

Composite Video Separation Techniques

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Introduction

The most fundamental job of a video decoder is to separate the color from the black and white information for video composite signals. This task has been achieved many ways since the introduction of color television over 50 years ago. Many different separation methods have been used through the years. With the availability of new cost effective technologies, the consumer has been seeing a gradual improvement in picture quality and detail. Advances in display tube technology and semiconductor processes have pushed the technological envelope providing sharper, more robust video. But separating the chrominance from the luminance information is especially challenging due to the fact that the signals overlap each other in the frequency spectrum. How do you separate them, while minimizing display artifacts?

Composite Signal Construction

The composite video signal is constructed with 3 basic elements:

- Luminance Information from DC to 5.5MHz (B&W Detail)
- Chrominance Information modulated onto a carrier (at 3.58MHz or 4.43MHz)
- Synchronization Information (Horizontal and Vertical Sync)

The three analog elements of a composite video signal carry all the information necessary to display a two dimensional picture on a cathode ray tube (CRT) television.

Luminance (a B&W World)

The luminance signal carries the black and white parts of the picture. This component of the composite video signal requires the most bandwidth (typically 5MHz), and signal integrity, to convey sharp and clear images. Edge information, brightness, and contrast of the image are entirely contained in the luminance portion of the signal. Until 1947 the broadcast video signal was only black and white. To maintain compatibility with the installed equipment of the time, color or chrominance information was added to the luminance signal to create the color composite signal as we know it today. Figure 1 shows the specified bandwidths for NTSC and PAL.

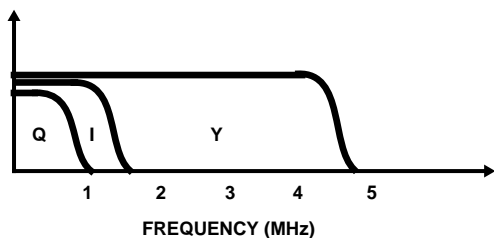


FIGURE 1A. Y-I, Q SIGNAL BANDWIDTHS (NTSC)

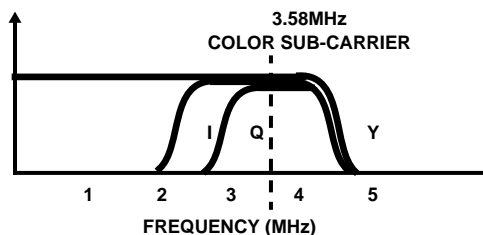


FIGURE 1B. NTSC COMPOSITE SPECTRUM

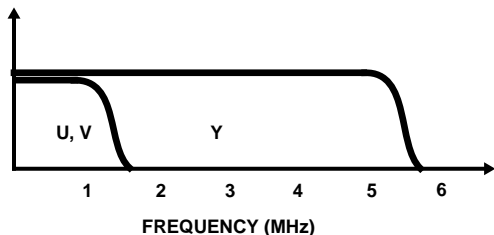


FIGURE 1C. Y-U, V SIGNAL BANDWIDTHS (PAL)

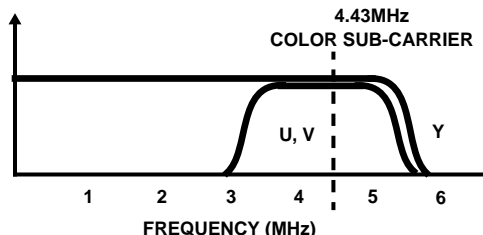


FIGURE 1D. PAL COMPOSITE SPECTRUM

FIGURE 1. COMPOSITE VIDEO SIGNAL BANDWIDTHS

Chrominance (an Add-On)

The chrominance information is quadrature modulated onto the luminance information. The chrominance is interleaved into the video signal bandwidth between luminance spectra. The chrominance modulation scheme utilizes an I, Q (U, V for PAL) coordinate system where hue and saturation is in vector format. A camera sensor captures light in Red, Green, and Blue (RGB) format. The RGB signal is converted into Y (luminance signal) and I, Q (Color Difference signal) format along with the synchronization information. The I, Q (commonly referred to as C) color information occupies a smaller bandwidth than the Y signal. C bandwidths typically range from 0.6MHz to 1.3MHz. The chrominance signal is modulated onto a carrier. The carrier resides at 3.58MHz for NTSC signals and 4.43MHz for PAL signals. The chroma information must be separated out of the video signal to demodulate it to baseband. This is difficult because luminance information that resides from 2MHz to 5MHz cannot be differentiated from chroma information. Several techniques have been tried over the years to improve separating Y and C, each increasing in complexity and performance.

Don't Forget the Sync

The synchronization information is also imbedded in the composite video signal and occupies precious amplitude range of the video signal. Horizontal Sync, Vertical Sync (also know as Vertical retrace) and the Color Reference Bursts are embedded in the composite waveform. Figure 2 shows a typical composite signal.

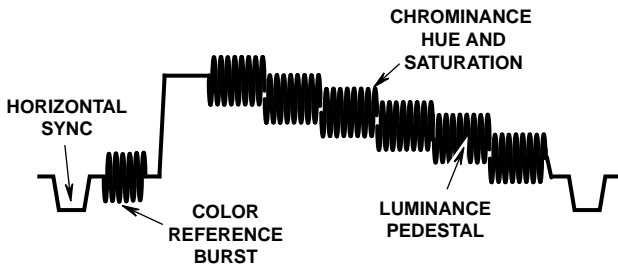


FIGURE 2. AN EXAMPLE OF A COMPOSITE VIDEO LINE

Determining the Separation Method

To determine what separation method is being used it is best to start with an ideal test signal that contains frequency based information like the Multiburst. Figure 4A contains a picture of a Luminance Multiburst with vertical bars from 0.5MHz to 5.0MHz. The 6 groups of bars are increasing frequency bursts of 0.5, 1.0, 2.0, 3.0, 3.58, and 5.0MHz. Figure 4B shows a VM700 scope trace of one line of the multiburst video pattern. Depending on the Y/C separation method used, the multiburst will illuminate the effects.

Method #1: Low Pass/High Pass Filter Separation Technique

One of the initial separation techniques used was the Low Pass/High Pass Filter technique to separate the luminance and chrominance signals from the composite video signal. This was the simplest and least costly to implement when color TV was first available. To extract luminance (Y) information a low pass filter with a cutoff around 2MHz to 2.5MHz is used. A high pass filter with a bandpass characteristic of 2.5MHz to 5MHz is used to pass the chrominance (C) information. This method works because the C information is centered around 3.5MHz (4.43MHz for PAL) and extends down to 2.5MHz. Figure 3 shows a typical frequency plot of this technique. The drawback of this technique is loss of detail. High frequency luminance information is removed from the signal and as a result much detail is lost. Edges of objects in a scene contain very high frequency information, loss of these frequencies blur the picture. Some other artifacts from using this technique are high frequency luminance crosstalk and serious cross-color effects. This method, although low in cost, produces poor quality video, subsequently this technique is used only on very low cost VCRs these days.

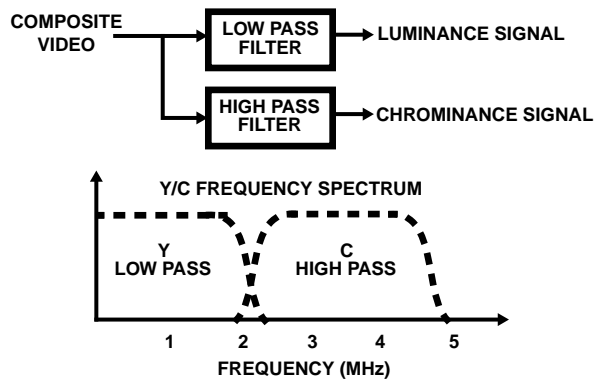


FIGURE 3. LOW PASS FILTER TECHNIQUE SPECTRUM

Figure 5A shows a picture of the multiburst pattern after it has been processed through the Low Pass/High Pass filter technique. Notice the attenuation of frequencies at 2MHz continuing up through the color subcarrier frequency, and up to 5.0MHz. Figure 5B demonstrates how severe the video multiburst line is altered by this technique.

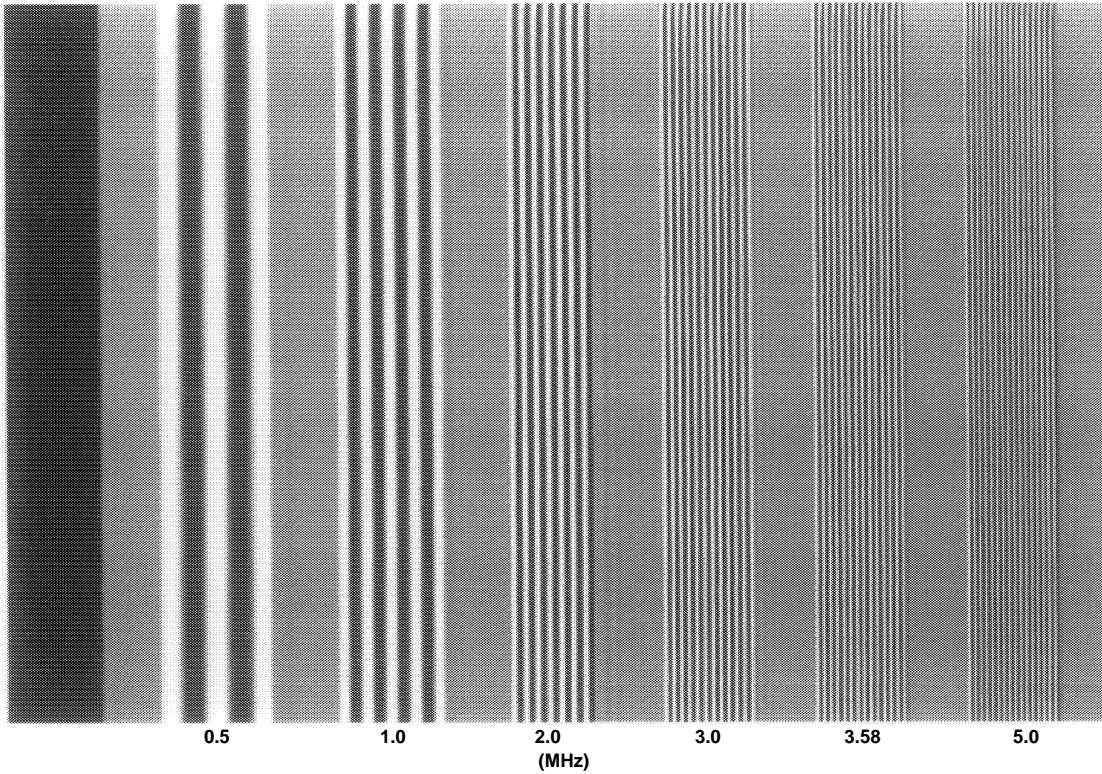


FIGURE 4A. MULTIBURST FROM VIDEO GENERATOR

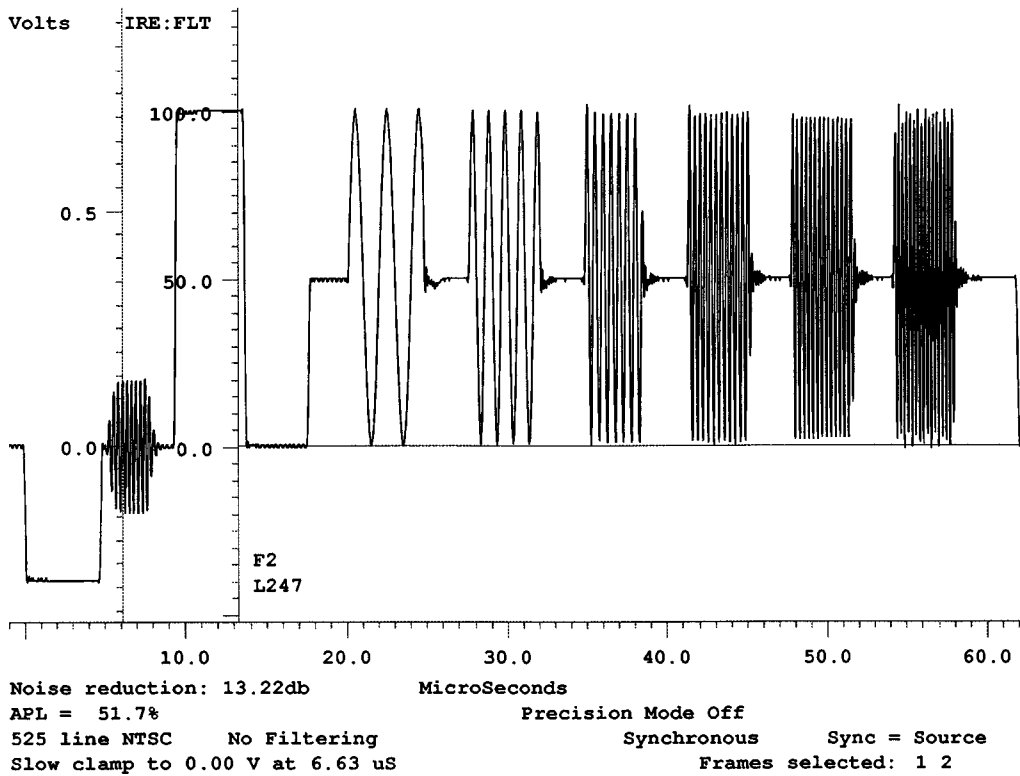


FIGURE 4B. IDEAL MULTIBURST WAVEFORM FROM VIDEO GENERATOR

Application Note 9644

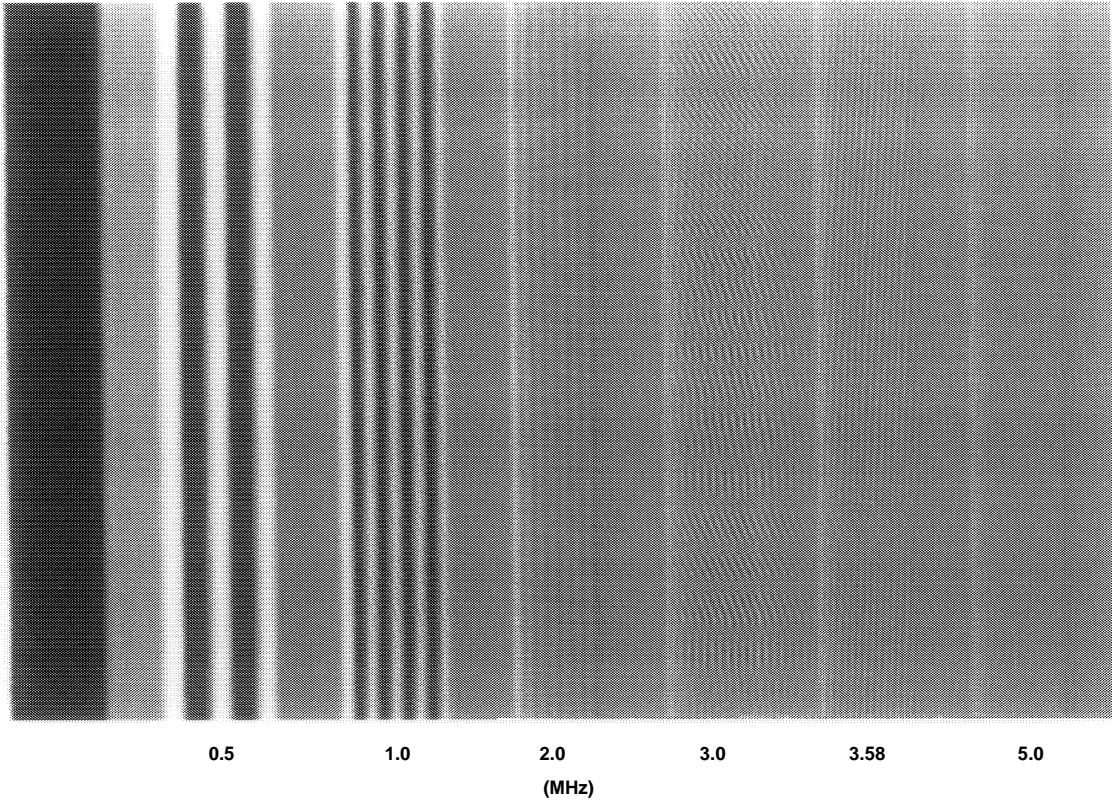


FIGURE 5A. MULTIBURST HIGH PASS/LOW PASS

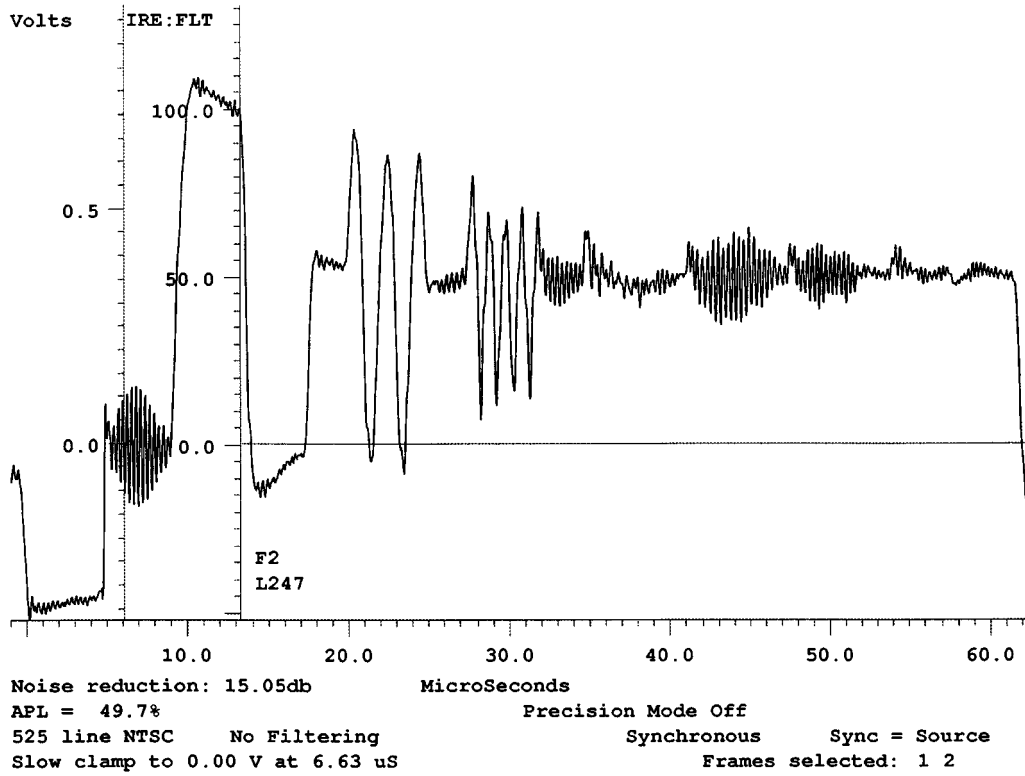


FIGURE 5B. MULTIBURST WAVEFORM FROM HIGH PASS/LOW PASS

Method #2: Color Trap Filter Separation Technique

Another technique to separate Y and C is the color trap filter method. A notch filter centered at the color subcarrier frequency is used to extract C information from 2.5MHz to 4.5MHz. Figure 6 shows the frequency plot of this technique. This method has two drawbacks to it. First, it limits the C bandwidth (which extends to 2.1MHz) cutting out fine color detail. Second, luminance information in the notch frequency range contaminates the C signal and generates unwanted color or rainbows. This is most noticeable with pictures that contain closely spaced black and white lines, like when a person wearing a herringbone jacket is recorded. The high frequency luminance will produce rainbows of colors due to the cross color effects.

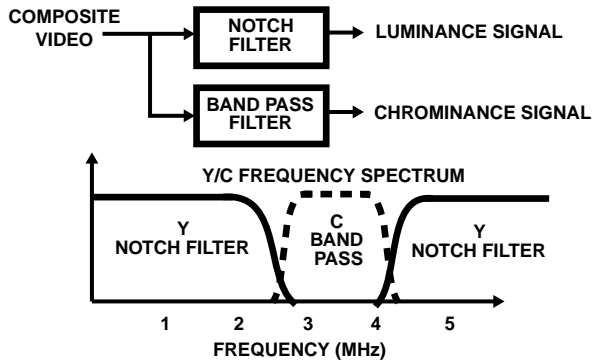


FIGURE 6. TRAP FILTER SEPARATION TECHNIQUE

Figure 9A shows a picture of the multiburst pattern after it has been processed through the Trap filter technique. Notice the attenuation of frequencies at 3.58MHz color subcarrier frequency continuing up through the color subcarrier frequency, and up to 5.0MHz. Figure 9B demonstrates how severe the video multiburst line is altered by this technique.

Comb Filter Separation Technique

Early implementations of this technique used analog storage elements such as glass delay lines and CCD arrays. The Digital Comb filter uses a line store memory. The comb filter takes advantage of the 1/2 line spacing of the spectral details of the composite signal. Figure 7 shows the overall spectrum of the comb filter processing technique.

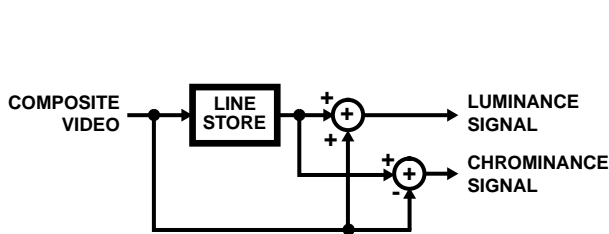


FIGURE 7A.

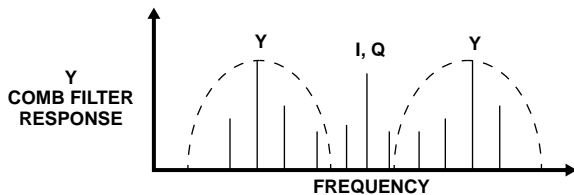


FIGURE 7C.

The comb filter relies on the fact that in NTSC the chrominance phase is inverted from line to line. This is because the chrominance information was interleaved into the luminance signal at 1/2 line offsets. When the present line and the previous line are added together the inversion in chrominance phase cancels out chrominance information and full bandwidth luminance data is stripped of chroma. The chrominance data is created by adding the present line and the inverted previous line to yield a double sized chroma amplitude signal. The comb filter has the benefit of producing full bandwidth, sharp luminance and low cross color products. The comb filter method was employed because of the advent of graphic overlays appearing in television broadcasts, which require all the luminance bandwidth available to produce a crisp image. The comb filter, however is not without it's flaws. When a sharp vertical transition is encountered, then a pattern known as hanging dots is produced by high frequency alias products. Hanging dots look like small black and white alternating dots that appear at the vertical transition. In a still picture these are very noticeable but in moving pictures they are not visually perceivable.

Figure 10A shows a picture of the multiburst pattern after it has been processed through the Comb filter of the HMP8112 video decoder. Notice that all of the bursts are intact all the way out to 5MHz. Figure 10B plot shows how much information is available up to 5MHz.

For the Phase Alternating Line (PAL) video standard a 2 line comb is not adequate enough to separate luma and chroma. In the PAL system the chrominance information is interleaved at 1/4 line offsets into the video composite signal. The comb filter technique does a simple subtraction or addition of two lines of video to separate the composite signal into luma and chroma components. Due to the 1/4 line offset and the phase alternation of the V component of the chroma a 2 line comb is not enough. A "correction" factor must be applied to the chroma signal to move the information to a 1/2 line spectral spacing. Only then can the comb filter start to do an adequate job of separation. Notice in Figure 8B the close proximity of luminance and chrominance data in the spectral domain. Figure 8C shows how the comb filter cannot remove all of the chrominance information from the luma signal. The leftover chrominance signal will cause cross luma (color interpreted as luminance) effects that will look like moving dots in the picture.

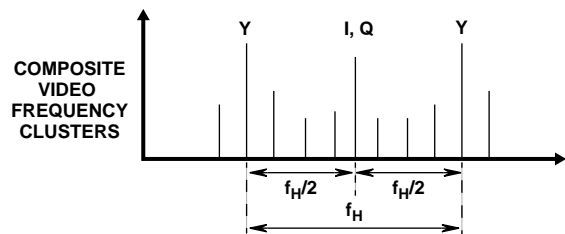


FIGURE 7B.

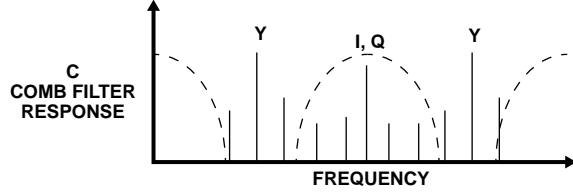


FIGURE 7D.

FIGURE 7. LINE COMB FILTER TECHNIQUE

Application Note 9644

For this reason to fully separate luma and chroma in a PAL system the additional use of a trap filter is needed to ensure low cross color and cross luma effects (see Figure 8A). Another reason for employing the help of a trap filter with the comb for the PAL system is because of the 25Hz offset that

is also a part of the PAL standard. The 25Hz offset was employed by the designers of the PAL system to keep cross color and cross luma effects moving in the picture which allows the human eye to filter out the moving dot patterns.

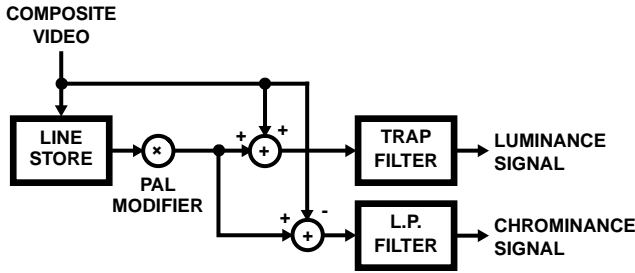


FIGURE 8A. PAL LINE COMB FILTER TECHNIQUE

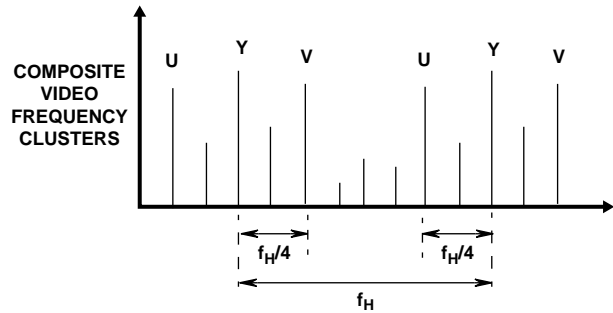


FIGURE 8B. COMPOSITE PAL INTERLEAVE SCHEME

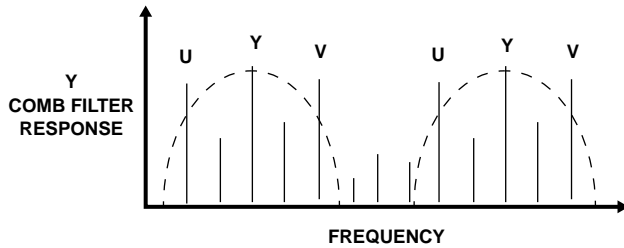


FIGURE 8C. Y COMB FILTER RESPONSE

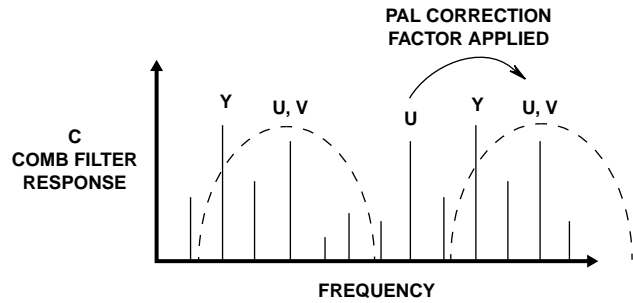


FIGURE 8D. C COMB FILTER RESPONSE

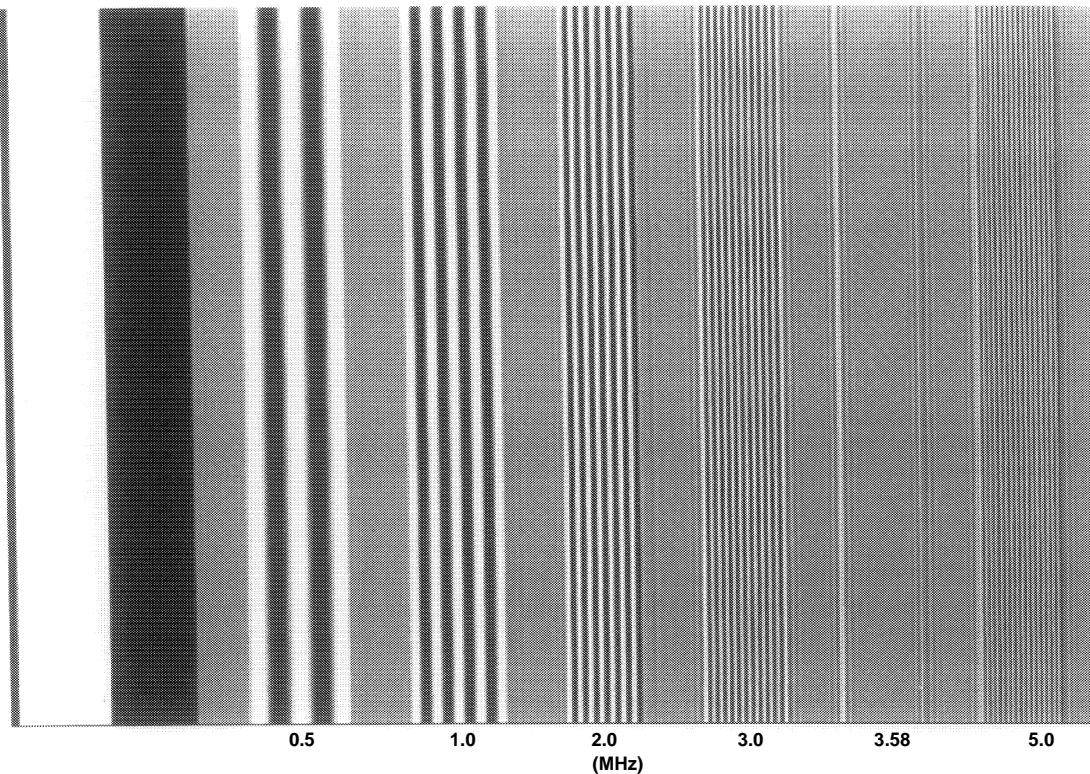


FIGURE 9A. COLOR TRAP FILTER

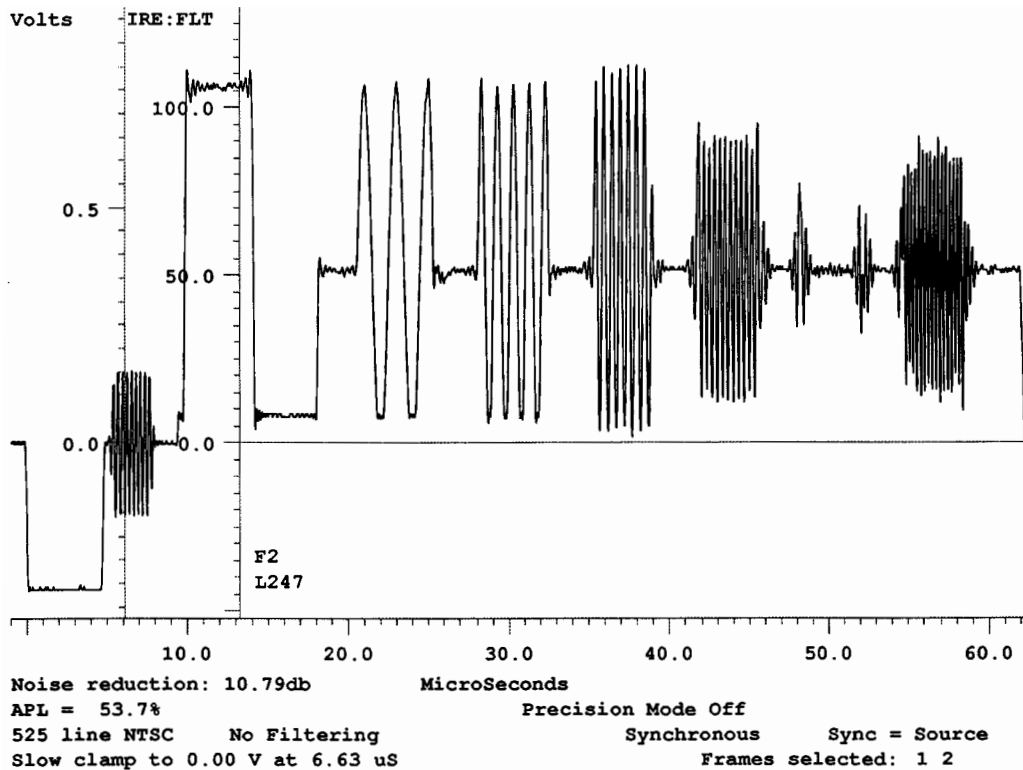


FIGURE 9B. MULTIBURST WAVEFORM FROM TRAP FILTER

Solving the Comb Filter Problems

There are a few ways to solve the comb filter "dots" problem. One method is the 3 line adaptive comb filter. This method switches between the trap and comb filter methods. An edge detection circuit is employed and when a sharp vertical transition is detected then the comb is disabled and the trap is enabled. This method is gaining wide acceptance in the industry but carries a cost burden of more video storage memory needed in 2 line stores versus 1. Another method is to not work with composite sources but rather use component sources like RGB, or YUV. These are not readily available to the commercial users and no standard has been accepted by the market at large. The S-Video standard (Separate Luminance and Chrominance Analog Signals) is gaining wide acceptance in the consumer ranks for higher video quality. The S-Video standard uses two analog signal lines, one for luminance, and one for chrominance, has no need to be separated. This removes the concern for cross color and luma effects generated by the separation process of a decoder. But as this is still an analog standard and is prone to power line noise and thermal variations. Digital video systems are debuting throughout the industry and are challenging present day analog systems. They boast crystal clear image quality, and high noise immunity but require high

bandwidth digital lines to be transmitted. A transition is happening in the professional and broadcast ranks but your average consumer still has commercial composite equipment. Once the costs start dropping and the quality difference is understood by the average user, hopefully things will migrate to the component type digital video.

Summary

The Harris HMP8112 employs an advanced 2 line comb processing technique, targeting noise sensitive applications such as video compression and video in a window on a computer. The high bandwidth processing offered by the 2 line comb yield sharper images with less cross color artifacts.

The comb filter provides full luminance bandwidth without destroying precious high frequency information so important for sharpness in an image. The comb also provides superior separation of luma and chroma without creating spectral anomalies that are interpreted as valid information by a compression engine. So for compression and high image quality applications the comb filter has distinct advantages for the consumer over traditional separation techniques.

Application Note 9644

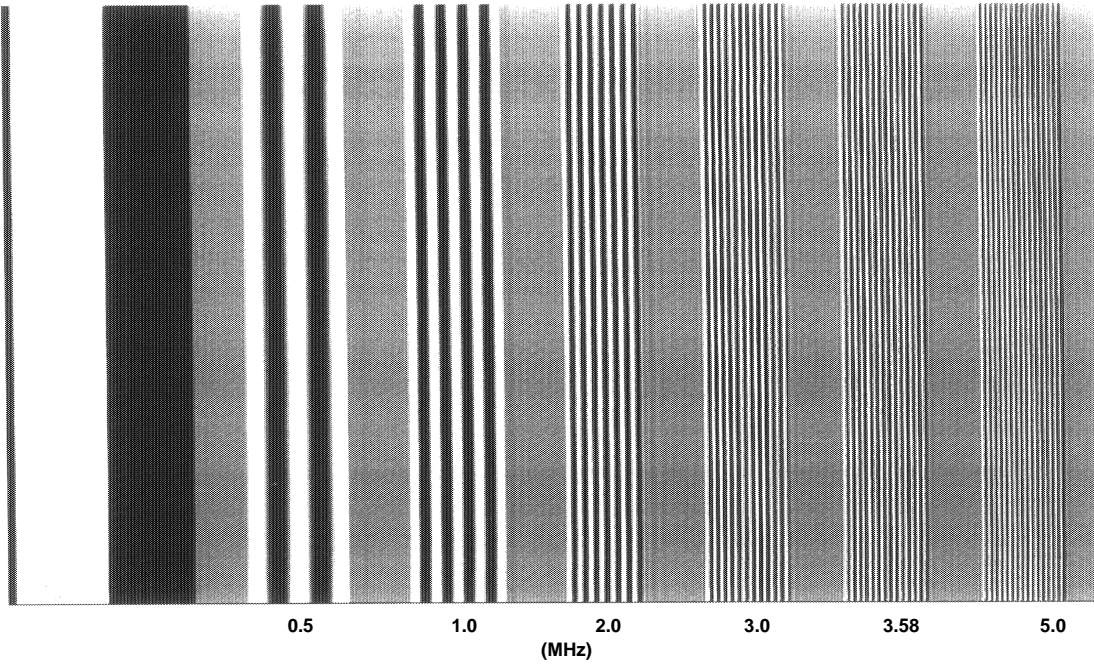


FIGURE 10A. HMP8112 COMB FILTER

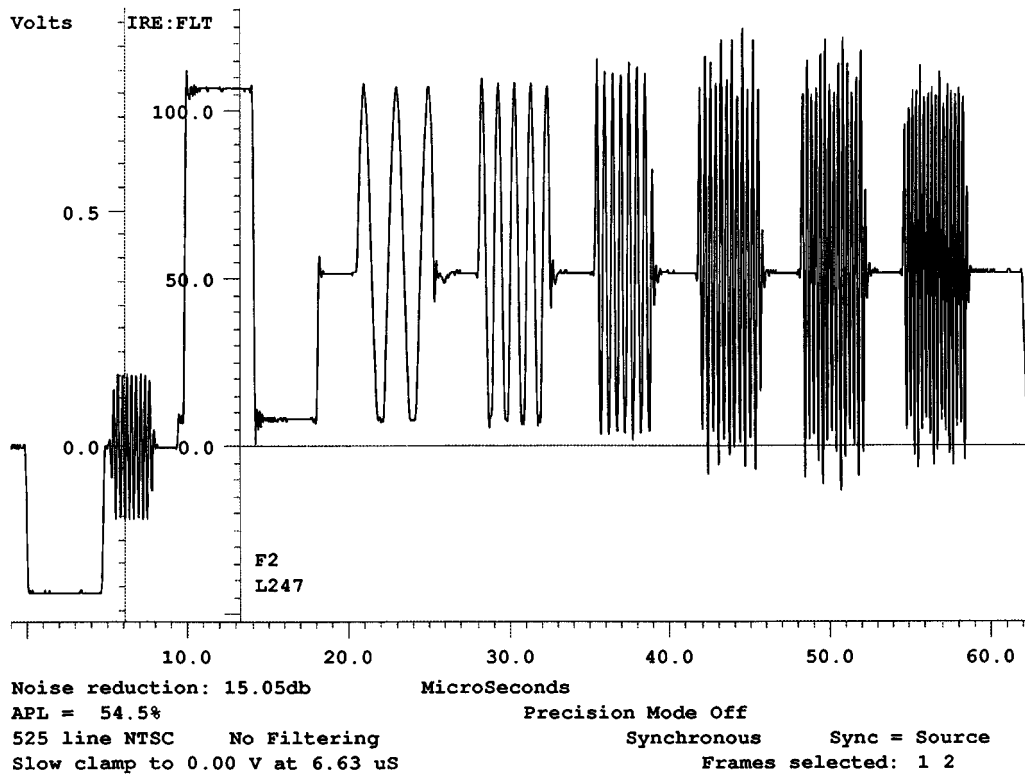


FIGURE 10B. MULTIBURST WAVEFORM FROM COMB FILTER

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