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MEMORANDUM FOR: [redacted]

This SMPTE paper explains some of the "image manipulation" used in the TV industry. [redacted]

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Declass Review by NGA.

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[redacted] have copies of this. Please return to me.

Russ

12 Dec 63
(DATE)

Thanks Russ — [redacted]

Has [redacted] seen this? This is the electrical equivalent of large processing edge effects

[illegible]

FORM NO. 101 REPLACES FORM 10-101 WHICH MAY BE USED
(47)

A New Crispener Circuit for Television Images

By EARL F. BROWN

The subjective definition of a television image may be improved by overemphasizing and/or increasing the steepness of its luminance transitions. A new crispener circuit capable of performing either or both these functions using linear circuitry is described and illustrated with low-resolution television images. It is shown that the effect of overemphasizing or steepening the rise-times of the luminance transitions appear to be comparable in improving the subjective quality of the resulting picture whereas a combination of the two is superior to either. Applications of the crispener circuit in outlining television images and reducing overshoot and ring due to sharp cutoff filter characteristics are also described and illustrated. It is shown that when the ring and overshoot in an image are reduced, the sharpness of the image is likewise reduced.

Introduction

The objective of television is to place before an observer a satisfactory and pleasing image of a distant scene. Some researchers believe that of the ingredients of a reproduced image among the most important are the edges or brightness boundaries of the image. Surely this must have some substance since many scenes are identifiable from an outline of their luminance boundaries alone. The filling in of tones between the boundaries in general serves to enhance the aesthetic value of the image.

In their natural setting luminance boundaries appear with varying degrees of abruptness. It behooves us to recreate these boundaries as accurately as possible. The steepness of luminance boundaries in a television image is proportional to the bandwidth of the system. In television systems of narrow bandwidth, the slowly changing boundaries are normally accurately reproduced, but the initially abrupt boundaries are smoothed out, sometimes radically. It appears advisable to operate on the resolved boundaries, at the receiver, in such a way that only the degraded boundaries, i.e., the formerly abrupt boundaries, are affected.

Earlier researchers[1,2] have demonstrated that steepening and/or overemphasizing these boundaries will provide some restoration or apparent restoration of these boundaries towards their original steepness. A linear crispening circuit has been designed with this purpose in mind. This circuit is capable of steepening and/or overemphasizing the deteriorated luminance signal boundaries and has negligible or no effect on the slowly changing boundaries.

The application of this circuit in the outlining of television images and the reduction of overshoot and ring due to the sharp cutoff characteristics of filters is also described.

Crispening

Crispening is here defined as the addition of an inverted second derivative (or approximate) of the image signal to the image signal. A crispening signal may be used to steepen and/or overemphasize the luminance transitions of the image. With signal amplitudes and bandwidth held constant, the ratio of the duration of the crispening signal to the duration of the luminance transition signal is the controlling factor in determining the amount of steepening obtained. When this ratio becomes unity (i.e., the crispening signal becomes a true second derivative of the transition signal) the maximum increase in steepness is obtained. The maximum ratio of crispening signal duration to image signal duration is two to one, where steepening of the luminance transitions is negligible. Above this ratio the crispening signal has a deteriorating effect similar to echoes in an image. The degree of overemphasis is a function of the amplitude of the crispening signal.

The subjective impression on the observer of crispening is a sharper picture, apparent increase in resolution, improved contrast and an improvement in the perception and clarity of liminal detail.

Design Considerations

In television the abruptness of luminance changes in the direction perpendicular to a scanning line is limited by the number of scanning lines in the television raster. Changes in luminance along a scanning line are limited by aperture effects of the scanning mechanisms and the bandwidth of the transmission system. We will be concerned in this paper with those luminance changes occurring along a scanning line.

Abrupt luminance boundaries may be thought of as isolated steps in terms of waveforms. When we decrease the slope of a step waveform by limiting the frequency band, as shown in Fig. 1(a), we decrease the sharpness of the luminance step. We may increase the sharpness of luminance boundaries along a line by crispening the image signal as illustrated with the step signal in Fig. 1(c). Crispening requires that we derive an inverted second derivative or approximate, Fig. 1(b), from the step signal and subsequently add the derived signal to the step signal as shown in Fig. 1(c).

Crispener Circuit

The crispener circuit is shown schematically in Fig. 2. It is composed of an electromagnetic delay line, the input end of which is terminated in the characteristic impedance of the line while the other end is left open-circuited. A pickup coil is inductively coupled to the delay line. A bandlimited step signal, Fig. 3(a), converted into a current wave is impressed onto the delay line. As the current step wave passes the pickup coil on its

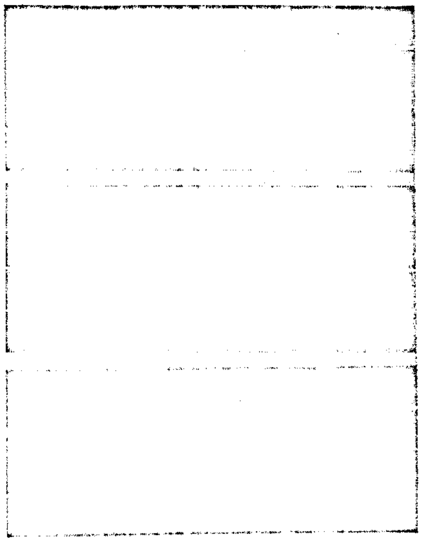

Fig. 1. Crispening of a degraded step signal: (a) top, input step signal; (b) middle, inverted second derivative of step signal; (c) bottom, crispened step signal, i.e., addition of waveforms (a) and (b).

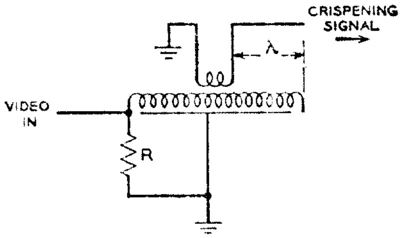

Fig. 2. Crispening signal generator.

Presented on April 24, 1963, at the Society's Convention in Atlantic City, N.J., by Earl F. Brown, Bell Telephone Laboratories, Inc., Murray Hill, N.J.
(This paper was first rec[illegible] and in final form on October 22, 1963.)

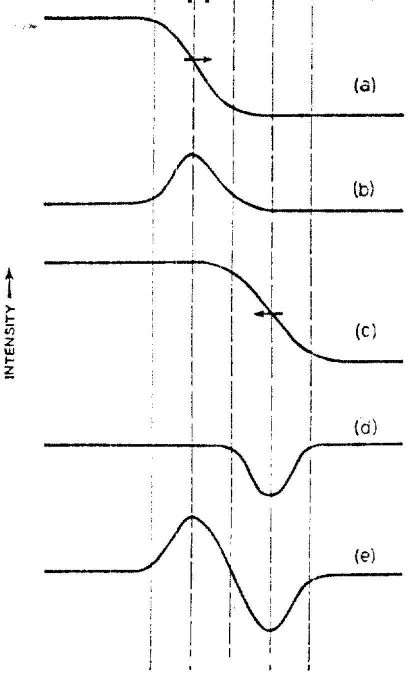

Fig. 3. Waveforms of crispening signal generator: (a) degraded current step signal launched on delay line on outward pass of pick-up coil; (b) voltage induced in pick-up coil by outward pass of step signal, i.e., inverted first derivative of step signal; (c) return current step signal; (d) voltage induced in pick-up coil by return pass of step signal, i.e., inverted first derivative of step signal; (e) summation on pick-up coil of induced voltages (b) and (d) or inverted approximate second derivative of input step signal (a).

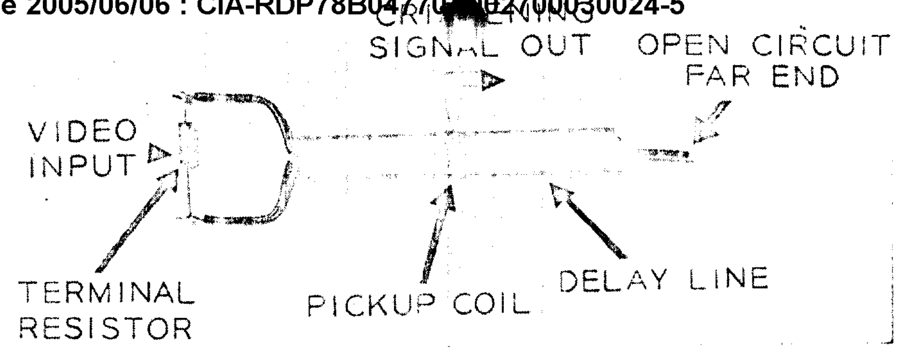

Fig. 4. Crispening signal apparatus.

outward trip a voltage, Fig. 3(b), is induced in the pickup coil which is proportional to the time derivative of the input wave. The input current step wave, Fig. 3(a), proceeds to the open-circuited end of the line where it is reflected with no change in polarity, Fig. 3(c), to the input end terminating resistance in which it is absorbed. On its return pass, a second voltage, Fig. 3(d), is induced in the pickup coil which is again proportional to the time derivative of the input current wave. The return current wave passes the pickup coil from the opposite direction, therefore the voltage induced in the pickup coil by the return wave will be opposite in polarity to the voltage induced by the outward current wave. Assuming no losses, the constant of proportionality of the two induced voltages is the same. The pickup coil is located on the delay line to provide a round-trip delay between passes equal to or less than twice the rise-time* of the degraded step wave. With this proportionment, the two induced voltages, Figs. 3(b) and 3(d) taken together, and of opposite polarity as seen by the pickup coil, form a crispening signal Fig. 3(e), of the input current wave. Figure 4 is a photograph of the crispening circuit.

When the round-trip delay between passes is of the order of twice the rise-time of an input step signal, Fig. 5(a), the crispening signal appears as two first derivatives of the input signal, Fig. 5(b). One is the negative of the other, separated by a time interval equal to the rise-time of the input signal. When added to the input step signal, with correct positioning, the maximum excursions of the crispened signal occur outside the transition region of the step signal. With these proportionments the effect on the rise-time of the input signal is negligible and only overemphasis of the input signal is realized Fig. 5(c).

As the round-trip delay between passes is reduced, the two first derivatives move closer together, finally merging and taking the form of a second derivative wave shape of the input signal. As the round-trip delay between passes of the pickup coil is reduced, the crispening signal, with amplitude held constant, becomes increasingly effective in steepening the rise-time of the input signal. Of course, when the round-trip delay between passes is zero, the signals developed by two successive passes cancel each other.

We might summarize at this point by stating that overemphasis and steepening of the luminance transitions are a function of the magnitude of the crispening signal. Steepening of the luminance transitions is also inversely proportional to the round-trip delay between passes of the pickup coil.

The polarity of the crispening signal

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* Rise-time is defined as that distance along the time axis between the 10% and 90% amplitude points of the signal.

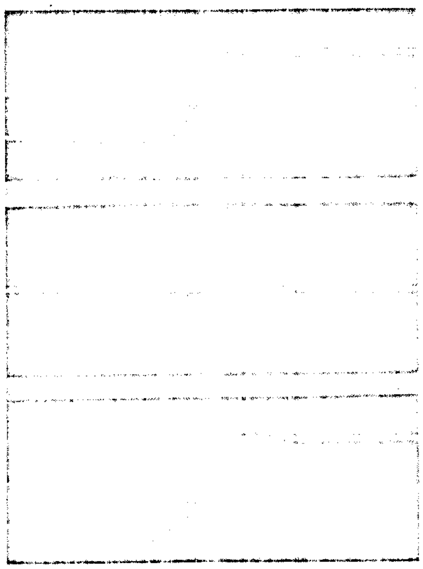

Fig. 5. Waveforms obtained when ratio of round-trip delay between passes and signal rise-time is 2 to 1: (a) top, input step signal; (b) middle, negative first derivatives of input current wave; (c) bottom, sum of crispening signal and input step signal showing overemphasis effect.

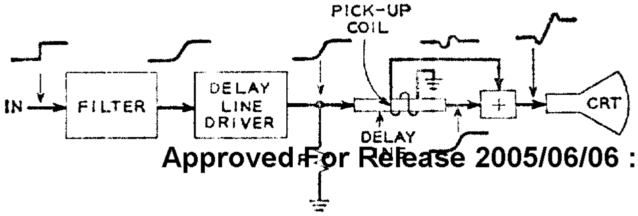

Fig. 6. Block diagram of television crispener.

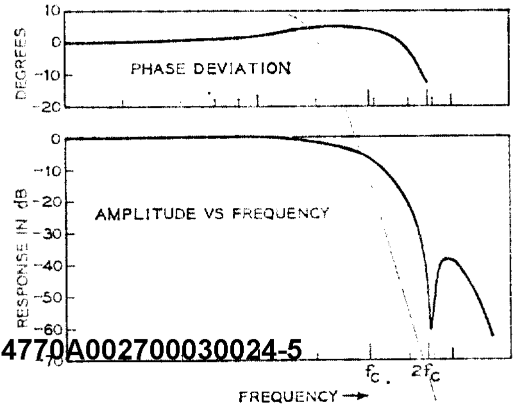

Fig. 7. Filter characteristics.

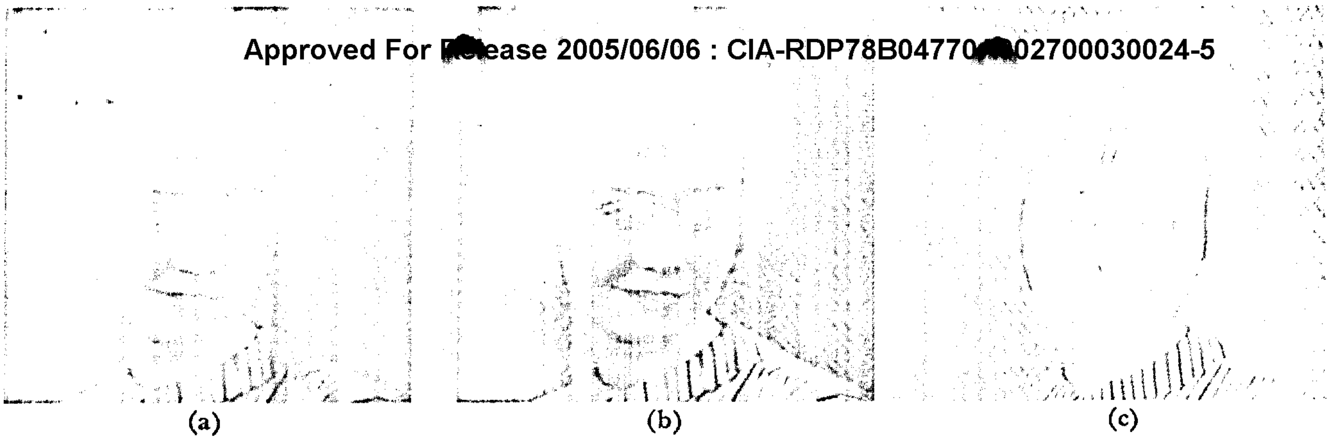
(a) (b) (c)

Fig. 8. A comparison of uncrispened and crispened television images: (a) uncrispened image bandlimited to 375 kc; (b) crispened image bandlimited to 375 kc; (c) crispening signals.‡

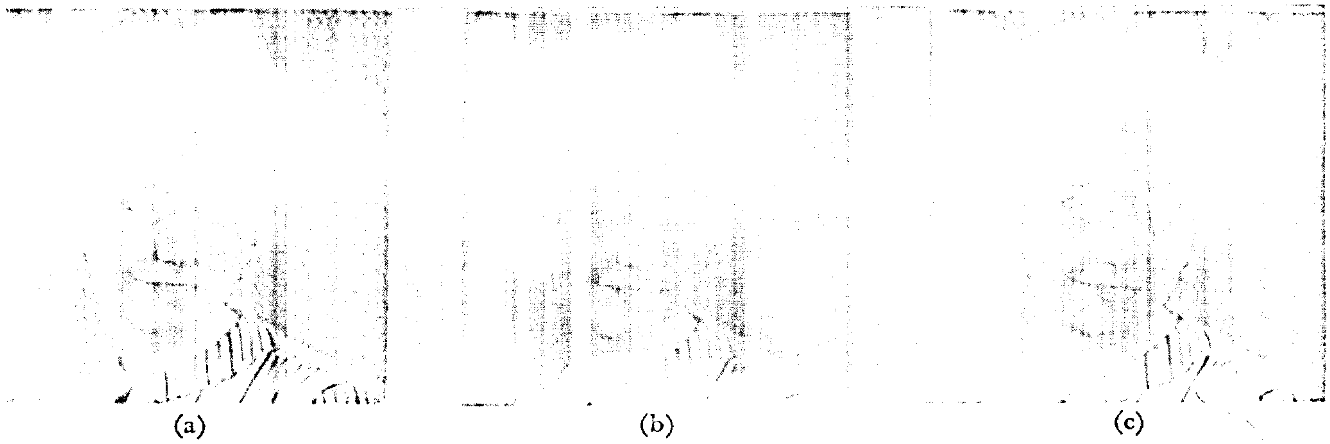
(a) (b) (c)

Fig. 9. A comparison of crispened television images: (a) bandlimited to 375 kc with 15% overemphasis and 2.2 to 1 decrease in rise-time with respect to original; (b) bandlimited to 750 kc, i.e., a 2 to 1 decrease in rise-time with respect to 375 kc original; (c) bandlimited to 375 kc with 15% overemphasis.

may be changed by switching the output leads of the pickup coil. The crispener circuit is shown in Fig. 6.

Experimental Results

The television system used in producing all of the illustrations was a 189-line, 30-pictures/sec, double interlaced system with a one-to-one aspect ratio and unless otherwise indicated is initially bandlimited to 375 kc.

Figure 7 illustrates the characteristics of the class of linear phase maximally flat low-pass filters[3] used unless otherwise indicated. The 6-db point is called the filter cutoff frequency. The first zero occurs at twice the cutoff frequency.

Figures 8 and 9 permit a comparison between crispened and uncrispened images. Figure 8(a) is a photograph of a television image bandlimited to 375 kc. Figure 8(c) shows the crispening signals obtained from the image of Fig. 8(a). Figure 8(b) is the crispened image, i.e., the sum of images 8(a) and 8(c). The overshoot in the crispened image is 15% of the signal amplitude with a 1.1 to 1 decrease in rise-time with respect to the rise-time of the original image signal.† The round-trip delay between passes in this case was approximately 1.9 μsec. Note that there is no real increase in resolution in the crispened image over that shown in the original image. However, there is a considerable increase in sharpness which psychologically produces an improvement in resolution. Note, also, the improvement in contrast of the crispened image, and the improvement in the perception and clarity of liminal detail.

The three images of Fig. 9 have been modified with a decrease in the signal rise-times of the luminance transitions, or an overemphasis of these transitions or both. Figures 9(a) and 9(c) are modified versions of the original image, Fig. 8(a). Figure 9(a) has 15% overshoot and a 2.2 to 1 decrease in signal rise-times. The round-trip delay between passes is 0.2 μsec. Figure 9(b) was obtained by band-limiting the image signal to 750 kc, thereby obtaining a 2 to 1 decrease in signal rise-times with no overshoot. Figure 9(c) is the same as Fig. 8(b) with 15% overshoot and a 1.1 to 1 decrease in signal rise-times. Photographs of television displays do not accurately portray the results observed on a monitor, thereby inhibiting subjective evaluations through photographic illustrations. Evaluation of the televised displays indicated

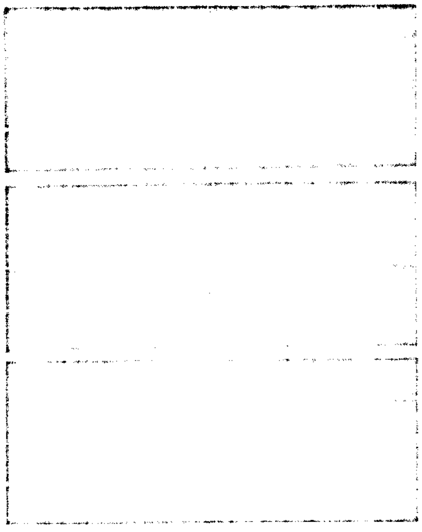

Fig. 10. Waveforms showing signal outlining processes: (a) top, input step signal; (b) middle, inverted first time derivative of input signal; (c) bottom, outlined step signal, i.e., the sum of signals (a) and (b).

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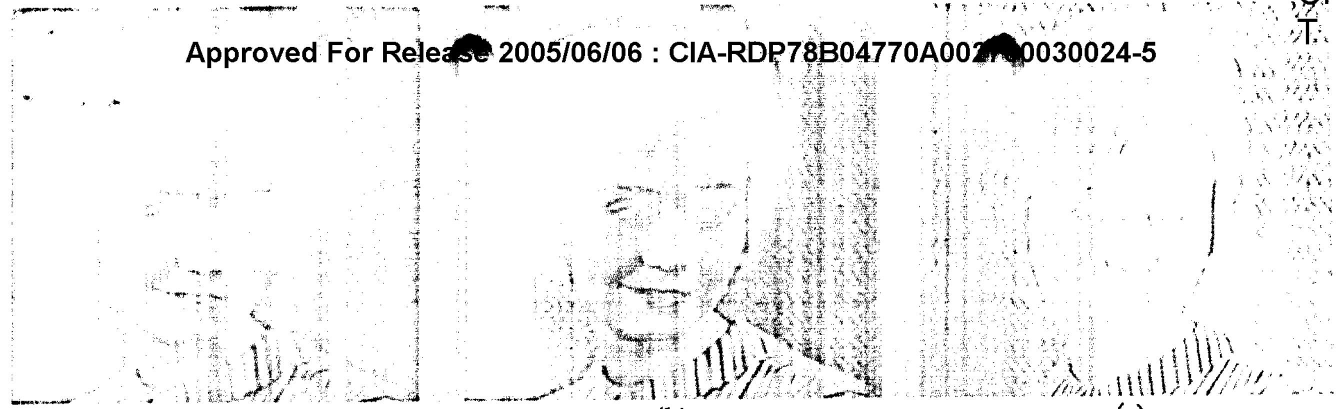
† The ratio of rise-times wa[illegible] oscilloscope using step signals which were processed in the same manner as the image signals.

‡*Edit. Note:* The moire patterns are due to interactions between the screen mesh used in the photo-engraving process and the scanning lines of the original picture. These interactions also tend to mask the effects we wish to show. Copies of the original photographs may be obtained from the author.



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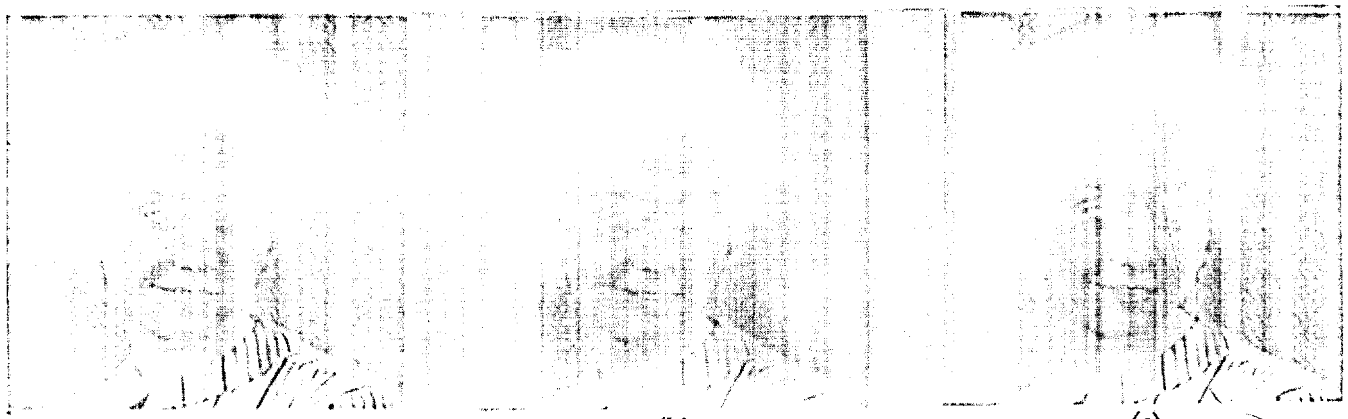

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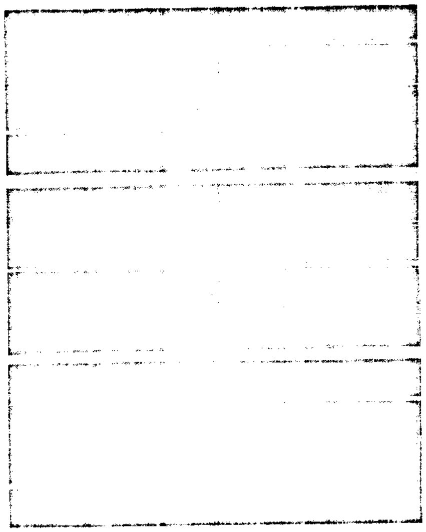

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(a) (b) (c) (d)

Fig. 11. A comparison of outlined television images: (a) original image bandlimited to 375 kc; (b) outlining signals; (c) outlined image, i.e., the sum of (a) and (b); (d) image bandlimited to 1.5 mc.

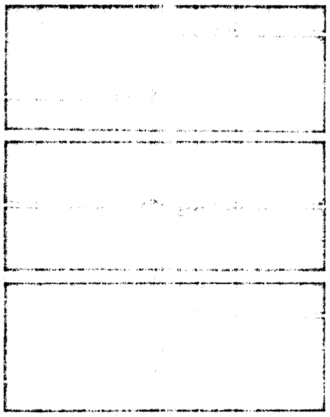
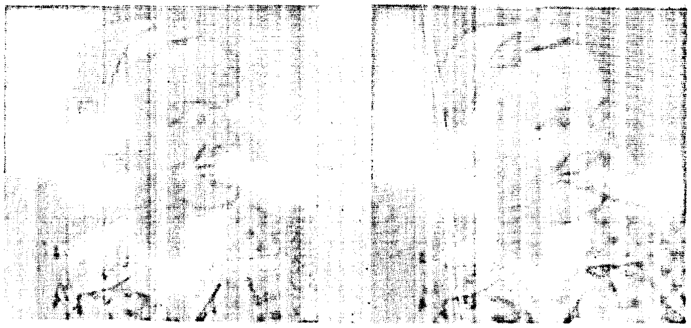


Fig. 12. Reduction of filter overshoot and ring associated with a step signal bandlimited by a six element Bode filter: (a) top, bandlimited step signal; (b) middle, approximate second-derivative of step signal (a); (c) bottom, sum of waveforms (a) and (b).



(a) (b)

Fig. 13. A comparison of television images: (a) image bandlimited to 350 kc by a six-element Bode filter; (b) image with reduced overshoot and ring, i.e., the sum of image (a) and its approximate second-derivative.

that Figs. 9(b) and 9(c) are comparable, whereas the image of Fig. 9(a) is slightly superior to the other two. We can conclude from this that overemphasizing or steepening the luminance transitions are probably equally effective in improving the subjective quality of a television image while a combination of overemphasizing and steepening is superior to either of the others alone. The equality of steepening and overemphasizing should be evaluated through subjective testing.

Contour Outlining

Contour outlining[4] is the delineation of the luminance contours or edges in an image with a black outline. This form of image enhancement is sometimes preferred over crispening in noisy systems since observers are in general more tolerant of black noise than of black and white noise. Outlining may be done simply by clipping the "white" excursions of the crispening signal before it is added to the image signal. Figure 10 illustrates the process of outlining a step signal: Fig. 10(a) is a step signal degraded by a low-pass filter; Fig. 10(b) shows the outlining signal obtained from the degraded step signal; and Fig. 10(c) is the outlined step signal, i.e., the sum of signals 10(a) and 10(b).

Figure 11 permits a comparison of a contour outlined image with others: Fig. 11(a) is the original image bandlimited to 375 kc; Fig. 11(b), the outlining signals; and Fig. 11(c), the outlined image, i.e., the sum of Figs. 11(a) and 11(b). Figure 11(d) is an image bandlimited to 1.5 mc for comparison.

Overshoot and Ring

F. F. Kuo[5] has suggested that the overshoot and ring of a filter step-response may be eliminated or reduced by obtaining a second derivative of the filtered signal and subsequently adding this signal to the filtered signal at the expense of a slight increase in the step signals rise-time. This operation is, in essence, the inverse of crispening. This effect is illustrated in Figs. 12 and 13, presumably for the first time. The upper step signal of Fig. 12(a) is bandlimited by a balanced six element Bode low-pass filter,[6] and Fig. 12(b) is the sum of the two upper waveforms. Note that the ring is barely perceptible while the rise-time has increased slightly.

Figure 13 illustrates this effect pictorially. The image of Fig. 13(a) is bandlimited to 350 kc by the Bode filter. Note particularly the ring around the hat and near the lapel of the girl's blouse. Figure 13(b) shows the ring and overshoot nearly eliminated through the addition of its approximate second derivative to the image. Also note the decrease in sharpness due to the increase in rise-times of the luminance transitions.

Other Proposed Applications

Aperture losses in television pick-up equipment are caused by the finite size of the scanning beams and by lens aberrations in the optical system. To compensate for these losses we require a circuit whose gain rises with frequency reaching its peak at about the first zero of the system's pickup response.[7] Its phase must also vary linearly with frequency. In practice, it has been found that a cosine-shaped response will satisfactorily compensate for these aperture losses.

Figure 14 shows the amplitude vs. frequency response of the crispener circuit. Note that the response characteristics meet all of the requirements to compensate satisfactorily for system aperture losses. The peak response of the circuit may be adjusted with respect to frequency simply by sliding the pickup coil up or down the delay line as required to complement the aperture losses.

Summary

A new crispener circuit has been described and its usefulness is illustrated in enhancing the definition of television images. This circuit is simpler than conventional techniques in that it produces a crispening signal in a single operation with linear circuits. Its design, construction and operation are simple. It may be used to overemphasize and/or decrease the rise-times of luminance transitions. Its usefulness in outlining low-resolution television images has been illustrated. Its usefulness in reducing the overshoot and ring associated with a sharp cutoff filter at the cost of a reduction in image sharpness has been illustrated.

It has also been illustrated that a picture overemphasized with 15% overshoot and one whose rise-times have been decreased by two to one are probably subjectively comparable, while a picture with overemphasis and decreased rise-times is superior to either of the two.

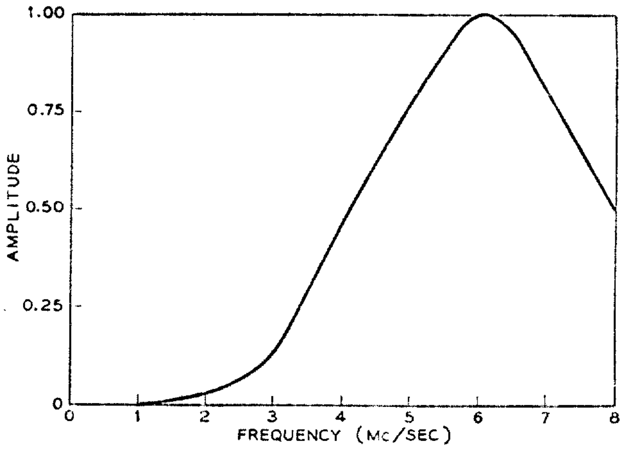


Fig. 14. The gain of the crispener circuit as a function of frequency. The round trip delay between passes equals 1/2 f where f equals frequency of peak amplitude response.

Acknowledgment: The guidance and assistance of Messrs. W. T. Wintringham, J. R. Hefele and E. M. Cherry of Bell Telephone Laboratories is gratefully acknowledged.

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Video Circuits for Transistor Television Cameras

By D. BRAY and
G. E. HAYDEN-PIGG

It is desirable that the next generation of broadcast-quality television cameras use semiconductors exclusively. The latest user specifications for television cameras demand a high standard of performance and facilities which presents a particularly difficult problem with regard to the video processing chain. A general design approach is outlined and particular design solutions are given.

Introduction

Video processing chains in television cameras present difficult design problems even with the use of thermionic valves. The performance specifications are of necessity very stringent, calling for wide-band amplification with special circuits to compensate for cable losses and device deficiencies. Figure 1 is a typical block diagram for the video processing chain of an image-orthicon camera channel. The function of the basic circuit blocks can be briefly expressed as follows.

Head Amplifier: converts the video signal current from the pickup tube to a level large enough to be transmitted down a 75-ohm coaxial (camera) cable.

Cable Compensation: corrects for the camera cable losses at all frequencies.

Gain Control: standardizes the variation of signal current from the pickup tube.

Aperture Correction: corrects for the finite spot size of the scanning beam in the pickup tube.

Voltage Amplifier: boosts the signal voltage to a level suitable for the gamma correction circuit.

Gamma Correction Circuit: predistorts the signal to correct for display tube characteristics.

Black/White Limiter: limits peak black and peak white signal excursions to some preselected value under overload conditions.

Output Amplifier: provides multiple 75-ohm outputs for distribution of the

Isolating Amplifier: provides a buffer amplifier for the external signal input.

Video Switching: routes and selects the required video signal.

Viewfinder Amplifier: amplifies the video signal to a level suitable for modulating the viewfinder display tube.

It is impossible in a paper of this nature to consider all aspects of performance, but a general specification for the video processing chain of an image-orthicon camera channel is given in Table I.

Problems Posed by Semiconductors

The stringent performance specification given in Table I presents a particularly difficult problem even with the use of thermionic valves. The use of semiconductors adds further problems to the circuit design. These additional problems can be discussed under several broad headings.

D-C Stabilization

The problem of stabilization of the transistor operating point is dealt with in most books concerning transistor circuits. The well-known method of base biasing in conjunction with emitter resistance

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Presented on April 24, 1963, at the Society's Convention in Atlantic City, by D. Bray (who read the paper) and G. E. Hayden-Pigg, EMI Electronics Ltd., Hayes, Middlesex, England. (Mr. Bray is now at Westinghouse Electric Corp., Research and Development Dept., Beulah Rd., [illegible]

SECRET

26 April 1963

Closed Circuit Television (CCTV):

P &DS is conducting a feasibility study of the application of CCTV to the operations of NPIC. This study is considering CCTV in terms of security, image quality, alternate approaches and, probably the most important, the savings in time.

At present it appears that CCTV will provide a secure, flexible means of transmitting visual information within the Center. The next step will be to borrow or rent sufficient equipment to conduct tests to assure us that CCTV is both secure and useful before any action is taken to obtain a more complex CCTV system.

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