DISCUSSION ON TIME BASE CORRECTOR FOR VIDEO DISC PLAYER

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1. Introduction

The time base error (TBE) in the reproduced signal of a video disc player (VDP) in which a plastic disc is used, is inevitable due to the disc center hold eccentricity, signal track distortion and Wow & Flutter of the player. Therefore, a time base corrector (TBC) is considered to be one of the key functions for the VDP.

The required performance of the TBC is determined through related items such as the amount of the TBE, characteristics of the TV receiver and the allowance for residual error in the reproduced picture (the luminance signal instability and poor color reproduction) and the reproduced sound (the sound signal Wow & Flutter.)

In this paper we discuss the required performance and related items of the TBE, i.e. the cross frequency of the spindle motor control loop (SPDL loop) and the tangential actuator control loop of the signal pick-up head (actuator loop) and a convenient analytical determination method at the nearby cross frequency area.
A problem and countermeasure of the TBC using the CCD (charge coupled device) as a variable delay line is also discussed.

2. The required performance of the TBC

2.1 TBC and related items:

The amount of the generated TBE, the characteristics of the horizontal line AFC loop and color APC loop in the TV receiver, the allowance in the reproduced picture (the luminance signal instability and poor color reproduction) and the allowance in the reproduced sound Wow & Flutter are related to the TBC as illustrated in fig. 1. Therefore, the performance of the TBC should be determined by taking into account all of these items.

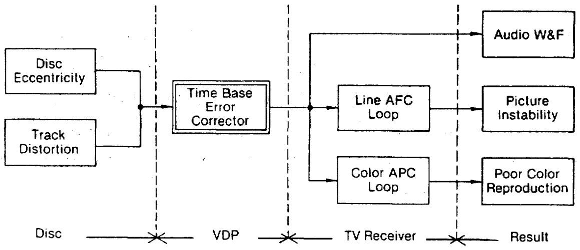


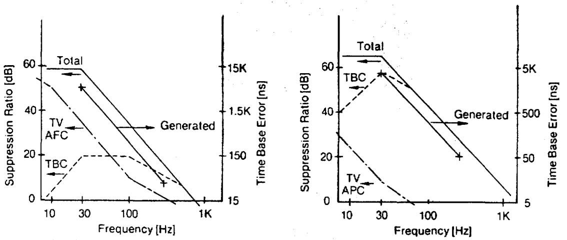
Fig. 1 TBC and Related Items

2.2 System design:

(1) The estimation of the generated TBE:
In the optical video disc system the amount of the generated TBE can be plotted with x-x from the disc standard as shown in fig. 2.
(2) The allowance:
The allowance in the reproduced signal, such as in the luminance, chrominance and sound signal, is determined as follows:

Luminance $\leq \pm$ 15ns
Chrominance $\leq \pm$ 5ns
Sound $\leq \pm 0.07\%_{WRMS}$

In this case, the allowance of the luminance signal, (± 15ns) is equivalent to a ± 0.12mm picture variation on the 20" (diagonal) display and the allowance of the chrominance signal (± 5ns) is equivalent to a ± 6.4 degree color signal phase difference; these allowances are considered to be reasonable in the consumer use player.
(3) Required Performance:
The required performance of the TBC in the VDP is determined by using the amount of the generated TBE, the allowances described above and the characteristics of the TV receivers as follows:
(a) the required total performance of the suppression ratio is determined so as to cover all of the generated TBE as indicated in fig. 2. The ratio can be expressed in dB in which 0dB corresponds to the allowance.
(b) The suppression ratios (approximated by open loop gain) of the TV line AFC loop and color APC loop are plotted in fig. 2 in accordance with the left (i.e.dB) vertical axis.
(c) The required performance of the suppression ratio for the TBC loop is determined by subtracting the total requirement of the suppression ratio by the suppression ratios of the line AFC loop and color APC loop.
(d) In fig. 2, the amount of the generated error (x-x), the total required performance of the suppression ratio (solid line), the characteristics of the TV receiver (chain lines) and the required performance (which is determined by the above method) of the suppression ratio for the TBC loop (dotted line) are shown. (Attention must be given to the fact that the characteristics of the TV receiver vary with the make and model of the TV.) This method can also be applied to fix the characteristics of other video disc systems such as the VHD of JVC and CED of RCA.



a) Luminance

(b) Chrominance

Fig. 2 The required performance of the TBC (Approx.)

Other video disc systems, as mentioned above, have the special color APC loop for color signal conversion from low color signal frequency to normal NTSC color signal frequency. However, in the optical video disc systems, the signal is pre-recorded through the direct

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FM record method without the color signal frequency being converted to low frequency. Therefore, the required performance of the TBC for the optical disc player should be determined to provide the loop gain for chrominance which requires a larger suppression ratio than the luminance as the special APC loop is not used in this player.

3. Related Matter

We will now consider the following matters which are related to the required characteristics of the TBC such as, the cross frequency between the SPDL loop and the actuator loop and problems and countermeasures of the TBC using CCD as a variable delay line.

3.1 Cross frequency between the SPDL loop and the actuator loop:

(1) A block diagram of an example of the TBC loop for the optical disc player is shown in fig. 3. The TBC is constructed using the SPDL loop to compensate the TBE at the low frequency area and the actuator loop, to compensate the TBE at the high frequency area as well as the disc rotation frequency. In the example given the relationship of ϕi (input phase error) and ϕ_o (output phase error) is shown as in expression (1).

$$\frac{\phi_o}{\phi i} = \frac{1}{1 + \mu_C G_C G_J + G_M (\mu_H G_H + \mu_C G_I)} \qquad (1)$$

Where:

μ_C, μ_H = Sensitivity of the phase detector for the tangential actuator/motor.

G_J, G_M = Transfer function of the tangential actuator/motor.

G_C, G_I, G_H = Transfer function of the phase compensated circuits.

The denominator of this expression (1) should be provided for the required performance of the suppression ratio for the TBC. In this case, because of the smaller suppression ratio requirement for the TBC loop in the lower frequency area (as in fig. 2) and the dynamic range of the tangential actuator, the characteristics of the SPDL loop and the actuator loop should be crossed in the low frequency area.

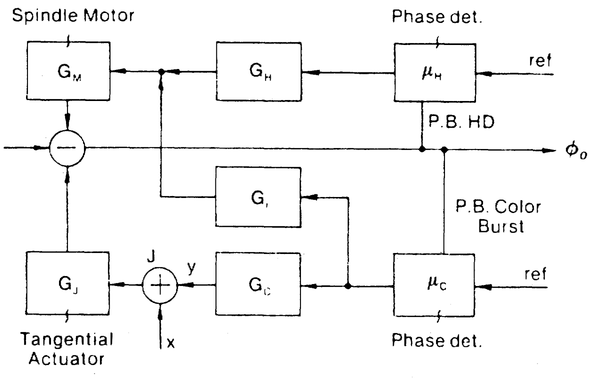


Fig. 3 Block diagram of the TBC

At this time, the cross frequency fc and phase difference $\Delta\theta$ between those two loops should be expected to be at least several Hz and less than 120 degrees. The reason for $\Delta\theta$ is as follows: The synthesized loop gain, $|G_S|$ of these two loops is indicated in expression (2) and is also shown in fig.4.

$$|G_S| = 2G \sin [(\pi - \Delta\theta)/2] \qquad (2)$$

that is, $|G_S|$ decreases very rapidly as $\Delta\theta$ approaches 180°.
Therefore, the phase difference should be expected to be less than 120 degrees to secure the synthesized loop gain $|G_S|$ at the cross frequency. It is essential to assure the characteristics of the TBC loop at the cross frequency area using two compensating loops crossing at the low frequency.

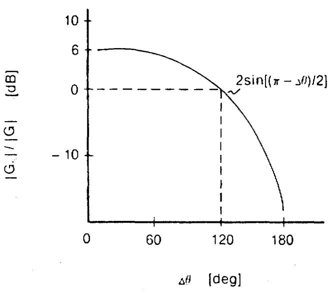


Fig. 4

A convenient analytical method used to determine the condition at the cross frequency fc and the phase difference $\Delta\theta$ at this frequency is as follows:
(2) The condition at the cross frequency:
The small fluctuation signal x is fed into the TBC loop from point J (in fig. 3) and response y is measured which aids in the examination of the condition of the TBC at the cross frequency area.
At this point the relationship of x and y is shown as in expression (3):

$$\frac{y}{x} = \frac{-\mu_C G_C G_J}{1 + \mu_C G_C G_J + G_M (\mu_H G_H + \mu_C G_I)} \qquad (3)$$

In the nearby cross frequency area $|\mu_C G_C G_J| \gg 1$, and $|\mu_C G_I| \gg |\mu_H G_H|$ the $\mu_C G_I$ loop is set for improvement of the characteristics at the nearby disc rotation frequency area which includes the cross frequency and which may also be written as in expression (4) below:

$$\frac{y}{x} = \frac{-1}{1 + G_M G_I / G_C G_J} \qquad (4)$$

Therefore, the $|G_M G_I / G_C G_J|$ and $|\angle G_M G_I - \angle G_C G_J|$ can be obtained from the measurement of $|y/x|$ and $|\angle y/x|$. The cross frequency fc, from $|G_M G_I / G_C G_J| = 1$, and the phase difference $\Delta\theta$ from $|\angle G_M G_I - \angle G_C G_J|$ at the cross frequency, can also be obtained; an example of the result of this examination is shown in fig. 5. In fig. 5 the cross frequency fc and the phase difference $\Delta\theta$ are shown as fc = 10Hz, $\Delta\theta$ = 125 degrees.
In this case, $|G_S/G| = 2 \sin [(\pi - 125)/2] = 0.92 \rightarrow -0.7\text{dB}$ shows that the synthesized gain of the two loops is reasonable and has not decreased excessively. We confirmed that the result obtained using this method is approximately the same as other methods using μ_C, G_I, etc. in calculating the cross frequency fc and phase difference $\Delta\theta$ and is more convenient and affords us a more direct way in which to study the conditions of the nearby cross frequency area.

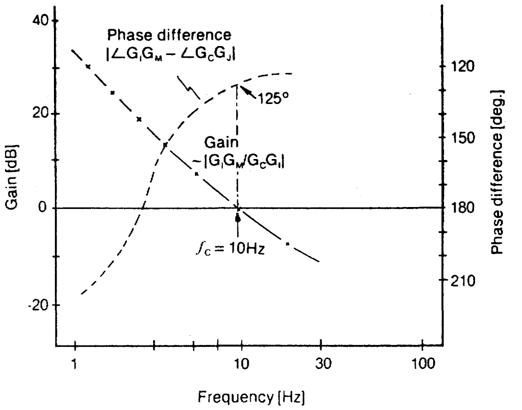


Fig. 5 The result of the measurement of the cross frequency.

3.2 TBC using CCD:

(1) The TBE using the CCD as a delay line is attractive because it eliminates the tangential actuator of the signal pick-up head and simplifies the pick-up head construction. However, in this type of application there remain some problems which must be resolved, such as:

(i) Phase delay of the control signal.

(ii) Output signal level fluctuation due to the signal transfer performance of the CCD and the change of the CCD drive frequency.

(2) Fundamentals of the TBC using CCD:

The error signal from the TBE detector (phase detector) causes the CCD driver to change the CCD drive clock frequency. This change of the CCD drive clock frequency alters the delay time of the CCD to compensate the TBE. In this case, the variation delay time Δt_{pp} of the CCD, and the average delay time τ_0 and phase delay difference θd of the control signal from the average delay time τ_0 are shown as follows:

$$\Delta t_{pp} = \frac{N}{f\ \text{min.}} - \frac{N}{f\ \text{max.}} \tag{5}$$

$$\tau_0 = \frac{N}{2}\left(\frac{1}{f\ \text{min.}} + \frac{1}{f\ \text{max.}}\right) \tag{6}$$

$$\theta d = \omega \cdot \frac{\tau_0}{2} \tag{7}$$

Where:

N = the number of CCD stages

f min., f max. = min. and max. CCD drive frequency

ω = angular frequency of the control signal

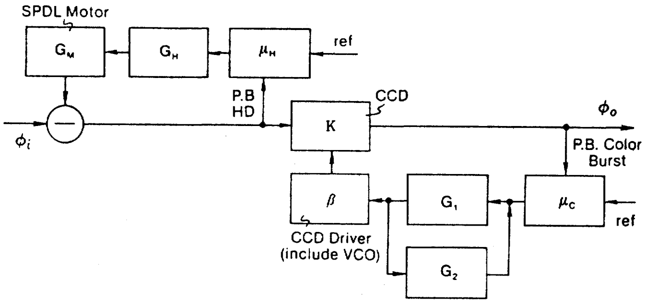
(b) Set of f min., f max.

The minimum CCD drive frequency f min. is set at least more than twice the signal transfer bandwidth (4.2MHz) eliminating the beat signal of the CCD drive frequency and allowing the transfer of a video signal in the CCD. The maximum CCD drive frequency is determined using the number of stages of the CCD N, required variable delay time Δt_{pp} and f min. Example values of this application are where N=910, f min.=10MHz and $\Delta t=30\mu_{Spp}$, so that the f max. is 15MHz [as in expression (5).]

The required characteristics of the CCD for the TBC should be able to transfer the required video signal without any change in the range of ten to fifteen MHz of the CCD drive frequency.

(d) A countermeasure for the phase delay of the control signal:

The phase delay of the control signal from the average delay time τ_0 on the TBC using the CCD is unique to this circuit [shown in expression (7).] The countermeasure is examined and an example blockdiagram of the



$$= \frac{1}{1+\mu_H G_H G_M} \cdot \frac{1}{1+\mu_C G_1 \beta K} \qquad \text{at: normal}$$

$$= \frac{1}{1+\mu_H G_H G_M} \cdot \frac{1}{1+\mu_C G_1 \beta K \cdot \dfrac{1}{(1-G_1G_2)}} \qquad \text{at: noise or transient time.}$$

where: μ_C, μ_H, G_H, G_M : same as fig. 3.
K : sensitivity of CCD
β : sensitivity of CCD Driver
G_1, G_2; Transfer function of the phase compensate circuits.

Fig. 6 . Block diagram of TBC using CCD (feedback loop)

This phase delay, θd, of the CCD is added to the phase delay caused by the line frequency (15.734 kHz) sample and hold circuit. In this case the larger phase delay makes very difficult the construction of the TBC loop (as in fig. 2: required loop gain $\geq$ 60dB at 30Hz and 0dB at 1kHz more.)

One solution, which we developed to alleviate this problem, is to use a conditionally stable feedback loop. An example of the frequency characteristics of such a loop is shown in fig. 7. When a transient signal or noise makes the loop unstable, a local phase lead circuit (G_2 loop in fig. 6) is activated to compensate the network and to stabilize the loop.

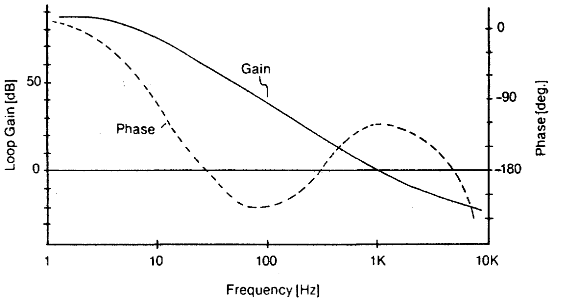


Fig. 7. The characteristics of the TBC using CCD

4. Conclusion:

4.1 The estimation of the required performance of the TBC and the design method of the TBC are studied systematically.

4.2 The related matter regarding the design of the TBC is also studied, such as:

(1) A simplified method by which to estimate the desired condition at the cross frequency between the spindly motor control loop and tangential actuator control loop.

(2) Problems encountered in the construction of the TBC using the CCD. For example, one countermeasure for the phase delay problem might be to use a conditionally stable feedback loop.

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