a tracking target value to perform tracking servo; and
means for setting said target value to a value proportional to the required displacement when the beam spot is to be jumped from one recording track to another recording track.

2. Apparatus according to claim 1 wherein said target value is set to zero when the beam spot is to scan a recording track.

3. Apparatus according to claim 1 or claim 2 wherein said tracking error signal is derived from an initial tracking error signal and a signal having a phase shift of 90^{o} with respect to said initial tracking error signal.

4. Apparatus according to claim 3 comprising processing means operative, when the track pitch is p and the displacement of a beam spot from the recording track is x, for processing the displacement x on the basis of the initial tracking error signal $A\sin(2\pi x/p)$ and a signal $A\cos(2\pi x/p)$.

5. Apparatus according to claim 4 further comprising level shifting means for level-shifting the displacement x when the displacement x is in the range:

$$p/4 \leq |x| \leq p/2$$

6. Apparatus according to claim 3, claim 4 or claim 5 wherein the initial tracking error signal is obtained by sample-holding an output from an optical pick-up supplied when the beam spot scans a tracking pit, and said shifted signal is obtained by sample-holding an output

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from said optical pick-up supplied when the beam spot scans a clock pit.

7. Apparatus according to any one of the preceding claims wherein said recording medium is an optical disc.

8. A tracking servo apparatus substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

9. A tracking servo apparatus substantially as hereinbefore described with reference to Figures 2 to 4 of the accompanying drawings.