

PLAYBACK COLOR PROCESSING CIRCUIT

This invention relates to a playback color processing circuit for a video tape recorder, more particularly to a color processing circuit processing good vertical resolution and phase stability.

Video tape recorders are widely employed professionally and in the home for recording video signal on magnetic tape and playing them back. A video signal comprises a chrominance signal containing color information and a luminance signal containing brightness information. To enable a video tape recorder to handle the wide range of frequencies in a video signal, the chrominance signal, which has a carrier frequency of 3.58MHz, is down-shifted to a lower frequency when it is recorded on the tape and up-shifted to its original frequency when played back. These frequency conversions are performed in the color processing circuits of the video tape recorder.

The playback color processing circuit thus receives a down-shifted chrominance signal and generates a chrominance output signal which has been restored to its original frequency. The playback color processing circuit includes an automatic phase control loop that locks the chrominance output signal in phase with a reference signal. As part of this loop, the color processing circuit has filters that remove unwanted frequency components from the chrominance signal and cancel crosstalk arising from adjacent tracks on the tape. To cancel crosstalk, prior-art color processing circuits generally use a simple comb filter comprising a single 1H

delay line. (The symbol 1H denotes one horizontal cycle of the video signal; that is, the time from one horizontal sync pulse to the next).

A problem with the use of this simple type of comb filter is that it degrades the vertical resolution of the circuit. Specifically, when chrominance is present in one raster line but not the next, the comb filter generates a spurious output signal in the next line with half the amplitude of the preceding chrominance signal. On the screen, this causes the color to appear smeared down into the next line.

A proposed solution to this problem employs a comb filter comprising a pair of 1H delay lines and other components interconnected in such a way as not to generate spurious output. This comb filter solves the vertical color resolution problem. However, it introduces a new problem in that the double delay slows the response of the automatic phase control loop. This leads to phase instability, which causes irregularities in hue.

It is accordingly an object of the present invention to provide a playback color processing circuit for a video tape recorder that possesses both good phase stability and good vertical color resolution.

A playback color processing circuit according to this invention receives a down-shifted chrominance signal and a

playback luminance signal with a horizontal sync signal. The playback down-shifted chrominance signal is converted to a carrier chrominance output signal and locks the chrominance output signal in phase with a reference oscillator output signal with the aid of an automatic phase control loop. The circuit comprises:

- a sync signal separator receiving the playback luminance signal and separating the horizontal sync signal from the playback luminance signal;

- a frequency multiplier receiving the sync signal from the sync signal separator and generating a signal of a frequency equal to the carrier frequency of the playback down-shifted chrominance signal;

- a first frequency converter receiving the output of the frequency multiplier;

- a second frequency converter converting the input playback down-shifted chrominance signal to a carrier chrominance signal, using the output of the first frequency converter as a carrier signal;

- a band-pass filter receiving the carrier chrominance signal output from the second frequency converter and removing unwanted frequency components therefrom to generate a band-limited chrominance signal, said automatic phase control loop including said first and second frequency converters and said band pass filter;

- a first comb filter disposed in the automatic phase

control loop for receiving the band-limited chrominance signal output from the band-pass filter and removing crosstalk contained in the carrier chrominance signal to generate a crosstalk-free chrominance signal; and

a second comb filter disposed outside the automatic phase control loop for receiving the band-limited chrominance signal output from the band-pass filter and removing crosstalk contained in the carrier chrominance signal to generate the carrier chrominance output signal.

It is preferable that said first comb filter comprises a first delay line for receiving said band-limited chrominance signal from said band-pass filter and delaying it by one horizontal cycle, and that first combining means is provided for combining said band-limited chrominance signal with the output of said first delay line to generate the crosstalk-free chrominance signal. The circuit may further comprise a burst separator for receiving said crosstalk-free chrominance signal and amplifying the burst component thereof, thus generating a burst signal;

an oscillator for generating the reference signal;

a phase detector for receiving said burst signal and said reference signal, detecting their phase difference, and generating a voltage signal proportional to said phase difference; and a voltage-controlled oscillator for receiving said voltage signal and generating an output

signal the frequency of which is responsive to said voltage signal;

wherein said first frequency converter receives the signal output by said voltage-controlled oscillator and said horizontal sync signal from said frequency multiplier and mixes them to generate said carrier signal.

The second comb filter may comprise a second delay line for receiving said band-limited chrominance signal from said band-pass filter and delaying it by one horizontal cycle and the circuit may further comprise a third delay line for receiving the output of said second delay line and delaying it by one further horizontal cycle, and second combining means for combining said band-limited chrominance signal with the outputs of said second and third delay lines to generate said chrominance output signal.

The first combining means may comprise a subtractor for subtracting the output of said first delay line from said band-limited chrominance signal.

In another aspect of the invention, the second combining means may comprise

inverting means for receiving and inverting the output of said second delay line;

a first MAX circuit for receiving said band-limited chrominance signal and the output of said inverting means and selecting the higher of them as its output;

a second MAX circuit for receiving the output of said inverting means and the output of said third delay line and selecting the higher of them as its output;

a first MIN circuit for receiving band-limited chrominance signal and the output of said inverting means and selecting the lower of them as its output;

a second MIN circuit for receiving the output of said inverting means and the output of said third delay line and selecting the lower of them as its output;

a third MIN circuit for receiving the outputs of said first MAX circuit and said second MAX circuit and selecting the lower of them as its output;

a third MAX circuit for receiving the outputs of said first MIN circuit and said second circuit and selecting the higher of them as its output; and

an adder for receiving the outputs of said third MIN circuit and said third MAX circuit and adding them to generate said chrominance output signal.

The second combining means may alternatively comprise:

an adder for receiving said band-limited chrominance signal and the output of said third delay line and adding them, thus generating a sum signal;

an attenuator for attenuating said sum signal; and

a subtractor for receiving the output of said attenuator and the output of said second delay line and

subtracting the output of said attenuator from the output of said second delay line to generate said chrominance output signal.

The invention may be understood more readily and various other aspects and features of the invention may become apparent from consideration of the following description.

Fig. 1 is a block diagram of a color processing circuit according to this invention.

Fig. 2 describes the operation of the first comb filter

in Fig. 1.

Fig. 3 is a block diagram of a comb filter that can be used as the second comb filter in Fig. 1.

Fig. 4 describes the operation of the comb filter in Fig. 3.

Fig. 5 is a block diagram of another comb filter that can be used as the second comb filter in Fig. 1.

Fig. 6 describes the operation of the comb filter in Fig. 5.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Fig. 1 is a block diagram of a novel playback color processing circuit according to this invention, which receives a down-shifted chrominance signal and a horizontal sync signal and generates a chrominance output signal.

The down-shifted chrominance signal is received at an input terminal 1 and fed to a first frequency converter 2, which mixes it with a cw signal to be described later, thus generating a carrier chrominance signal. A luminance signal is received at an input terminal 3 and fed to a sync separator 4. The sync separator 4 extracts the horizontal sync signal from the luminance signal and feeds it to a multiplier 5, which multiplies it by 40 and supplies the result to a second frequency converter 6. The second frequency converter 6 also receives the output of a voltage-

controlled oscillator 7; by mixing this output with the horizontal sync signal received from the multiplier 5, the second frequency converter 6 generates the cw signal supplied to the first frequency converter 2 as described above.

The carrier chrominance signal output by the first frequency converter 2 is fed to a bandpass filter 8 which removes unwanted frequency components, thus generating a band-limited chrominance signal. The band-limited chrominance signal is supplied to a first 1H delay line 9 that delays it by one horizontal cycle, and to a subtractor 10. The subtractor 10 also receives the output of the first 1H delay line 9, which it subtracts from the band-limited chrominance signal to generate a crosstalk-free chrominance signal. Together, the first 1H delay line 9 and the subtractor 10 form a first comb filter 30.

The crosstalk-free chrominance signal produced by this first comb filter 30 is fed to a burst separator 11 which amplifies the burst component therein to generate a burst signal. This burst signal is applied to a phase detector 12, which also receives a reference signal output by an oscillator 13, detects the phase difference between the burst signal and the reference signal and generates a voltage signal, corresponding to the phase difference, which is applied to the voltage-controlled oscillator 7 and

controls the frequency of the oscillator output signal supplied to the second frequency converter 6.

The novel playback color processing circuit also comprises a second comb filter 14 which receives the band-limited chrominance signal from the bandpass filter 8 and filters it to remove crosstalk, thus generating a chrominance output signal. This chrominance output signal is supplied to the output terminal 15 as the output of the playback color processing circuit.

The first frequency converter 2, the second frequency converter 6, the voltage controlled oscillator 7, the bandpass filter 8, the first LH delay line 9, the subtractor 10, the burst separator 11, the phase detector 12, and the oscillator 13 are well-known devices, and the circuit comprising these devices forms a well-known automatic phase control means 40.

The operation of the novel playback color processing circuit can be briefly described as follows. The down-shifted chrominance signal received at the input terminal 1 has a frequency of substantially $40f_H$, where f_H denotes the horizontal sync frequency of the video signal, and contains the color information from the track currently being scanned on the tape as well as a certain amount of crosstalk from adjacent tracks. The output of the voltage-controlled oscillator 7 has a frequency of substantially 3.58MHz. The

second frequency converter 6 mixes this 3.58MHz signal with a $40f_H$ signal received from the multiplier 5 to generate a cw signal having a frequency component of $3.58\text{MHz} + 40f_H$. The first frequency converter 2 mixes this cw signal with the down-shifted chrominance signal received from the input terminal 1 to generate a carrier chrominance signal having a carrier frequency of substantially 3.58MHz. Other, unwanted frequencies are rejected by the bandpass filter 8, which thus creates a band-limited chrominance signal. This band-limited chrominance signal is provided as feedback through the burst separator 11 and phase detector 12 to the voltage-controlled oscillator 7, to hold the output frequency of the voltage-controlled oscillator 7 at 3.58MHz and lock the phase of the burst signal in phase with the reference signal. For correct operation of this automatic phase control loop it is necessary to cancel adjacent-track crosstalk in the signal; this is the function of the comb filter 30. The band-limited chrominance signal is also fed to the output terminal 15 of the playback color processing circuit through the second comb filter 14. Adjacent-track crosstalk must also be canceled in this output signal; this is the function of the second comb filter 14.

Since quick response is required in the automatic phase control loop, the first comb filter 30 has a simple structure, comprising the first 1H delay line 9 and

subtractor 10, which can be represented mathematically by the transfer function $1 - e^{-j2\pi fH}$ (where f denotes frequency and H is one horizontal cycle) and which has a short group delay time of $H/2$. Fig. 2 illustrates the operation of the comb filter 30 for the case in which a chrominance signal (a) with amplitude A is present in raster line n , but no chrominance (b) is present in raster line $n + 1$. A spurious chrominance signal (c) with amplitude $A/2$ is generated as the output signal for raster line $n + 1$. It is this spurious signal that degrades vertical resolution in prior-art color processing circuits in which the output of the first comb filter 30 is also the chrominance output signal of the color processing circuit. The spurious signal does not, however, impair the performance of the automatic phase control feedback loop.

In the chrominance output signal, response speed is not such a critical factor but it is important to avoid spurious output like that illustrated in Fig. 2. To meet this requirement, the second comb filter 14 in Fig. 1 comprises a pair of $1H$ delay lines, which results in a longer group delay but provides means of eliminating most or all of the spurious output, thus generating a chrominance output signal with good vertical resolution. Two examples of possible designs for the second comb filter 14 will be described next.

Fig. 3 illustrates one possible configuration of the comb filter 14, comprising a second 1H delay line 16, a third 1H delay line 17, a first inverter 18, a second inverter 19, first, second, and third MAX circuits 20, 21, and 22 which are operational circuits that select the higher of two input signals, first, second, and third MIN circuits 23, 24, and 25 which are operational circuits that select the lower of two input signals, and an adder 26.

The band-limited chrominance signal from the bandpass filter 8 in Fig. 1 is supplied to the second 1H delay line 16, the first MAX circuit 20, and the first MIN circuit 23. The output of the second 1H delay line 16 is supplied to the third 1H delay line 17 and the inverters 18 and 19. The output of the third 1H delay line 17 is supplied to the second MAX circuit 21 and the second MIN circuit 24. The output of the first inverter 18 is supplied to the first and second MAX circuits 20 and 21. The outputs of the first and second MAX circuits 20 and 21 are supplied to the third MIN circuit 25. The output of the second inverter 19 is supplied to the first and second MIN circuits 23 and 24. The outputs of the first and second MIN circuits 23 and 24 are supplied to the third MAX circuit 22. The adder 26 adds the outputs of the third MAX circuit 22 and the third MIN circuit 25 to produce the output signal of the comb filter 14.

Fig. 4 illustrates the operation of the circuit in Fig. 3 when chrominance is present in the input signal A for raster line n but not in the input signals B and C for raster lines $n + 1$ and $n + 2$. At time $n + 2$ the output G of the second MAX circuit 21 is the higher of two signals: the input A at time n and the inversion B' of the input B at time $n + 1$. The output I of the first MAX circuit 20 is the higher of two signals: the input C at time $n + 2$ and the inversion B' of the input B at time $n + 1$. The output K of the second MIN circuit 24 is the lower of two signals: the input A at time n and the inversion B' of the input B at time $n + 1$. The output L of the first MIN circuit 23 is the lower of two signals: the input C at time $n + 2$ and the inversion B' of the input B at time $n + 1$. The output J of the third MIN circuit 25 is the lower of G and I. The output M of the third MAX circuit 22 is the higher of K and L. The output O of the adder 26 is the sum of J and M. It is clear that the output O is free of spurious contamination from the chrominance in raster line n . This circuit accordingly does not degrade vertical resolution.

Fig. 5 shows another, simpler circuit that can be used as the comb filter 14 in Fig. 1. This circuit comprises an input terminal 31, a second 1H delay line 32, a third 1H delay line 33, an adder 34, a 6dB attenuator 35, and a

subtractor 36. The band-limited chrominance signal received at the input terminal 31 is supplied to the second 1H delay line 32 and the adder 34. The output signal of the second 1H delay line 32 is supplied to the third 1H delay line 33 and the subtractor 36. The adder 34 adds the output of the third 1H delay line 33 to the original band-limited chrominance signal. The output of the adder 34 is attenuated by the attenuator 35 and supplied to the subtractor 36, which subtracts it from the output of the second 1H delay line 33 to generate the final output of the comb filter 14.

Fig. 6 illustrates the operation of the circuit in Fig. 5 for the case in which chrominance is present in raster line n but not in the next two raster lines. The chrominance signal in line n is added to the signal in line $n + 2$, but then attenuated by 6dB before being subtracted from the signal in line $n + 1$. As a result, a spurious signal is generated that causes some degradation of the vertical resolution, but the degradation is relatively small. If the input chrominance amplitude is A , the spurious output chrominance amplitude is only $A/4$. If this level of degradation of vertical resolution is acceptable, the circuit in Fig. 5 offers the advantage of simplicity over the circuit in Fig. 3.

By providing both a first comb filter with a short

delay time for automatic phase control and a second comb filter with a longer delay time but better spurious output characteristics for canceling crosstalk in the output chrominance signal, this invention is able to solve the problem of degradation of vertical resolution without impairing the stability of automatic phase control, thus markedly improving the quality of the chrominance signal.

The scope of this invention is not limited to the circuits shown in the drawings, but covers various modifications which will be obvious to one skilled in the art. For example, the circuits described above are suitable for magnetic recording and playback apparatus employing the NTSC system, but they can easily be adapted to the CCIR system by alteration of the delay of the comb filter 14.

CLAIMS:-

1. A playback color signal processing circuit including an automatic phase control loop, said circuit receiving a playback video signal including a playback down-shifted chrominance signal and a playback luminance signal with a horizontal sync signal, and converting the playback down-shifted chrominance signal to a carrier chrominance output signal and locking the chrominance output signal in phase with a reference oscillator output signal with the phase control loop, said circuit comprising:

a sync signal separator receiving the playback luminance signal and separating the horizontal sync signal from the playback luminance signal;

a frequency multiplier receiving the sync signal from the sync signal separator and generating a signal of a frequency equal to the carrier frequency of the playback down-shifted chrominance signal;

a first frequency converter receiving the output of the frequency multiplier;

a second frequency converter converting the input playback down-shifted chrominance signal to a carrier chrominance signal, using the output of the first frequency converter as a carrier signal;

a band-pass filter receiving the carrier chrominance



signal output from the second frequency converter and removing unwanted frequency components therefrom to generate a band-limited chrominance signal, said automatic phase control loop including said first and second frequency convertors and said band pass filter;

a first comb filter disposed in the automatic phase control loop for receiving the band-limited chrominance signal output from the band-pass filter and removing crosstalk contained in the carrier chrominance signal to generate a crosstalk-free chrominance signal and

a second comb filter disposed outside the automatic phase control loop for receiving the band-limited chrominance signal output from the band-pass filter and removing crosstalk contained in the carrier chrominance signal to generate the carrier chrominance output signal.

2. A color processing circuit according to claim 1 wherein said first comb filter comprises a first delay line for receiving said band-limited chrominance signal from said band-pass filter and delaying it by one horizontal cycle, and first combining means for combining said band-limited chrominance signal with the output of said first delay line to generate the crosstalk-free chrominance signal; and there is further provided

a burst separator for receiving said crosstalk-free chrominance signal and amplifying the burst component thereof, thus generating a burst signal;

an oscillator for generating the reference signal;



a phase detector for receiving said burst signal and said reference signal, detecting their phase difference, and generating a voltage signal proportional to said phase difference and

a voltage-controlled oscillator for receiving said voltage signal and generating an output signal the frequency of which is responsive to said voltage signal;

wherein said first frequency converter receives the signal output by said voltage-controlled oscillator and said horizontal sync signal from said frequency multiplier and mixes them to generate said carrier signal.

3. A color processing circuit according to claim 2 wherein said second comb filter comprises a second delay line for receiving said band-limited chrominance signal from said band-pass filter and delaying it by one horizontal cycle, a third delay line for receiving the output of said second delay line and delaying it by one further horizontal cycle, and second combining means for combining said band-limited chrominance signal with the outputs of said second and third delay lines to generate said chrominance output signal.

4. A color processing circuit according to claim 2 or 3 wherein said first combining means comprises a subtractor for subtracting the output of said first delay line from said band-limited chrominance signal.

5. A color processing circuit according to claim 3

wherein said second combining means comprises:

inverting means for receiving and inverting the output of said second delay line;

a first MAX circuit for receiving said band-limited chrominance signal and the output of said inverting means and selecting the higher of them as its output;

a second MAX circuit for receiving the output of said inverting means and the output of said third delay line and selecting the higher of them as its output;

a first MIN circuit for receiving said band-limited chrominance signal and the output of said inverting means and selecting the lower of them as its output;

a second MIN circuit for receiving the output of said inverting means and the output of said third delay line and selecting the lower of them as its output;

a third MIN circuit for receiving the outputs of said first MAX circuit and said second MAX circuit and selecting the lower of them as its output;

a third MAX circuit for receiving the outputs of said first MIN circuit and said second MIN circuit and selecting the higher of them as its output; and

an adder for receiving the outputs of said third MIN circuit and said third MAX circuit and adding them to generate said chrominance output signal.

6. A color processing circuit according to claim 3 wherein said second combining means comprises:

an adder for receiving said band-limited chrominance



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signal and the output of said third delay line and adding them, thus generating a sum signal;

an attenuator for attenuating said sum signal; and

a subtractor for receiving the output of said attenuator and the output of said second delay line and subtracting the output of said attenuator from the output of said second delay line to generate said chrominance output signal.

7. A color processing circuit according to claim 6 wherein said attenuator has an attenuation factor of about 6dB.

8. A color processing circuit substantially as described with reference to, and as illustrated in, any one or more of Figures 1, 3 or 5 of the accompanying drawings or any one of Figures 1, 3 or 5 in conjunction with Figure 2, Figure 5 or Figure 6 of the accompanying drawings respectively.
