Application Note 59

TMC22x5y Digital Decoder Data Sheet Supplement

Introduction

All composite video decoders perform fundamentally the same operation. The first stage is to separate the luminance and chrominance. The second stage is to lock the internally generated sine and cosine waveforms to the digitized burst on the decoded chrominance signal, demodulate, and then filter the chrominance signal to produce the color difference signals. The last stage either scales the luminance and color difference signals, or converts them into red, green, and blue component video signals. These three stages are shown in Figure 1: Fundamental decoder block diagram.

The complete separation of composite video signals into pure luminance (luma) and chrominance (chroma) signals is practically impossible, especially when the input source contains intraframe motion. Therefore, the luminance (luma) signal will generally contain some high frequency chrominance, termed ***cross luma***, and the chroma signal will contains some of the high frequency luma signal, centered around the subcarrier frequency, termed ***cross color***. The degree of cross luma and cross color is directly proportional to the filter used for the YC separation, the picture content, and the complexity of any post processing of the decoded signals.

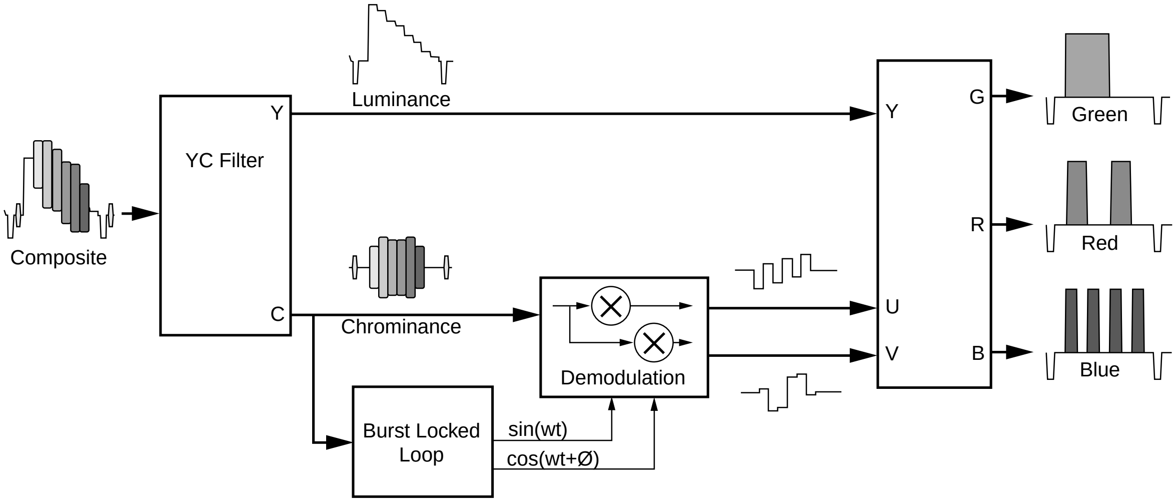

Figure 1: Fundamental decoder block diagram.

YC separation

The relationship between the chrominance and luminance bandwidths is shown for both PAL and NTSC in Figure 2, wherein the shaded area denotes the part of the composite video frequency spectrum shared by both the chrominance and high frequency luminance signals.

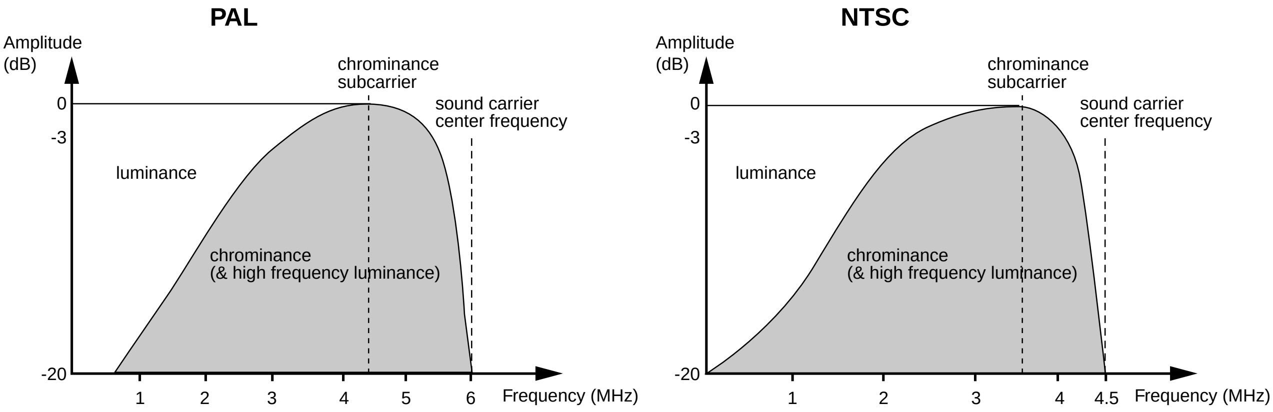

Figure 2: Comparison of the frequency spectrum of NTSC and PAL composite video signals

Simple bandsplit separation

The simplest method of separating these chrominance and luminance signals, is to assume the chroma bandwidth is limited to a few hundred kilohertz around the subcarrier frequency. In this case a notch filter designed to remove just these frequencies from the composite video frequency spectrum provides the luma signal, while a bandpass filter centered at the subcarrier frequency produces the chroma signal. This simple technique works well in pictures containing large flat areas of color, however this is rarely the case. If, as is generally true, the picture contains high frequency luma and chroma transitions, for example herring bone suit jackets, branches of trees, text, etc., cross color and cross luma artifacts are evident.

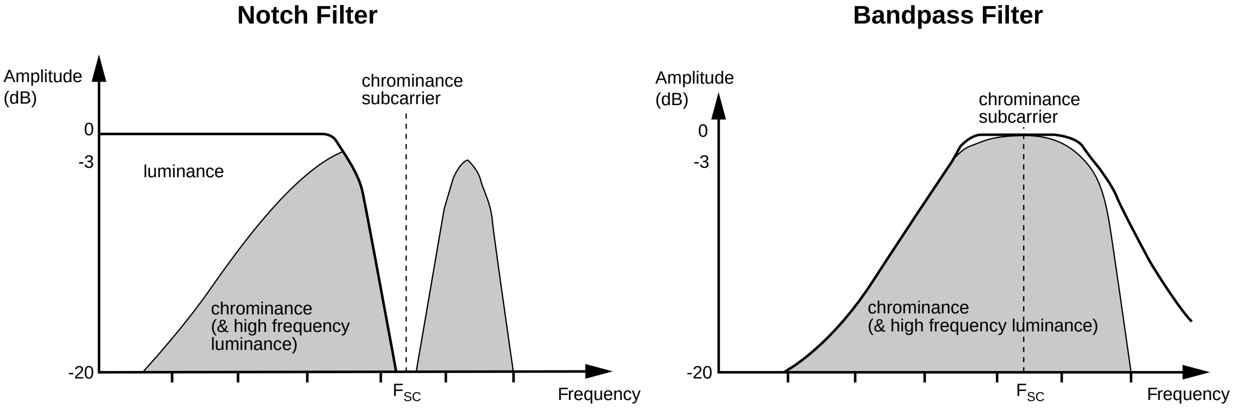

Figure 3: Examples of Notch and bandpass filters

The presence of cross color or cross luma is generally acceptable when viewing the decoded picture on a monitor from several feet, as would be the case in most homes on commercial television sets. However, these artifacts become increasingly difficult to process, or ignore, when the image is to be compressed or manipulated. In these cases more sophisticated methods of separating the luma and chroma signals, such as frame, field, or line based comb filter decoders, are required.

Comb filter architectures

A comb filter uses the relationship between the number of subcarrier cycles per line period, to cancel the chrominance signal over multiple line periods. This is shown for an NTSC two line comb filter in Figure 4. In NTSC there a 227.5 subcarrier cycles per line period, therefore the subcarrier can be canceled by simply adding two consecutive scan lines. In PAL(B/I/ etc.) there are 283.7516 subcarrier cycles per line period, ignoring the 0.0016 cycle advance caused by the 25Hz offset, the PAL subcarrier can be canceled by adding the first and third line of three consecutive scan lines. Due to the 270 degree advance, it is not possible to use information from consecutive field lines without adding a PAL modifier. A PAL modifier produces a 90 degree phase shift in the chrominance signal by multiplying the chrominance signal by a signal at two times the subcarrier frequency that is phased locked to the subcarrier burst reference in the composite video waveform. In addition the PAL modifier inverts the V component of the chrominance signal. This document refers to line based comb decoders when discussing decoders that use inputs from sequential scan lines from the same field, field based comb decoders when describing decoders that use inputs from sequential fields, and finally frame based comb decoders when examining decoders that use inputs from sequential frames.

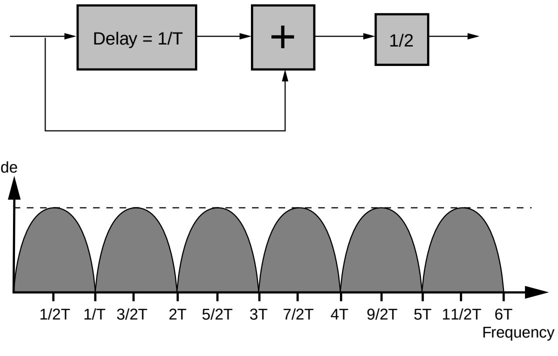

Figure 4

Composite Line-based comb decoders

The phase relationship of the quadrature modulated chrominance signal can also be represented as in Figure 5. The three line comb based decoder is clearly biased towards `1H' which illustrates the inherent one line delay through a 3 line comb, while a two line comb based decoder is biased towards `0H'. In the following discussions a flat color represents video of constant luma and chroma magnitude and phase.

In NTSC, adding two adjacent lines of flat color will cancel the chroma and leave the luma whereas subtracting two lines of flat color will cancel the luma and leave the chroma. In a 3 line comb filter the flat color on 0H and 2H is added to provide the flat color average before adding or subtracting from 1H.

In PAL, adding the flat color from 0H & 2H will cancel the chroma and leave the luma while subtracting the flat color from 0H & 2H will cancel the luma and leave the chroma. However, chroma generated in this manner has no simple phase relationship to the chroma on 1H. Therefore normally 0H & 2H are added together to produce the average luma across 3 lines and this is then subtracted from 1H to produce the combed chroma.

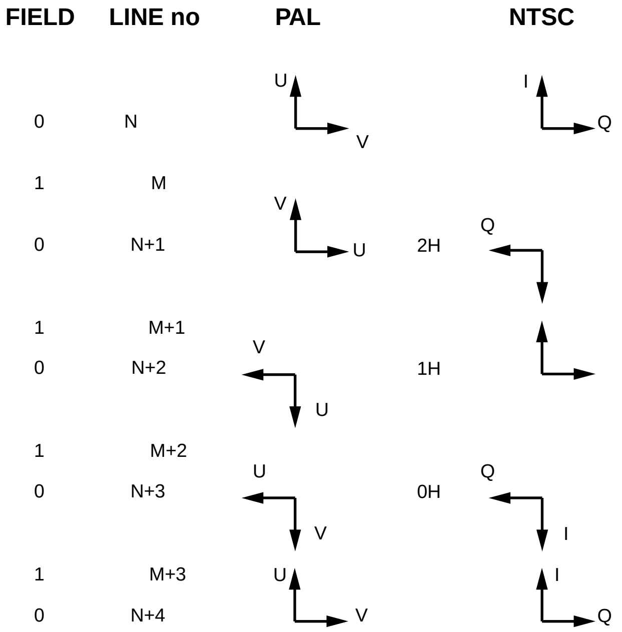

Figure 5: Chrominance vector rotation in PAL and NTSC

YC Line-based comb filters

The luminance and chrominance signals, are by definition, already separated for YC inputs. However, if the original source was composite, there is a distinct possibility that there is some residual luminance (cross color) in the chrominance signal and some residual chrominance (cross luma) in the luminance signal. It is therefore legitimate to treat these signals as if they were simply the output of a bandsplit filters and comb the luma and chroma signals accordingly.

D1 Line-based comb filters

A D1 data stream consists of multiplexed Y, C_b and C_R component data. If the original source was composite there maybe luminance (cross color) in C_BC_R and chrominance (cross luma) in Y. In the first case any luminance that was passed through a demodulator along with the chroma to produce the baseband C_BC_R color difference signals would have the same characteristics as chroma. That is to say, the cross color would advance by 180° every line in NTSC and every 2 lines in PAL. It is therefore possible to remove this cross color in a comb filter. In the latter case any chrominance that is still in the Y data can obviously be removed in a comb filter as well.

The original source for the D1 signal could also have been computer graphics. In this case, the comb filter can be used to remove the picture flicker and convert the output to RGB.

NTSC frame and field based decoders

Composite frame-based comb filters

In NTSC the chrominance vectors advance by 180 degrees every line, therefore after 525 lines the 2 adjacent frame lines 0H and FR0H and the two consecutive field lines FR0H and FR1H are 180 degrees apart. The flat color on FR0H and FR1H can be added or subtracted to provide the luminance or chrominance to subtract from 0H.

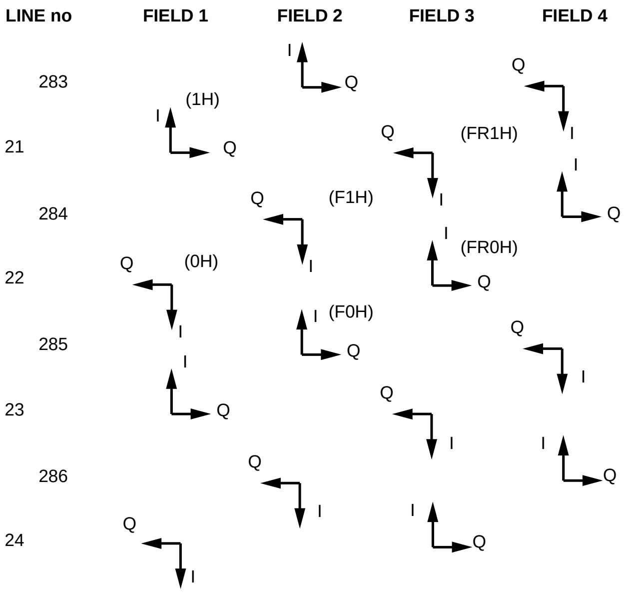

Figure 6: Chrominance vector rotation over 4 fields in NTSC

Composite field-based comb filters

In NTSC field based comb decoders, there is an external delay of 263 lines, therefore the 2 adjacent picture lines 0H and F0H and the two consecutive field lines F0H and F1H are 180 degrees apart. The flat color on F0H and F1H can be added or subtracted to provide the luminance or chrominance to subtract from 0H.

PAL frame- and field-based decoders

Composite PAL frame-based comb filters

In PAL the chrominance vectors advance by 270 degrees every line. After 625 lines the two adjacent frame lines 0H and FR0h are 90 degrees apart. It is therefore necessary to delay the FR0H data by an addition line so that 0H and FR0H are 180 degrees apart. The flat color on 0H and FR0H can now be added to provide the luminance or subtracted to produce chrominance. Due to the 270 degree advance, it is not possible to use information from consecutive field lines without adding a PAL modifier.

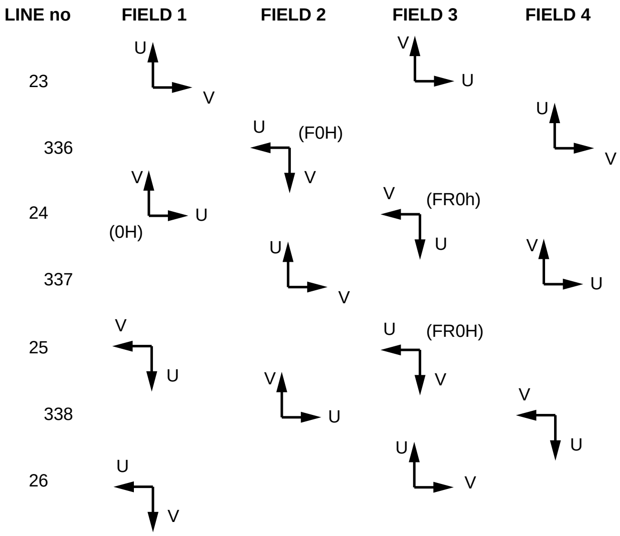

Figure 7: Chrominance vector rotation over 4 fields in PAL

In fields 5, 6, 7, and 8 the U and V vectors are 180 degrees advanced from fields 1, 2, 3, and 4.

Composite, PAL field-based comb filters

In PAL field based comb decoders, there is an external delay of 312 lines, therefore the 2 adjacent picture lines 0H and F0H are 180 degrees apart. Due to the 270 degree advance, it is not possible to use information from consecutive field lines without adding a PAL modifier. In fields 5, 6, 7, and 8 the U and V vectors are 180 degrees advanced from fields 1, 2, 3, and 4.

The TMC22x5y comb filter architecture

The TMC22x5y, when implementing a line based comb filter, has a core architecture as shown in Figure 8. The concept of the complementary bandsplit filter is also observed in the complementary comb filter architecture. It is therefore possible to adapt between the complementary comb filter and bandsplit filter without throwing away any of the original composite video frequency spectrum.

The first step in the complementary comb filter is to separate the high frequency luminance from the chrominance signal. This combed high frequency luma signal is shown as ***YCOMB*** in Figure 8. The second step is to produce an array of comb filter error signals that indicate the degree of confidence that the ***YCOMB*** signal is just the high frequency luma

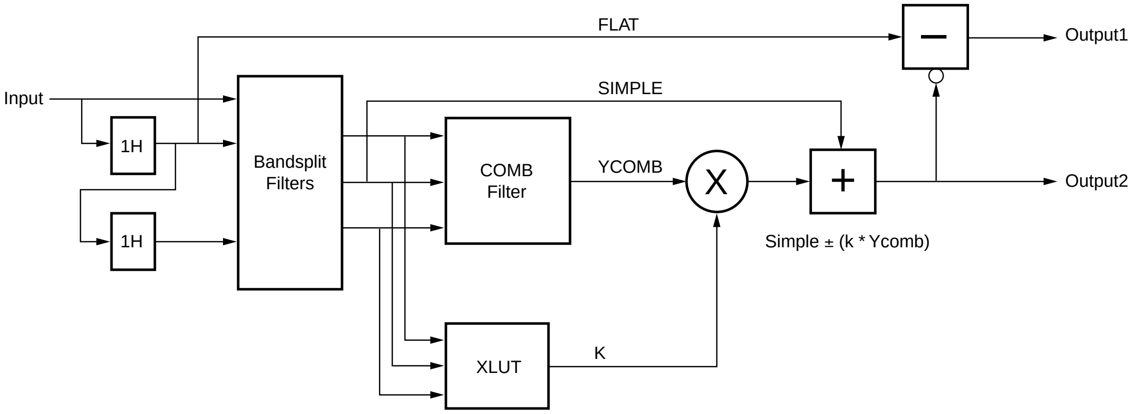

Figure 8: TMC22x5y line based comb filter architecture

and not a combination of high frequency luma and chroma smeared over the number of lines used in the comb filter. The signal representing this degree of confidence is termed ***K*** in Figure 8. The last step is to provide a complementary cross fade between the ***YCOMB*** signal and the output of the complementary bandsplit filter, shown as ***SIMPLE*** in Figure 8. The ***FLAT*** signal is simply a delayed version of the input to the comb filter, therefore the sum of ***Output1*** and ***Output2*** will always be equal to the ***FLAT*** video input.

The TMC22x53 comb filter architecture has three taps. These taps are three consecutive field lines in a line based comb, three consecutive picture lines in a field based comb, or lines that are one frame and one field line apart in the frame based comb. In addition to these different inputs to the comb filter, NTSC and PAL video signals comb over different taps in different architectures.

Input processor

The input processor selects between the two external video sources on VIDEO A and VIDEO B. If the TRS stripper or GRS stacker is active, then the user must select the input with either the GRS (in genlock mode) or with the embedded TRS words as output VA. If the input data are separate luma and chroma or Y and C_BC_R data the input processor must be programmed to put the chrominance or C_BC_R onto output VB and the luminance or Y onto VA.

To ensure that the chrominance data or the C_BC_R data are in two's complement arithmetic format, the register bit MSBI inverts the msb of the DB input. For composite inputs, the IPCMSB register bit should be set LOW, as the ABMUX register bit is used to select the input(s) to the comb filter.

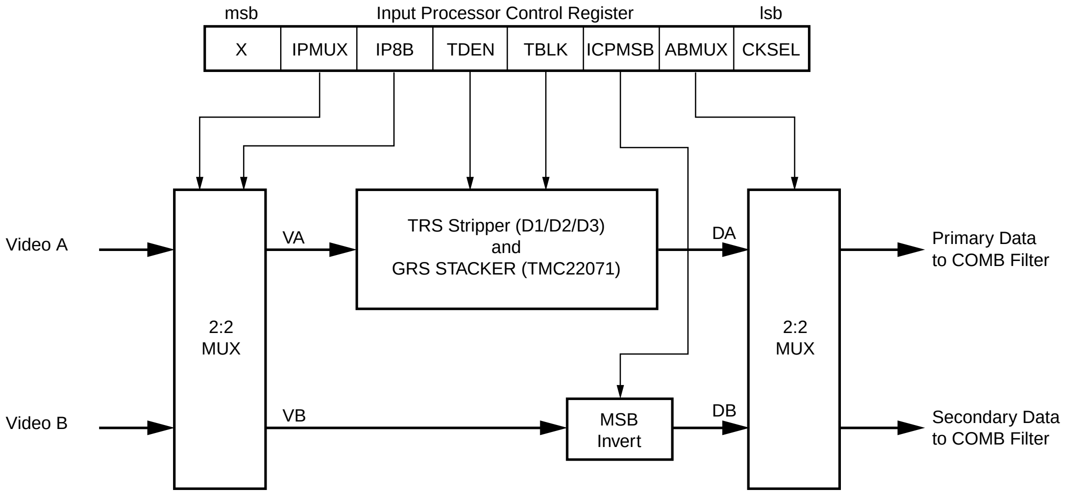

Figure 9. Input Processor

TMC22x5y 'simple' mode of operation

In its' 'simple' mode of operation, the TMC22x5y uses a complementary bandsplit filter, and not a notch filter for the luma and a bandpass for the chroma. The notch and bandpass filter technique, removes frequency bands from the composite video spectrum which can never be retrieved. The complementary bandsplit filter technique, shown in Figure 10, allows the decoded component video signals to be re-encoded into a composite video signal with the minimum of losses to the composite video spectrum.

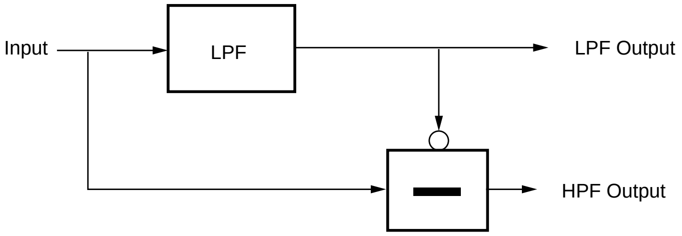

Figure 10: Complementary bandsplit filter

The complementary bandsplit low pass frequency response is shown in Figure 11 and Figure 12.

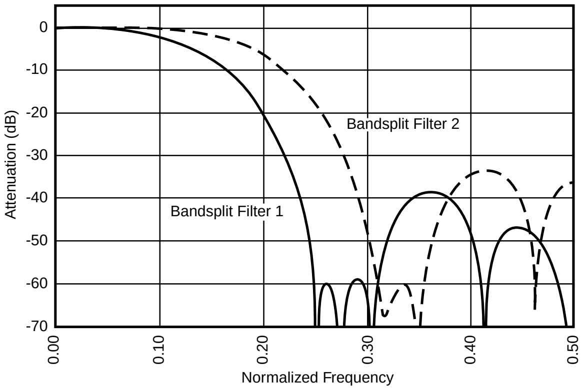

Figure 11: Bandsplit filter, full frequency response

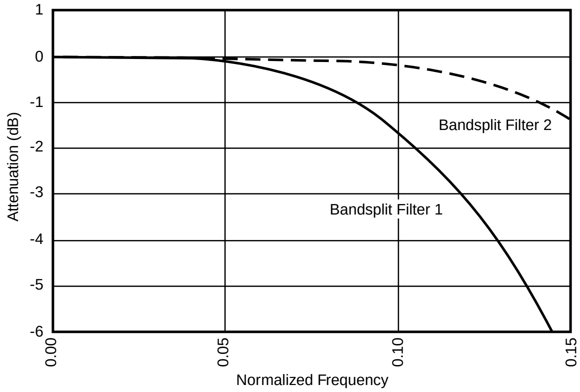

Figure 12: Bandsplit filter, passband response

The complementary bandsplit filter separates the base band composite video into two bands by passing it through a low pass filter and subtracting the low pass (luma) data from the composite video to produce the high pass (chroma) data. As the bandwidths and normalized subcarrier frequencies vary between different PAL and NTSC video standards, and the decoder must work with a wide range of pixel data rates, two different low pass filters are used. A comparison of the different data rates to normalized subcarrier frequencies is provided in Table 1. The selection of the bandsplit filter is controlled by the BSFSEL register bit.

Table 1: Normalized subcarrier frequency as a function of pixel data rates

Pixel Rate (MHz)	Normalized F_{SC}	Comments
12.27	0.2917	NTSC square pixel rate
13.50	0.2652	NTSC D1 pixel rate
13.50	0.3284	PAL D1 pixel rate
14.32	0.2500	NTSC four times subcarrier (D2/D3)
14.75	0.3006	PAL square pixel rate
15.00	0.2956	PAL square pixel rate
17.73	0.2500	PAL four time subcarrier (D2/D3)

Comb Filter input..

The inputs to the comb filter are selected from either the high frequency outputs of the bandsplit filters, if using a chroma comb filter, or the full composite waveforms when implementing a luma comb. The two sets of high and low frequency signals from the bandsplit filters are used for both the luma and chroma ***SIMPLE*** signals, and in the generation of the comb fail signals. These signals are denoted xHL, xHH, and xHF where 'L' denotes the low frequency portion of the signal, 'H' the high frequency portion of the signal and 'F' the full frequency spectrum of the input signal from line 'x'; and are shown in Figure 13: Block diagram of comb filter input.

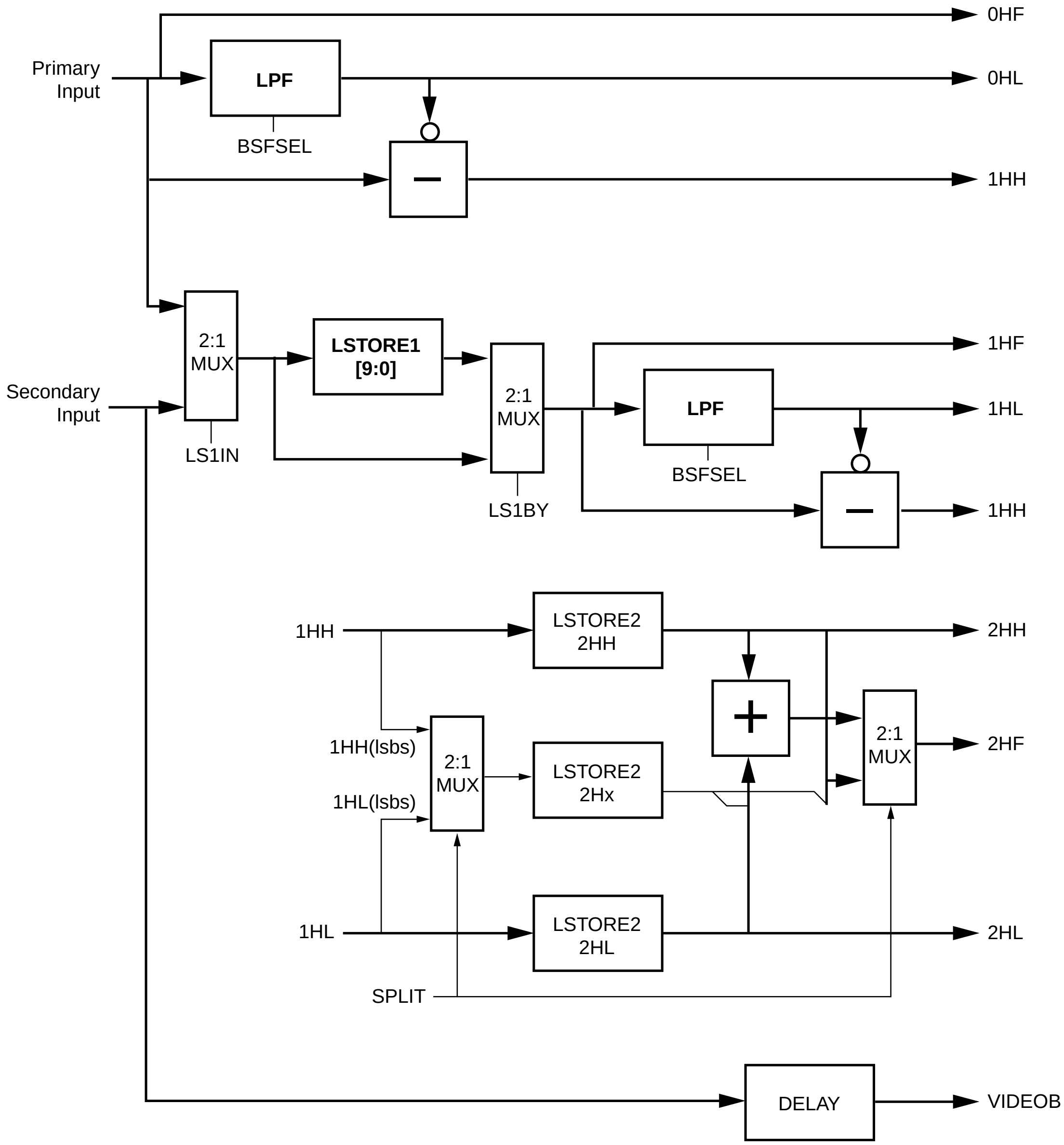

Figure 13: Block diagram of comb filter input

The primary and secondary inputs are selected within the input processor. The primary input is normally the undelayed composite video signal in line, field, and frame based comb filters or either the luma or chroma channel when processing YC or D1 signals. The secondary provides the field or frame delayed composite input for field and frame based comb filters and the chroma or luma channel when processing YC or D1 signals.

When implementing a line based comb filter the outputs of 1H bandsplit filter, ie 1HH, 1HL, are delayed through the second line store, LSTORE2. The number of bits delayed is dependent upon the type of comb filter being implemented. For chroma comb filters all the bits of the 1HH signal are delayed, as this information supplies the outer tap of the chroma comb filter, while only the upper bits of 1HL are delayed as this data is used only in the generation of the luma error signals. In the case of luma combs an equal number of bits of the 1HH and 1HL signals are delayed and summed together to produce the 2HF signal for the outer tap of the luma comb filter. The configuration of LSTORE2 is determined by the SPLIT register bit.

It is important to note that when implementing a field or frame based comb filter the secondary input must be selected by setting the LSIN register bit HIGH, and the first line store, LSTORE1, must be bypassed by setting the LS1BY register bit HIGH.

For YC and D1 processing the secondary input bypasses the comb filter completely and provides the VIDEOB signal input the 3:1 multiplexer used to select the FLAT signal, see Figure 14: Signal flow around the adaptive comb filter.

Signal flow around the adaptive comb filter

The IPCF[1:0] register bits select the inputs to the adaptive comb filter, this would normally be xHH for chroma combs, xHF for luma combs, and xHL if the luminance signal was to be sampled dropped on the output of the TMC22x5y. The Gaussian filters in the sample drop mode already limit the chrominance bandwidth to 1.3MHz allowing a [2:1:1] data format on the output, with the luminance signal having been vertically filtered by a fixed 3 line comb filter.

The SIMP selection bit is an internally generated signal based upon the comb filter selected. If a 3 line chroma, luma, or D1 comb filter is selected, due to the internal 1H delay inherent with this type of comb filter, the 1HL and 1HH signals are selected for the respective luma and chroma ***SIMPLE*** data signals. When any other type of comb filter is selected 0HL and 0HH are selected.

The DLYF selection bit is also internally generated from the type of comb filter selected and whether or not the input is in either the YC or Y & CbCr (ie D1 input) data formats. The ***VIDEOB*** data is always selected when the YCCOMP register bit is HIGH, ie for YC inputs. The selection of 1HF or 0HF depends upon the SIMP selection bit only when the YCCOMP register bit is LOW. Therefore, when YCCOMP is LOW and 0Hx is selected by SIMP then 0HF is selected for the ***FLAT*** signal, and when 1Hx is selected by SIMP then 1HF is selected for the ***FLAT*** signal. This ensures that the ***FLAT*** and ***SIMPLE*** data selected for any comb filter is delayed by the same amount as the data processed through the comb filter to produce the ***COMB*** output.

The final selection is the output required for the combed luminance and chrominance data. The output selection can be ***SIMPLE***, ***COMB***, ***FLAT-COMB***, or ***FLAT***. Generally ***COMB*** is selected based upon whether a luma or chroma comb was selected and the complementary output selects ***FLAT-COMB***. In the YC and Y & CbCr data modes the ***FLAT*** signal selects the secondary data and ***SIMPLE*** or ***COMB*** can be used to select the primary signal. In these modes the bandsplit filter can be bypassed or used to remove low frequency noise from the chrominance signal if chroma was selected as the primary signal.

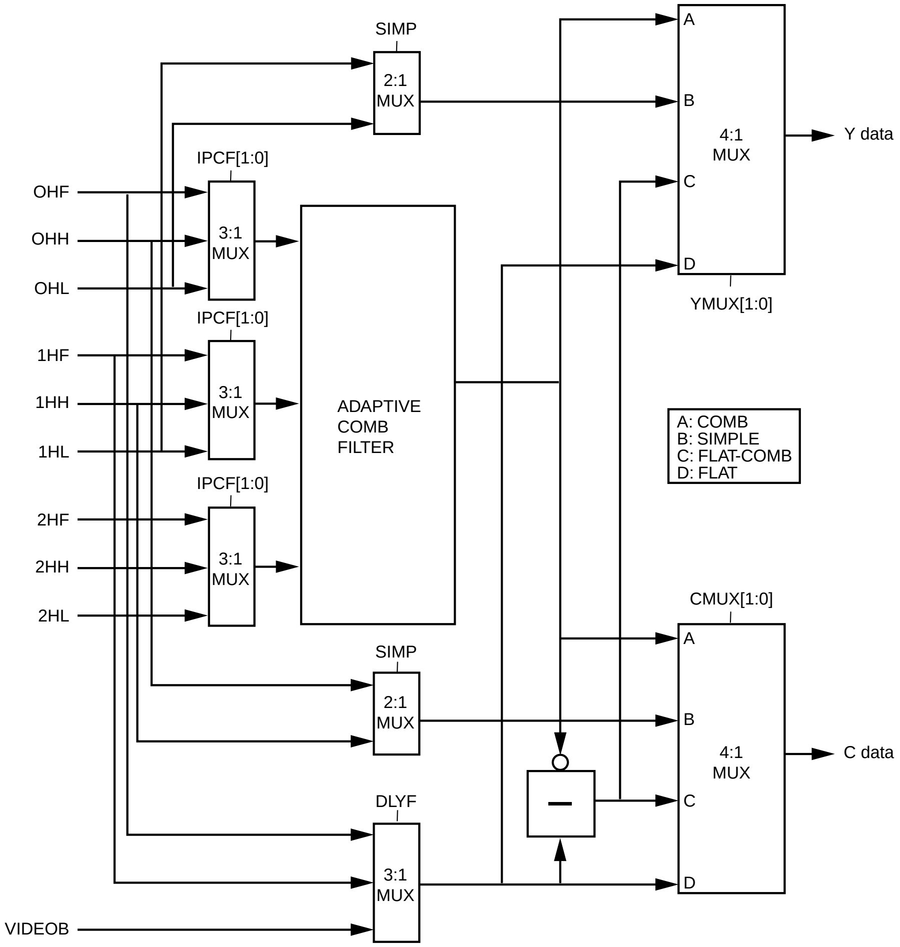

Figure 14: Signal flow around the adaptive comb filter.

Generation of the *COMB* signal.

The comb filter architecture performs chrominance or luminance comb filtering on PAL or NTSC video signals, by implementing one of sixteen independent chroma and luma comb filter algorithms. The highest level of the adaptive comb filter configuration is determined by the STA[3:0] register bits as shown in Table 2.

Table 2: Comb filter architecture

STA[3:0]	Comb Filter Description
0	YC or Composite, PAL or NTSC, 3 line comb
1	YC or Composite, NTSC, 3 line comb (0H & 1H)
2	YC or Composite, NTSC, 3 line comb (1H & 2H)
3	YC or Composite, NTSC, 2 line comb (0H & 1H)
4	YC or Composite, NTSC, (2 line) field comb
5	YC or Composite, NTSC or PAL, field comb
6	YC or Composite, NTSC, (2 line) frame comb
7	YC or Composite, NTSC or PAL, frame comb
8	D1, Y or C_BC_R, 3 line comb
9	D1, Y or C_BC_R, 3 line comb (0H & 1H)
10	D1, Y or C_BC_R, 3 line comb (1H & 2H)
11	D1, Y or C_BC_R, 3 line comb (0H & 2H)
12	D1, Y or C_BC_R, (2 line) field comb
13	D1, Y or C_BC_R, field or 2 line comb (0H & 1H)
14	D1, Y or C_BC_R, (2 line) frame comb
15	D1, Y or C_BC_R, Frame

The ***COMB*** signal can be produced in two ways. The first method uses the comb fail detection circuits to select one of several comb filter architectures. These comb filter architectures weight the three lines by varying degrees depending upon the degree of picture correlation between the inputs to the comb filter. The simple example in Table 3 shows how this process works, in which upper denotes error comparisons between the two lines stores and lower denotes error comparisons between the input and the first line store. The 0H, 1H, and 2H terms used in the mathematical description of the comb filter selection refer to the position with respect to the internal line stores. The 0H term is the undelayed input, 1H is the output of line store 1, and 2H is the output of line store 2.

In this example a 3line comb is implemented when in the flat areas of blue or yellow. However, when a difference between the inputs is detected the 3 line comb filter adapts to the 2 line comb filter whose inputs have the smallest difference. This illustrated on line ‘n+4’, at which time the comb filter adapts to inputs from 1H (blue) and 2H (blue) and ignores the 0H (yellow) inputs. In cases where there is a difference between all inputs to the comb filter, a 3 line comb filter is selected and the highest set of comb fail signals are sent to the XLUT input logic.

Table 3: Simple example of an adaptive comb filter architecture

Line no.	Input color	Error signals						Comb filter selection
		upper luma	upper sat.	upper hue	lower luma	lower sat.	lower hue	
n+6	blue	x	x	x	x	x	x	unknown without line n+7
n+5	blue	0	0	0	0	0	0	[0H/4] + [1H/2] + [2H/4]
n+4	blue	0	0	0	>0	0	180	[0] + [1H/2] + [2H/2]
n+3	yellow	>0	0	180	0	0	0	[0H/2] + [1H/2] + [0]
n+2	yellow	0	0	0	0	0	0	[0H/4] + [1H/2] + [2H/4]
n+1	yellow	0	0	0	>0	>0	>0	[0] + [1H/2] + [2H/2]
n	black	x	x	x	x	x	x	unknown without line n-1

This technique would work well if pictures only contained vertical transitions, which is obviously not the case. Therefore the weighting of these comb filter taps, (0H, 1H, and 2H), are rarely just the simple ratios shown in Table 3. It is worth noting that comb filters that use an even number of lines in the comb filter architecture produce chrominance and luminance signals that are vertically offset by one picture line, i.e. in the middle of the even number of lines used in the comb filter input. While comb filters that use an odd number of lines, in the comb filter architecture, the chrominance and luminance produced is referenced to the center, i.e. the middle line, of the comb filter. This approach can consequentially cause aliasing in decoding composite video signals containing high frequency diagonal transitions. The FAST register bit, when set LOW, filters the comb filter selection to decrease the sensitivity of the adaption algorithm. The second method completely disables the adaption between different comb filters, by setting the ADAPT[1:0] register bits accordingly (Table 4).

In either of these methods, the ***K*** signal can be used to cross fade between the ***YCOMB*** and the ***SIMPLE*** bandsplit signals. The resulting comb filter equation can be expressed as:

Combed Luma = Simple + (K * Combed High Frequency Luma)

Combed Chroma = Simple - (K * Combed High Frequency Luma)

In the case of the chroma comb, the weighted combed high frequency luma is subtracted from the ***SIMPLE*** high pass filter output to produce the combed chroma signal, and for luma comb filters the weighted combed high frequency luma is added to the ***SIMPLE*** low pass filter output to provide the combed luminance signal.

Comb fails

The inputs to the comb filter are monitored to detect discontinuities that would cause the comb filter operation to fail. Whenever a significant failure is predicted, the comb filter architecture is modified and an error signal proportional to the discontinuity is produced. For flat areas of color, it is a relatively simple to produce an error signal that switches between the outputs of the comb filter and the simple band split filter without visibly softening the picture horizontally or vertically. However, as horizontal frequencies increase during vertical transitions, so the decision for switching between the comb and simple bandsplit decoder becomes more complex.

A line based comb filter can separate the luma and chroma signals from line repetitive composite video signals, with no loss of luma or chroma bandwidth. However, if there is a vertical transition, i.e. a change from one scan line to the next, as shown for a NTSC two line comb in Figure 15, a ***comb fail*** occurs. The comb fail shown in Figure 15, clearly illustrates the resulting vertical smearing of the luma and chroma signals.

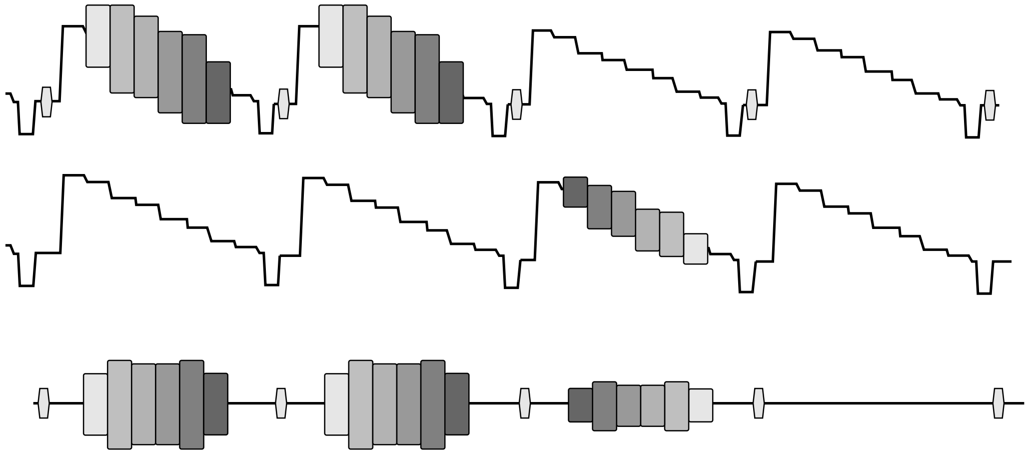

Figure 15: Example of a comb fail using a NSTC two line comb filter

In addition to the smearing, the resulting phase of the chrominance signal with respect to the burst can cause hue errors in the demodulated picture. In this example, the chrominance signal would be demodulated with a 180 degree phase error. Unlike the ‘simple’ decoder technique any errors in the comb filter decoding produce components that if re-encoded will never reproduce the original composite video waveform. It is therefore imperative that the number and magnitude of comb fails be kept to its absolute minimum. This is not possible with non-adaptive comb filter architectures, and all vertical and diagonal transitions in the picture will cause irreversible picture degradation. For this reason, all the TMC22x5y comb filter decoders implement an adaptive comb filter architecture.

To aid in this decision making process, comprehensive comb fail signals are generated and fed to a user-programmable lookup table (XLUT). The output of the lookup table provides the control for the cross fade between the comb and simple bandsplit decoder.

Comb fail detection

The traditional approach of using the low frequency data to look for vertical luma transitions, and rectifying the high frequency data to estimate vertical transitions in the chroma provides adequate comb fail detection. However, chroma signals that are equal in magnitude but 180 degrees apart in phase, which can also have a small difference in luma level, for example green and magenta, can produce undetected comb fails in the comb filter output.

In the TMC22x5y each input to the comb filter is passed through a simple bandsplit decoder. This provides a luma signal from the low frequency portion of the comb filter input, and the hue (phase) and saturation (magnitude) from the high frequency portion of the comb filter input. These signals are compared and the differences in luma, hue, and saturation are used to determine the type of comb filter used to generate the ***YCOMB*** signal and to provide the cross fade control signal ***K***. The ***K*** signal can be weighted within the XLUT lookup table, allowing the user to tailor the comb filter response to their system requirements.

Generation of the comb fail signals

The same xHL and xHH signals used as as inputs to the adaptive comb filter are processed to produce the comb fail error signals.

Luma error signals.

The signals from the 3 low pass filters, 0HL, 1HL, and 2HL are subtracted from one another to produce an error signal proportional to the luma comb fail. The resulting signals (0HL - 1HL), produces ***LYE,*** and either (1HL - 2HL) in NTSC or (0HL - 2HL) in PAL produces ***UYE***. The ***LYE*** and ***UYE*** luma error signals are rectified if negative. In cases where the luminance component is constant, the error will be zero. Where the luminance goes from black to white over 2 lines, the error signal will go to its maximum value.

The luma error signals can be doubled to facilitate inputs with low picture levels by setting the YESG register bit HIGH. The resulting signal is clipped to ensure no overflow occurs

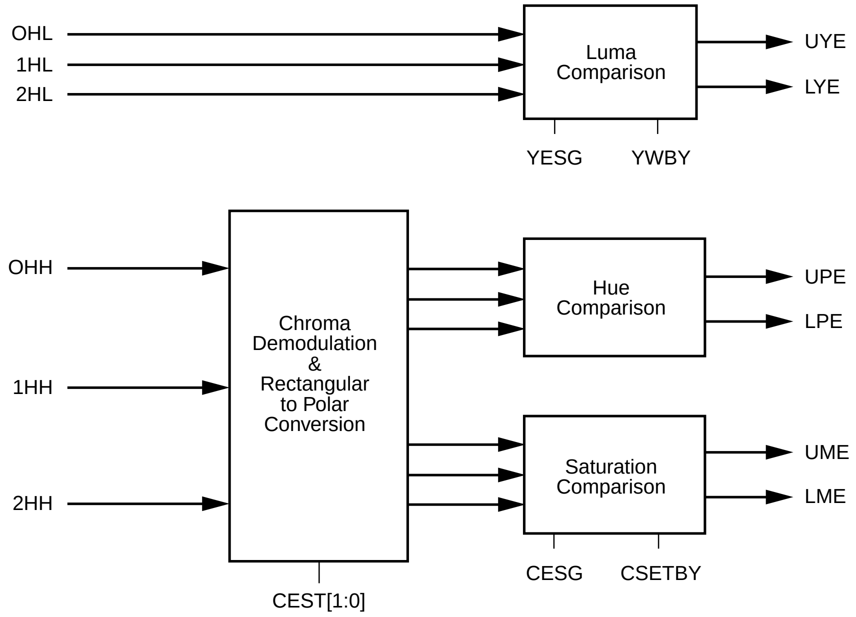

Figure 16: Generation of “upper” and “lower” comb fail signals

Hue and Saturation error signals

In the past, comb decoders have relied upon comparing the difference in chroma magnitude between two lines to determine a comb fail. In fact, this chroma signal is normally the output of the high-pass or band-pass filter, and therefore contains all the high frequency luminance information as well. As this signal was never demodulated, the sign bit was immaterial and was used only to rectify the chroma signal. This allowed chroma signals which where equal in magnitude but opposite in phase, and high frequency luminance signals, to fool the comb fail circuit.

The TMC22x5y uses a new, innovative approach to overcome this problem. To detect comb failures in the high-frequency portion of the video signal the outputs from the three high-pass filters, 0HH, 1HH, and 2HH, are passed through simple demodulators. The outputs from which provide the phase and magnitude of the “in phase” and "quadrature" components of the high frequency data. These components are compared to determine the difference in phase and magnitude between 0H & 1H in all configurations, ***LME*** and ***LPE***, and between 1H & 2H in NTSC or 0H & 2H in PAL, ***UME*** and ***UPE***. The magnitude error signals can be doubled to facilitate inputs with low picture levels by setting the CESG register bit HIGH. The doubled magnitude error signals are limited to ensure no overflow occurs

The algorithm used to separate the quadrature components depends upon the relationship between the normalized subcarrier frequency and the number of pixels per line. This algorithm is preset for either a NTSC/M or PAL/I subcarrier frequency and a pixel data rate of 13.5MHz. It is therefore necessary to compensate for other pixel data rates by selecting the appropriate default using the CEST[1:0] register bits.

Picture correlation

The degree of picture correlation depends upon the differences between the ***UYE, UME,*** and ***UPE*** upper error signals and the ***LYE, LME,*** and ***LPE*** lower error signals, and is measured as a percentage of full scale error. In flat fields of color you would have 0% error in picture correlation, however in sharp vertical transitions say between yellow and blue you would have large % errors between ***UYE*** and ***LYE*** and between ***UPE*** and ***LPE***, while there would be 0% error between ***UME*** and ***LME***.

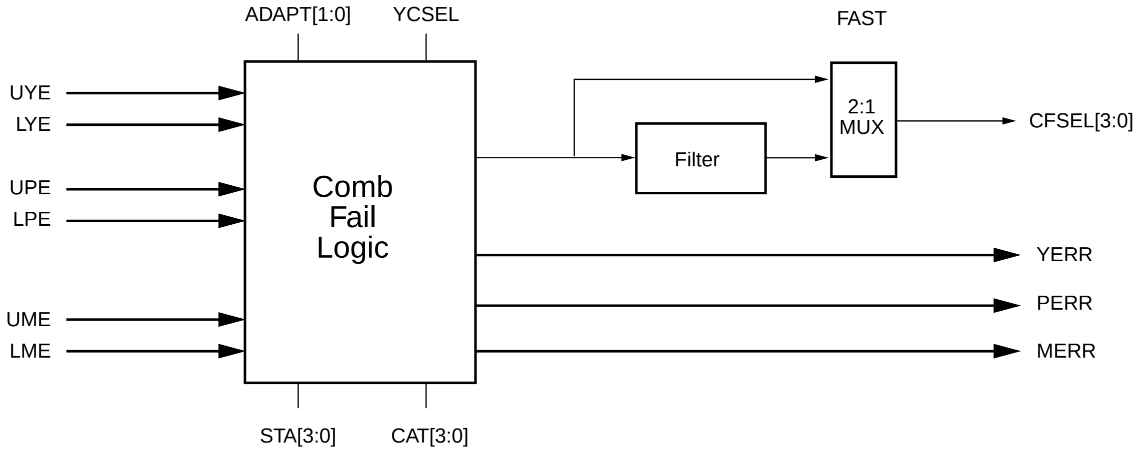

Figure 17: Comb filter selection

Adapting the comb filter

In NTSC it is possible to switch from a 3 line comb to a 2 line comb, and then to a simple decoder output. The 3 line comb to 2 line comb switch can be disabled, forcing the 3 line comb to switch directly to simple. The switching between these two comb architectures is independent of the mix signal, K. For 3-line Y/C comb filters, an external 1H delay is required in the uncombed channel to compensate for the comb filter delay.

This principle is equally true for NTSC frame and field based comb decoders. The feature is not available for any of the PAL comb filter architectures.

The ‘Comb filter Adaption Threshold’ register bits CAT[1:0] determine if 5%, 15%, 25%, or 50% errors in picture correlation is required to adapt the NTSC comb filter. In NTSC, due to the 180 degree advance in subcarrier phase per line, it is possible to switch between the 3 line comb and the choice of either the upper two line comb or the lower two line comb. If this switching occurs on a pixel by pixel basis the picture will contain vertical alias components. This artifact can be reduced by either setting the FAST register bit LOW, which filters the comb filter selection, and/ or setting the CAT[1:0] register bits to a higher percentage threshold.

The comb filter adaption is further controlled by the ADAPT[1:0] register bit selection, when the COMB[3:0] register bits select a 3 line comb. These bits control if the comb filter adapts from a 3 line comb to the best of the upper or lower 2 line combs, from a 3 line comb to just the lower 2 line comb, performs a fixed 3 line comb, or implements a best of two 3 line combs in PAL. If the COMB[3:0] register bits select one of the 2 line comb filters, the ADAPT[1:0] register bits are ignored, and no adaption is implemented. The CFSEL[1:0] signal, shown in Figure 17, controls which comb filter is selected on a pixel by pixel basis, and can be externally monitored by reading CFSTAT[1:0] in register 4Bh.

Table 4:

ADAPT[1:0]	Function
00	Adapts to the best of 3 types of line based comb filters in NTSC only.
01	3 line (tap) comb always adapts to lower 2 line (tap) comb, when the 3 line (tap) comb fails. Normally used with NTSC field and frame based comb filters.
10	3 line (tap) comb only. Never adapts to a 2 line(tap) filter. The higher set of comb filter error signals are sent to the XLUT. NTSC or PAL comb filter.
11	Adapts to best of two 3 line comb filters in PAL only.

XLUT

The comb fail signals control both the comb filter adaption and the cross fade between the adaptive comb filter output ***YCOMB*** and the ***SIMPLE*** bandsplit signal. Which of the fail signals is fed to the XLUT is determined by which comb filter is selected in NTSC. When a 3 line comb filter is selected, the larger set of error signals are sent to the XLUT, when a upper 2 line comb is selected ***UYE***, ***UME***, and ***UPE*** error signals are selected, and when a lower two line comb filter is selected the ***LYE***, ***LME***, and ***LPE*** error signals are selected. For PAL comb filters the ***LYE***, ***LME***, and ***LPE*** errors signals are always selected by default. In this way the error signals into the XLUT always represent the comb filter being implemented. The resolution of the error signals selected is controlled by the XIP[1:0] register bits as shown in Table 5: XLUT input selection. The position of these error signals on the XLUT input address X[7:0] is also shown.

Table 5: XLUT input selection

XIP[1:0]	Function
00	2 bits of phase error (X[7:6]), 3 bits of chroma (X[5:3]) and luma magnitude error (X[3:0]).
01	4 bits of chroma (X[7:4]) and luma magnitude error (X[3:0]).
10	3 bits of phase error (X[7:5]), 3 bits of chroma magnitude error (X[4:2]), and 2 bits of luma magnitude error (X[1:0]).
11	4 bits of phase error (X[7:4]) and chroma magnitude error (X[3:0]).

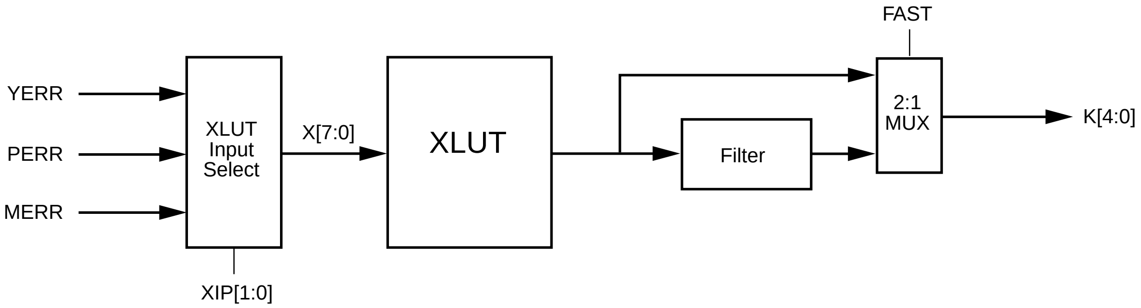

Figure 18: XLUT input selection

The selected comb fail signals are translated by the user-programmed configuration within the 256*5 XLUT into the mix signal (K) which controls the 30 levels of cross-fade between the weighted comb filter and the band split filters. The 1 to 31 mix signal is modified on the input to the cross-fade to produce a 0 to 32 control signal, as shown in **Table 6. XLUT Output Function**.

Table 6. XLUT Output Function

XLUT OUTPUT	K
0	Special function (e.g. luma comb and HPF on chroma)
1	0 - 100% Bandsplit
2	2
3	3
:	:
16	16 - 50% Bandsplit, 50% Comb
:	:
29	29
30	30
31	32 - 100% Comb

The special function assigned to K=0 is programmed into the XSF[1:0] register bits, as shown in Table 7.

Table 7. XLUT special function definitions

	XLUT special function selection	
KIP_{1-0}	Y	C
00	comb	simple
01	simple	comb
10	flat with notch	simple
11	flat with notch	comb

The “Flat with notch” selection passes the ***FLAT*** input through onto the luminance channel and selects the notch filter, centered at 0.25 of the normalized clock frequency. This mode is therefore only useful with inputs at 4*Fsc or in cases when a notch at 0.25 of the normalized clock frequency is adequate for application.

The XLUT output, is fed through a bypassable low-pass filter KLPF to avoid switching between comb and simple decoders on a pixel by pixel basis. When the special function is selected (K=0) the input to the KLPF is held and the filter is automatically bypassed. The output of the XLUT can be externally monitored by reading XOP[4:0] in register 4Bh.

Notes:

Notes:

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