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VIDEO SIGNAL PROCESSING

The present invention concerns video signal processing.

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FIGURE 1 shows the gamma of various aspects of a video signal transmission system, with curve 1a representing the transfer characteristic of the transmission side, curve 1b representing the transfer characteristic of the picture tube (CRT), and curve 1c representing the overall transfer characteristic.

The transmitted video signals of the NTSC, PAL and SECAM television (TV) standards have a gamma of 0.45 to 0.5 while the picture tube of color television (CTV) receivers have a gamma of 2.8 to 3.1. As a result, the overall transfer curve (light in to the camera - light out from the picture tube) is not linear and the overall gamma is in practice about 1.35 instead of a unity gamma. This implies that the exponential transfer characteristic of the picture tube is not fully compensated, leading to compression of the dark picture portions of the display. Such compression causes picture details near black to be lost, and colored areas to fade to black. Concurrently, whites are excessively amplified with respect to the dark portions to the point of often reaching picture tube saturation and blooming. A linear overall transfer characteristic avoids this black compression and can be obtained by an additional gamma correction of 0.8 in each of the red, green, and blue (R, G, and B) amplifiers in the television receiver. However, picture tubes have a relatively small dynamic range of light output which cannot be enlarged without reaching picture tube saturation causing blooming. Therefore, gamma correction to increase amplification of dark image areas causes a signal compression of the high signal level whites. This is illustrated by Figure 2a showing a gamma corrected ramp signal. Peak white must be kept at the same level as in the uncorrected case, the dashed line to avoid picture tube blooming. As a consequence, the upper portion of the ramp signal has a reduced slope as shown in Figure 2b. The viewer perceives this as a lack of contrast in grey to white picture areas resulting in washed out pictures. In such an event, the improvement of contrast of low-brightness portions of the image is obtained at the expense of high-brightness contrast deterioration.

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According to an aspect of the invention, the perceived contrast of an image is improved by non-linear processing of the video signal. More specifically, a video signal is separated into a low level amplitude signal portion (near black) and a higher level amplitude signal portion (near white) for separate non-linear processing of each signal portion. The low-level amplitude signal portion is non-linearly processed and combined with the original linear signal. In accordance with a further aspect of the invention, the higher level amplitude signal portion is non-linearly processed and high-pass frequency filtered, and combined with the original linear signal. In accordance with an even further aspect of the invention, the non-linearly processed low level amplitude signal portion and the non-linearly processed and high pass filtered high level amplitude signal portion are combined with the original linear signal to produce a gamma corrected video signal with enhanced detail signal contrast in the grey to white picture areas.

The invention will be described by way of example with reference to the drawings in which:

FIGURE 1, previously described, shows transfer characteristics of a transmitter, a television receiver, and the overall television system including the transmitter and receiver.

FIGURE 2, previously described, shows a graphical representation of a ramp signal which has undergone gamma correction useful in understanding an advantage of the arrangement of Figures 3 and 4.

FIGURE 3 shows a block diagram representation of an exemplary arrangement according to an aspect of the present invention.

FIGURE 4 shows a more detailed block diagram representation of the arrangement of Figure 3 according to an aspect of the present invention.

FIGURES 5 and 6 show time and frequency domain waveforms, respectively, useful in understanding the operation of the arrangement of FIGURES 3 and 4.



FIGURE 7 shows a detailed schematic diagram of a circuit implementation of the arrangement of FIGURE 4 according to another aspect of the present invention.

5 FIGURE 8 shows a detailed schematic diagram of the preferred circuit implementation of the arrangement of FIGURE 4 according to still another aspect of the present invention.

In the figures, corresponding elements are identified by the same reference numbers.

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FIGURE 3 shows a block diagram representation of the subject arrangement coupled between a luminance-chrominance processor 10 and a video output amplifier 12 of a color television receiver. While similar arrangements are used in the green (G) and blue (B) channels, only the arrangement for the red (R) channel is shown. The R output signal of
15 processor 10 is shown by way of example to be linear ramp 14 with a superimposed detail signal 16 indicated by the short vertical lines. The detail signals 16 are video signals at frequencies higher than 0.5 MHz and correspond to picture details smaller than 1.2 cm in the horizontal
20 direction on a 28 inch screen size color television receiver.

The R signal is coupled to a non-linear or soft signal splitter 18 which "gradually" splits the signal into a low level portion (black to grey picture area) and a high level portion (grey to white picture areas). The high level signal portion is filtered by a high-pass filter 20 which can
25 include capacitor C. The low level signal is DC coupled to an adder 22. The high pass filtered portion of the high level signal is AC coupled to adder 22 through capacitor C. The original R signal, the low level signal portion and the high-pass filtered high level portion are combined by adder 22 to produce the output signal coupled to amplifier 12. The addition of the low
30 level portion (black to grey) to the R signal provides gamma correction. The further addition of the high-pass filtered portion results in contrast enhancement of the high level (grey to white) video detail signal.

FIGURE 4 shows the arrangement of FIGURE 3 in greater detail. The waveforms of FIGURES 5 and 6 help illustrate the operation of the
35 arrangement of FIGURE 4. Waveform 5a shows the input signal V_1 composed of a staircase 15 and a superimposed detail signal 16 at about 2MHz. Waveforms 5b and 5c show the "soft" signal splitting performed by



nonlinear signal splitter 18. Note that the differential amplitude of V_2 gradually decreases and that of V_3 gradually increases. The sum of V_2 and V_3 equals the input voltage V_1 . The frequency response of the signal splitting is flat as shown by the corresponding frequency response curves of FIGURES 5a'-c'. Video output amplifier 12 is driven by voltages V_1 and V_2 via respective resistors, R_1 and R_2 , where R_2 has a value equal to that of R_1 . The decreasing differential amplitude of V_2 represents a gradual variation of gain of video output amplifier 12 from 60 to 30 corresponding to a gamma of 0.8. This is illustrated in FIGURE 6a and a' showing the sum of V_1 and V_2 . The differential amplitude (contrast) decreases gradually toward higher signal levels. A high frequency detail signal V_4 is derived by passing V_3 through a high-pass filter 20. The output voltage and the frequency response of V_4 is illustrated by FIGURES 5d and 5d'. Voltage V_4 is coupled capacitively (through capacitor C_2) to video amplifier 12 for producing the signal $V_1 + V_4$ shown in FIGURE 6b and 6b'. A 6 dB boost of the detail signal is obtained by the relatively low value coupling resistor R_4 (value = $R_1/2$). Coupling capacitor C_2 prevents any brightness signal (DC component) from being added to the input of video amplifier 12. FIGURE 6c and 6c' illustrate the drive current i_5 which is similar to the inverted amplifier 12 output voltage. The low frequency staircase signal of FIGURE 6c is similar to that of FIGURE 6a but the detail signal is strongly boosted to obtain an enhanced contrast of picture details in bright areas. The average beam current does not increase significantly due to the AC coupling. A small amount of V_3 is also added through coupling capacitor C_1 and resistor R_3 (value = $5R_1$) to avoid color desaturation in large, bright picture areas.

FIGURE 7 shows a schematic of an exemplary nonlinear signal processor according to the present invention. RGB processor 10, integrated circuit TDA3506 manufactured by, e.g., the Philips Corporation of the Netherlands, drives video output amplifier 12 via resistor 30. Feedback resistor 32 defines the gain of the amplifier 12. The spot cut-off voltage of the picture tube is set to 150 volts by biasing resistor 34 for the condition when drive current i_5 is equal to zero. This condition requires an appropriate CRT grid number 2 adjustment (not shown). Automatic kinescope biasing (AKB) circuit 36 sets the black levels of the outputs of processor 10 such that i_5 is zero for a black signal. The bias current of Q3



flows through resistor 30 into processor 10 and causes a black level of 2 volts as indicated at V_1 .

5 Transistor Q1 is a unity gain inverter and DC level shifter. Differential amplifier Q2, Q3 and Q4 provide the signal splitting as shown by the waveforms of FIGURE 5b and 5c. The bases of Q3 and Q4 are biased so that for a signal corresponding to a black image, Q3 is conducting and Q4 is cut off. Current source Q2 inverts the signal so that current i_2 is in phase with voltage V_1 .

10 The increasing ramp voltage V_1 generates an increasing ramp current i_2 which adds to the drive current i_5 into amplifier 12 and produces the gamma correction. Current i_2 is of same shape as voltage V_2 of FIGURE 5b. The emitter voltage of Q2 is coupled to the base of Q4 via resistor 38. The increasing voltage V_1 causes the emitter voltage of Q2 to decrease and the base voltage of Q4 decreases until Q4 starts conducting. 15 As a result, voltage V_3 of FIGURE 5c gradually increases and the slope of V_2 gradually decreases. Feedback resistor 40 provides a smooth changeover of the collector current of Q2 between Q3 to Q4 as shown by waveforms 5b and 5c. A further increase of V_1 causes i_2 to remain constant and V_3 to increase at the same rate as V_1 . This is obtained with 20 Q4 having a gain of one due to the values of resistors 38, 40 and 42.

The separated medium to high level signal V_3 developed across resistor 42 is fed to emitter follower Q5 which drives a high-pass filter including a resistor 44 and a capacitor 46. A small amount of V_3 signal is fed to the output amplifier 12 via a capacitor 48 and a resistor 50. As 25 earlier noted, this AC coupled wide band signal improves color saturation in bright picture areas which otherwise would be slightly desaturated due to signal compression caused by gamma correction. The medium to high level detail signal voltage V_4 is amplified by an amplifier including transistor Q6 to obtain a 6 dB boosted detail signal. The detail signal is 30 coupled to the output amplifier 12 via a capacitor 54 and a resistor 52. Also as earlier noted, the advantage of the AC coupling is improved brilliance (contrast of details) without increasing the average beam current and without changing the black level.

FIGURE 8 shows the circuit diagram of the preferred 35 embodiment of a non-linear video processor according to the present invention using a TDA3552 integrated circuit as signal source 10. The circuit employs an active-load video output amplifier as amplifier 12.



Voltage feedback is provided via resistor 64 to obtain a low impedance summing point at its input 66.

An input emitter follower Q10 acts as low impedance source for video voltage V_1 . The differential pair Q12, Q13 splits the video voltage V_1 into the low and high brightness signals I_2 and V_3 . Transistor Q12 fully conducts at signal levels corresponding to very low image brightness. Thus, resistors 68 and 70 are coupled in parallel causing output amplifier 12 to produce a gain of 60. The signal splitting of this circuit produces a drive current I_2 in place of voltage V_2 shown in FIGURE 4.

Transistor Q12 conducts less as V_1 increases, and a gain of 30 is reached when transistor Q12 is cut off. The gradual change of gain of the output amplifier, as effected by I_2 , produces the desired gamma correction. Transistor Q13 starts to conduct before transistor Q12 goes into cut-off at a medium brightness signal level and produces voltage V_3 at its collector. Voltage V_3 represents picture information containing brightness levels between grey and peak white. Signal voltage V_3 is applied to emitter follower Q14 driving a high-pass filter including resistor 72 and capacitor 74. This high-pass filter separates the signal V_4 corresponding to grey to white area detail signal used for contrast enhancement. Signal V_4 is amplified by transistor Q15 to produce a detail signal which is coupled to amplifier 12 via capacitor 82 and resistor 84. As mentioned earlier, a small amount of the V_3 signal is AC fed directly to output amplifier 12 via capacitor 76 and resistor 79.

The bases of transistors Q12 and Q13 are biased at fixed relative potentials established by diodes D1 and D2. A resistor 78 produces a quiescent current of 0.3 mA through transistor Q13, preventing transistor Q13 from being cut off by signal peaks at grey level.

The spot cut-off voltage of the picture tube (not shown) is set to approximately 160 V at the cathode 80 by setting the black level voltage at the emitter of transistor Q10 to 3.5 volts, and by appropriately adjusting the grid No. 2 voltage of the CRT.

The present circuit does not require alignment between the RGB channels to avoid tracking errors. This is due to the gradual signal splitting.

The present arrangement makes use of the fact that the eye appears to be more sensitive to contrast changes in small picture areas, as opposed to changes extending over large areas. Frequencies produced by



picture details of medium to high brightness are boosted and AC coupled to the main video signal. This results in a significant improvement of the brilliance without increasing the average beam current. The AC coupling only increases the so-called detail contrast, while DC brightness signals and
5 large area contrast are not affected. The picture tube can be driven to higher beam currents during small area details than during large area signals before picture tube blooming occurs. This improvement of brilliance is of particular importance with very large picture tubes which appear dimmer and less contrasty than smaller tubes because the large
10 tubes are limited by gun, shadow mask, and phosphor to about the same peak beam currents as the smaller tubes while the picture is spread out over a much larger area.

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CLAIMS:

1. Video signal processing apparatus characterized by:
means for dividing (18) a video signal (V1) into a first
5 signal (V2) corresponding to relatively low amplitude levels of said
video signal (V1), and a second signal (V3) corresponding to
relatively higher amplitude levels of said video signal (V1),
means for high-pass frequency filtering (20) said second
signal (V3), and
10 means for combining (R1,R2,R4)said video signal (V1),
said first signal (V2) and said high-pass frequency filtered second
signal (V4) to produce a combined signal (i5).
2. The apparatus of claim 1 characterized in that said
15 means (18) for dividing gradually divides said video signal (V1) into
said first (V2) and second signals (V3).
3. The apparatus of claim 1 characterized in that said
high-pass frequency filtered second signal (V4) is AC coupled (C2) to
20 said means for combining.
4. The apparatus of claim 3 characterized in that said
first signal (V2) is DC coupled (R2) to said means for combining.
- 25 5. The apparatus of claim 4 characterized in that said
means for combining comprises an adder.
6. The apparatus of claim 1 characterized in that said
video signal (V1) is at least one of red, green, and blue signals.
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7. The apparatus of claim 4 characterized in that at least
a portion of said second signal (V3) is AC coupled (C1) to said means
for combining.

