METHOD AND APPARATUS FOR SCRAMBLING AND DESCRAMBLING OF VIDEO SIGNALS WITH EDGE FILL

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BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to signal processing of time domain electronic signals, such as video information signals. In particular, the invention relates to improvements in scrambling and descrambling such signals to prevent unauthorized use thereof, including several improvements in security and concealment.

Description of Related Art

Commonly assigned U.S. Patent No. 5,058,157 issued October 15, 1991 to John O. Ryan (incorporated herein by reference) discloses a method and apparatus for encrypting (scrambling) and decrypting (descrambling) information signals normally arranged as a succession of lines of active information, with each line having a line timing reference, such as color video (television) signals. The active video portion of each line is time shifted with respect to the horizontal sync portion of that line using a predetermined slowly varying time-shifting function. The time-shifting information is conveyed to the decryption site by encoding the instantaneous value of the time-shifting waveform for the beginning of each field in the vertical blanking portion of that field. To provide a reasonable maximum time-shifting range, portions of the trailing edge of the active video in the preceding line and portions of the leading edge of the active video in the current line are discarded. During decryption, the original line timing and colorburst signals are discarded and new signals are generated which are time displaced

from the active video portion by the original amount before encryption. This provides a secure video type information encryption and decryption technique compatible with all video tape formats and transmission systems, and which is free of picture impairments caused by the interaction of the scrambling algorithm and the chrominance consecutive line averaging systems used in color-heterodyne recording.

The type of time shifting performed may comprise any one of a number of slowly varying functions, such as a sinusoidal waveform or a linearly changing ramp signal. The rate of change in the signal, i.e. the "wobble", is relatively slow when compared to the line rate of the input signals to be processed. For video type signals, a sinusoidal waveform having a frequency of no more than about 20 Hz is used. The absolute amount of time shifting performed is preferably limited to a maximum value which, in the case of NTSC video signals, does not exceed a total of 4 microseconds (plus or minus 2 microseconds in each direction).

The instantaneous value of the time shifting waveform function at the beginning of each field is conveyed along with the field information, typically during the vertical blanking interval. For example, with respect to a sinusoidal time shifting function, the starting amplitude of the waveform during a given field is transmitted during the vertical blanking interval as a single byte of information which, when combined with a separately provided authorization key, enables a descrambling circuit to synthesize the scrambling waveform function. Decryption is performed by restoring the original timing relationship between the horizontal sync (and colorburst) and the active video portion of the corresponding line. This is done by generating new line timing reference signals (horizontal sync and colorburst) which bear the same timing relationship to the active video portion as do the original line timing reference signals before

encryption. The resulting descrambled signals still contain time base errors, but these errors are within the capture or correction range of the follow-on television monitor/receiver.

Figures 1A and 1B herein correspond to Figures 3A and 3B of the above cited U.S. Patent No. 5,058,157, and illustrate the manner in which the scrambled signals are descrambled at the reception site, i.e. the descrambler. With reference to Figure 1A, three successive lines of NTSC video are shown which have been time shifted successively by increasing amounts. (The active video portions of each of the lines in Figures 1A and 1B are only fractionally illustrated.) The topmost line represents a line N having no time shifting between the active video portion and the end of horizontal blanking, and the time between the beginning of a horizontal sync portion and the active portion is designated as t_1. The next line N+1 has undergone time shifting in the delay direction so that the time between the beginning of the horizontal sync portion and the beginning of active video portion is t_2, greater than t_1. Line N+2 has undergone even more time shifting in the delay direction by an amount labeled t_3 which is greater than t_2. These three successive lines represent lines from the upper portion of a raster image. The line timing reference part of each of lines N, N+1 and N+2 are all temporally aligned in Figure 1A; the leading edge of the horizontal sync portion of each line is exactly aligned with the leading edge of the horizontal sync portion of the other lines. The same is true of the location of the colorburst portions (hatched areas). The active video portions, however, are deliberately misaligned in lines N+1 and N+2 with respect to line N.

Figure 1B illustrates the signals for the same three lines after descrambling, i.e. decryption. As can be seen in this figure, the leading edges of the horizontal sync portions of the three lines are no longer precisely

aligned, but are rather staggered; however, the distance between the leading edge of the horizontal sync portion and the beginning of active video is the same for all three lines, i.e. the value t_1. Similarly, the colorburst portions (hatched areas) of the three lines are no longer temporally aligned, but are rather staggered in the same fashion as the horizontal sync portions. Relative positioning of the active video portion of the three lines remains the same.

Although the descrambled signals are still relatively misaligned, the precise timing relationship t_1 between the leading edge of horizontal sync and the beginning of active video ensures that each line of information, as processed by the follow-on television receiver or monitor, can be properly displayed, provided that the timing error in a given line does not exceed the capture range of the television receiver or monitor synchronization circuitry. The time shifting applied to the original signals during encryption is relatively slowly varying (20 Hz for NTSC TV) compared to the video line rate.

Figures 2A and 2B herein are the same as Figures 4A and 4B of U.S. Patent No. 5,058,157. These figures show in block diagram form a scrambler system capable of providing the above-described scrambling. As seen in Figures 2A and 2B, input video to be scrambled is coupled to an input terminal 11 of a video input processor unit 12. Processor 12 functions to normalize the incoming video signal relative to gain, DC offset and bandwidth and provides a stable low impedance buffer unit for the video appearing on output terminal 13. In addition, the incoming vertical and horizontal sync portions are separated from the input video by processor unit 12 and supplied as input to a sync/timing generator and phase locked loop 15.

The signals from processor unit 12 appearing on output terminal 13 are coupled to a conventional NTSC decoder and anti-alias filter 16 in which the luminance

component Y and chrominance quadrature components I,Q are separated for three channel parallel processing in the digital domain. The Y output of unit 16 is coupled to an analog-to-digital converter 18 in which the luminance is converted from analog to digital form at a preselected clock rate by means of an input sample clock signal supplied on clock input line 19. The input of converter 18 is coupled to an input portion of a dual-ported luminance memory unit 20. This is then the Y channel memory connected to the Y channel D/A converter 22. Memory unit 20 is configured as a memory in which a word is written from A/D converter 18 into every memory cycle and a word is read from memory unit 20 to a digital-to-analog converter unit 22 every memory cycle.

Read/write control signals and multi-bit address signals are supplied to the luminance memory unit 20 from a memory controller unit 24. The output of luminance channel memory unit 20 is coupled to the input of a digital-to-analog converter 22, in which the multi-bit digital words output from memory 20 are converted into analog samples at the clock rate by clock signals supplied from unit 15 on clock input line 23. The output of converter unit 22 is coupled to the input of an NTSC encoder and low pass filter unit 25 in which the luminance signal is combined with the I and Q chrominance components and renormalized with respect to band-width and DC offset. The I, Q chrominance quadrature components are processed in an essentially identical manner to that described above for the luminance component Y in respectively units 18', 20' and 22' and 18", 20", and 22", which function in the same manner respectively as do units 18, 20 and 22.

Sync timing unit 15 generates the input clock signals used to provide the sample clock for A/D converter unit 18, the read and write clock signals from memory unit 20, and the clock signals for D/A converter unit 22. Preferably, unit 15 is comprised of a discrete phase detector, a number of sampling gates, and error amplifier

and a crystal clock oscillator.

The above described units are coupled to a user interface device 32, such as a keyboard terminal, via controller unit 34 and a plurality of control registers 36.

The above described device and the associated scrambling method have several shortcomings.

First, the device is relatively expensive and complicated in that there are three sets of A/D converters and associated memories, one for each of the Y, I, and Q components. Thus, there are three independent channels for digital processing, each channel requiring relatively expensive components, thus increasing the cost and complexity of the scrambling device.

Secondly, the method of scrambling as depicted in Figures 1A and 1B while reasonably secure has the potential defect that in the process of moving the active portion of the video to the right as shown in the drawings, the leading and trailing edges of the horizontal sync signal have both been moved to the right also. This displacement of the normally well known position of horizontal sync within the horizontal blanking interval could be detected by a clever pirate, i.e. unauthorized user, to determine the amount of wobble (time displacement) in each line. The pirate would be able at least in theory to descramble the signal to determine what the amount of wobble and reverse the process, thus obtaining a descrambled and viewable signal. Thus, the method as depicted in Figures 1A and 1B is lacking in the very high degree of security desirable for a commercial scrambling system.

Another shortcoming of the above-described scrambling system is that while providing security, i.e. generally preventing unauthorized use, the scrambled signal when viewed on a normal television set is not completely concealed. That is, a determined viewer who is willing to watch a television picture which is in effect horizontally

jumping back and forth can still watch the program and understand at least partly what is going on. This is undesirable for transmission for instance of adult type material where it is desired to prevent children from watching even the scrambled picture. This is especially problematic because it has been determined by experimentation that such adult type material, i.e. depictions of sexual activity, is particularly easy to follow on the picture by a viewer even though the picture is scrambled. This is another way of saying that the scrambling while relatively secure does not provide an adequate level of concealment for all program material.

Another problem associated with the above described device is one common to comb-type NTSC decoders in which the composite video is subjected to a one-line delay. Simple addition of the delayed video to the same video before the delay causes the chrominance portion of the two signals to cancel, leaving only luminance. Similarly and simultaneously, subtraction of the delayed signal from the undelayed signal (or vice versa) causes the luminance portion to cancel, leaving only chrominance. This problem is not specific to a scrambling device but is typically encountered in video processors which perform NTSC decoding and is the reduction of vertical detail, resulting in smeared vertical edges in the picture. This is due to the two-line summation process of the Y, I and Q components in which fine grain picture detail tends to be lost when the composite video is converted to digital and then in the digital domain a luminance/chrominance separation is performed. It is known that this problem can be overcome by complicated and expensive circuitry which takes the incoming composite video signal in the analog domain, using a band pass or high pass filter to isolate the chrominance component before separation. The band pass filtered signal is then delayed and subjected to the subtraction process. The band pass filtering removes the vertical luminance edges because they are low

frequency in nature. Thus the chrominance separation is performed only on the high frequencies and having done this, the resultant separated chrominance has no luminance component. Finally the luminance signal is isolated by subtracting the finished, high frequency chrominance signal from the incoming composite video so there is no loss of vertical detail. This process is effective but when done digitally requires two A/D conversions: one for the band passed (or high passed) chrominance and one for the broad band composite video. It would be desirable to eliminate or simplify this process in order to reduce the number of components needed and reduce the amount of processing on the signal.

Thus, the method and apparatus disclosed in the above cited patent while adequate is still subject to significant improvement in both security, concealment, and complexity.

It is to be understood that the above cited patent is commonly assigned with the present invention and that the above description is not an admission that the subject matter disclosed and claimed in the above cited patent is necessarily prior art with respect to the subject matter of the present disclosure and claims.

SUMMARY OF THE INVENTION

A scrambler and descrambler are provided in accordance with the invention to overcome the above described shortcomings of the method and apparatus disclosed in the above cited patent and also to provide improved security and concealment and greater flexibility i.e. additional applications.

In accordance with the invention, first the problem of the easily detected edge of horizontal blanking in the scrambled signal is overcome by filling in the gap between the position where active video would nominally start or end and where it actually starts and ends due to the scrambling process of Figure 1A. This gap is filled with

signals which are undetectable compared to the expected active video, preventing the pirate from building a device which would be able to track electronically the transition at the gap. This "edge fill" process recognizes that for four adjacent (successive) pixels, the luminance will generally be relatively static and the chrominance will describe one complete cycle in these four pixels. Thus if at the edge of the active portion of the video, i.e. the edge of the picture, four adjacent pixels are repeated in sequence, this provides a continuous unbroken chrominance sine wave with exactly the phase and amplitude of those four sampled pixels and a luminance signal which mimics that of the four pixels. This in effect generates a continuous signal which matches the single set of four pixels for as long as is desired, i.e. the sequence of four pixels may be repeated as long as desired to fill the gap. A number of pixels other than four may also be used.

In accordance with the invention this edge fill is provided in the digital domain by stopping the normal incrementation of the address counters for the eight most significant of the ten bits which define the location of each pixel, while the two least significant bits continue to run, i.e. to increment normally. Thus the eight "frozen" most significant bits define a set of four pixels, and the two running least significant bits cycle through those four. Thus at the right edge of the picture where the active video has been moved to the left due to the scrambling process (see Fig. 1A) opening a gap at the right edge of active video, if the address performs its normal incrementation until the edge of the active video is reached, at that point the eight most significant bits in the pixel value are stopped and the two least significant bits are allowed to run. This generates a repetitive set of four pixels defined by the changing of the two least significant bits. This "pseudo-active" video is stretched as long as desired, defining the desired pseudo-active video fill at the edge of the

picture, i.e. at the end of the active video portion of one line. Similarly, at the left edge of the picture, the eight MSB's are set to the address of the first four pixels of the active video and the two LSB's allowed to run. This "anticipates" the video content of the left edge of the picture in a manner identical to that described above; when the left-edge gap has been filled, the eight MSB's are released or "unfrozen" and the address increments normally.

In a refinement of this edge fill process, to prevent a clever pirate from detecting that at the edge fill each pixel would be identical, a low level and low frequency noise signal is added, i.e. a random noise overlay, so as to slightly disturb the steady state which is the repeated pixel data. This insertion of what amounts to edges, i.e. variation, in that portion of the active video would prevent the pirate from distinguishing the edge fill from the active picture by observing where there is no change. This random noise is provided on luminance and also both portions of the chrominance (for Y, I and Q). Otherwise, an extremely clever pirate could decode all three signals and look for a steady state on any one of them. This random noise is provided in either the digital or analog domain in various embodiments of the invention.

Also in accordance with the invention, the problem of the relative complexity of the three channel NTSC digital decoder as described above and shown in Figures 2A and 2B is overcome by a simplification which only separates luminance from chrominance, thus using only two channels instead of three; thus Y, I and Q instead become only luminance which is Y and chrominance designated C. Luminance is then caused to "wobble" (time shift) in terms of the location of the beginning of active video in each line directly, with the separated chrominance portion identically wobbling and then processed by a heterodyne circuit which frequency stabilizes the chrominance. Thus the processing is done in only two channels - luminance

and chrominance, which saves substantially on the amount of expensive circuit elements provided and improves the tracking of chrominance with respect to colorburst. Additionally, advantageously the reduction of the amount of encoding and decoding for NTSC signals reduces the generation of undesirable artifacts in the picture.

In accordance with another aspect of the invention, a sync "wiggle" is provided as a concealment overlay to the main timeshifting scrambling system. This means that there is a further modification of the video signal which obscures the picture when viewed prior to descrambling, thus preventing an unauthorized person from seeing anything recognizable on the picture if he attempts to view the picture without having descrambled it. This concealment overlay involves in one embodiment time shifting in a pseudo random fashion the location of the horizontal sync signal in each line. In another embodiment, the sync signal location is wiggled in a more complex fashion by using two non-fixed, i.e. genuinely random patterns, hence moving the location of the sync signal in a more complex fashion.

In another version, the sync wiggle also includes a vertical sync wiggle, i.e. the locations of the vertical sync signals in the vertical blanking interval are wiggled in pseudo-random or other fashion in addition to the horizontal wiggle, thus adding a vertical rolling effect to the appearance of the scrambled picture when displayed on a television screen. The resulting patterns tend to roll through the picture vertically, obscuring the picture in two dimensions. In one embodiment the vertical wiggle is performed in a four field sequence in which in the first field the vertical sync is reinserted so as to be advanced, i.e. move forward in time. In the second field the vertical sync is removed. In the third field the vertical sync is reinserted so as to be moved far back, i.e. to the right in time as far as possible. In the fourth field in the sequence again the vertical sync

signal is removed. This process confuses both newer type television sets which have line counters which attempt to track the moving vertical sync and hence will become confused developing a jump, and also, will confuse the older type television sets in which the absence of the sync pulse will cause uncontrollable rolling again completely obscuring the picture.

In accordance with another aspect of the invention, the above-described problem of loss of vertical detail in NTSC decoders is overcome by recovering the missing vertical detail from the pre-existing chrominance channel. This is performed by providing as described above the two separated signals chrominance ("chroma") and luminance ("luma"). The chroma signal also contains the "missing" luma vertical detail. The chroma channel data in the digital domain will in any case be converted to analog form. Then in all portions of the video picture outside the vertical blanking interval the chroma information is low pass filtered to remove the chrominance itself, leaving the missing vertical detail information, which is simply added back into the luma analog signal. This restores the missing vertical detail without any extra, expensive digital processing or extraneous A/D conversion steps.

In accordance with another aspect of the invention, the predetermined slowly varying time shifting function (the wobble) is provided by digitally generating a low frequency, randomly frequency modulated sine wave. This is done by operating a digital counter from a randomly-varying clock source, and applying the output of the counter as an address to a programmable read-only memory (PROM) which holds the sine wave function. Thus at each step the PROM outputs a digital word representing one point on the sine curve. This data is then applied to a digital analog converter providing an analog output signal. In accordance with the invention the above described sine wave would in most cases provide excessive

amounts of information which it would not be possible to process. Thus in accordance with the invention instead the sine wave is sampled at the field rate, i.e. 60 Hz, and only the samples are transmitted. Then the decoder may reconstruct the same sine wave from the sampled data.

The predetermined slowly varying time shifting function, as described above, varies at about 20 Hz or less which is less than half the 60 Hz sample rate, thereby allowing perfect reconstruction of the original sine wave in accordance with well-known sampling theory requirements. Thus in accordance with the invention the digitally generated sine wave from the PROM is latched once per video field, i.e. at 60 Hz, into a latch which holds the digital word to suitable precision over the timed duration of the entire video field. Then once in each video field the data is read out from the latch and applied to a D/A converter, thereby generating an analog-domain version of the sampled sine wave. This wave form is smoothed by a conventional filter and applied to the circuitry which controls the position of the picture in the output video signal.

Simultaneously, the latched digital data is transmitted to the decoder, which then performs in the same order the similar function in extracting the digital word, latching this word and holding it over one video field and applying the data to a digital to analog converter, thus providing the output function which allows descrambling of the signal. The step approximation then is smoothed through an identical RC filter to that in the encoder, thereby restoring an analog type sine wave matching that in the encoder. The decoder has then merely to regenerate horizontal sync, horizontal blanking, and colorburst signals in accordance with the recovered/reconstructed sine wave and insert them into the received scrambled video wave form to complete the descrambling process.

In accordance with another aspect of the invention,

for use with a dedicated video system (non network compatible) the time-shift wobbling of the active video portion of the line is allowed to result in a narrowed horizontal blanking interval. This allows maintenance of the full width of the active video and hence an improved picture at the picture edges. Although such a system would not be compatible with for instance broadcast or cable television, it would be suitable for use with dedicated system such as a video cinema application where transmission is not required, but where it is desired to retain the full width of the picture. Thus it is possible to reduce the duration of the horizontal blanking interval to provide space for the active portion of the video i.e. the picture to "wobble into" without having to lose any portion of the signal thereby. If the width of a horizontal blanking interval is thus reduced, there is still the necessity to transmit an adequate length colorburst portion of the signal. This is performed in accordance with the invention by locating a portion of the colorburst on the front porch of the horizontal blanking interval and the remainder of the colorburst conventionally on the rear porch of the horizontal blanking interval. In a variation, the colorburst can be started on the front porch and allowed to continue all the way through the sync pulse.

Also in accordance with the invention a video inversion picture concealment method is provided wherein on a line-by-line basis particular lines of the picture are inverted in random fashion, i.e. the light portions are dark and the dark portions are light. The pattern of which lines are inverted or not inverted changes in random fashion at a predetermined rate so as to offer the desired degree of concealment. Such video inversion is also relatively secure in the sense that it would be difficult for a pirate to determine in real time whether any particular line is inverted or not and hence it would be difficult to defeat this concealment technique.

Also provided in accordance with the invention is a vertical wobble in the active video in the sense of time displacement of the location of the vertical blanking interval in a slowly varying fashion in succession video fields, analogously to the previously described horizontal wobble.

BRIEF DESCRIPTION OF THE FIGURES

Figures 1A and 1B show scrambled and descrambled signals as disclosed in U.S. Patent No. 5,058,157.

Figures 2A and 2B show a block diagram of a scrambler unit as disclosed in U.S. Patent No. 5,058,157.

Figure 3 shows a flowchart of the scrambling process in accordance with the present invention.

Figure 4 shows a block diagram of a scrambling device in accordance with the present invention.

Figure 5 shows a block diagram of random noise overlay circuitry in accordance with the present invention.

Figure 6 shows a block diagram of the input board portion of the circuitry of Figure 4.

Figure 7A shows a block diagram of the control board portion of the circuitry of Figure 4.

Figure 7B shows the wide band oscillator portion of the circuitry of Figure 7A.

Figure 8 shows a block diagram of the RAM board portion of the circuitry of Figure 4.

Figure 9 shows a block diagram of the output board portion of the circuitry of Figure 4.

Figures 10A, 10B, 10C, 10D, and 10E show spectra depicting a heterodyne function performed by the circuitry of Figure 9.

Figure 11 shows in block diagram form another version of the heterodyne circuitry of Figure 9.

Figure 12 shows a flowchart of the descrambling process in accordance with the present invention.

Figure 13 shows a block diagram of a descrambler in

accordance with the present invention.

Figures 14A, 14B, 14C depict waveforms relating to the descrambler of Figure 13.

Figures 15A, 15B, 15C show the use of pre-burst in the scrambler of Figure 4.

Figures 16A, 16B show block diagrams of descramblers using digital HBI synthesis and interpolation in accordance with the invention.

Figure 17 shows a vertical wobble, i.e. scrambling function, in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

SCRAMBLER OPERATION

Throughout the description following, specified parameters ("eight-bit", "ten-bit", "0-909 counters" etc.) refer to the preferred embodiment of the invention in the particular case of a 4-times subcarrier frequency sampled NTSC-standard unit. The principles described herein are generally applicable to other standards (such as PAL), and other sampling rates by applying detail modifications in accordance with principles well known to those versed in the art.

Figure 3 is a flowchart showing scrambling in accordance with the invention as performed in the scrambling device. Beginning at step 42, the incoming analog video signal is digitized and written into a conventional random access memory. In parallel, the conventional random-number generator generates a randomly varying number in step 44. Then the randomly generated number is converted to an analog waveform and the waveform is used to make the wobbling time base for purposes of video encryption in step 46.

Step 46 generates an analog waveform in conjunction with the randomly frequency modulated sine wave which is used to generate a wobbling time base. In an alternative embodiment, the wobbling time base can be generated digitally, identically to the process described for the

digital descrambler (Fig. 16A). The 1:1880 counter 588 referenced there provides precisely the desired address bus. In step 48, for the digitized video previously written into memory, the luminance Y is separated from the chrominance C by an addition and subtraction process and both of the signals Y, C are read out of memory with the same randomly wobbling timing. This provides both luminance and chrominance which are wobbling. Since there is intrinsically a one line delay in this separation process of step 48, the vertical blanking interval video, which is not scrambled but needs to match time-wise with luminance and chrominance, is delayed by one line in step 50 so as to maintain its time alignment with the luminance and chrominance portion of the signals.

This provides three signals: luminance, chrominance and vertical interval. The luminance signal is wobbling, the chrominance signal is wobbling, and the vertical interval signal is stable in terms of time. There is need then to restore the phase stability of the chroma signal, as is done in the heterodyne process of step 52. Then the composite video signal is reconstructed in step 60 by putting the chroma back on the luma, reblanking, then generating sync. Thus the wobbling luma and the phase stable, heterodyned wobbling chroma are combined and in the vertical interval the output signal is switched over to the stable vertical interval output signal from step 54. In the horizontal interval there is a need to synthesize a sync pulse which wiggles for purposes of concealment. This is done in step 58 where there is synthesis of a position modulated horizontal sync for concealment overlay. This synthesized sync is then added into the composite video signal in step 60.

There is also a need to transmit the information needed for descrambling to the decoder device (not shown). Thus the randomly varying number from step 44 is latched into one line of the vertical blanking interval in step 56. This data is formally encrypted by conventional means

in order to prevent a pirate (unauthorized person) from extracting the randomly varying number.

Figure 4 shows a block diagram of a scrambler for the process of Figure 3. Beginning in the upper left hand portion of Figure 4 the conventional input video signal is input to frame input buffer 66. The conventional clamping and AGC (automatic gain control) processes are performed in block 72. Conventional genlock is performed on the input video signal in block 68 by operating a crystal oscillator at four times the subcarrier frequency which is phase-locked to the incoming colorburst signal. The output of the genlock circuitry 68 is then the write clock signal. The incoming video signal is applied to a video analog-to-digital converter 74, outputting from A/D converter 74 a digitized video signal.

This digitized video signal is then applied to a digital system which includes a one horizontal line buffer 76 providing a one video line delay. Both the input and output of the buffer 76 are provided to adder block 78 and summed therein digitally. The output of adder block 78 is the Y (luminance) signal. Similarly the input and output of buffer 76 are subtracted in subtractor block 80, the output of which is the C (chrominance) signal. Thus the input video signal is separated into a two channel signal i.e., chrominance and luminance. The outputs of adder 78 and subtractor 80 are still stable in terms of time. The output of adder 78 is provided to buffer 82 which is also one video line in length. The output of subtractor 80 (which is the chrominance signal) is provided to buffer 84 which is also one video line long.

Each of buffers 76, 82, and 84 are so-called "ping-pong RAM's" i.e., dual banked random access memories providing double buffering. Thus each of these buffers includes two random access memory banks, one of which is written into and on the next video line the second one is written into while the first one is being read out from. In alternate embodiments, any suitable "real-time" FIFO-

type memory or shift register may be used.

Write address block 70 receives the write clock signal from genlock circuitry 68. Thus the write address block is locked in time to the input write clock signal, and thereby to the input video signal. That write clock signal is four times the subcarrier frequency and is stable so that the luminance and chrominance are written in a stable synchronous fashion to the buffers 82 and 84 respectively.

In order to write to the buffers 82 and 84 three steps are taken. First, it is necessary to apply the signal data which it is desired to write. Secondly, one must supply addresses of the location in the buffers to which the data is to be written to. Third, it is necessary to tell the buffers when the writing is to take place. Thus the write address block 70 also provides the write timing. There is a 10 bit wide address bus from write address block 70 and also a clock line connecting block 70 to each buffer 82 and 84. The write address system i.e., both the address bus and the clock, are stable with respect to the input video signal. The read address (which is provided from read address circuitry 94) and its corresponding clock signal are wobbling in time as described below.

Thus when the contents of the luminance buffer 82 and the chrominance buffer 84 are output with the wobbling address signal from read address block 70, the resultant is a wobbling video signal. At this point luminance and chrominance from respectively buffers 82 and 84 are wobbling time-wise in the digital domain. These two signals are fed respectively to luma digital to analog (D/A) converter 104 and chroma digital to analog (D/A) converter 98 along with the matching clock signals and the address bus data. Thus the output of chroma D/A converter 98 and luma D/A converter 104 are analog signals.

The chroma signal output by chroma D/A converter 98 is heterodyned to achieve phase stability; this function

is performed in the heterodyne block 100 as explained in detail below.

Now referring to the center left hand portion of Figure 4, a randomly varying number is generated by random number generator 88 which outputs a frequency modulated sine wave in the digital domain. This is latched once per video field and provided to data digital to analog (D/A) converter 90 thus providing a stepped approximation of the sine wave. This stepped approximation of the sine wave is smoothed and drives a phase lock loop (PLL) 92 so that the frequency provided out of phase lock loop 92 is tracking the sine wave, i.e., tracking the phase of the phase lock loop, thereby generating a read clock signal which includes the wobble in terms of time. This read clock signal is then applied to a counter in read address block 94. This read address block 94 outputs a running address bus which is applied to buffers 82 and 84 as described above. Read address block 94 is essentially a counter. Thus the read address signal from block 94 is wobbling in time, unlike the write address signal from block 70 which is stable in time. The output of both write address block 70 and read address block 94 are on 10 bit wide buses and the output signals of these two counters 70 and 94 are ramping i.e., counting up.

Thus data is written simultaneously to both buffer 82 and buffer 84 and both buffer 82 and buffer 84 are read simultaneously. The write address bus signals provided from write address block 70 are on a 10 bit wide bus and the data i.e., the addresses, are counting up from 0 to 909 which is the digital length conventionally assigned to one video line, in an NTSC system with a $4F_{SC}$ sampling rate. Similarly, the read address from read address counter 94 is counting from 0 to 909, but the timing thereof varies with respect to the write address by the amount of the wobble which typically varies from +2 to -2 microseconds. Thus another way of describing the wobble is that if one looks at the instant in which the write

address has a value $0F_h$, the read address at that same time would have a different value and might not reach $0F_h$ until 2 microseconds later or perhaps 2 microseconds earlier.

Thus the chroma analog signal from block 98 and the luma analog signal from block 104 are wobbling in time when read respectively in digital form from buffers 84 and 82. As described above, the chroma signal from block 98 must be heterodyned to maintain its relative phase. That is, it is desired to maintain stability of the relative phase with respect to colorburst of the chroma signal, but still to allow the amplitude and phase modulation envelopes to wobble. This is done as described in further detail below by using the read clock signal from phase lock loop 92 which also includes a wobble which is identical to that in the chroma signal, and applying the read clock signal to a double balanced modulator circuit in heterodyne circuit 100. Then if the difference is taken between the two signals, the wobble on the read clock signal is subtracted from the wobble on the chroma signal, resulting in a phase-stable chroma signal with its envelope wobble unaffected.

Also, the digitized video output from buffer 76 is also delayed one line as applied to vertical blanking interval D/A converter 106. The vertical blanking interval data is not wobbling but is stable. Thus the vertical and horizontal blanking interval signals are regenerated in vertical blanking interval and horizontal blanking interval regenerator 108.

Then all three signals from blocks 100, 104, and 108 are combined together in video adder 102 to reform composite video with the vertical interval data inserted during the proper time. Also inserted is the encryption data from encrypt data block 96, which is typically inserted in the region of line 20 of the vertical blanking interval. Then the output of the video adder 102 is provided to output driver 110 (which is a conventional

amplifier) providing output analog video signal as shown.

The various blocks shown in Figure 4 in the preferred embodiment of the invention in the scrambling device are embodied in circuitry conventionally located on various printed circuit boards which include integrated circuits and discrete components. In the preferred embodiment the scrambling device includes four such printed circuit boards, the first of which is the input board which includes input buffer 66, genlock circuitry 68, clamping AGC circuitry 72, and video A/D converter 74. The second board is the RAM (random access memory) board which includes buffer 76, adder 78, subtractor 80, buffer 82, and buffer 84. The third board is the control board which includes write address circuitry 70, randomly varying number generator 88, data D/A 90, phase lock loop 92, read address circuitry 94, and encrypt circuitry 96. The fourth board is the output board which includes chroma D/A 98, heterodyne circuitry 100, video adder 102, luma D/A 104 VBI D/A 100, VBI/HBI regeneration 108, and output driver 110. Each of these boards is discussed below in further detail.

Figure 5 shows the random noise overlay generation circuitry as discussed above which provides the added concealment to the edge fill. There are four different parameters in the edge-fill region that must be randomized for full security: (1) the luminance ("Y"), (2) the in-phase chrominance component ("I"), (3) the quadrature chrominance component ("Q"), and (4) the envelope or timing of the inserted noise ensemble. It should be pointed out that any or all of these may be omitted for a simpler but less secure implementation. Alternatively, the entire system may be implemented as shown but using fewer than four independent noise generators (that is, sharing noise sources), again with reduced effectiveness.

As shown in Figure 5, random noise generator #1 122, and the 2MHz LPF 124 generate random luminance. Random noise generator #2 138 and its associated balanced

modulator 140 generate a random "I" chroma components; random noise generator #3 128, the 90-degree phase shifter 136 and the related balanced modulator 130 generate a random "Q" 136 chroma component; the two are combined in the first summing stage 132 and band-passed 134 to form a totally random chroma signal. The random luma and random chroma are combined in the second summing stage 126 and gated 118 on and off so as to generally fill the "edge-fill" region of the frame. The transition from edge-fill noise to standard video and back again, at the left and right sides of the frame, respectively, must be sufficiently random in time and gentle in amplitude so as not to permit detection; to this end, random noise generator #4 112 generates a random timing function using generator 114 which when filtered 116 is applied to the noise gate 118. The edges of the gating waveform are softened by the 200-nanosecond shaping filter 116 to avoid detectability of the gating function itself, and the resultant gated composite noise waveform is simply added linearly 120 at a suitable low level to the wobbled video signal. The output of the circuit of Figure 5 is provided in the video output board (see below, Figure 9) at some suitable point, for instance into the luma blanking switch stage 414.

Note that the filter characteristics described above are indicative only; other cutoff frequencies, bandwidths and risetimes could be used as the application warrants.

SCRAMBLER INPUT BOARD

Figure 6 shows in detail the circuitry of the input board as discussed above which includes (with reference to Figure 4), input buffer 66, genlock 68, clamping AGC circuitry 72, and video A/D circuitry 74. Each of the blocks shown on input board circuitry in Figure 6 is conventional and well known in the video area. The clamping and AGC circuitry 72 of Figure 4 is shown on Figure 6 as including conventional AGC circuitry 140,

amplifier 144, back porch clamp 146, amplifier 144, second back porch clamp 142 for the AGC circuitry 140, sync tip AGC circuitry 148, white peak AGC circuitry 150 and 5 MHz LPF 154. The processed video is provided to four times subcarrier to the four times subcarrier frequency A/D converter 74 which outputs digital video to the RAM board discussed below. The genlock circuitry also includes the voltage control crystal oscillator 158 which is at four times the subcarrier frequency. This four times subcarrier frequency is then divided by four in divider 160 and provided to a subcarrier phase detector 152 which compares the output frequency from divider 160 to the colorburst of the incoming signal from amplifier 144. Thus this ensures that the voltage control oscillator 158 does operate in exact synchronicity with the incoming colorburst.

Thus the output of voltage control oscillator 158 is the reference frequency which is four times the subcarrier frequency. Also the output of divider 160 is the reference frequency subcarrier signal. Also provided as part of the input board are conventional horizontal timing one shots 164 which are for various internal timing purposes.

The lower portion of Figure 6 shows the digital circuitry for generating the timing pulses for the horizontal reset signal which is provided to the RAM board as described below, as well as vertical timing for various internal purposes ("housekeeping").

SCRAMBLER CONTROL BOARD

Figure 7A shows the control board which includes (referring to Figure 4) the write address block 70, randomly varying number generator 88, data D/A 90, phase lock loop 92, read address block 94, and encryption circuitry 96. Beginning at the upper left hand portion of Figure 7A, the reference 4 times subcarrier frequency and horizontal reset signals are received from the input board

circuitry of Figure 6. These input signals are then provided to the write counter 200 which generates the stable (non-wobbled) write address on a ten bit bus as shown. The output of the write counter is also provided to write EPROM 202 which at the proper point in the video line in response to the count from counter 200 outputs respectively signals for generating the sync gate, burst gate, and the line 20 gate signals, and for resetting the counter itself.

An output of the write EPROM 202 is also provided to read counter 204 for initial synchronization purposes. Read counter 204 outputs a count to the read PROM 206 which in response then generates the phase lock loop gating pulse. Blocks 208 through 230 and including also 258 generate the wobbled read address (RADR) which is used by the RAM board as described below for purposes of scrambling.

The lower line of circuit blocks of Figure 7A provide the sync overlay concealment function i.e, the wiggled sync signal as a fixed pseudo-random pattern. The output CS designates composite sync. Beginning at the left hand portion of the bottom portion of Figure 7A, the input signal is the vertical blanking interval pulse. This signal is used to reset a line counter 262 which is incremented by the write beginning of line (WBOL) command which comes from WBOL comparator 210.

The line counter 262 is used because in this particular embodiment the sync wiggle is provided in a fixed pseudo-random pattern on various lines of each video field. Thus one runs a line rate address count which is provided to a sync pattern EPROM 264 and line-by-line the sync pattern EPROM describes the off-set i.e., amount of wiggle that is desired on the horizontal sync pulse in each line. That offset value from EPROM 264 is applied to sync/burst logic and one shots 266 to generate the actual sync pulses. Circuit 266 is also controlled by two switches one of which is the sync overlay switch which

determines if the sync overlay is functioning or not, and also a sync width switch which determines whether the width of the inserted sync signal is less than nominal. The output of the one shots in block 266 is the CS (composite sync) signal which is provided to the output board as described, and the burst gate signal which is provided to the blanking portion of the blkg/invert logic in order to "unblank" the colorburst. The sync width switch connected to circuitry 266 allows the reduction of width in the horizontal sync signal in order to accommodate the wiggle of sync. This is therefore non-network compatible video, i.e., non-NTSC standard video which in fact can be used successfully by most video equipment including standard television sets, but may upset or be affected by various types of transmission equipment.

The blanking and invert logic 270 receives the output signal from the sync/burst logic one shots 266 for purposes of performing inversion of video for further concealment under control of the attached invert switch. Thus the "invert" line which is one output of block 270 indicates that a given video line is inverted or not. CB refers to composite blanking which is provided as a control line to the output board for determining when to blank and when not to blank. The logic for video inversion as shown in block 270 is that in order to avoid clues to a pirate as to the presence of video inversion, when inverting it is desired that the colorburst remain noninverted. Thus the inverted line must be in its non-inverted position during the horizontal blanking interval. Thus block 270 is gated by both vertical blanking interval and also by the horizontal blanking pulse.

With reference to the concealment by use of overlays, the sync/burst logic and one shots 266 are controlled by a sync overlay switch as shown. It is possible to drive this switch by a random number generator (as described above with reference to Figure 5) thus providing a random

form of sync concealment. This "sync wiggle" has been found to operate well at 330 Hz. This, of course, does not provide any problem in removal of same by the descrambler which invariably regenerates new sync for each blanking interval in any case. Also, in accordance with the invention it is a further modification to "double-wiggle" the horizontal sync using two dissimilar frequencies to provide further concealment as in Figure 5. Furthermore, it is also possible at the same time to vary the location of the vertical sync signals, i.e, a vertical sync wiggle, which would add further concealment.

The second to last row of circuit blocks in Figure 7A begins with the random clock generator 240 which provides (in response to write address signals) random numbers to frequency modulated counter 242 which then causes the sine EPROM 244 to output an 8 bit data word to vertical latch 246. The sine EPROM 244 is controlled by a switch PK which enables or disables the EPROM and thereby turns the basic wobble "on" or "off." The 8 bit data word from the sine EPROM 244 is also encrypted in encryptor 271 and provided to a parallel to serial converter 272. Thus the 8 bit words output by the sine EPROM 244 are put into serial form and inserted as data on line 20 or thereabouts, as the application suggests, of the vertical blanking interval of each video field for transmission to the descrambler for descrambling purposes. Then the descrambler (as described below) removes the 8 bit data words, decrypts them and applies them to an identical set of circuitry for purposes of descrambling.

Frequency modulated counter 242, applied to sine EPROM 244, generates a randomly FM'd sine wave output, typically in the region of 3-15Hz. The output of vertical latch 246 when enabled at line 19 of the VBI is then provided to digital to analog converter 248 to output an analog signal which is then smoothed by a conventional RC low pass filter 250 with a time constant of the order of 10 milliseconds, and provided to comparator 252, the

second input of which is connected to a ramp generator 258 which provides in response to write address 7 line a ramp or "sawtooth" wave form at a rate of four times horizontal frequency.

Thus comparator 252 generates a set of moving edges which are moving in time exactly as it is desired for the picture to wobble. The 4H phase detector 254 compares those moving edges to a phase lock loop (PLL) gate signal from EPROM 206, thereby locking the read clock and the read address to those edges by means of error amplifier 256. The output of the error amplifier 256 is the amplified output of phase detector 254 which is provided to voltage controlled crystal oscillator 258 which is designated as the "read" oscillator and is operating at four times the subcarrier frequency (fsc). The output of voltage oscillator 258 is the read clock (RDCK). This read clock signal is thus wobbled i.e., operating at exactly four times subcarrier frequency but displaced from its nominal location by up to ± 2 microseconds as controlled ultimately by the action of random number generator 240.

Thus read oscillator 258 provides a wobbled read clock signal RDCK, which is in contrast to the analogous oscillator 158 which provides a stable reference signal of 4 times subcarrier frequency reference signal. Thus these two oscillators 158 and 258 one of which (158) is stable and one of which (258) is wobbling provide timing signals applied to respectively the write counter 200 and the read counter 204 of Figure 7a. Both counters 200, 204 are divide by 910 counters (since there are 910 cycles of four times subcarrier per NTSC video line); thus counters 200 and 204 are both running at the video line rate. This is conventional except that the read counter 204 is wobbling. The outputs of counters 200, 204 are provided respectively to the write address bus WADR which is stable and the read address bus RADR which is wobbled. Each of these buses are 10 bit width buses as shown.

With regard to the remainder of the circuitry shown in Figure 7A, as discussed above if the active portion of the video on each line is moved to the right a gap is developed on the left edge which must be filled in; thus there are two points of interest in time at the left edge of each video line. The first point of interest is when it is needed to have the video (at the beginning of the gap) and the second time is when the video will be available (the end of the gap.) In between those two defined times it is necessary to provide an "edge fill" signal resembling the active video. It will be seen that these two times correspond respectively to the beginning of the active line for the write cycle and the beginning of the active line for the read cycle. It will be seen that an identical situation occurs on the right side of the picture when the picture is moved to the left. In this case the two times of interest are (a) when the read video has been exhausted and (b) when the video is no longer required. These two times correspond respectively to the end of the active line for the read cycle and the end of the active line for the write cycle.

The problem is that the read system and the write system are asynchronous, meaning that they cannot remain in the proper time relationship. Thus an interface is provided in which the address or addresses that are the desired beginning and end of the lines i.e., "BOL" and "EOL" for the write system and for the read system are defined. Then the write end of line (WREOL) comparator 208, the read end of line (RDEOL) comparator 209 and the write beginning of line (WRBOL) comparator 210 and the read beginning of line (RDBOL) comparator 212 compare the actual addresses coming out of the read counter 204 and the write counter 200 to the preset values corresponding to the desired read & write BOL & EOL. When these addresses match the preset values, that says that each counter has reached the point where it is desired to start filling in the active video, or has reached the point

where it is no longer necessary to continue to fill in the video because now the actual active video is being provided (on the left edge) or the beginning of horizontal blanking interval has been reached (on the right edge).

Block 218 is the "fill end-of-line" one-shot circuitry, and below that is the "fill beginning-of-line" one-shot circuitry 222. For the left edge, the write beginning of line comparator 210 defines the left edge of the active video where it is desired to start the filling process. The read beginning of line comparator 212 determines when it is possible to stop the filling i.e., edge fill process. Thus both the outputs of comparators 210 and 212 are provided to the fill beginning of line one shots 222 and the output of one shots 222 is a pulse which is high only when is necessary to fill the left edge of the line. Thus the end of that pulse is moving with the wobble. On average, half the time that pulse is not provided because it is not necessary to fill in the left edge of the line because the picture has been moved to the left instead of to the right.

For the right edge of the picture, the fill end of line one shots 218 similarly are controlled by the write end of line comparator 208 and the read end of line comparator 209, and provide an analogous output signal looking for the end of each video or an active portion. Thus the "fill end-of-line" one-shots 218 generate a single pulse that is high when it is desired to fill the end of the line. The output of one shot circuits 218 and 222 are displaced from one another by the width of horizontal blanking; the inner edges correspond to the edge of formal blanking and the outer edges correspond to the edge of the moving active portion of video.

The portion in between the two pulses is the region in which a stable colorburst must be generated which matches in amplitude and phase the moving colorburst which intrinsically results from the wobbling read cycle. The "fill burst" flip flop is set by the trailing edge of the

EOL pulse and reset by the leading edge of the BOL pulse. The "end-of-line" tri-state 228 looks at the address defined as the read end-of-the-line (that is, the address which is to be used to fill the right-side gap period,) and similarly the "beginning-of-line" tri-state 224 provides an analogous signal for the left-side gap. For the "fill burst" region the address used is that of the center of colorburst. Thus under control of the command signals from the one shots 218 and 222, an address is either provided at the end of line or the address of the middle of the colorburst or the address of the beginning of the line as provided on the bus which is connected to the eight most significant bit read address select circuitry 230.

Note that all of the busses in the central portion of Figure 7A are only eight bits wide, because it is the two least significant bits of the ten bit address system which are allowed to run (as described above). Thus the select circuitry 230 selects between three fixed addresses corresponding to the end of line, the colorburst, and the beginning of line. The burst (colorburst) tri-state 226 as shown is controlled by the output of the fill burst flip-flop and also by the burst address. The effect of setting the eight MSB's of the address buss to the address corresponding to the center of colorburst is to fill the entire read-cycle HBI with a continuous sine wave exactly matching the input colorburst, regardless of the wobble state. The desired output colorburst can then simply be gated out. Thus the select address provided on read address bus RADR switches between the actual running address count from the read counter 204 and the static states which are the output of the select circuit 230, which runs normally during active video but is frozen at the end of line, or beginning of line, and in the middle of the burst. Thus the ten bit read address is wobbled and at the desired intervals stops to perform the fill process.

The four times subcarrier frequency voltage controlled crystal oscillator 258 of Figure 7A also described with other embodiments in copending and commonly owned U.S. patent application serial no. 07/860,643 entitled "Wide Frequency Deviation Voltage Controlled Crystal Oscillator", inventor Ronald Quan, attorney docket no. M-1854, incorporated herein by reference. Figure 7B of the present disclosure is one embodiment of the wide frequency deviation voltage controlled crystal oscillator. In Figure 7B the output signal ("OUT") corresponds to the wobbled read clock (RDCK) of Figure 7A and the voltage control input ($V_{CONTROL}$) corresponds to the output of error amp 256 of Figure 7A.

With reference to Figure 7B, first crystal 313 is connected in series with resistor 312. The series combination of resistor 312 and crystal 313 is driven by a first driving transistor 325. Current supplies 327 and 328 connect the emitters of transistors 325 and 326 to a negative supply voltage V_{EE} and the collector of transistor 325 to a positive supply voltage V_{CC}. The phase control circuit includes a varactor (voltage controlled variable capacitor), diode 320 along with capacitors 321, 322 and 323 and an inductor 324. The phase imposed by the phase control circuit is varied by adjusting the $V_{CONTROL}$ which changes the capacitance of the varactor diode 320. Diodes 329, 329' limit the amplitude of the oscillations in the circuit.

A second transistor 325', a second crystal 313' and a resistor 312' are coupled to common base amplifier transistor 326 emitter transistor 325, first crystal 313 and first resistor 312. The emitter of transistor 325' is connected to a current source 327' to negative supply voltage V_{EE}, and a collector of transistor 325' is connected to positive supply voltage V_{CC}. Crystals 313 and 313' are driven in-phase with each other. The varactor diode 320 has a relatively low ratio (i.e. 2:1) of maximum to minimum capacitance.

The resonant frequencies of crystals 313 and 313', respectively, are selected such that they are spaced at a predetermined interval (e.g. 3 KHz). The value of resistors 312 and 312' is typically about 150 to 300 ohms. Unity-gain buffer 330 provides the output signal.

SCRAMBLER RAM BOARD

Figure 8 depicts in detail the RAM board which includes certain blocks of Figure 4 including buffer 76, adder 78, subtractor 80, Y buffer 82, and C buffer 84. As shown in Figure 8, there is an input latch 340 (not shown in Figure 4) receiving the video from the input board and supplying same to ping-pong RAM buffer 342, 344. Adder 78 and subtractor 80 as shown in Figure 8 are the same as in Figure 4. The buffer 82 for the Y luminance channel of Figure 4 in Figure 8 is shown as a ping-pong RAM including dual RAM banks 350 and 352 each of one horizontal line (1H) length. Similarly, the buffer 84 for the chrominance channel of Figure 4 is shown in Figure 8 as being ping-pong RAM 360, 362.

Both the luma and chroma channel which are desired to be wobbled must switch from the write address system to the read address system because the write address and the write clock are stable as coming in, i.e. WADR and WRCK, whereas the read address RADR and read clock RDCK are both stable. The selector circuits 354 and 364 steer the clocks and address busses respectively for the luma channel and the chroma channel so that at any given video line one of the buffers in each pair of buffers 350, 352, and 360, 362 is writing and the other is reading. The horizontal blanking interval reset signal is provided to the 1H flip-flop 356 for control of the select circuitry 354 so that the buffer pairs alternate reading and writing appropriately.

SCRAMBLER OUTPUT BOARD

The output board portion of the block diagram of

Figure 4 includes the chroma D/A converter 98, the luma D/A converter 104, the vertical blanking interval D/A converter 100, the heterodyne circuit 100, the video adder 102, the output driver 110, the VBI/HBI regeneration 108.

As can be seen in Figure 9 showing the output board, the luma DAC (digital to analog converter) 104, VBI DAC 106, chroma DAC 98, and output driver 110 are the same blocks as in Figure 4. Additionally, Figure 9 shows the line 20 data at the upper left hand portion of the figure which is provided as discussed above from the control board of Figure 7A going to a line 20 inject circuitry 400 which is then provided to luma blanking switch 414. Additionally, the video invert signal also provided as shown in the lower right hand portion of Figure 7A is provided in the upper left hand portion of Figure 9 to the luma DAC 104 which also receives the luma digital signal from the RAM board output bus as shown. Additionally, the digitized vertical blanking interval signal from the RAM board (which is time stable) is provided to the VBI DAC 106 and the chroma digitized signal from the RAM (which is wobbled) is provided from the RAM board also to chroma DAC 98; the chroma DAC is controlled by the source video invert signal as is the luma DAC.

The VBI switch 406, controlled by the VBI signal, switches in the vertical blanking interval as desired in the appropriate portion of the signal. The output of VBI switch 406 is then filtered by a conventional inverse sine X/X type filter to compensate for sampling-induced high frequency roll off. The output of the filter 410 is then provided to summing amplifier 412. The output of summing amplifier 412 is provided to the luma blanking switch 414. The "fill burst" action replaces the entire HBI signal with continuous burst at the output of the RAM board. The action of the luma blanking switch is to re-insert H blanking and H sync, and to get the continuous burst to form the expected colorburst, thereby regenerating the desired HBI format. The output of luma blanking switch

414 is then filtered by low pass filter 416 for removing the extraneous sampling sidebands frequencies above about 5 MHz. The output of low pass filter 416 then is provided to the output driver amplifier 110.

Similarly, the output of the chroma DAC 98 is connected to vertical blanking interval switch 420 for switching out the chroma signal during vertical blanking. The output of the vertical blanking switch 420 is then subject to low pass filter 422 to remove the chroma frequencies above about 2 MHz and then also subject to the black clipper 412 and hence follows the same path as described above for the luma DAC.

With regard to restoration of the vertical detail from the chroma channel output, this is performed by the output board circuitry of Figure 9. As shown, this takes place except during vertical blanking under control of vertical blanking switch 420 which switches out chroma during vertical blanking. This chroma signal during the active video portion of the line is filtered by low-pass filter 422 and black clipped at summing amplifier 412 and recombined with luma, thus restoring the missing vertical detail. This is because the missing vertical detail appears in the chroma channel, so low pass filtering removes the chroma content, leaving only the vertical detail, and adding it back to the luma channel restores the missing vertical detail. Sync shaper 426 and blanking shaper 428 convert the logic-level CS (composite sync) and CB (composite blanking) signals to analog signals of the required levels and having the standard rise and fall times, i.e., 140 microseconds for NTSC.

The lower part of Figure 9 is the heterodyne circuit 100 of Figure 4. As shown, analog chroma data from chroma DAC 98 is provided to an inverse sine X/X filter 424 to restore losses in high frequencies due to sample and holding in A/D. This filtered chroma signal (which is wobbling in time) is not however at the nominal 3.58 MHz subcarrier frequency. Thus this signal is provided to

balance modulator 438 for further processing.

Subcarrier frequency voltage controlled crystal oscillator 450 is part of a loop including subcarrier frequency phase detector 446 which drives error amplifier 448 which in turn drives subcarrier frequency voltage control oscillator 450. The output of frequency control oscillator 450 is divided by 2 by divider 452 to provide a frequency one-half of the subcarrier frequency. The output of divider 452 is provided to two band pass filters 436, 454; the first filter 436 passes only the fifth harmonic of half of the subcarrier frequency i.e., 5/2 Fsc. The second band pass filter 454 is passing only the third harmonic, i.e. 3/2 Fsc. Band-pass filter 454 then outputs the stable carrier 3/2 F_{SC} signal which is applied to balance modulator 456 which mixes this with the divided-by-4 Read clock signal (RDCK) which is wobbled and is equal to (four times the subcarrier frequency/4).

This RDCK signal is divided by four at divider 458 thus outputting the wobbled subcarrier frequency, which at balance modulator 456 is modulated with the 3/2 of the subcarrier frequency. The output of balance modulator 456 is then filtered at band-pass filter 460 to select the 5/2 of subcarrier frequency (upper sideband) which contains the wobbled subcarrier frequency. In the figure, this is labeled "wobbled carrier" and is then applied to balance modulator 442.

The upper arm of the heterodyne circuit as shown accepts the fifth harmonic of the stable subcarrier frequency divided by 2 from band-pass filter 436 and modulates that at balance modulator 438 with the wobbled chroma from filter 424. The output of balance modulator 438 is then filtered by band-pass filter 440 (having a pass band about 3 MHz wide) to select the 7/2 of the subcarrier frequency. The output of band-pass filer 440 is then 7/2 of subcarrier frequency (upper sideband) which contains wobbled chroma, which when mixed in balance modulator 442 with the wobbled carrier provides a stable

chroma signal at 3.58 MHz (to the chroma blanking switch 430) via lower sideband output of balance modulator 442.

The object of this heterodyne circuit is that the amount of wobbling (jittering) of the video line is well known via the master clock, via the read clock (RDCK) timing signals. That is, this master clock's signal is actually tied to the changes in frequency in proportion to the changes in the scrambled chroma frequency, i.e., the wobbling. Thus this read clock signal can be used as a form of cancellation to remove the wobbling from the chroma signal in terms of the frequency. As shown, the burst signal which helps control subcarrier frequency phase detector 446 is the colorburst signal from the output video. The video output colorburst thus matches the input video source colorburst.

The operation of this heterodyne circuit is shown with further reference to the frequency spectra of Figures 10A through 10E. Starting with Figure 10A, the input program chroma signal (prior to scrambling) is shown distributed over a spectrum centered at 3.58 MHz i.e., the subcarrier frequency. Upon scrambling in Figure 10B, the wobbling chroma which is provided from the chroma DAC 98, is shown "jittering" (wobbled) by ΔF and having a center frequency of 3.58 MHz $\pm \Delta F$. The master clock at the same time is "jittering" (wobbling) by exactly the same amount at four times the subcarrier frequency, i.e., centered at 14.32 MHz with a jitter of 4 times ΔF, as shown in Figure 10C. This is because the wobble in the chroma is exactly one-quarter of the master clock.

As shown in Figure 10D, by band-pass filtering the heterodyne circuit selects 7/2 of subcarrier frequency which confirms wobbling chroma and the 5/2 of subcarrier frequency, both of which include the same amount of wobble, i.e., $\pm \Delta F$.

Thus by subtracting out (modulating and selecting the lower sideband) the 7/2 of subcarrier frequency chroma from 5/2 subcarrier frequency (both of which include the

ΔF wobbling), one arrives at the output of the low-pass filter which is a stable 3.58 MHz and which is the desired stable chroma signal.

Figure 11 shows a different version of the heterodyne circuit in accordance with the invention as applied to the above-described scrambling system. As shown, the master clock varies in frequency by ± 4 times ΔF due to the scrambling process, in order to cause the desired wobbling in the video thereby scrambling the video. The "program in" video is digitized by the A/D converter in block 470 and separated into the Y (luminance) and C (chrominance) channels, each of which is processed to be wobbled by the master clock by ±4 ΔF. After the master clock varies both Y and C components i.e., wobbles them in a time-varying way, the C chrominance component has color frequencies that are undesirably not stable ("jittered"). Thus the object of the heterodyne circuit is to stabilize the scrambled chrominance component frequency so that the television receiver can view the color with use of a simple low-cost descrambling device.

It is known that the master clock is at 4 times subcarrier frequency ±4 ΔF. As shown, after the digital processing, both the Y and the C signals are converted back to analog by D/A converters in block 470, thus outputting the so-called "Y" jittered (wobbled) signal and the "C" jittered (wobbled) signal which is the undesirably unstable carrier frequency. The heterodyne circuit at the lower left-hand portion of the figure applies the master clock signal (which is also designated the RDCK signal) which is divided by 4 at divider 474 and which is then multiplied by a stable 3/2 times the subcarrier frequency by balance modulator 476. As noted, the subcarrier frequency is 3.58 MHz. The upper sideband of the output of balance modulator 476 is selected by band-pass filter 478 to obtain 3/2 of the frequency subcarrier plus the subcarrier frequency ± ΔF. At the same time the C' (wobbled chroma) component which is subcarrier frequency ±

ΔF is first filtered at hand pass filter 482 by the inverse sign X/X filter 424 of Figure 9. The output of band-pass filter 482 is then multiplied by a stable 5/2 subcarrier frequency signal at modulator 484 and the output of modulator 484 is filtered at band pass filter 486 to pass the upper side-band to provide 7/2 times the subcarrier frequency ± ΔF.

As noted above (see Figure 9), the stable 3/2 subcarrier frequency and 5/2 subcarrier frequency are provided from a phase-locked voltage controlled oscillator that is locked to incoming stable video color frequency, i.e., the reference subcarrier frequency. The outputs of band-pass filters 478 and 486 are multiplied by balance modulator 480 and then filtered at band-pass filter 488 so that the lower sideband output is a chroma signal at frequency subcarrier which is free of the ±ΔF wobble. As shown in Figure 9 (but not in Figure 11), the burst from the output low pass filter 432 is sent back to the phase detector 446 to phase lock the subcarrier frequency voltage control oscillator 450 to incoming video color frequency. As shown in Figure 11, the output chroma signal from band-pass filter 488 is then added by a video adder to the wobbled luminance signal Y', the output of which is low-pass filtered at 490 to provide the output video which includes the wobbled luminance signal and a wobbled chroma signal with stable subcarrier frequency.

In conventional heterodyne color stabilizers the master clock/4 is really the colorburst from the input video. This could have been done here as well in a similar way by taking the wobbled colorburst from inverse Sin X/X filter 424; but the color chroma stabilization would not have been as effective and thus chroma would be more unstable. For the best chroma stability RDCK (unique to this system) is used as described above.

With regard to the above-described heterodyne circuit, its applicability is in addition to use in scrambling. For instance, it is suitable for use with any

sort of video processing which involves time-base errors.

DESCRAMBLER

The wobbled video output signal from the encoder or scrambler circuitry of Figure 4 is transmitted conventionally by coaxial cable, satellite, broadcast television, cable television or otherwise to a descrambler (decoder), which typically is located in a home and the descrambled output of which is connected to a conventional home television set or monitor. One of the objects of the present invention is to provide a system which is highly secure, offers adequate concealment, and yet compatible with a low cost and reliable decoder. This is because there are thousands or tens of thousands of decoders made and used and hence, is essential that they be relatively low cost and require little servicing since they are located at the home. Note that this is not the case with the scrambler which is typically located at a head-end and of which there are relatively few (one per TV channel) in any one television system.

Figure 12 is a flowchart of the descrambler signal processing. In step 500 the scrambled video is received and the encrypted random number (which is the decoding seed) extracted. From this extracted number, in step 502 the random number is decrypted and converted to an analog wave form. Then in step 504, this analog wave form generates a wobbling time base which tracks the input video, i.e., includes the information necessary to indicate exactly how the video is wobbling. From that data it is possible to synthesize in step 506 the required wobbling horizontal sync, blanking, and colorburst. In step 508 the input signal's complete horizontal blanking interval is replaced with a complete synthesized wobbling horizontal blanking interval made up from the synthesized sync, blanking, and colorburst which tracks the video, thus allowing the signal to be viewed on a conventional television receiver.

Figure 13 shows in block diagram form one embodiment of the decoder for performing the processing of Figure 12. In the upper left hand portion the scrambled video input signal is provided to an input buffer 520. In the descrambling data path, the data is extracted by data extractor 522 and then conventionally decoded by decryptor 524. The data has been converted from digital to analog form in block 526, smoothed by low pass filter 528 and provided to comparator array 530.

Meanwhile phase lock loop 534 is locked to the horizontal line rate of incoming horizontal sync, to drive an analog ramp generator 536. The comparator rate 530 then compares the horizontal ramp with the varying DC (direct current) signal coming out of low pass filter 528 to provide a moving edge at the point at which they cross, i.e. where the comparison is made, from which edge it is possible to time scale all elements of the horizontal blanking interval.

This comparator data is then used to generate burst, horizontal sync, and blanking pulses using colorburst regenerator 542 and horizontal blanking interval regenerator 544 which are applied to video switch 548. Video switch 548 switches between the active video which (with one exception) is not to be processed by the descrambler and the horizontal blanking interval which is processed by the lower portion of the circuitry of Figure 13. The video switch 548 is driven by the regenerated horizontal blanking.

The input video from buffer 520 is processed by the descrambler only to the extent that the video is re-inverted wherever it has been previously inverted by the scrambler in order to restore the original video. This now fully non-inverted video is provided to video switch 548, the output of which then is provided to output driver 550 for the video output to the TV receiver or monitor.

The analog ramp generator 536 generates a series of waveform ramps as shown in Figure 14A which are clocked

with horizontal sync from PLL 534. As shown in Figure 14A each ramp has the duration adequate to cover the entire regenerated HBI including the wobble -- that is, around 20 microseconds. Thus the comparator compares the ramps with a reference voltage which is shown as a horizontal line in Figure 14A. The comparator provides as output the square pulses shown in Figure 14B each of which is wobbling in time synchronously with the wobble present in the input video, as shown by the horizontal arrows at the leading edge of each horizontal pulse in Figure 14B.

As shown in Figure 14B, there is one such square pulse output of the comparator for each video line. Thus this edge moves in time synchronously with the wobble. Then using the single wobbling edge for each line as shown in Figure 14B, it is possible fully to reconstruct the horizontal blanking interval, as shown in Figure 14C by the vertical arrows which indicate six edges which are: (1) the leading edge of horizontal blanking; (2) the leading edge of the horizontal sync pulse; (3) the trailing edge of the horizontal sync pulse; (4) the leading edge of colorburst; (5) the trailing edge of colorburst; and (6) the end of the horizontal sync pulse. In accordance with one embodiment of the invention, this is done by providing an array of six different comparators each with an offset to the preceding one. Alternatively a single comparator would generate the first edge and then a sequence of timed one-shots would provide the other five edges of the horizontal blanking interval.

The chief task of the descrambler, in addition to removing the inversion of the active portion of the video, is to generate a horizontal synchronization pulse which moves in exact synchronism with the time induced wobble and a colorburst which moves in exact synchronism with the time-induced wobble. The restoration of the sync pulse is relatively straightforward, but the restoration of the colorburst is more difficult as shown with reference to Figure 1B. In line N the colorburst occurs in time

advanced as regards to location of the colorburst in line N+1 and the colorburst in line N+2 is retarded relative to the location of the colorburst in line N+1. Thus the descrambler must provide a sine wave which matches in amplitude and phase a colorburst which has not yet occurred for certain particular lines.

Thus the circuitry must anticipate the location of colorburst for particular lines. This is performed in the descrambler in one embodiment by using the colorburst to ring a crystal filter in the burst regenerator 542 of Figure 13, so that the filter rings at the same amplitude and phase for an entire line thus generating a continuous wave having the same amplitude and phase as the colorburst. This typically requires two cascaded oscillating crystals to provide a filter that rings well enough (that is having a high enough Q) so that the output has not dropped away to zero prior to the end of the video line.

One improvement in accordance with the invention over use of these two cascaded crystals is to provide a non-standard form of the colorburst, by dividing the colorburst into two portions (or more) in the scrambler. Figure 15A shows a conventional RS-170A horizontal blanking interval with colorburst ("burst") on the back porch. Figure 15B shows in accordance with the invention that instead a first portion of the burst is a pre-burst portion provided on the front porch of the horizontal blanking interval of each video line, with the remaining of the colorburst located conventionally on the back porch of HBI. Thus there would be no need to make the crystal filter ring for more than about 5 microseconds i.e., not even the full duration of horizontal blanking. This has the advantage of allowing use of a simpler and less expensive descrambler, but is a non-standard format due to the need for the provision of the pre-burst. This, therefore, is a non-network transparent, i.e., non-NTSC compatible system suitable for use with for instance a

video cinema application.

An alternative approach (shown in Figure 15C) is to superimpose a continuous "colorburst" upon the entire HBI -- that is, start "burst" at the beginning of blanking and let it run all the way through, adding the sync pulse linearly.

DESCRAMBLER WITH DIGITAL SYNTHESIS OF HBI

The above described descrambling process involves synthesizing (regenerating) horizontal sync, blanking, and colorburst that track the video "wobble", and replacing the incoming standard sync, blanking and burst with them to form a video signal having a unified time-base variation (the "wobble"), which the TV receiver can track in order to present a stable, "descrambled" picture.

In another embodiment those sync, blanking, and burst signals are generated digitally in the descrambler. The subsequent insertion into the analog signal, and all of the video signal processing (clamping, AGC, inversion, etc.) remain in the analog domain as with the above described "analog" embodiment of Figure 13.

The following circuitry is for NTSC; PAL works similarly but with different numerical values, as will be apparent to one skilled in the art. The horizontal offset required for each line's horizontal blanking interval (HBI) is mathematically calculated based upon some suitable interpolation algorithm from the field-rate data byte sent in the vertical interval. That offset is applied as a preset or preload to a "divide-by-1820" counter running at 8 times subcarrier frequency, nominally organized so that the counter counts out the entire line -- that is, the count of 1820 takes 63.555 microseconds. It will be seen that, if the counter is preset with a value of, say "10", the counter will finish with its count to 1820 in a time 349 nanoseconds sooner than if it had not been so preset. If the counter is in fact designed to count to 1880, and provision made for preloads ranging

from 0 to 120, the net effect is that the line-time as set by the counter can be varied by ±2 microseconds, in increments of 35 nanoseconds.

In practice, with the present scrambling process, the line-to-line variation of line length is no more than 10 nanoseconds; thus the counter need only achieve a count of 1820 +/- 1, or 1821 with a preset ranging from 0 to 2. (It will be seen that the time offset accumulation over 240 lines in a single frame, at 10 nanoseconds/line, is 2.4 microseconds).

Then referring to the block diagram of Figure 16A, the top row of blocks is the analog video processing corresponding to the similarly numbered elements of Figure 13. In the second row, an oscillator 578 operating at 8*Fsc is phase-locked to incoming colorburst by the subcarrier PLL 576. Its output is divided by eight at divider 580 to produce a 3.58 MHz signal which is gated by burst gating 582 to form the new colorburst, as well as providing a clock for the 1:1880 counter 588.

In the third row, the data byte in the vertical interval is separated from the incoming video and decrypted in block 584, and supplied to the line-offset calculator 586 (a microprocessor). The calculator 586 calculates in real time the line-by-line offset required to fit the vertical-rate data byte, and supplies that number (still in real time) to the divide-by-1880 counter 588. The calculator 586 can be simple since at most it only has to calculate one number to eight-bit precision every 63.555 microseconds; moreover, it will generally have at least four lines (or 245 microseconds) in which to work. In an alternative embodiment of Figure 16B (otherwise similar to that of Figure 16A), in order to reduce the required clock speed without degrading the fineness of time resolution, the system runs at 4* Fsc instead of 8* Fsc, and the counter is preloaded with only the 7 most significant bits of the offset word. This limits the shift to a minimum increment of 70 nanoseconds;

the last bit (LSB) which defines the 35 nanosecond shift is used to invert the clock in an XOR gate 587. The inversion causes the "trailing edge" to be the active edge instead of the "leading edge", into latch 589, and thereby shifts the latch output by the desired 35 nanoseconds.

Referring to both Figures 16A and 16B, the 11-bit output of the counter 588 is conventionally decoded at edge decoder 590 to provide six timing edges corresponding to leading and trailing edges of the desired sync, blanking, and burst gate pulses; it will be seen that these edges are moving, as an ensemble, with the declared "wobble" due to the line-rate varying preset to the counter. The timing edges are conventionally applied to three R-S flipflops 592 to generate the actual pulses. In practice, additional "house-keeping" pulses can be similarly decoded and formed as required.

In the fourth row, the sync signal is separated at sync stripper 594 from the video and separated further into horizontal and vertical sync pulses at separation block 596. The horizontal sync is used to reset the 1880 counter 588; the vertical is used to reset a divide-by-525 counter 596, which is clocked by horizontal sync and used to count lines in the frame in line number decoding block 600 for various house-keeping purposes -- in particular, to inhibit the HBI regeneration process in block 544 during the 22 lines of the vertical interval.

VERTICAL SYNC TIMESHIFT SCRAMBLING

The object of this embodiment is to cause the picture wobble in the vertical as well as horizontal. The implementation requires only that the present one-line memory (RAM) which drives the adder 78 and subtractor 80 on the RAM board be extended to something like twenty-one lines, with provision to select the output of any of the twenty-one lines randomly. In practice, then, compared with the video out of the eleventh of the twenty-one memory stages, video from the first is advanced by ten

lines and video from the last is delayed by ten lines; twenty lines peak-to-peak out of 240 active lines per field compares directly to 4 microseconds horizontal motion out of 52 microseconds active picture width. A second randomly frequency modulated digital sine-like signal (analogous to the one which varies the read address for horizontal wobble) is used to select the output of different pairs of 1H buffer delays to be applied to the adder and subtractor for Y/C separation.

The number of 1H memory buffers can be varied for different applications and any suitable rate of variation can be used; in particular the rate of variation can be randomly controlled as with the horizontal scrambling of the Figure 4 system, in which case a second byte of data would be added to the vertical interval to describe the vertical variation, analogous to the first byte used to describe the horizontal variation. The second byte would of course be encrypted like the first byte.

Figure 17, shows such a system with a 5-line variation and replaces <u>in toto</u> the block 76 labelled "1H BUFFER" of Figure 4. Figure 17 shows portions corresponding to the circuitry of Figure 9 including video A/D 74, adder 78 and subtractor 80. Five 1H buffers 602, 604, 606, 608, 610 replace the single 1H buffer 76 of Figure 4. The buffers 602, ..., 610 are selected according to a randomly varying number generated by random number generator 612, which as described above generates a frequency modulated digital sine wave-like signal to select one of buffers 602, ..., 610 for each video field thus randomly varying the amount of vertical timeshifting. In any case, for the selected buffer, the adder 78 and subtractor 80 are driven with the selected buffer's input and output, analogously to the circuit of Figure 4. Thus at all times the adder 78 and subtractor 80 are presented with two video signals differing by exactly one line (1H) and thus the Y-C separation proceeds uninhibited.

Descrambling requires simply that the vertical sync

signal be wobbled to match the picture, analogously to the above-described horizontal wobble; TV sets, monitors or projectors which use line-counting vertical deflection systems would be modified to accept a time-varying line-count, while the older multivibrator-based TV units would require no modification.

Edge-fill provisions similar to those described above are used to fill the top of the frame when the picture is shifted downward and the bottom of the frame when the picture is shifted upward; minor variations of the above described edge fill circuitry accomplish this.

The above description of the invention is illustrative and not limiting; further modifications will be apparent to one of ordinary skill in the art in the light of this disclosure and the appended claims.

CLAIMS

We claim:

1. A method for restoring vertical detail in an NTSC television decoder where a video signal is separated into a luma signal and a chroma signal, comprising the steps of:

selecting the active video portions of the separated chroma signal;

filtering away high frequency parts and thereby the chroma portion of the selected active video portions; and

combining the remaining portions of the chroma signal which consist of the desired vertical detail, with the luma signal.

2. The method of Claim 1, further comprising adding the chroma signal back to the combined signal to provide an output signal.

3. The method of Claim 1, wherein the step of filtering removes those parts of the signal exceeding approximately 2 MHz.

4. A method for modifying a scrambled standard television signal by use of a shortened horizontal blanking interval for receipt by a descrambler where the descrambler regenerates the colorburst portion of the signal, comprising the steps of:

extending an active video portion of at least one video line of the television signal into a horizontal blanking interval of the standard television signal;

providing a first portion of the colorburst for that line on a front porch of the horizontal blanking interval; and

providing a second portion of the colorburst for that line on a rear porch of the horizontal blanking interval.

5. The method of Claim 4 wherein the colorburst begins on the front porch and extends through the horizontal sync pulse of the horizontal blanking interval, thereby filling the entire horizontal blanking interval with colorburst.

6. The method of Claim 4, wherein both steps of providing comprise the steps of:

generating a colorburst signal extending a full width of the horizontal blanking interval; and

switching the colorburst into the video signal only at a portion of the front porch and a portion of the rear porch.

7. A method of providing a scrambled non-standard video signal with a shortened horizontal blanking interval for use in a television system not requiring a standardized signal, comprising the steps of:

timeshifting the active portion of each video line relative to the horizontal sync signal of that line; and

inserting into the video line an indication of the amount of timeshifting; wherein the amount of timeshifting in at least one line of the video signal causes the active video portion to extend into the horizontal blanking interval, thereby narrowing the horizontal blanking interval.

8. A system for decrypting previously scrambled non-standard video signals having a shortened horizontal blanking interval to permit the use thereof, the encrypted video signals having been produced by timeshifting the active video portions of at least some of the lines with

respect to the horizontal sync signal of the associated line, said system comprising:

a scrambler for providing an indication of the amount of timeshifting performed on a given line, the amount of timeshifting in at least some of the lines being sufficient to shift the active video portion into the horizontal blanking interval thereby narrowing the horizontal blanking interval to be non-standard.

9. A method providing sync wiggle concealment for a video signal when viewed on a television, comprising the step of in each of a plurality of lines at the video signal, timeshifting the location of the horizontal sync signal relative to the beginning of the horizontal blanking interval, the amount of timeshifting in each successive line changing at a predetermined frequency.

10. The method of Claim 9, further comprising the step of also changing the amount of timeshifting in each successive line by a second predetermined frequency.

11. The method of Claim 9, further comprising the step of timeshifting the location of the vertical sync signal in at least some video fields relative to the beginning of the vertical blanking interval in that field, the amount of timeshifting in each successive field varying in a predetermined pattern.

12. The method of Claim 10, the pattern being that of four successive video fields, wherein in the first field the vertical sync is timeshifted forward, in the second field the vertical sync is removed, in the third field the vertical sync is timeshifted backwards, and in the fourth field the vertical sync is removed.

13. An apparatus for concealing a video signal by sync wiggle when viewed on a television, comprising:

a line counter for counting video lines of a field of the video signal; the line counter counting from the vertical blanking interval of the field;

a memory holding a set of predetermined quantities by which in each line of the field the horizontal sync signal is to be timeshifted relative to the start of the horizontal blanking interval of that line, the memory reading out one of the set of quantities in response to each line counted by the line counter; and

logic circuitry for generating new horizontal sync pulses in response to each read-out quantity for insertion into each video line in place of the horizontal sync signal originally present in that line.

14. The device of Claim 13, further comprising a sync width control for setting a duration of the new horizontal sync pulses to be other than the nominal value.

15. A color video signal encoder for two channel digitally processing a video signal comprising:

an analog to digital converter for converting a video signal to digital data;

a buffer for holding at least one video line of the digital data for the period of one horizontal line and outputting the one video line;

an adder for summing an input and an output of the buffer, thereby arriving at a luminance signal;

a subtractor for subtracting the input from the output of the buffer, thereby arriving at a chrominance signal;

a luminance buffer for holding one line of the luminance signal, and outputting the one line with a portion thereof timeshifted;

a chrominance buffer for holding one line of the

chrominance signal, and outputting the one line with a portion thereof timeshifted;

a first digital to analog converter for converting the one line of the chrominance signal to a chrominance analog signal;

a second digital to analog converter for converting the one line of the luminance signal to a luminance analog signal;

a heterodyne stabilizer for stabilizing the frequency of the analog chrominance signal; and

an adder for combining the stabilized chrominance signal with the analog luminance signal thereby providing a composite video signal.

16. The device of Claim 15, for restoration of lost vertical detail further comprising a switch for receiving an output of the second digital to analog converter and passing only the active video portions of each line;

a filter for removing selected higher frequency portions of the passed active video portions; and

a summer for accepting the remaining lower frequency portions and combining the remaining lower frequency portions with an output of the first digital to analog converter, thereby restoring lost vertical detail to the video signal.

17. The device of Claim 15, wherein the heterodyne stabilizer comprises:

an oscillator for providing a reference frequency equal to a normal subcarrier frequency of the video signal;

a divider for providing a frequency equal to one half of the oscillator reference frequency;

a first filter for providing 5/2 of the reference frequency from the divider;

a second filter for providing 3/2 of the reference frequency from the divider;

a first multiplier for combining the 3/2 of the reference frequency with a timeshifted reference signal;

a filter for passing the upper sideband output of the first multiplier;

a second multiplier for combining the 5/2 of the reference frequency with the output of the third digital to analog converter;

a filter for passing the upper sideband output at the second multiplier;

a third multiplier for multiplying the upper sideband output of second multiplier with the upper sideband output at the first multiplier; and

a filter for passing only selected lower sideband frequency portions of the output of the third multiplier, thus providing a chrominance signal which is frequency stable with regard to the subcarrier frequency.

18. The device of Claim 15, wherein the heterodyne stabilizer comprises a source of a 5/2 and a 3/2 of a reference frequency equal to a normal subcarrier frequency of the video signal;

a first multiplier for multiplying the 3/2 of the reference frequency with a timeshifted reference signal;

a first filter for passing selected portions of an output of the first filter;

a second filter for passing selected portions of the output of the second digital to analog converter;

a second multiplier for multiplying the output of the second filter with the 5/2 of the reference frequency;

a fourth filter for passing selected portions of the output of the third multiplier; and

an adder for combining the output of the first digital to analog converter with the output of the

fourth filter, thereby providing a video signal having a chrominance component with a stable subcarrier frequency.

19. A descrambler for descrambling timeshifted video signals having data present in the signal indicating the amount of timeshifting, comprising:

means for generating horizontal blanking interval signals for each line of the video signal;

an extractor for extracting from the video signal the data indicating the amount of timeshifting; and

means for inserting the generated signals at a location in each line of the video signal as determined by the extracted data, thereby providing a descrambled video signal.

20. A method for two channel digitally encoding a color video signal comprising the steps of:

converting the color video signal to digital data in a single analog to digital converter;

separating the digital data into only the two components of luminance and luminance;

timeshifting portions of the chrominance and luminance components of each video line in relation to other portions of the video line;

converting the chrominance and luminance timeshifted components back to analog signals using only two digital to analog converters, one converter being associated with each component;

heterodyne stabilizing the analog chrominance signal with respect to a subcarrier frequency; and

combining the luminance signal with the stabilized analog chrominance signal, thereby providing a scrambled signal.

21. The method of Claim 20, wherein the step of heterodyne stabilizing comprises the steps of:

multiplying 3/2 of the subcarrier frequency with a timeshifted reference frequency;

multiplying a selected portion of the analog chrominance signal with 5/2 of the subcarrier frequency;

multiplying the upper sidebands of the outputs of the two steps of multiplying; and

selecting a portion of the output of the third step of multiplying as the analog chrominance signal, thereby stabilizing the analog chrominance signal with regard to the subcarrier frequency.

22. A descrambler for descrambling timeshifted video signals and digitally synthesizing the time reference portions of each line of video signal comprising:

a calculator for calculating an offset value for each horizontal video line from decrypted data in the video signal;

a counter for providing a plurality of timing edges in response to the offset value, the timing edges defining portions of the horizontal blanking interval of each video line;

logic circuits for generating a plurality of pulses derived from the timing edges; and

a switch for adding the generated pulses into the video signal in place of the original horizontal blanking internal.

23. A method for descrambling timeshifted video signals by synthesizing the time reference portions of each video horizontal line, comprising the steps of:

calculating an offset value for each horizontal video line from decrypted data in the video signal;

digitally counting from the offset value a plurality of timing edges each defining a portion of

the horizontal blanking internal of each video line;

generating a plurality of pulses derived from the counted timing edges; and

adding the generated pulses into the video signal in place of the original horizontal blanking interval.

24. The method of Claim 23, further comprising the step of reducing a required clock speed for the step of digitally counting by using the reduced clock speed to enable an exclusive OR gate, a second input of which is the least significant bit the calculated offset value, to provide the enabling clock to a data latch, thereby time-shifting the latched data by one-half the period of the reduced clock speed.

25. A system for vertically scrambling video signals, comprising:

means for timeshifting the horizontal lines of the video signal relative to the vertical sync signal of that field, wherein the horizontal lines in each field are timeshifted by an amount different from the amount of timeshifting of the horizontal lines in a previous video field; and

an encryptor for inserting into the video signal an encrypted indication of the amount of timeshifting.

26. The system of Claim 25, wherein the means for timeshifting comprises:

a plurality of series connected delays each capable of storing one horizontal video line; and

a random number generator for determining which of the plurality of delays the horizontal lines in a particular video field are to be passed through, thereby varying the amount of timeshifting in each successive field.

27. A method for vertically scrambling video signals comprising the steps of:

timeshifting the horizontal lines of the video signal relative to the vertical sync signal in each video field, wherein the horizontal lines in each successive field are timeshifted by a different amount;

encrypting an indication of the amount of timeshifting; and

inserting the indication into the video signal.

28. A method for concealing the presence in a scrambled video signal of the location of the edge of active video timeshifted relative to the horizontal blanking internal in each video line by filling at the edge, comprising the steps of:

generating a signal matching the active video signal at the edge of the active video; and

inserting the generated signal at the edge of the active video.

29. The method of Claim 28, wherein the step of generating comprises the steps:

determining the endpoints of a time gap between the timeshifted edge of active video and a nominal position thereof;

during the duration of the time gap, repeating a selected set of a predetermined number of pixels from the edge of active video; and

inserting the repeated set of pixels into the video signal during the duration of the time gap.

30. The method of Claim 29, wherein the predetermined number of pixels is four.

31. The method of Claim 29, further comprising the steps of:

generating a stable colorburst signal matching in amplitude and phase the colorburst of the scrambled video signal; and

inserting the generated stable colorburst signal into the scrambled video signal.

32. The method of Claim 29, further comprising a random noise method for concealing the gap comprising the steps of:

generating a random noise at a particular frequency associated with one component of the video signal;

adding the random noise to the video signal during the duration of the time gap.

33. The method of Claim 32, further comprising the steps of:

generating additional random noise at a particular frequency associated with a second component of the video signal; and

adding the additional random noise to the video signal during the duration of the time gap.

34. A system for concealing the presence in a scrambled video signal of the location of the edge of timeshifted active video relative to the horizontal blanking interval in each line by filling at the edge, comprising:

at least two comparators for defining respectively the beginning and end of a time gap between the timeshifted edge of the active video and a nominal non-timeshifted position thereof;

logic circuitry for generating signals at the defined beginning and end of the time gap;

a select circuit for selecting a series of

pixels at the time gap;

means for repeating the series of pixels for the duration of the time gap; and

means for inserting into the video signal the repeated series of pixels during the duration of the time gap.

35. The device of Claim 34, further comprising a random noise system to conceal the time gap, comprising:

at least one noise generator for generating noise at a frequency associated with one of the components of the video signal; and

means for inserting the noise into the video signal during the duration of the time gap.

36. A method for scrambling video signals by use of sampling comprising the steps of:

generating a predetermined pattern;

holding a value of the predetermined pattern once per field of the video signal; and

timeshifting the active video portion of each horizontal line of the video signal relative to the horizontal blanking interval of that line, wherein the amount of timeshifting in each line differs from that of the previous line by the held value of the predetermined pattern; wherein the amount of timeshifting in successive lines varies at frequency less than half of the video field rate.

METHOD AND APPARATUS FOR SCRAMBLING AND DESCRAMBLING OF VIDEO SIGNALS WITH EDGE FILL

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ABSTRACT

A video-scrambling system induces a random wobble i.e., time shifting, in the location of active portion of the video frame, without affecting the horizontal sync signal and colorburst in each video line, thus providing both security and concealment. The security is enhanced by filling in the gap between the nominal beginning of active video and the actual beginning of active video with a synthesized video signal which replicates the adjacent active video using a digitally generated filling pattern. Also, a random noise overlay further conceals the location of the gap. Additional concealment is provided by wiggling in time the location of the horizontal sync signal using one or two frequencies and also by randomly altering the location of the vertical sync signal. The NTSC digital encoding in accordance with the invention is simplified by using only two channels, chrominance and luminance, and by a heterodyne circuit for chrominance stability. NTSC encoding is enhanced by providing detail normally lost, by use of the chroma channel. Additionally, a non-standard video signal may be provided with a portion of the colorburst on the front porch of the horizontal blanking, thus allowing use of a relatively simple decoder.

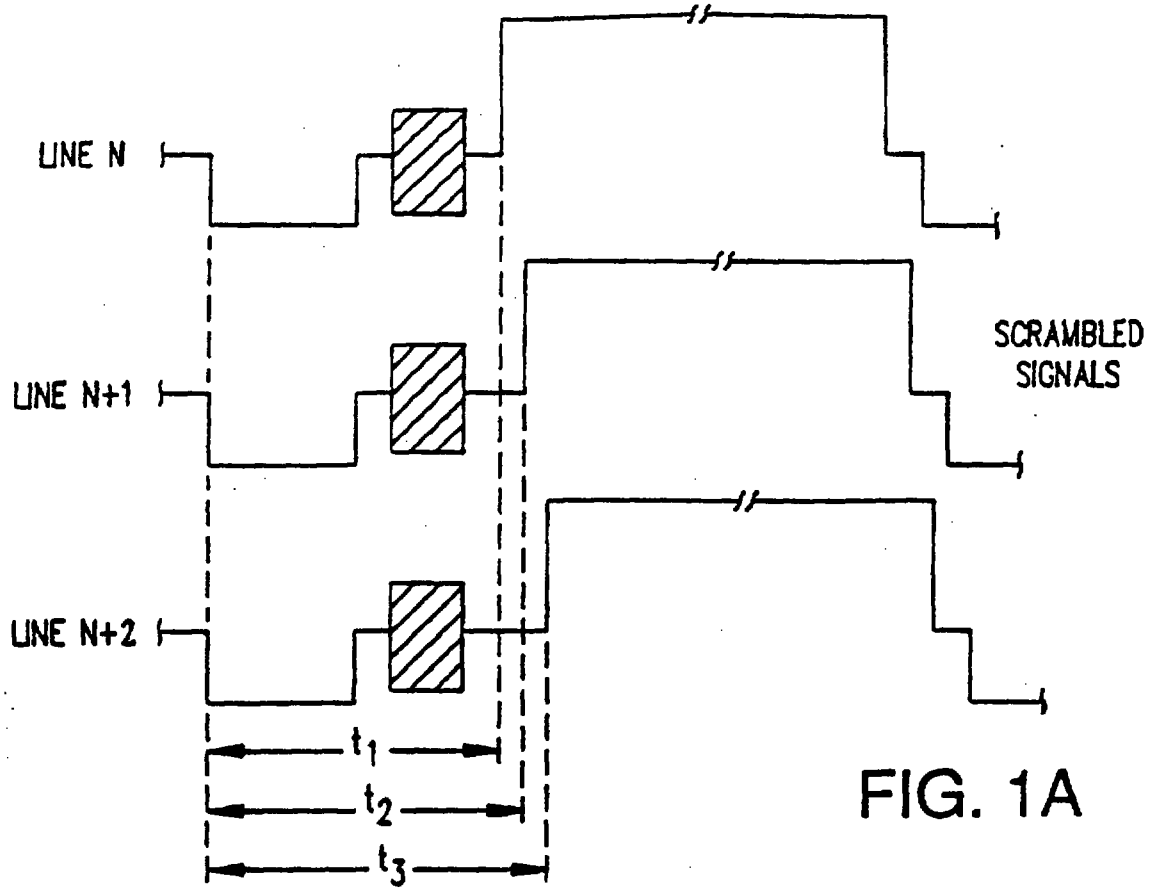

LINE N
LINE N+1
LINE N+2
SCRAMBLED SIGNALS
t_1
t_2
t_3

FIG. 1A

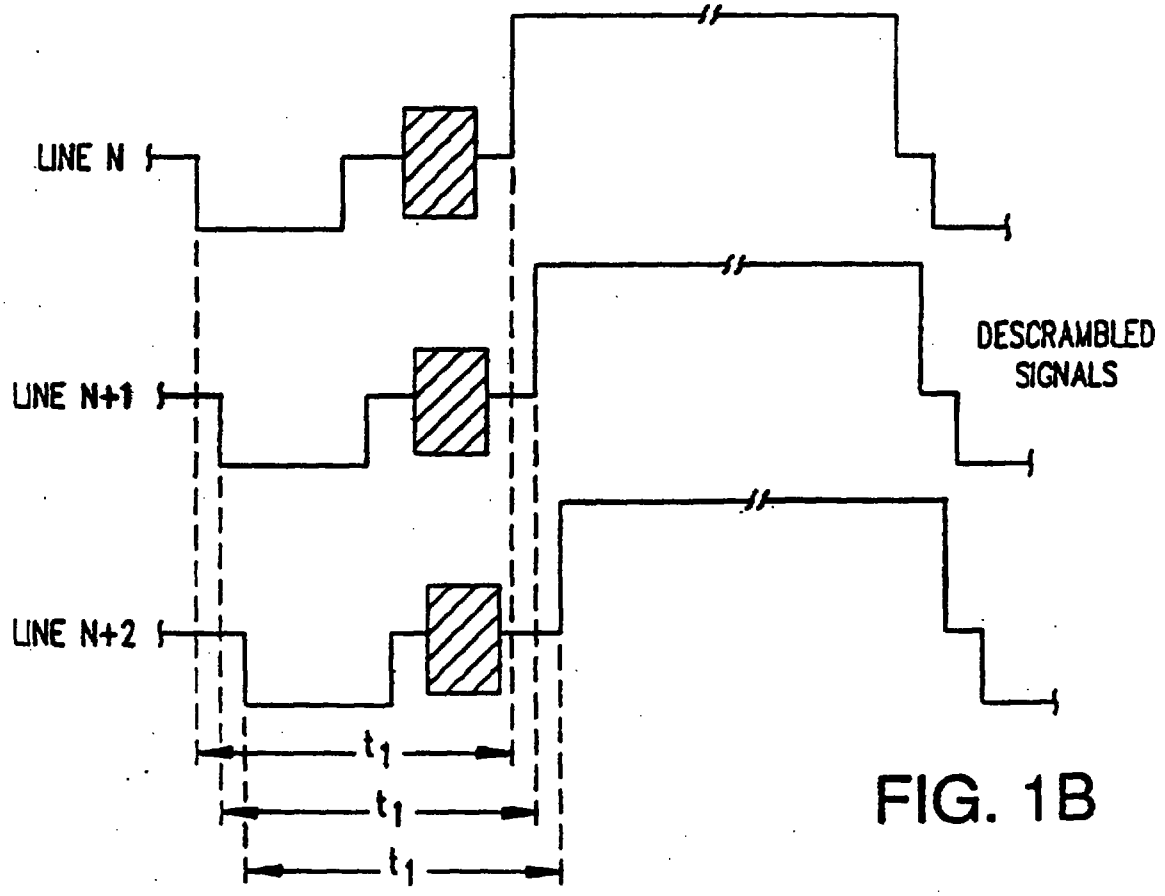

LINE N
LINE N+1
LINE N+2
DESCRAMBLED SIGNALS
t_1
t_1
t_1

FIG. 1B

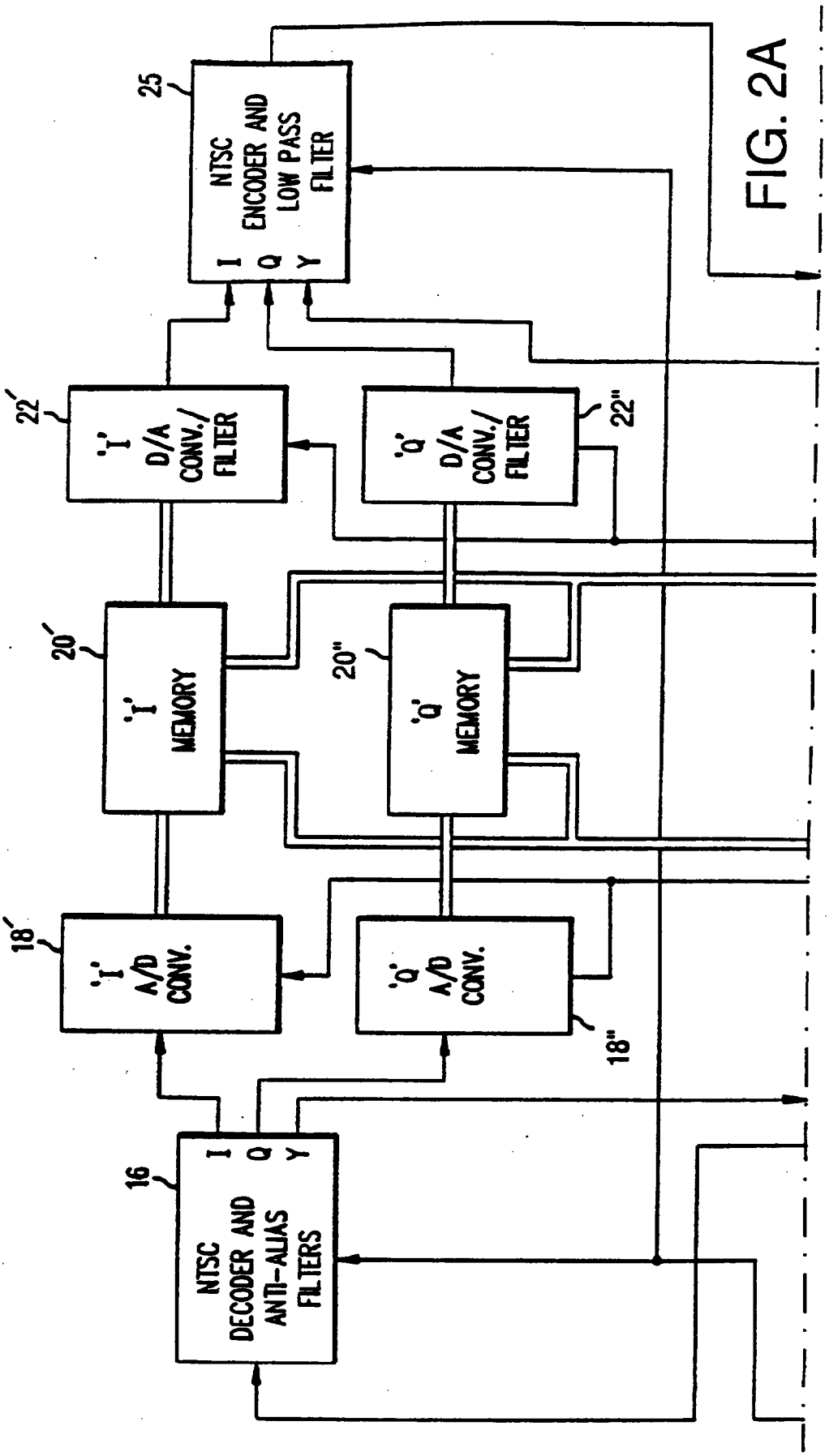
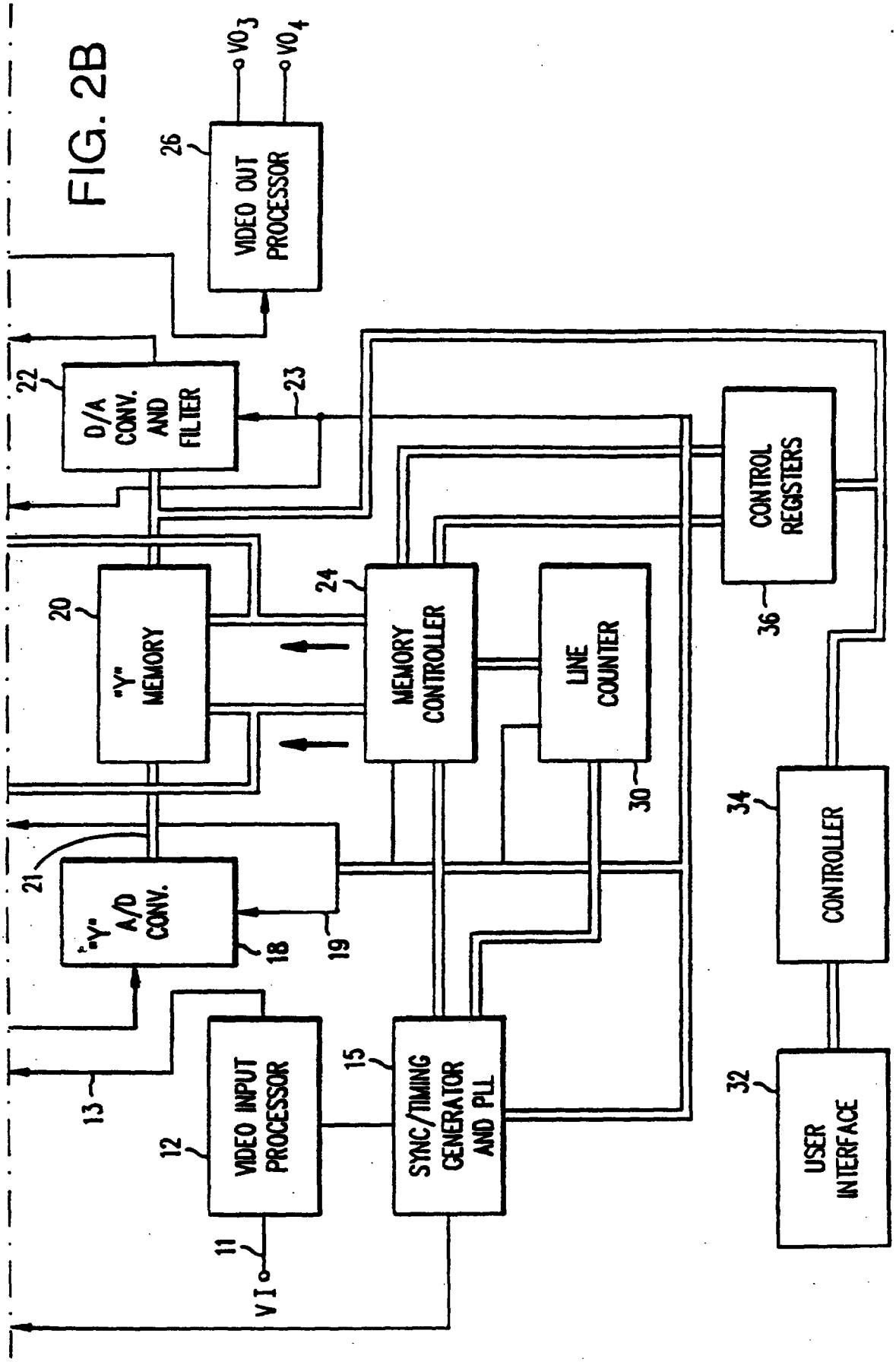

25
NTSC ENCODER AND LOW PASS FILTER
I Q Y
22'
'I' D/A CONV./ FILTER
'Q' D/A CONV./ FILTER
22"
20'
'I' MEMORY
20"
'Q' MEMORY
18'
'I' A/D CONV.
'Q' A/D CONV.
18"
16
NTSC DECODER AND ANTI-ALIAS FILTERS
I Q Y

FIG. 2A

FIG. 2B


VO3
VO4
26
VIDEO OUT PROCESSOR
22
D/A CONV. AND FILTER
23
CONTROL REGISTERS
36
20
"Y" MEMORY
24
MEMORY CONTROLLER
LINE COUNTER
30
21
"Y" A/D CONV.
18
19
34
CONTROLLER
13
12
VIDEO INPUT PROCESSOR
15
SYNC/TIMING GENERATOR AND PLL
32
USER INTERFACE
11
VI

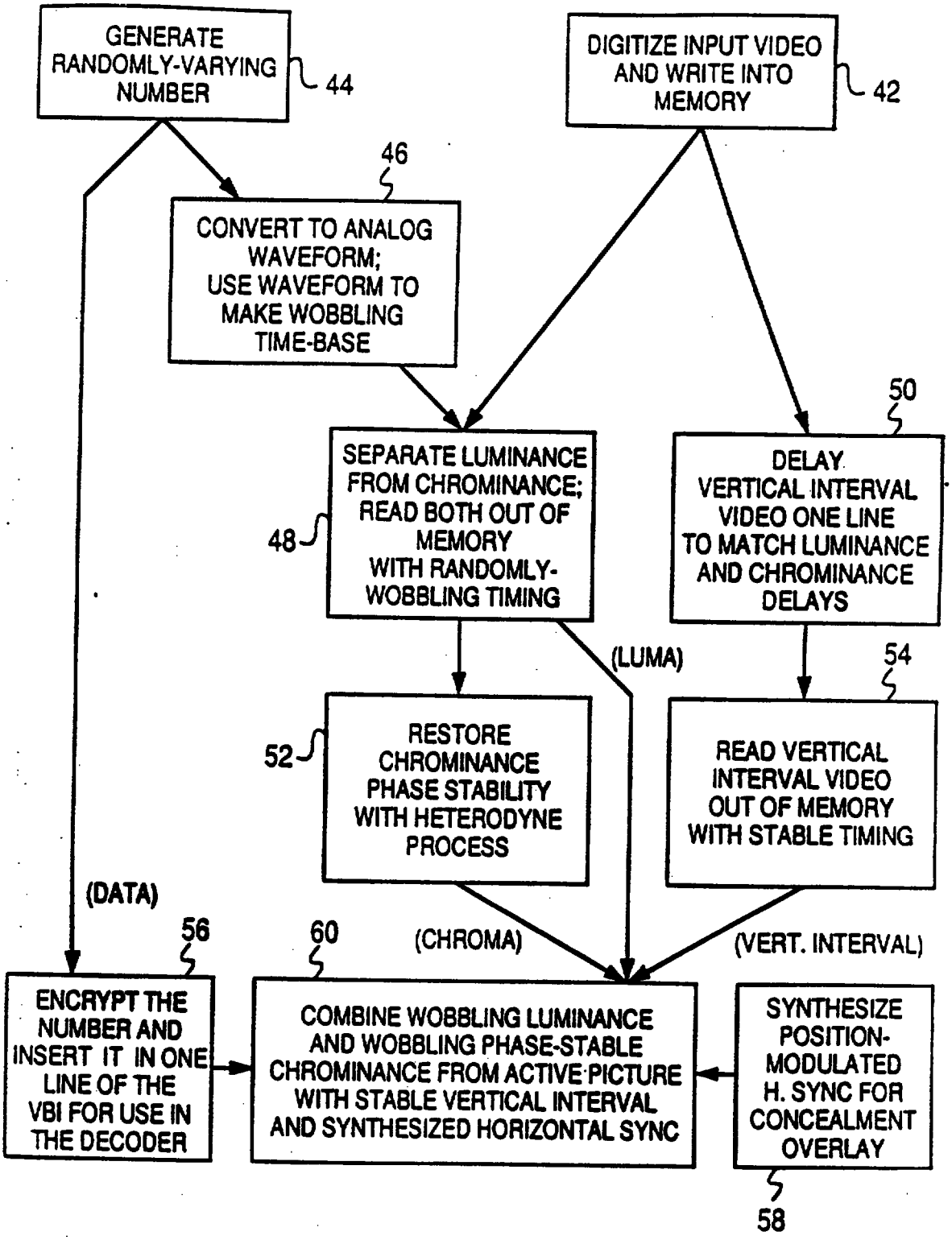

GENERATE RANDOMLY-VARYING NUMBER
44
DIGITIZE INPUT VIDEO AND WRITE INTO MEMORY
42
46
CONVERT TO ANALOG WAVEFORM; USE WAVEFORM TO MAKE WOBBLING TIME-BASE
50
SEPARATE LUMINANCE FROM CHROMINANCE; READ BOTH OUT OF MEMORY WITH RANDOMLY-WOBBLING TIMING
48
DELAY VERTICAL INTERVAL VIDEO ONE LINE TO MATCH LUMINANCE AND CHROMINANCE DELAYS
(LUMA)
54
52
RESTORE CHROMINANCE PHASE STABILITY WITH HETERODYNE PROCESS
READ VERTICAL INTERVAL VIDEO OUT OF MEMORY WITH STABLE TIMING
(DATA)
56
60
(CHROMA)
(VERT. INTERVAL)
ENCRYPT THE NUMBER AND INSERT IT IN ONE LINE OF THE VBI FOR USE IN THE DECODER
COMBINE WOBBLING LUMINANCE AND WOBBLING PHASE-STABLE CHROMINANCE FROM ACTIVE PICTURE WITH STABLE VERTICAL INTERVAL AND SYNTHESIZED HORIZONTAL SYNC
SYNTHESIZE POSITION-MODULATED H. SYNC FOR CONCEALMENT OVERLAY
58

FIG. 3

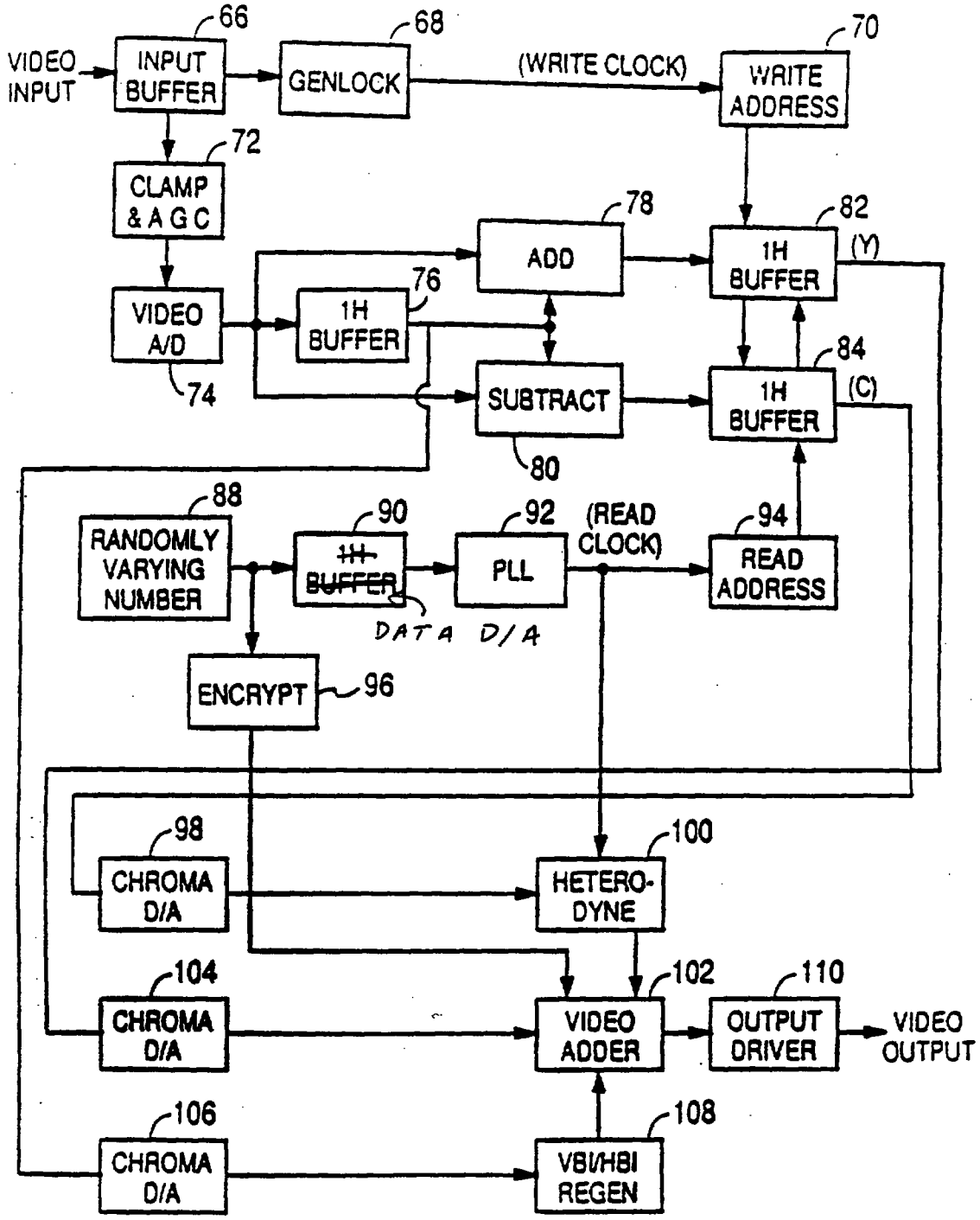

VIDEO INPUT
66
INPUT BUFFER
68
GENLOCK
(WRITE CLOCK)
70
WRITE ADDRESS
72
CLAMP & A G C
78
ADD
82
1H BUFFER
(Y)
VIDEO A/D
74
76
1H BUFFER
SUBTRACT
80
84
1H BUFFER
(C)
88
RANDOMLY VARYING NUMBER
90
1H BUFFER
DATA D/A
92
PLL
(READ CLOCK)
94
READ ADDRESS
ENCRYPT
96
98
CHROMA D/A
100
HETERO-DYNE
104
CHROMA D/A
102
VIDEO ADDER
110
OUTPUT DRIVER
VIDEO OUTPUT
106
CHROMA D/A
108
VBI/HBI REGEN

FIG. 4

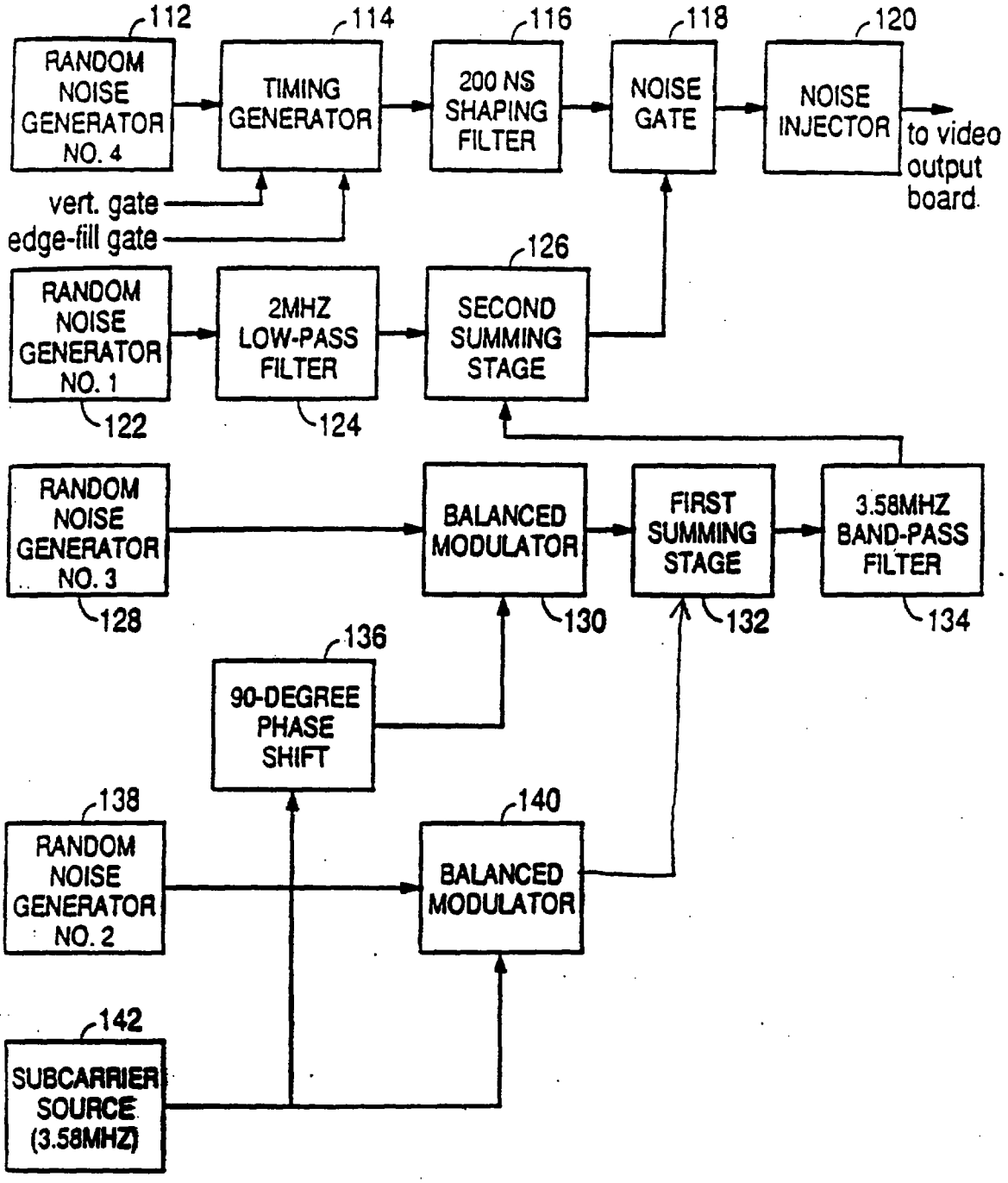

112
RANDOM NOISE GENERATOR NO. 4
114
TIMING GENERATOR
116
200 NS SHAPING FILTER
118
NOISE GATE
120
NOISE INJECTOR
to video output board
vert. gate
edge-fill gate
126
RANDOM NOISE GENERATOR NO. 1
2MHZ LOW-PASS FILTER
SECOND SUMMING STAGE
122
124
RANDOM NOISE GENERATOR NO. 3
BALANCED MODULATOR
FIRST SUMMING STAGE
3.58MHZ BAND-PASS FILTER
128
130
132
134
136
90-DEGREE PHASE SHIFT
138
RANDOM NOISE GENERATOR NO. 2
140
BALANCED MODULATOR
142
SUBCARRIER SOURCE (3.58MHZ)

FIG. 5

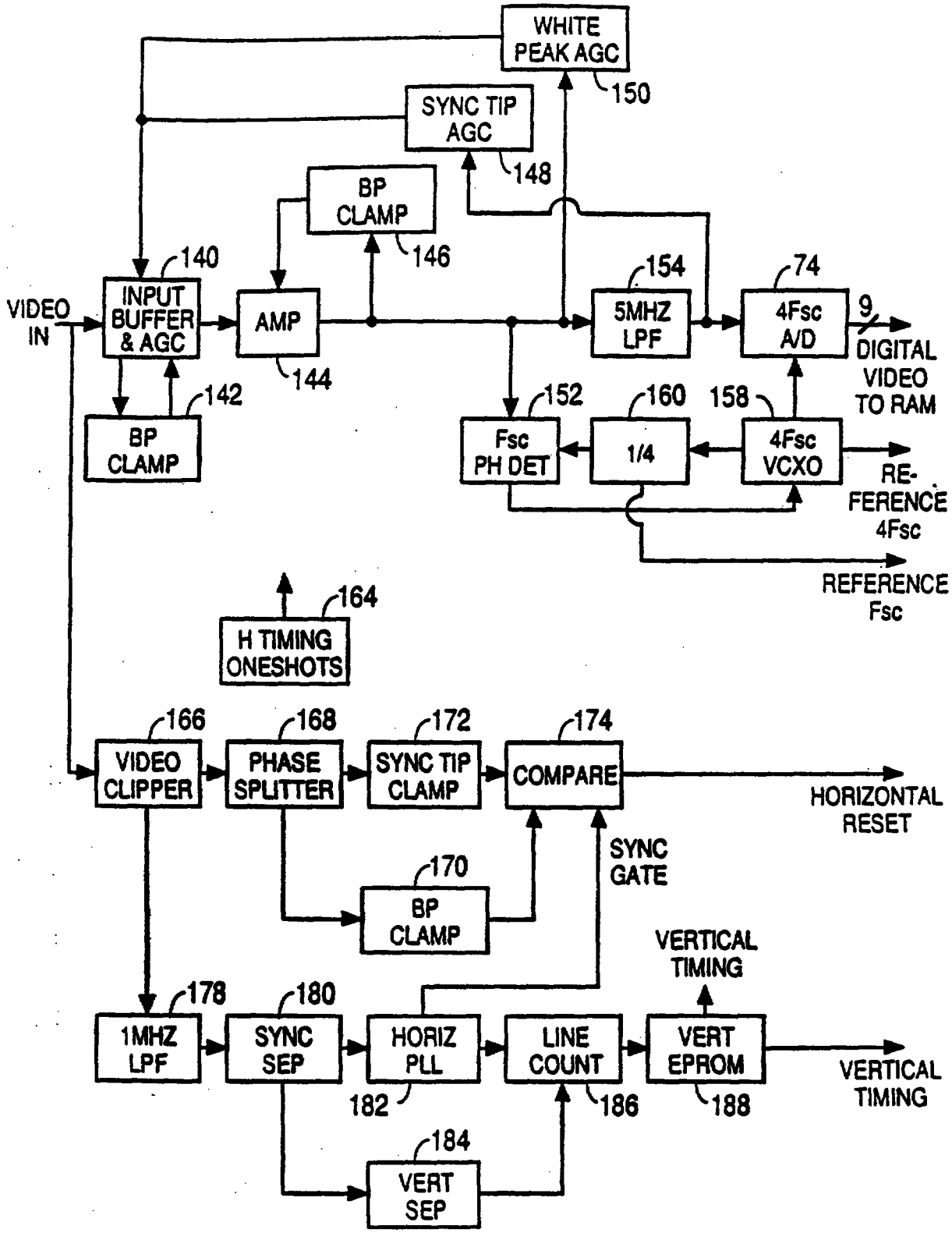

WHITE PEAK AGC
150
SYNC TIP AGC
148
BP CLAMP
146
140
INPUT BUFFER & AGC
AMP
144
154
5MHZ LPF
74
4Fsc A/D
9
DIGITAL VIDEO TO RAM
VIDEO IN
142
BP CLAMP
152
Fsc PH DET
160
1/4
158
4Fsc VCXO
RE-FERENCE 4Fsc
REFERENCE Fsc
164
H TIMING ONESHOTS
166
VIDEO CLIPPER
168
PHASE SPLITTER
172
SYNC TIP CLAMP
174
COMPARE
HORIZONTAL RESET
SYNC GATE
170
BP CLAMP
VERTICAL TIMING
178
1MHZ LPF
180
SYNC SEP
HORIZ PLL
182
LINE COUNT
186
VERT EPROM
188
VERTICAL TIMING
184
VERT SEP

FIG. 6

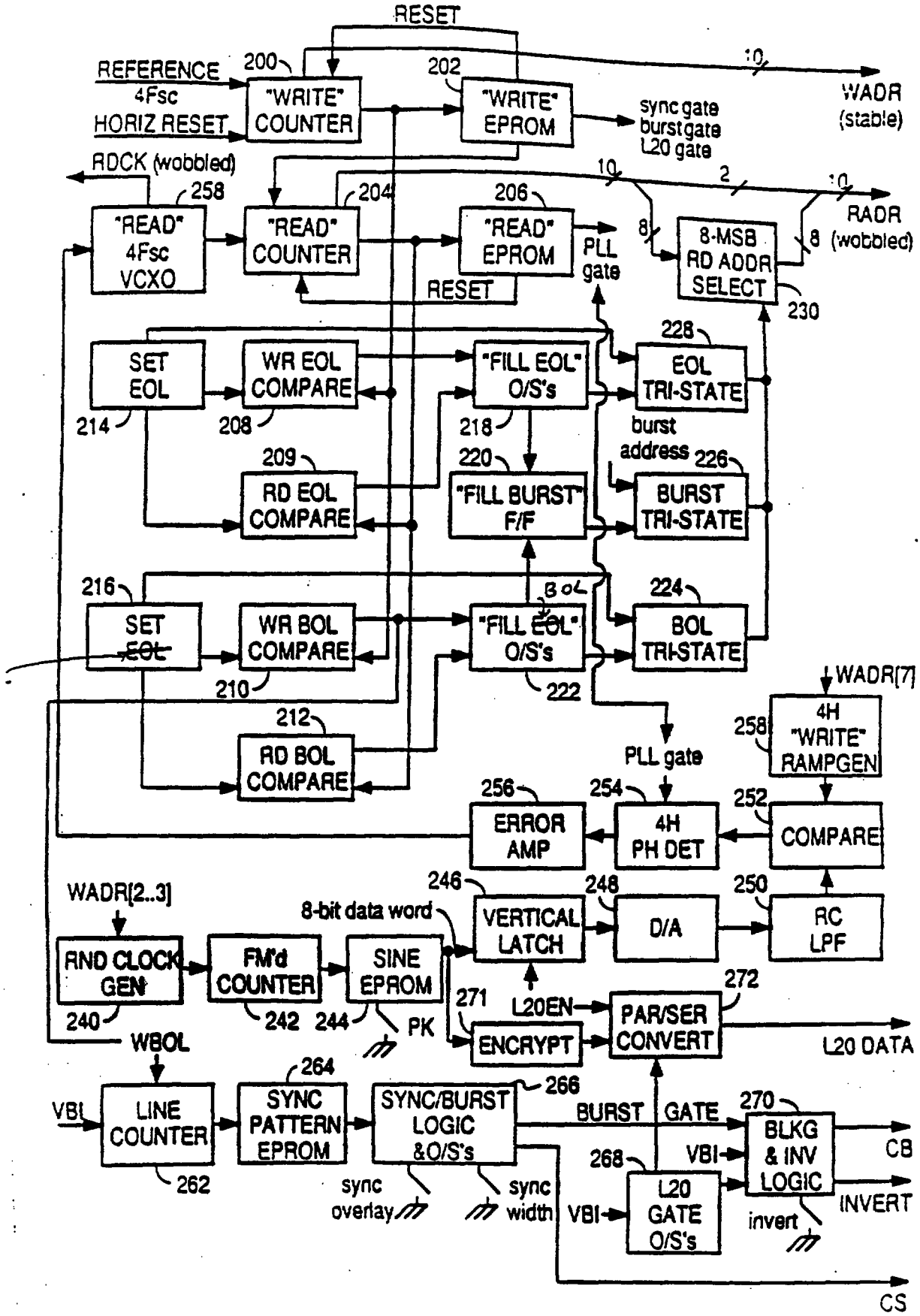

RESET
REFERENCE
4Fsc
HORIZ RESET
200
"WRITE" COUNTER
202
"WRITE" EPROM
sync gate
burst gate
L20 gate
10
WADR (stable)
RDCK (wobbled)
258
"READ" 4Fsc VCXO
204
"READ" COUNTER
206
"READ" EPROM
PLL gate
8
8-MSB RD ADDR SELECT
10
2
10
8
RADR (wobbled)
RESET
230
228
SET EOL
214
WR EOL COMPARE
208
"FILL EOL" O/S's
218
EOL TRI-STATE
burst address
209
RD EOL COMPARE
220
"FILL BURST" F/F
226
BURST TRI-STATE
216
SET EOL
WR BOL COMPARE
210
"FILL EOL" O/S's
222
224
BOL TRI-STATE
212
RD BOL COMPARE
PLL gate
WADR[7]
4H "WRITE" RAMPGEN
258
256
ERROR AMP
254
4H PH DET
252
COMPARE
WADR[2..3]
246
8-bit data word
VERTICAL LATCH
248
D/A
250
RC LPF
RND CLOCK GEN
240
FM'd COUNTER
242
244
SINE EPROM
PK
271
L20EN
ENCRYPT
272
PAR/SER CONVERT
L20 DATA
WBOL
VBI
LINE COUNTER
262
264
SYNC PATTERN EPROM
SYNC/BURST LOGIC &O/S's
266
BURST GATE
270
BLKG & INV LOGIC
CB
INVERT
VBI
268
L20 GATE O/S's
sync overlay
sync width
VBI
invert
CS

FIG. 7A

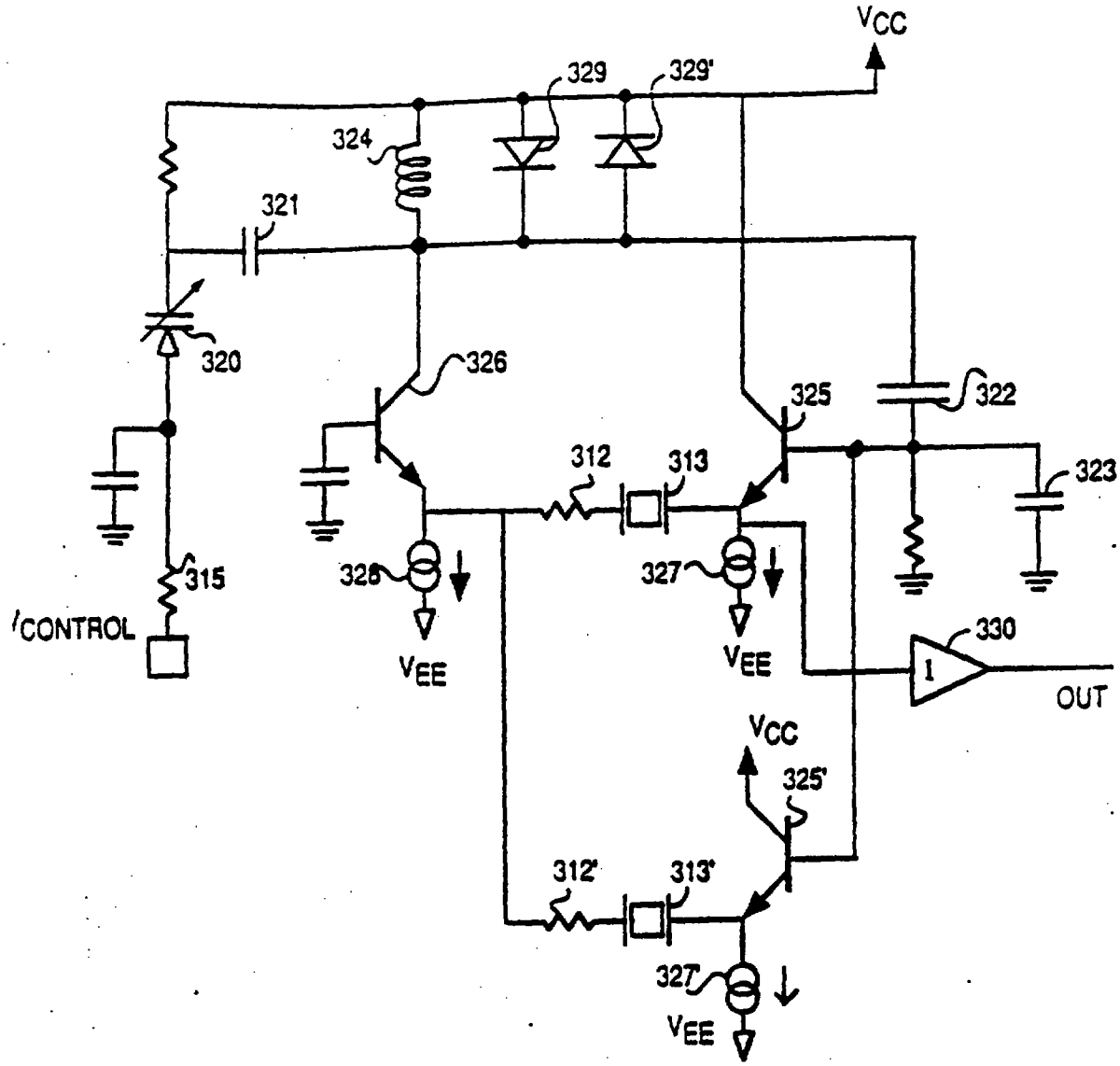

VCC
329
329'
324
321
320
326
325
322
312
313
323
315
ICONTROL
328
327
VEE
VEE
330
1
OUT
VCC
325'
312'
313'
327'
VEE

FIG. 7B

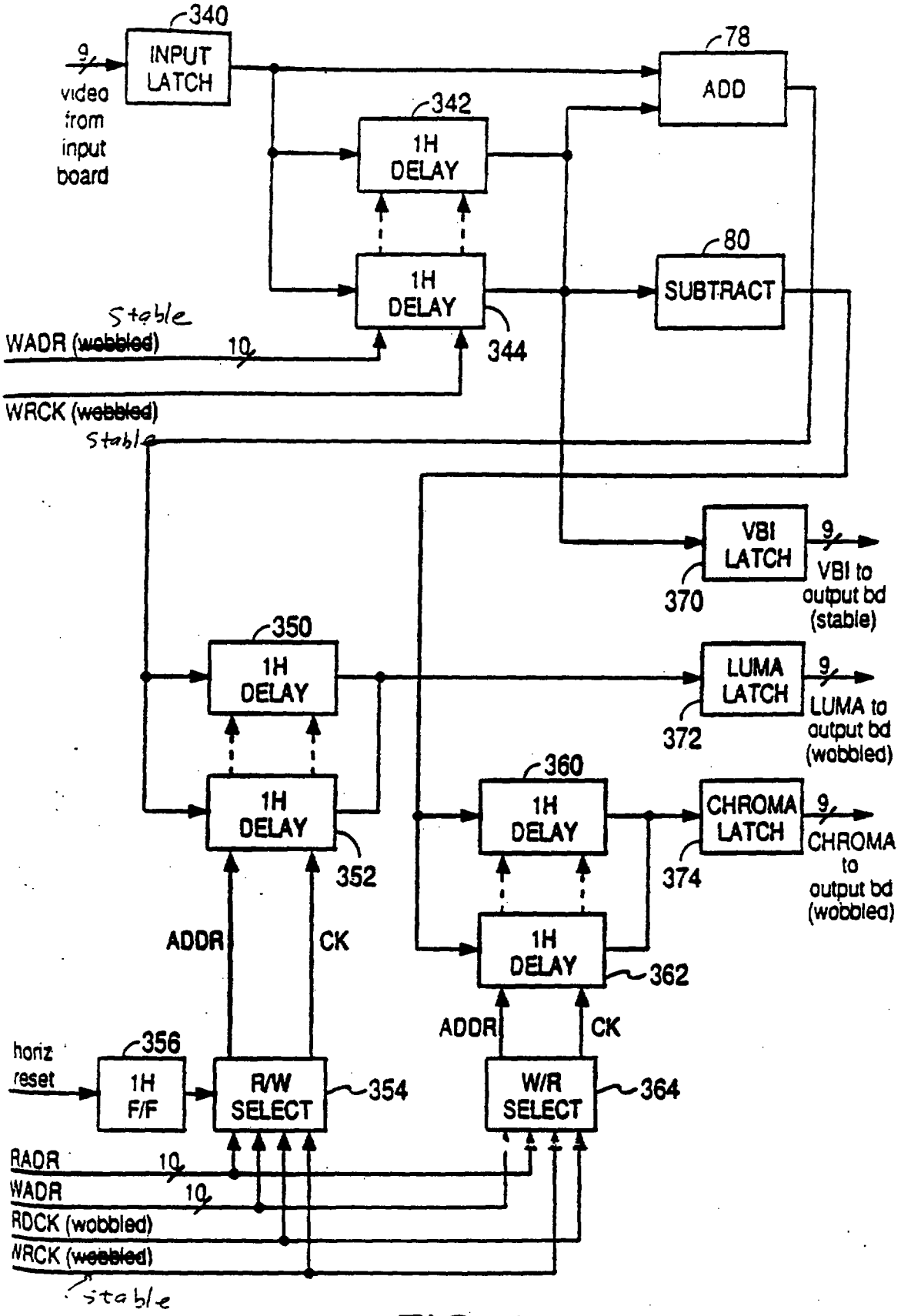

340
INPUT LATCH
9
video from input board
78
ADD
342
1H DELAY
80
SUBTRACT
1H DELAY
344
stable
WADR (wobbled)
10
WRCK (wobbled)
stable
VBI LATCH
9
VBI to output bd (stable)
370
350
1H DELAY
LUMA LATCH
9
LUMA to output bd (wobbled)
372
1H DELAY
352
360
1H DELAY
CHROMA LATCH
9
CHROMA to output bd (wobbled)
374
ADDR
CK
1H DELAY
362
ADDR
CK
horiz reset
356
1H F/F
R/W SELECT
354
W/R SELECT
364
RADR
10
WADR
10
RDCK (wobbled)
WRCK (wobbled)
stable

FIG. 8

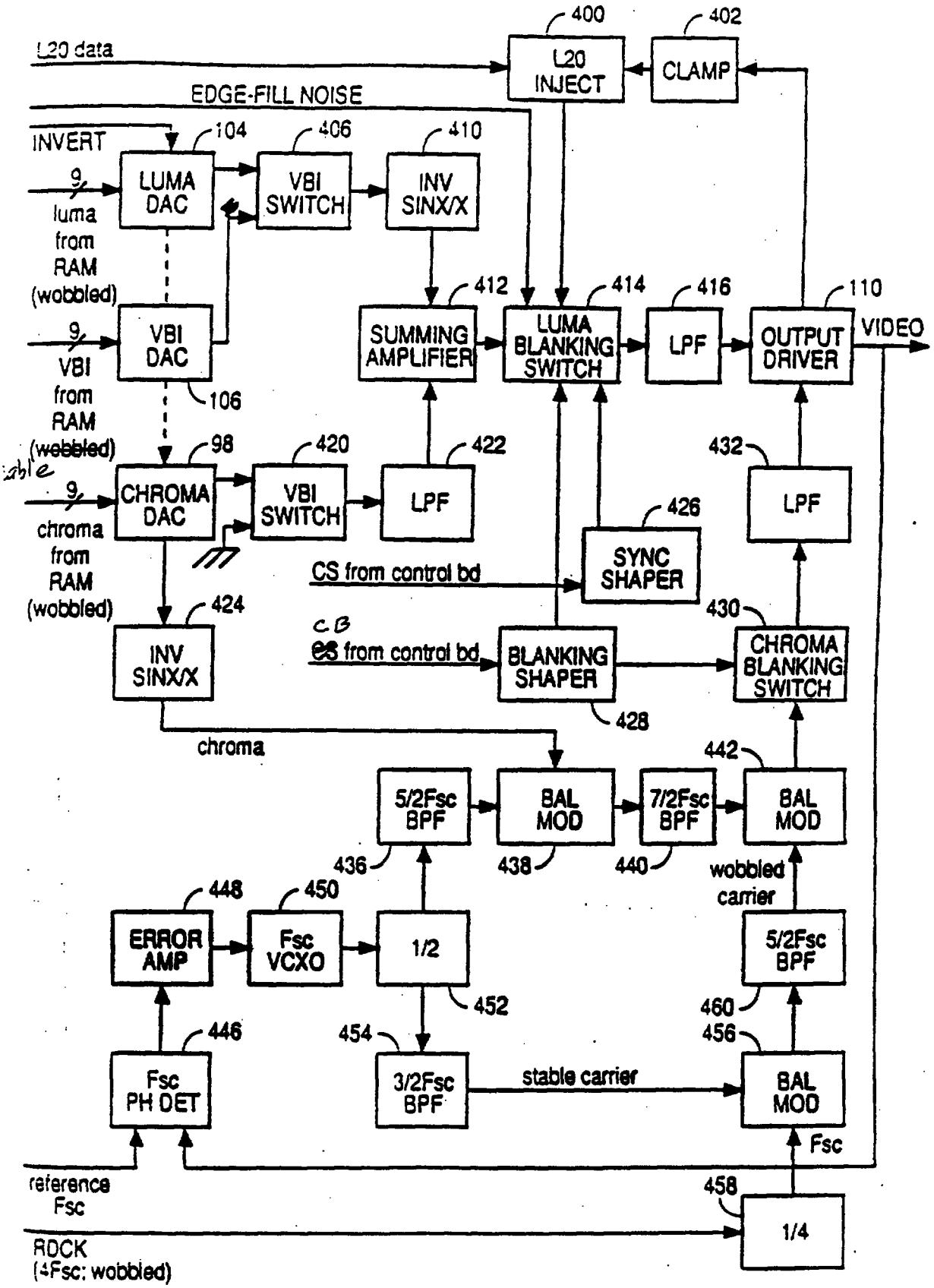

L20 data
EDGE-FILL NOISE
INVERT
9
luma from RAM (wobbled)
9
VBI from RAM (wobbled)
9
chroma from RAM (wobbled)
LUMA DAC
VBI DAC
CHROMA DAC
VBI SWITCH
INV SINX/X
LPF
SUMMING AMPLIFIER
LUMA BLANKING SWITCH
OUTPUT DRIVER
VIDEO
SYNC SHAPER
CS from control bd
BLANKING SHAPER
CB from control bd
CHROMA BLANKING SWITCH
chroma
5/2Fsc BPF
BAL MOD
7/2Fsc BPF
wobbled carrier
ERROR AMP
Fsc VCXO
1/2
Fsc PH DET
3/2Fsc BPF
stable carrier
reference Fsc
RDCK (4Fsc: wobbled)
1/4
Fsc
L20 INJECT
CLAMP
104
106
98
400
402
406
410
412
414
416
110
420
422
424
426
428
430
432
436
438
440
442
446
448
450
452
454
456
458
460

FIG. 9

FIG. 10A

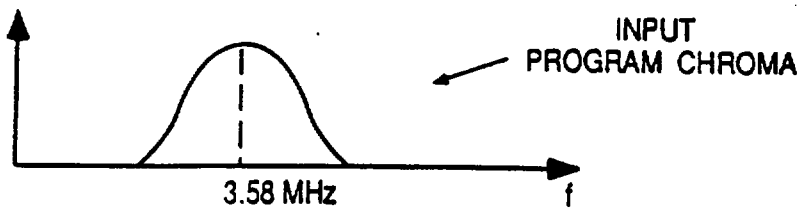


FIG. 10B

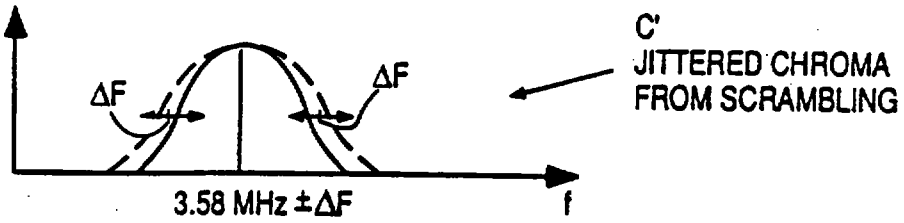


FIG.10C

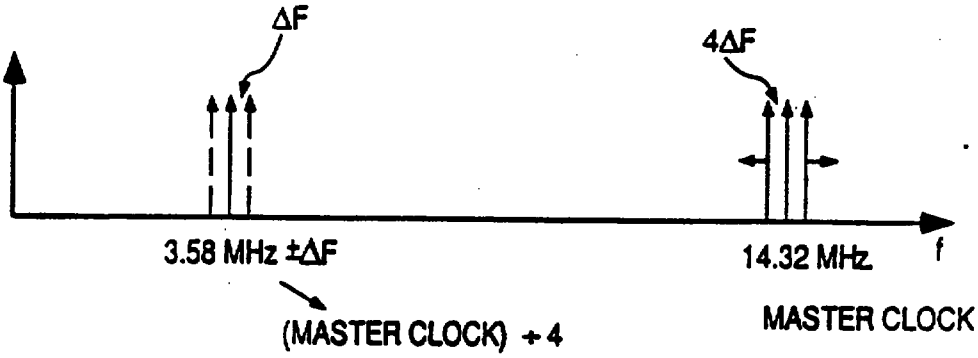


FIG. 10D

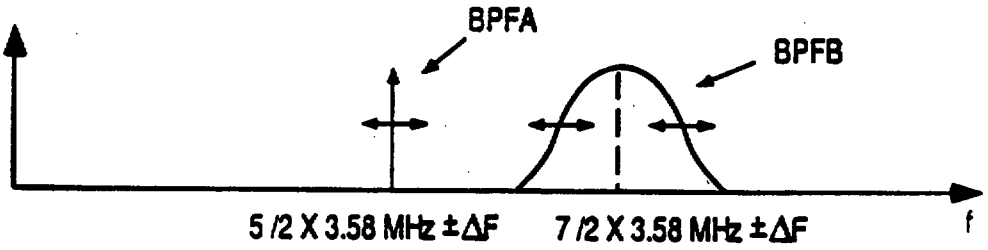
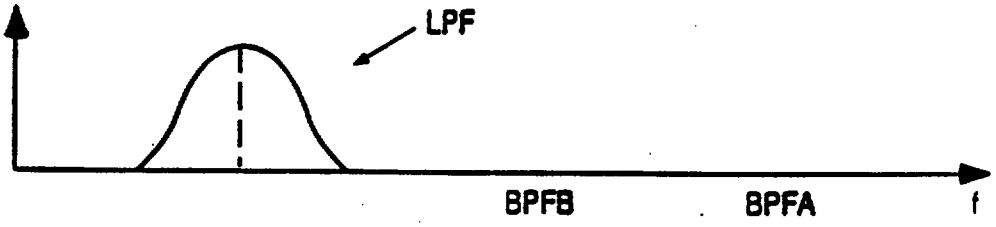


FIG. 10E



3.58 MHz = (7/2 X 3.58 MHz ±ΔF) - (5/2 X 3.58 MHz ±ΔF

= (2/2 X 3.58 MHz±ΔF - (±ΔF)

= 3.58 MHz

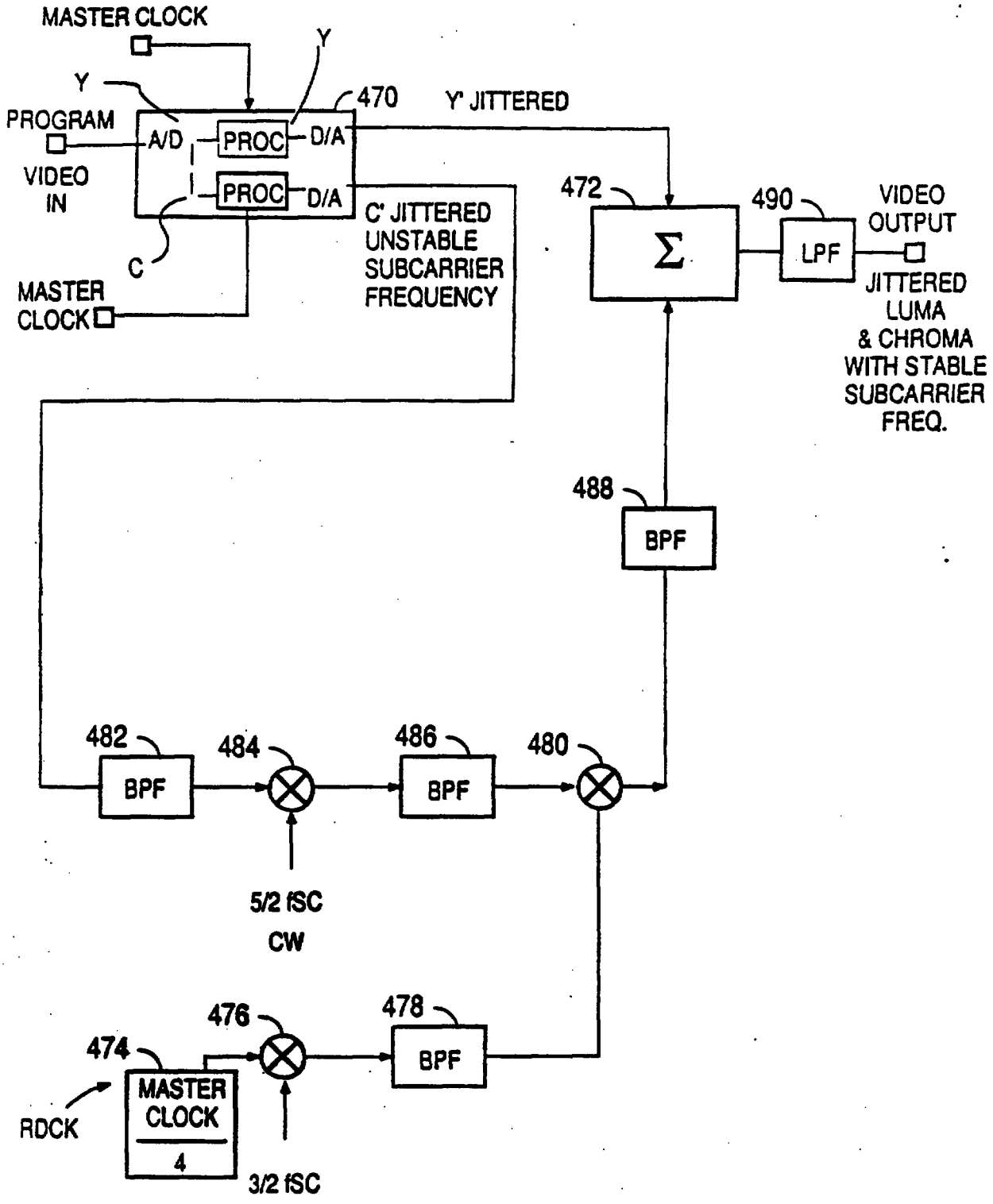

MASTER CLOCK
Y
Y
PROGRAM
VIDEO IN
A/D
PROC
D/A
PROC
D/A
470
Y' JITTERED
C
MASTER CLOCK
C' JITTERED UNSTABLE SUBCARRIER FREQUENCY
472
Σ
490
LPF
VIDEO OUTPUT
JITTERED LUMA & CHROMA WITH STABLE SUBCARRIER FREQ.
488
BPF
482
BPF
484
486
BPF
480
5/2 fSC
CW
476
478
BPF
474
MASTER CLOCK
4
RDCK
3/2 fSC

FIG. 11

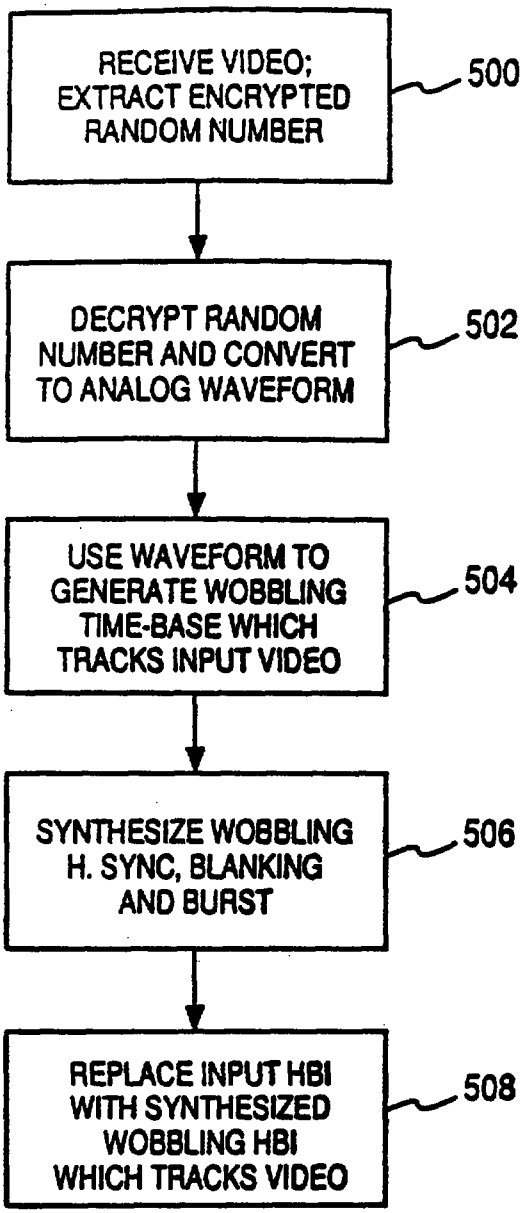

RECEIVE VIDEO; EXTRACT ENCRYPTED RANDOM NUMBER
500
DECRYPT RANDOM NUMBER AND CONVERT TO ANALOG WAVEFORM
502
USE WAVEFORM TO GENERATE WOBBLING TIME-BASE WHICH TRACKS INPUT VIDEO
504
SYNTHESIZE WOBBLING H. SYNC, BLANKING AND BURST
506
REPLACE INPUT HBI WITH SYNTHESIZED WOBBLING HBI WHICH TRACKS VIDEO
508

FIG. 12

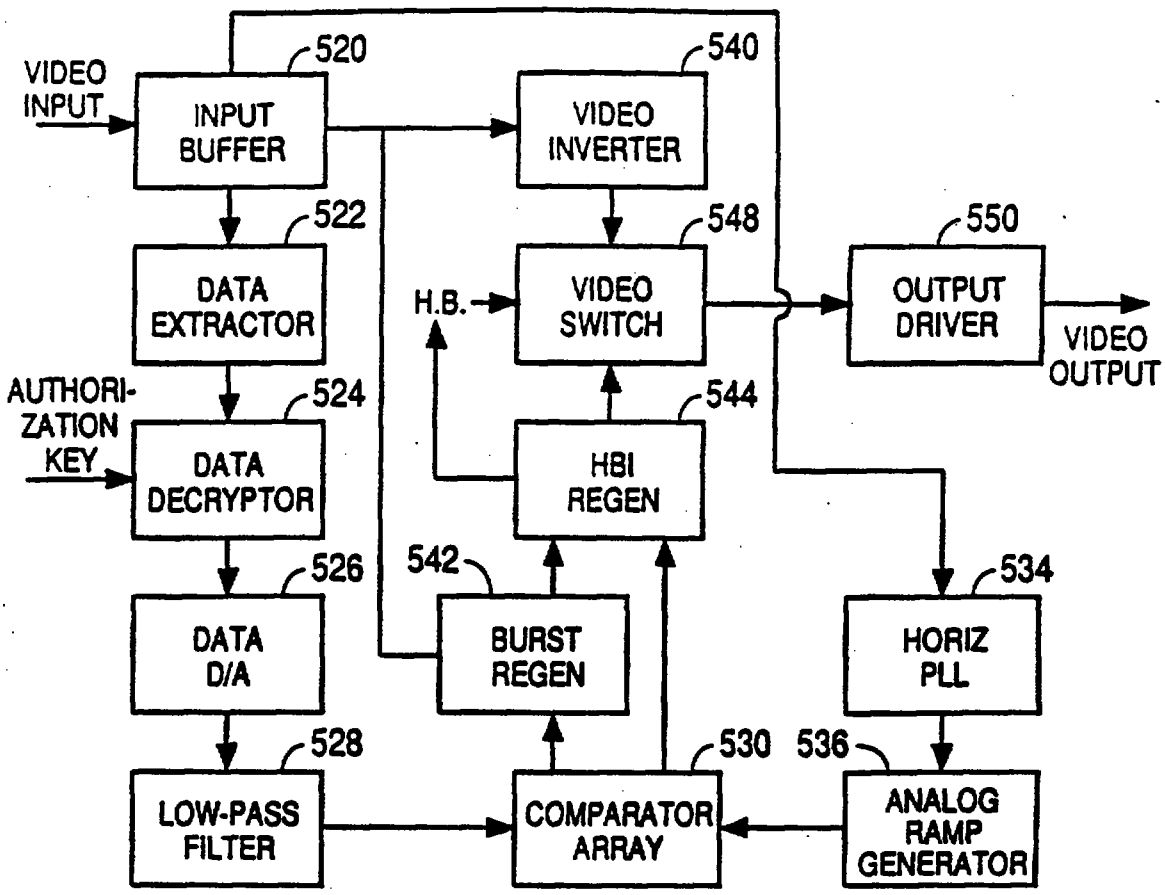


FIG. 13

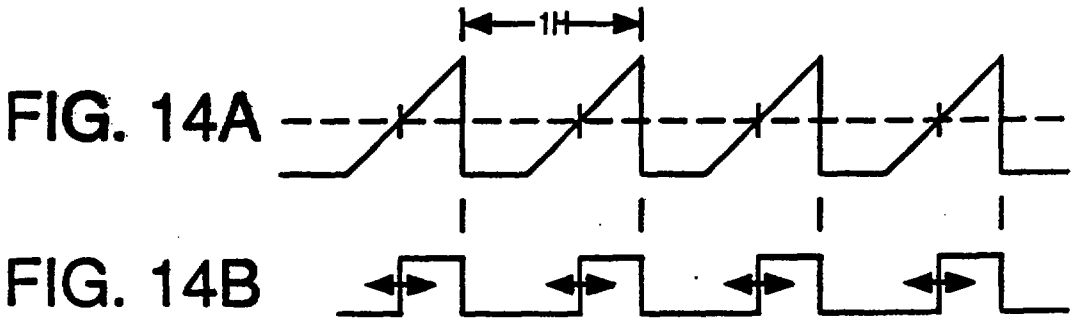


FIG. 14A

FIG. 14B

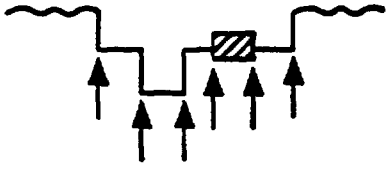


FIG. 14C

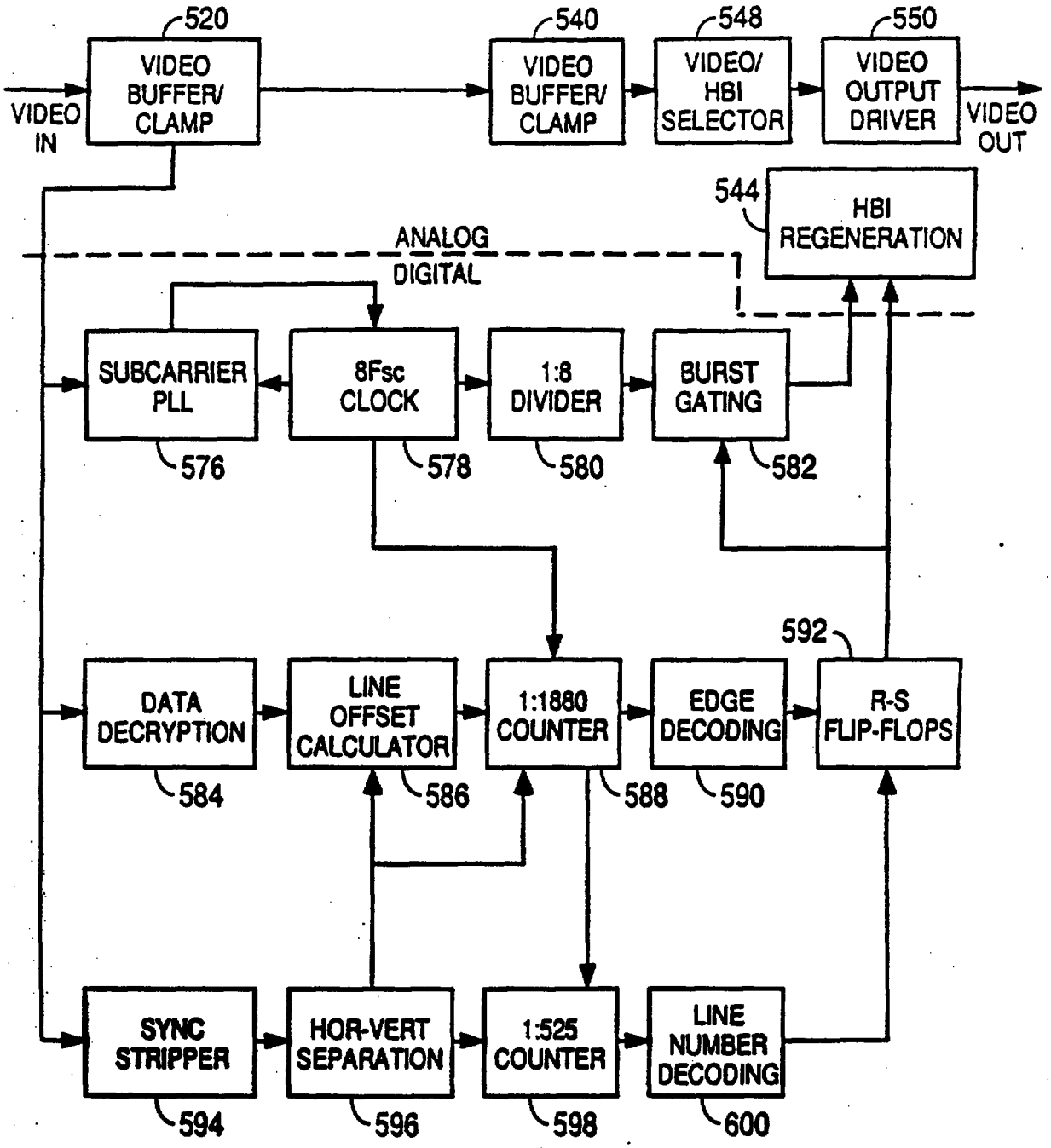

520
VIDEO BUFFER/ CLAMP
VIDEO IN
540
VIDEO BUFFER/ CLAMP
548
VIDEO/ HBI SELECTOR
550
VIDEO OUTPUT DRIVER
VIDEO OUT
544
HBI REGENERATION
ANALOG
DIGITAL
SUBCARRIER PLL
576
8Fsc CLOCK
578
1:8 DIVIDER
580
BURST GATING
582
592
DATA DECRYPTION
584
LINE OFFSET CALCULATOR
586
1:1880 COUNTER
588
EDGE DECODING
590
R-S FLIP-FLOPS
SYNC STRIPPER
594
HOR-VERT SEPARATION
596
1:525 COUNTER
598
LINE NUMBER DECODING
600

FIG. 16A

FIG. 15A

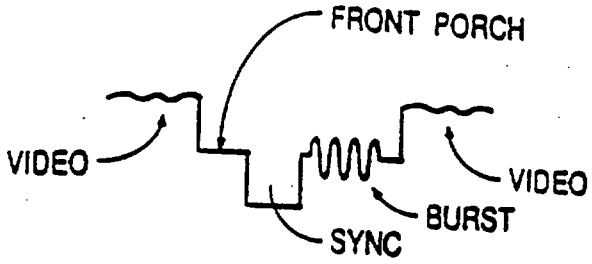


FIG. 15B

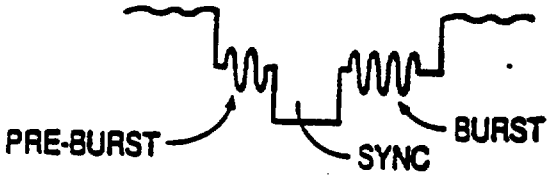
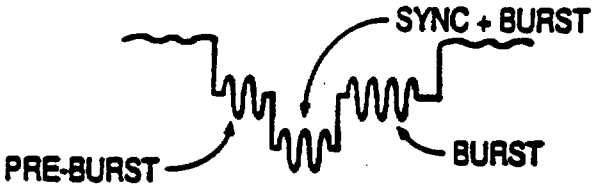


FIG. 15C



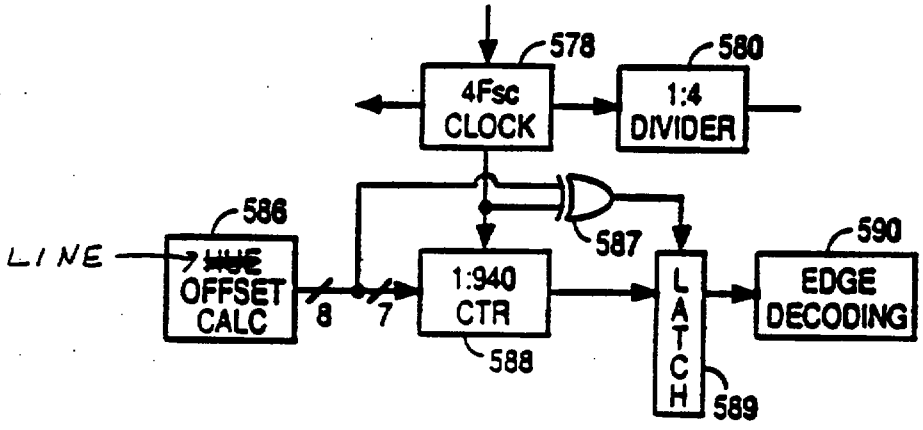


FIG. 16B

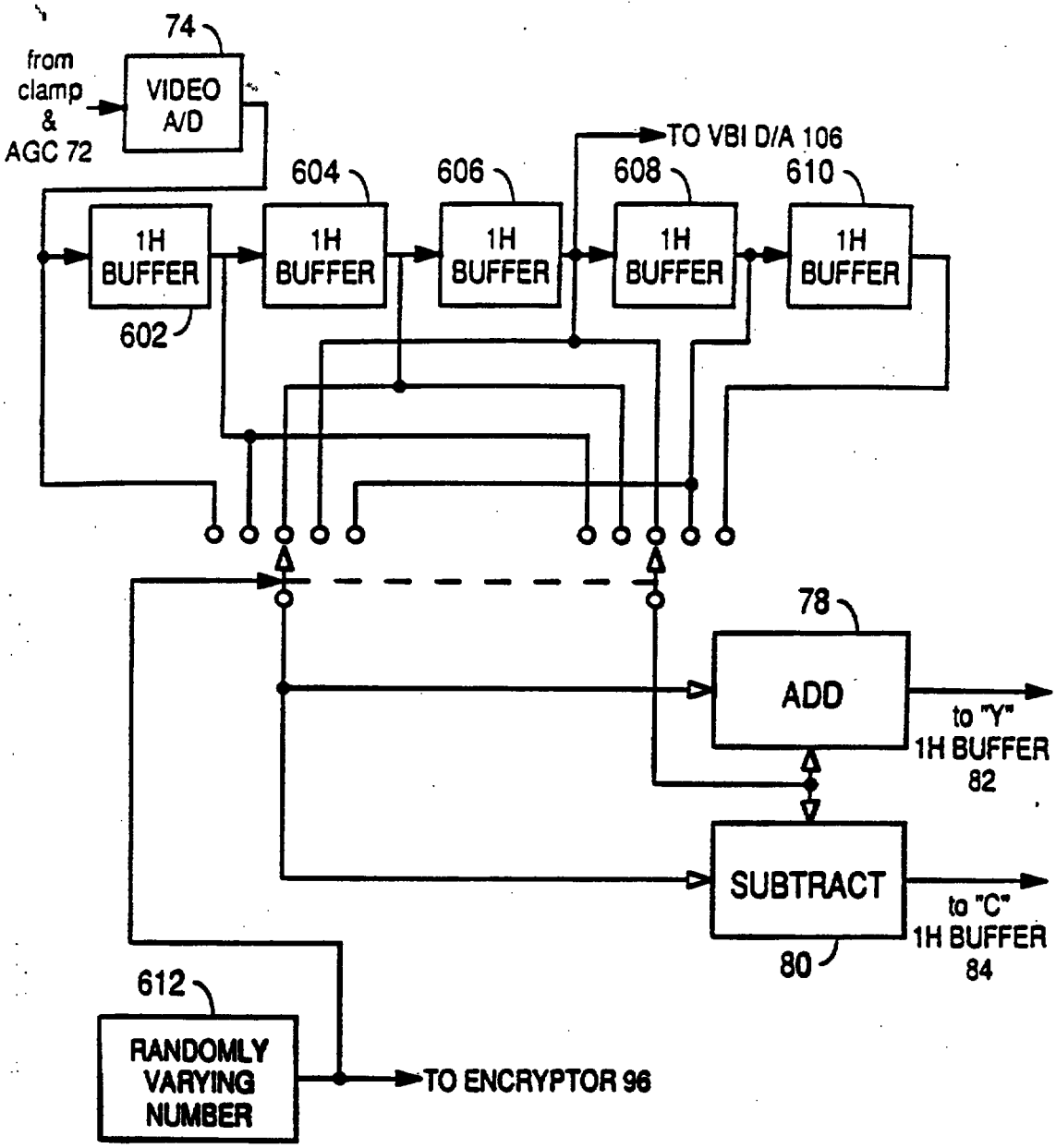

74
from clamp & AGC 72
VIDEO A/D
TO VBI D/A 106
604
606
608
610
1H BUFFER
1H BUFFER
1H BUFFER
1H BUFFER
1H BUFFER
602
78
ADD
to "Y" 1H BUFFER 82
SUBTRACT
to "C" 1H BUFFER 84
80
612
RANDOMLY VARYING NUMBER
TO ENCRYPTOR 96

FIG. 17