

1 VERTICAL DETAIL ENHANCER FOR A VIDEO DISPLAY SYSTEM

 The present invention relates to vertical detail enhancement in a video signal processor the processed signal from which can be used to produce a progressively scanned image display.

 It has been found desirable in video signal processors to modify the video signal in order to enhance the appearance of vertical transitions of the luminance component in a reproduced image. This is particularly true in color television video signal processors which use a comb filter to separate the luminance and chrominance components from the composite video signal. For example, a line delay comb filter adds signals representing two adjacent lines (in essence, taking their average) to generate a comb filtered luminance signal. This averaging reduces the vertical resolution.

 The above is also true when a progressively scanned image is reproduced. In such a case, signals representing interstitial lines are produced from the signals representing interlaced lines received by the video signal processor. One method of producing a signal representing an interstitial line to be displayed between two interlaced lines is to use, as the interstitial line signal, the average of the signals representing the two adjacent lines between which the interstitial line is to be displayed (called a line progressive scan system). In a video signal processing system including a comb filter, the signal representing the interstitial line may be the comb filtered luminance signal representing the current image line.

 One standard enhancement for vertical transitions is to artificially make the transition seem larger. For example, an undershoot and overshoot are generated for a leading edge transition; and an undershoot and backswing are generated for a trailing edge transition. In other words, just before a dark-to-light transition, the reproduced image is made darker, and just after the transition, the reproduced image is made brighter. In a progressively scanned video signal

1 processor, this enhancement is applied to both the
received signals representing interlaced lines and the
produced signals representing interstitial lines.

It is known that if a vertical detail
5 enhancement signal, generated in response to the received
signal representing interlaced lines, is added to the
received signal representing interlaced lines and is
subtracted from the produced signal representing
10 interstitial lines, then vertical transitions in the
progressively scanned image are enhanced. An example of
such a system is described in U.S. Patent No. 4558347
entitled "Progressive Scan Television System Employing
Vertical Detail Enhancement" issued December 10, 1985 to
D.H. Pritchard et al.

15 In the above-mentioned U.S. Patent, it was noted
that such arrangement may effect some residual flickering
where transitions occur. It was concluded, however, that
the overall effect is subjectively pleasing.

It has now been determined determined that the
20 residual flickering resulting from the arrangement of the
above-mentioned U.S. Patent is particularly objectionable
under certain circumstances. For example, displayed
letters or other figures having well defined horizontal
lines, tend to have a flicker at the upper and lower edge
25 which make those edges fuzzy. With the increasing use of
video signal displays as output devices for computers, and
development of over-the-air information systems, it
becomes desirable to reduce the flickering without unduly
degrading the vertical detail enhancement. It is
30 especially desirable to reduce the flicker within the
memory constraints of a line progressive scan system.

In accordance with the present invention in a
vertical detail enhancer receptive of luminance signals,
interstitial luminance signals are produced in response to
35 the luminance signals. Transitions in the luminance and
interstitial luminance signals are modified by having only
overshoot for transitions of a given sense, and by having
only undershoot for transitions opposite the given sense
to produce vertical detail _____

1 enhanced luminance and interstitial luminance signals.
Further means sequences the vertical detail enhanced
luminance and interstitial luminance signals to produce a
signal representing a progressively scanned image.

5 In the drawings:

FIGURE 1 is a block diagram of a video signal
processor embodying a vertical detail enhancer;

FIGURE 2 is a block diagram of a prior art
vertical detail enhancer which may be used in the video
10 signal processor of FIGURE 1;

FIGURE 3(a) through (j) are waveform diagrams
useful in understanding the operation of the apparatus
illustrated in FIGURES 1 and 2;

FIGURE 4(a) through (c) are waveform diagrams
15 illustrating the source of flickering in the vertical
detail enhancer of FIGURES 1 and 2;

FIGURE 5 is a block diagram of a vertical detail
enhancer embodying the present invention;

FIGURE 6(a) through (c) are waveform diagrams
20 illustrating the reduction in flickering of the vertical
detail enhancer of FIGURE 5;

FIGURE 7 is a block diagram of a vertical detail
enhancer also embodying the present invention; and

FIGURE 8(a) through (c) are waveform diagrams
25 illustrating the reduction in flickering of the vertical
detail enhancer of FIGURE 7.

FIGURE 1 illustrates a vertical detail enhancer
which operates in a similar manner to that described in
the above-mentioned U.S. Patent No. 4558347. In FIGURE 1,
30 an interlaced video signal from, for example, the front
end of a standard color television receiver (not shown) is
supplied to a comb filter 5. Comb filter 5 produces a
comb filtered luminance Y and a comb filtered chrominance
C signal. The comb filtered luminance signal Y is
35 supplied to an interstitial line producer 15 and one input
of an adder 14. The output of adder 14 is supplied to one
input of a signal combiner 25. The output of signal
combiner 25, representing the vertical detail enhanced
interlaced signal, is supplied to one input of luminance

1 processing and speed up circuit 30. The output of
interstitial line producer 15 is coupled to one input of a
subtractor 12. The output of subtractor 12 is supplied to
one input of a signal combiner 20. The output of signal
5 combiner 20, representing the vertical detail enhanced
interstitial signal, is supplied to another input of
luminance processing and speed up circuit 30.

The comb filtered chrominance signal C is
supplied to vertical detail extractor circuit 7 and both
10 inputs of chrominance processing and speed up circuit 35.
The output of vertical detail extractor 7 is supplied to
other inputs of adder 14 and subtractor 12 respectively,
and to a non-linear function circuit 55. The outputs of
non-linear function circuit 55 are coupled to other inputs
15 of signal combiners 20 and 25 respectively. Chrominance
and luminance processing and speed up circuits 35 and 30
respectively process, and properly sequence, the signals
at their respective inputs to create a signal representing
a progressively scanned image. They could for example,
20 supply such signals to an image display device (not shown)
which could display a progressively scanned image. The
operation of FIGURE 1 will be explained below.

In FIGURE 2, vertical detail information from
vertical detail extractor 7 of FIGURE 1 is supplied to
25 non-linear function circuit 55. Non-linear function
circuit 55 generates a vertical detail enhancement signal.
One appropriate non-linear function is to core low
amplitude signals, to peak medium amplitude signals and to
pare high amplitude signals. An example of such a
30 function is described in U.S. Patent 4,245,237 entitled
"Controllable Non-Linear Processing of Video Signals"
issued January 13, 1981 to W. A. Lagoni.

The vertical detail enhancement signal from
non-linear function circuit 55 is supplied to one input of
35 adder 40 and subtractor 45 respectively. The vertical-
detail-restored interlaced comb filtered luminance signal
 Y_{11} from adder 14 is supplied to another input of adder
40. The output of adder 40 is the vertical detail
enhanced interlaced luminance signal. The vertical-detail

1 restored interstitial comb filtered luminance signal Y_{is}
from subtractor 12 is supplied to another input of
subtractor 45. The output of subtractor 45 is the
vertical detail enhanced interstitial comb filtered
5 luminance signal. These two vertical detail enhanced comb
filtered luminance signals are supplied to luminance
processing and speed up circuit 30 of FIGURE 1.

The operation of the prior art vertical detail
enhancer illustrated in FIGURES 1 and 2 can be better
10 understood by reference to the waveform diagrams
illustrated in FIGURE 3. Waveform (a) is a representation
of the brightness information of a scene along a line
running from the top to the bottom of the reproduced
image. The scene is dark gray at the top, a light gray in
15 the middle and dark gray at the bottom. Waveform (b) is
the signal level of the odd field interlaced luminance
signal for the odd lines representing the scene which was
transmitted and represents the signal at the input of comb
filter 5 of FIGURE 1.

20 Waveform (c) is the luminance output of the comb
filter 5 of FIGURE 1. The comb filter output for a given
line is the average (i.e. one-half of the sum) of the
current and preceding transmitted line. Waveform (d) is
the vertical detail output from vertical detail extractor
25 7 of FIGURE 1. It is one-half of the difference between
the current and the preceding line. Waveform (e) is a
vertical-detail-restored interlaced luminance signal Y_{il}
and is the signal at the output of adder 14. It is the
sum of the comb filtered luminance waveform (c) and
30 vertical detail waveform (d) signals. As restored, this
restored luminance signal closely matches the transmitted
luminance signal illustrated in waveform (b).

Waveform (f) is the interstitial luminance
signal produced by interstitial line producer 15 of FIGURE
35 1. These lines are the average of the current and
preceding interlace line and are timed to be displayed in
the interstices between the two averaged lines (i.e. in
the even numbered lines). Waveform (g) is the
interstitial luminance signal restored by subtracting the

vertical detail signal illustrated in waveform (d) from the produced interstitial lines and is the output Y_{1s} of subtractor 12 of FIGURE 1. The two restored signals closely represent the brightness of the scene transmitted.

5 As discussed above, however, it is desirable to enhance vertical transitions.

The vertical detail enhancer illustrated in FIGURE 2 operates as follows to enhance the transitions. Assume for this description that non-linear function circuit 55 in this case operates to pass this particular vertical detail signal without change. Waveform (h) is the sum of the restored interlaced luminance signal of waveform (e) and the vertical detail signal of waveform (d) and is the output of adder 40 of FIGURE 2. This results in a higher luminance signal for line number 5 (leading edge overshoot), and a lower luminance signal for line number 11 (trailing edge back-swing, or overshoot). Waveform (i) is the restored interstitial luminance signal of waveform (f) minus the vertical detail signal of waveform (d) and is the output of subtractor 45 of FIGURE 2. This results in a lower luminance signal for line 4 (leading edge undershoot) and a higher luminance signal for line 10 (trailing edge undershoot). Waveform (j) is the enhanced progressive scan signal for the odd field representing the scene brightness of waveform (a). A similar enhanced progressive scan signal for the even field may also be generated.

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FIGURE 4 illustrates the source of flickering inherent in the vertical detail enhancer of FIGURE 2. Waveform (a) is the enhanced progressive scan signal for the odd field and is the same as FIGURE 3 waveform (j). Waveform (b) is the enhanced progressive scan signal for the even field, which is generated in the same manner as is that for the odd field. It is displaced by one display line, however. Waveform (c) shows the superposition of the even field enhanced progressive scan signal (solid line) on the odd field enhanced progressive scan signal (dashed line).

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On lines 5 and 11, it is seen that the signal alternates between a bright signal on one field and a dim signal on the next. Thus, the top and bottom lines of the

light gray portion of the displayed image flicker between bright and dim at the field repetition rate, making the top and bottom appear fuzzy and objectionable.

FIGURE 5 is an embodiment of a vertical detail enhancer which reduces this objectionable flicker according to the present invention. Elements similar to those in FIGURES 1 and 2 have the same reference numbers and operate in the same manner. They will not be discussed in detail below. In FIGURE 5, the output of non-linear function circuit 55, which is the vertical detail enhancement signal, is supplied to an absolute value circuit 60. The output of absolute value circuit 60 is supplied to one input of adders 40 and 62 respectively. The vertical-detail-restored interlaced signal Y_{il} from adder 14 is supplied to another input of adder 40. The vertical-detail-restored interstitial signal Y_{is} from subtractor 12 is supplied to another input of adder 62. The respective outputs of adders 40 and 62 are supplied to the luminance processing and speed up circuit 30.

In operation, the vertical detail enhancer illustrated in FIGURE 5 combines the signals whose waveforms are illustrated in FIGURE 3 in a different manner than that of the FIGURE 2 embodiment. The absolute value of the vertical detail signal of waveform (d) is added to the restored interlaced luminance signal Y_{il} of waveform (e) to form an enhanced interlaced luminance signal. This signal is illustrated as the solid vertical lines in FIGURE 6 waveforms (a) and (b).

Referring again to FIGURE 3, the absolute value of the vertical detail signal of waveform (d) is added to the vertical-detail-restored interstitial luminance signal Y_{is} of waveform (g) to form an enhanced interstitial luminance signal. This signal is illustrated as dashed vertical lines in FIGURE 6 waveforms (a) and (b).

The undershoot provided by the prior art vertical detail enhancement circuit of FIGURES 1 and 2 has been attenuated in line 4 of waveform (a) and line 5 of waveform (b) of FIGURE 6. Also, the backswing (trailing edge overshoot) has been attenuated in line 11 of waveform (a) and line 12 of

1 waveform (b). FIGURE 6 waveform (c) shows, by its solid
and dashed lines respectively, the superposition of
waveform (a) and (b) representing the odd-field and
even-field vertical-detail-enhanced luminance signals.
5 The flicker at lines 5 and 11 is much reduced compared to
that shown in FIGURE 4 waveform (c). On the other hand,
the transitions from dark to light and from light to dark
require two lines for the FIGURE 5 embodiment, compared to
one line for the prior art FIGURE 2 circuit.

10 FIGURE 7 is another embodiment of a vertical
detail enhancer which reduces the objectionable flicker
according to the present invention. Elements similar to
those in FIGURES 1 and 2 have the same reference numbers
and operate in the same manner. They will not be
15 discussed in detail below. In FIGURE 7, the output of the
non-linear function circuit 55 is supplied to one input of
adder 40 and subtractor 45 respectively. The restored
interlaced luminance signal Y_{11} from adder 14 is supplied
to another input of adder 40. The restored interstitial
20 luminance signal Y_{is} from subtractor 12 is supplied to
another input of subtractor 45.

The output of adder 40 is supplied to one input
of a maximizing non-additive mixer 65. The restored
interlaced luminance signal Y_{11} from adder 14 is supplied
25 to the other input of maximizing non-additive mixer 65.
Maximizing non-additive mixer 65 operates to pass the
larger of its input signals. The output of subtractor 45
is supplied to one input of a maximizing non-additive
mixer 70. The restored interstitial luminance signal Y_{is}
30 from subtractor 12 is supplied to another input of
maximizing non-additive mixer 70. The outputs of
maximizing non-additive mixers 65 and 70 are supplied to
the luminance processing and speed up circuit 30.

In operation, maximizing non-additive mixer 65
35 passes the larger of the restored interlaced luminance
signal of FIGURE 3 waveform (e) or the enhanced interlaced
signal of waveform (h). This is illustrated as the solid
vertical lines in FIGURE 8 waveforms (a) and (b).
Maximizing non-additive mixer 70 passes the larger of the

1 restored interstitial luminance signal of FIGURE 3
2 waveform (g) or the enhanced interstitial luminance signal
3 of waveform (i). This is illustrated as the dashed
4 vertical lines of FIGURE 8 waveforms (a) and (b). FIGURE
5 8 waveform (c) shows the superposition of waveform (a) and
6 (b), representing the odd-field and even-field vertical
7 detail enhanced signal, respectively. The undershoot is
8 attenuated in line 4 of waveform (a) and line 5 of
9 waveform (b) relative to the prior art vertical detail
10 enhancement circuit of FIGURES 1 and 2. In addition, the
11 backswing in line 11 of waveform (a) and in line 12 of
12 waveform (b) is attenuated.

13 The flicker at lines 5 and 11 is greater than
14 that of the embodiment illustrated in FIGURE 5 but is
15 still less than that produced by the prior art vertical
16 detail enhancer of FIGURE 2. The transitions from dark to
17 light and from light to dark require only one line for the
18 FIGURE 7 embodiment -- the same as the prior art vertical
19 detail enhancer.

20 For both the FIGURE 5 and FIGURE 7 embodiments,
21 the flicker is reduced from the prior art levels. Thus,
22 letters etc. are displayed with sharper top and bottom
23 edges. In addition, these embodiments required no more
24 memory than that required to implement a line progressive
25 scan system.

26 The above embodiments of the invention have been
27 described in conjunction with a video processing system
28 which uses a line delay comb filter to separate the
29 luminance and chrominance components from the composite
30 signal. However, a vertical detail enhancer according to
31 the present invention will properly operate on luminance
32 components separated by any means. In addition, such a
33 vertical detail enhancer will properly operate in NTSC,
34 PAL or SECAM television video signal processors.

35 The present invention may be implemented in
36 either continuous analog or sampled data form. In sampled
37 data form, the embodiment may be implemented in analog or
38 digital form.



CLAIMS:

1. A vertical detail enhancer for a progressively scanned image display, said enhancer being receptive of luminance signals and comprising:
 - 5 a producer of interstitial luminance signals derived from said luminance signals;
means for modifying transitions of said luminance and interstitial luminance signals to produce vertical-detail-enhanced luminance and interstitial
 - 10 luminance signals having only overshoot for transitions of a given sense and having only undershoot for transitions of the opposite of said given sense; and
means for sequencing said vertical-detail-enhanced luminance and interstitial luminance signals to
 - 15 create an output signal representing a progressively scanned image.
2. A vertical detail enhancer as in Claim 1, wherein said modifying means comprises:
 - 20 means for generating a vertical detail enhancement signal; and
means for combining said vertical-detail-enhancement signal with said luminance and said
 - 25 interstitial luminance signals respectively.
3. A vertical detail enhancer as in Claim 2, receptive of composite luminance and chrominance signals and wherein said vertical-detail-enhancement signal generating means comprises:
 - 30 a source of line-delay comb-filtered chrominance signals;
a vertical detail extractor responsive to said comb filtered chrominance signals for extracting a
 - 35 vertical detail signal; and
means for producing the absolute value of said vertical detail signal as said vertical-detail-enhancement signal.



1 4. A vertical detail enhancer as in Claim 3,
wherein said vertical detail enhancement signal generating
means further comprises:

5 a non-linear function circuit coupled between
said vertical detail extractor and said absolute value
producing means.

10 5. A vertical detail enhancer as in Claim 2, 3
or 4 wherein said combining means comprises:

 means for adding said vertical detail
enhancement signal to said luminance signals and said
interstitial luminance signal to produce said
vertical-detail-enhanced luminance and interstitial
15 luminance signals respectively.

 6. A vertical detail enhancer as in Claim 2,
wherein said combining means comprises:

20 means for adding said vertical-detail-
enhancement signal to said luminance signals;

 means for subtracting said vertical-detail-
enhancement signal from said interstitial luminance
signals;

25 first maximizing non-additive mixer means for
passing the larger of said luminance signals and the
output of said adding means as said vertical-
detail-enhanced luminance signals; and

 second maximizing non-additive mixer means for
30 passing the larger of said interstitial luminance signal
and the output of said subtracting means as said vertical
detail-enhanced interstitial luminance signals.

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7. A vertical detail enhancer as in Claim 6, receptive of composite chrominance and luminance signals and wherein said vertical-detail-enhancement signal generating means comprises:

- 5 a source of line delay comb filtered chrominance signals and;
 a vertical detail extractor responsive to said comb-filtered chrominance signals for extracting a vertical detail signal.

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8. A vertical detail enhancer as in Claim 7, wherein said vertical-detail-enhancement generating means further comprises:

- a non-linear function circuit responsive to said
15 vertical detail signal for producing said vertical-detail-enhancement signal.

9. A vertical detail enhancer as in any preceding claim including also means for restoring vertical detail
20 to said luminance and interstitial luminance signals prior to the vertical-detail-enhancement thereof.

10. A vertical detail enhancer for a progressively scanned image display, said enhancer being
25 receptive of interlaced composite video signals and comprising:

- a line delay comb filter producing interlaced comb filtered luminance and chrominance signals;
 a producer of interstitial luminance signals
30 responsive to said interlaced luminance signals;
 a vertical detail extractor responsive to said comb filtered chrominance signal for producing a vertical detail signal;
 a first adder for adding said vertical detail
35 signal to said interlaced luminance signal to



produce a vertical-detail-restored interlaced luminance signal;

5 a subtractor for subtracting said vertical detail signal from said interstitial luminance signal to produce a vertical-detail-restored interstitial luminance signal;

a non-linear function circuit responsive to said vertical detail signal;

10 an absolute value circuit responsive to the output from said non-linear function circuit for producing a vertical-detail-enhancement signal;

a second adder for adding said vertical-detail-enhancement signal to said vertical-detail-restored interlaced luminance signal to produce a vertical-detail-enhanced interlaced luminance signal;

15 a third adder for adding said vertical-detail-enhancement signal to said vertical-detail-restored interstitial luminance signal to produce a vertical-detail-enhanced interstitial luminance signal;

20 a luminance signal processor for sequencing said vertical-detail-enhanced interlaced and interstitial luminance signals to produce a luminance signal representing a luminance component of a progressively scanned image; and

25 a chrominance signal processor for sequencing said comb filtered chrominance signal to produce a chrominance signal representing a chrominance component of a progressively scanned image.

11. A vertical detail enhancer for a progressively scanned image display, said enhancer being
30 receptive of interlaced composite video signals comprising:

a line-delay comb filter producing interlaced comb filtered luminance and chrominance signals;

35 a producer of interstitial luminance signals responsive to said interlaced luminance signals;



1 a vertical detail extractor responsive to said
comb filtered chrominance signal for producing a vertical
detail signal;

5 a first adder for adding said vertical detail
signal to said interlaced luminance signal to produce a
vertical-detail-restored interlaced luminance signal;

10 a first subtractor for subtracting said vertical
detail signal from said interstitial luminance signal to
produce a vertical-detail-restored interstitial luminance
signal;

 a non-linear function circuit responsive to said
vertical detail signal for producing a vertical detail
enhancement signal;

15 a second adder for adding said vertical-detail-
enhancement signal to said vertical detail restored
interlaced luminance signal;

 a second subtractor for subtracting said
vertical detail enhancement signal from said vertical-
detail-restored interstitial luminance signal;

20 a first maximizing non-additive mixer for
passing the larger of said vertical-detail-restored
interlaced luminance signal and the output of said second
adder to produce a vertical detail enhanced interlaced
luminance signal;

25 a second maximizing non-additive mixer for
passing the larger of said vertical-detail-restored
interstitial luminance signal and the output of said
second subtractor to produce a vertical-detail- enhanced
interstitial luminance signal;

30 a luminance signal processor for sequencing said
vertical-detail-enhanced interlaced and interstitial
luminance signals to produce a luminance signal
representing a progressively scanned image; and

35 a chrominance signal processor for sequencing
said comb filtered chrominance signal to produce a
chrominance signal representing a progressively scanned
image.



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12. A vertical detail enhancer substantially in accordance with any of the alternatives hereinbefore described with reference to Figures 5-8 of the accompanying drawings.
