Designing a High Performance NTSC/PAL Decoder

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Introduction

Designing a NTSC/PAL decoder requires understanding not only the video standards, but also real-world video signals and how to best deal with them. In addition, there are many tricks and techniques used by the pro-video market, that may now be cost-effectively implemented on a standard decoder product. Vertical blanking interval (VBI) data capture is also now common, requiring understanding real-world implications of VBI processing.

This Application Note discusses the architecture and features of the decoder core used in several Intersil NTSC/PAL decoders, such as the HMP8116 and HMP8117.

Analog Video Inputs

Standard video practice is to have the analog inputs be AC-coupled to the video signals, with an AC and DC input impedance of 75Ω.

The video signal must then be further processed to position the blanking level to a known value, and automatic gain control done, to be able to handle real-world video signals.

Clamp Circuit

Since the input is AC-coupled, the clamp circuit positions the video signal such that during the sync tip the ADC generates a known value (in this case, a code of 0).

Automatic Gain Control (AGC)

Four types of gain control for the composite video signal (or the Y and C signals in s-video applications) are useful:

1. Automatic gain control.
2. Freeze automatic gain control.
3. No gain control.
4. Fixed gain control.

The last three modes are useful in pro-video editing applications, where the quality of the video signal is known, and the user wishes to optimize the video capture quality, or compensate for variations in the signal.

Many of these modes require the determination of the blanking level from the ADC. To do this, the output of the ADC is lowpass filtered to remove color subcarrier information and noise. The back porch is sampled multiple times to determine the average value, and this value is averaged over three scan lines to limit line-to-line variations.

During “automatic gain control” operation, the AGC attenuates or amplifies the entire video signal to ensure that the blanking level from the ADC is a specified value. This mode of operation is the most common where the quality of the video signal is unknown.

During “freeze automatic gain control” operation, the amplitude of the video signals is multiplied by a constant. This constant is the value the AGC circuitry generated when the “freeze automatic gain” command is selected.

During “no gain control” operation, the amplitude of the video signal is not modified, regardless of variations in the sync amplitude. Thus, a gain of 1x is always used. This mode of operation is useful when the amplitude of the active video is known to be correct, but the sync amplitude may be incorrect. The circuit must ensure the blanking level from the ADC is always a specified value by adding or subtracting a DC offset to the video signal.

During “fixed gain control” operation, the amplitude of the video signal is multiplied by a constant, regardless of variations in the sync amplitude. A gain of 0.5x to 4x is typically used. Limiting the gain to 4x limits the amount of amplified noise. This mode of operation is useful when there is a correlation between the sync amplitude and the active video amplitudes, and the video levels are known and constant. Again, the circuit must ensure the blanking level from the ADC is always a specified value by adding or subtracting a DC offset to the video signal.

A/D Conversion

To simplify analog anti-aliasing filters, the video data is 2x oversampled and an internal digital anti-aliasing filter is used. Since Intersil decoders use a proprietary Y/C separation algorithm, the digitized video data is then processed by an input sample rate converter.

Unlike many decoders, the gain circuitry and ADC operation are designed to handle 100% color saturation without introducing artifacts or amplitude limiting. Many video sources now contain computer-generated text and graphics, and highly-saturated colors may be present. Although the transmission of video via RF modulation limits the color to 75% saturation, there is no such limit for baseband video (not RF modulated). Thus, 100% saturated colors may be present on the outputs of settop boxes, DVD players, etc.

Input Signal Detection

A nice feature is the ability to detect whether or not an input video signal is present. If a video signal is detected, then “lost”, the decoder may generate an interrupt to the system. This allows the decoder, through software, to optionally generate a blue screen, black screen, or freeze the video output timing and data.

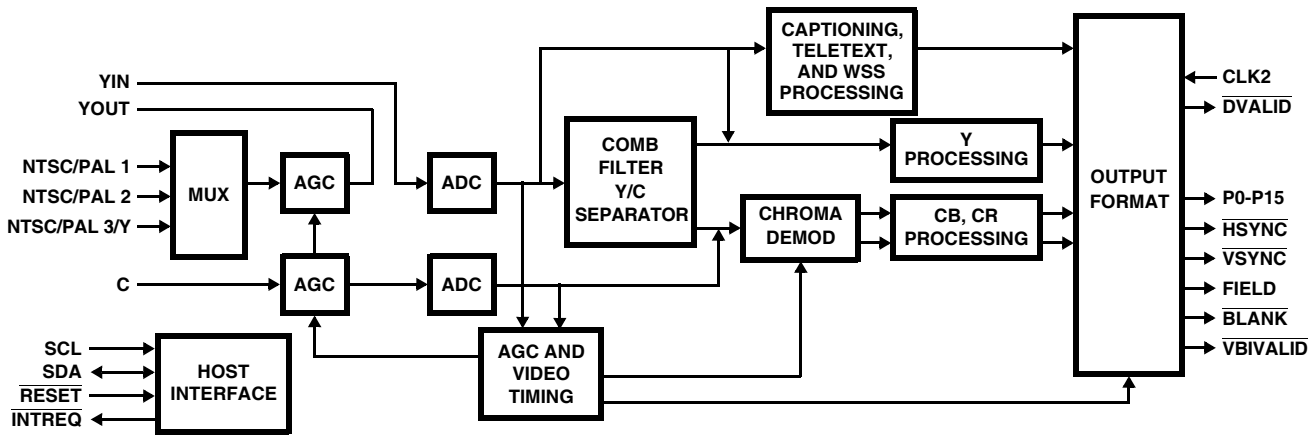

FIGURE 1. HMP8116 NTSC/PAL DECODER BLOCK DIAGRAM

The blue screen option is common in consumer applications. The black screen and freeze video output timing options are common in video editing to minimize editing artifacts.

Y/C Separation

An input sample rate converter converts composite or Y/C video data from the 2x sample rate to a virtual $4xF_{SC}$ sample rate for comb filtering and demodulation.

Although many decoders use a comb filter, it is usually to remove any remaining chroma from the Y signal because a relatively simple Y/C separator is used. Better decoders, such as the HMP8116 and HMP8117, use a true comb filter to provide Y/C separation.

An improvement over standard comb filters is “adaptive comb filters”. These comb filters detect the conditions under which dot crawl (or “hanging dots”) occur around edges of objects, and use a different Y/C separation algorithm to eliminate them.

High-end TVs use a 3D comb filter with motion compensation for the best possible Y/C separation. However, this implementation requires field store memory.

Chroma Demodulation

Demodulation, based on the Walsh-Hadamard Transform, is done at a virtual $4xF_{SC}$ sample rate, generating U and V data.

The output sample rate converter converts the U and V data from a virtual $4xF_{SC}$ sample rate to the desired output sample rate (i.e., 13.5MHz). It also vertically aligns the samples based on the horizontal sync information embedded in the digitized video data stream.

The U and V signals are then scaled and offset to generate Cb and Cr data with a nominal 8-bit range of 16-240.

Y Processing

The black level is subtracted from the Y data to remove sync and any blanking pedestal information. Unlike many decoders, negative values of Y are supported at this point to allow proper decoding of “below black” luminance levels. This allows video test signals, self-keying information, and real-world video to be passed through the decoder with minimum degradation.

Scaling is then done to position black at 8-bit code 0 and white at 8-bit code 219 to match the dynamic range used by BT.601 and BT.656.

A chroma trap filter may be used to remove any residual color subcarrier from the luminance data. This is particularly useful in PAL applications, since the performance of the comb filter degrades due to the closeness of the Y and U/V frequency packets. The center frequency of the chroma trap is automatically determined from the video standard being decoded. The chroma trap should be disabled during s-video operation to maintain maximum luminance bandwidth. Alternately, a 3MHz lowpass filter may be used to remove high-frequency Y data, making a noisy image more pleasing to the user, although softer.

Coring of low-level high-frequency Y data and low-level Y data about black may be done to help reduce noise.

High-frequency components of the luminance signal may be “peaked” to control the sharpness of the image. Maximum gain may be selected to occur at either 2.6MHz or the color subcarrier frequency. This may be used to make the displayed image more pleasing to the user. It should not be used if the output video will be compressed, as this technique introduces high-frequency components that will reduce the compression ratio.

The brightness control adds or subtracts a user-specified DC offset to the Y data, while the contrast control multiplies the Y data by a user-specified amount. These may also be used to make the displayed image more pleasing to the user.

Finally, a value of 16 is added to generate a nominal range of 16 (black) to 235 (white). Values of 0 are made 1, and values of 255 are made 254 to be BT.656 compliant.

CbCr Processing

After demodulation, the CbCr data is lowpass filtered to either 0.85 or 1.5MHz (selectable) to remove alias components as a result of the demodulation process. Coring of the CbCr data may also be done to reduce low-level noise around zero.

The saturation control, which multiplies the CbCr data by a user-specified amount, may be used to make the displayed image more pleasing to the user.

Many decoders have a color shift when adjusting the contrast since they do not modify the CbCr gain in addition to the Y gain. Intersil decoders allow the contrast control to optionally control the CbCr gain, implementing a true TV-like contrast adjustment.

The hue control provides a user-specified phase offset to the color subcarrier during decoding. During NTSC operation, this may be used to correct slight hue errors due to high-frequency phase shifts during transmission. PAL decoding uses line averaging, so a hue control is not normally supported for PAL video.

Finally, Cb and Cr values of 0 are made 1, and values of 255 are made 254 to be BT.656 compliant.

Genlocking

The ability to lock to a real-world video signal and recover the horizontal timing, vertical timing, and color subcarrier timing is the most difficult function of a decoder. The genlock circuits must be able to robustly handle missing and additional sync pulses, noise, VCR head switching, VCR fast-forward and reverse modes, and timing variations.

Televisions are able to handle such diverse conditions by adopting the rule of “never do anything quickly”. For example, they wait for several lines of missing sync pulses before taking corrective action.

A chroma PLL is used to maintain chroma lock for demodulation of the color information. It must be able to lock to low-amplitude color bursts (12.5% of nominal), and be able to accurately regenerate the color subcarrier.

The horizontal PLL is used to track the horizontal sync pulses to maintain vertical sample alignment. It must be able to handle missing or additional sync pulses, and line timing variations. The ability to handle line timing variations determines how well the decoder will handle VCR video signals.

Adaptive sync slicing (averaged over four lines) is used to automatically determine the mid-point of the horizontal sync amplitude for optimum horizontal PLL timing. Averaging over several lines avoids minor line-to-line variations, and improves the ability to handle low-amplitude video signals.

Although not usually a true PLL, vertical timing must be recovered from the video signal. Again, the ability to handle extended or missing vertical syncs determines how well the decoder will handle VCR video signals.

Another PLL is commonly used to generate a line-locked sample clock, ensuring a constant number of clock cycles are generated each scan line. This may be done by multiplying the horizontal sync timing by a constant (such as 858 to generate a 13.5MHz sample clock).

Most decoders implement a “TV/VCR” control bit that is used to adjust the time constants of the PLLs. If the input video signal is nice and stable, the TV mode is used, and the PLL time constants are selected such that the genlock circuits respond slowly to change. If the input signal is unstable, such as the output of a VCR, the VCR mode is used, and the PLL time constants are changed so that the genlock circuits respond more quickly to change.

Genlock Loss Detection

A nice feature is the ability to detect when genlocking to the input source has been lost, so the decoder may generate an interrupt to the system. This allows the decoder, through software, to optionally generate a blue screen, black screen, or freeze the video output timing and data.

Timing Control

Intersil decoders, such as the HMP8116, generate $\overline{\text{HSYNC}}$ (horizontal sync), $\overline{\text{VSYNC}}$ (vertical sync), $\overline{\text{BLANK}}$ (composite blanking), and FIELD control signals. The timing control signals have selectable polarity, simplifying interfacing to a wide variety of ICs. The output timing is compatible with other decoders on the market, simplifying the system design.

For flexibility, the $\overline{\text{BLANK}}$ output timing is programmable, allowing the horizontal and vertical timing to be configured for specific applications. Most systems expect 480 active scan lines per frame for 525/60 video systems. Therefore, during (M) NTSC and (M) PAL operation, the active scan lines decoded should be 23-262 for odd fields, and 286-525 for even fields, resulting in 240 active lines per field. During (B, D, G, H, I, N, NC) PAL operation, the active scan lines decoded should be 23-310 for odd fields, and 336-623 for even fields, resulting in 288 active lines per field.

A separate $\overline{\text{VBIVALID}}$ output signal is used to indicate when VBI data is output onto the pixel outputs during the vertical blanking intervals. This is useful to enable GUI chips and ASICs to separate the video and VBI data.

Since the some decoders, such as the HMP8116, do not generate a true line-locked clock, a $\overline{\text{DVALID}}$ (data valid) output signal may be used to indicate when valid pixel data is present on the pixel outputs. This signal is common on NTSC/PAL decoders that use DSP techniques for decoding video. The major advantages of this technique are lower sample clock jitter and the ability to handle VCR video signals more robustly.

BT.656 and VIP Interface

The BT.656 and VIP interface are rapidly gaining acceptance as standard digital video interfaces for ICs. The advantage is that the video timing information is embedded in the video stream, reducing pin count. In addition, they support the transmission of other digital data, such as audio and VBI data (either “sliced” or “raw”) in the blanking intervals.

For further information on the BT.656 and VIP interface, see Application Notes AN9728, and AN9792.

VBI Data Capture

Most video decoders now support several types of VBI (vertical blanking interval) data capture. Many designs for multimedia PCs, settop boxes, digital VCRs, recordable DVD, and TVs require support for these VBI data types.

During (M) NTSC operation, the first possible line of VBI data is lines 10 and 272, and the last possible lines are the last blanked scan lines. Lines 1-9 and 264-271 are always blanked.

During (B, D, G, H, I, N, NC) PAL operation, the first possible line of VBI data is lines 6 and 318, and the last possible lines are the last blanked scan lines. Lines 623-5 and 311-317 are always blanked.

During (M) PAL operation, the first possible line of VBI data is lines 7 and 269, and the last possible lines are the last blanked scan lines. Lines 523-6 and 261-268 are always blanked.

When the decoder is outputting “sliced” or “raw” VBI onto the pixel outputs, the $\overline{\text{VBIVALID}}$ output signal may be used to indicate when VBI data is present. This simplifies the design of GUI chips and ASICs that are required to separate the VBI data from the active video data.

"Sliced" VBI Data Capture

To simplify the handling of VBI data by the host processor, and reduce PCI bandwidth in multimedia PC applications, a decoder may generate "sliced" or binary VBI data. Once the VBI data has been captured, an interrupt may be generated to inform the host that new VBI data has been captured.

For all the VBI data capture types discussed below, hysteresis is used to prevent the VBI decoders from rapidly turning on and off due to noise and transmission errors. In order to handle real-world signals, the VBI decoders also compensate for DC offsets, amplitude variations, and timing variations. Ghost cancellation for the VBI data should also be implemented.

Closed Captioning. Closed captioning has been a standard feature for quite some time now for decoders. The closed caption decoder monitors the appropriate scan lines looking for the clock run-in and start bits used by captioning. If found, it locks to the clock run-in, the caption data is sampled and loaded into shift registers, and the data is then transferred to the caption data registers.

If the clock run-in and start bits are not found, it is assumed the scan line contains video data unless other VBI information is detected, such as teletext.

Widescreen Signalling (WSS). Widescreen signalling is a relatively new feature, used to indicate the aspect ratio of the program. This allows a WSS-enabled 16:9 TV to display the program to the best of its ability, or however the user specifies. For PAL systems, this signal also contains the CGMS (copy guard management system) bits.

For further information on Widescreen Signalling, see Application Note AN9716.

The WSS decoder monitors the appropriate scan lines looking for the run-in and start codes used by WSS. If found, it locks to the run-in code, the WSS data is sampled and loaded into shift registers, and the data is then transferred to the WSS data registers.

If the run-in and start codes are not found, it is assumed the scan line contains video data unless other VBI information is detected, such as teletext.

Teletext. The capture of ITU-R BT.653 teletext system A, B, C, and D is rapidly becoming a common feature. Teletext allows the transmission of text, graphics, and almost any other type of data. NABTS (North American Broadcast Teletext Specification) is the same as BT.653 525-line system C. WST (World System Teletext) is the same as BT.653 system B.

Many proprietary systems that use the vertical blanking interval to transmit data use the teletext physical layer. Some of these include Intel Intercast™, WavePhore™ WaveTop™, and Wink ITV.

The teletext decoder monitors the scan lines, looking for the 16-bit clock synchronization code used by teletext. If found, it locks to the clock synchronization code, the teletext data is sampled and loaded into shift registers, and the data is then transferred to teletext data registers.

If the clock synchronization code is not found, it is assumed the scan line contains video data unless other VBI information is detected, such as WSS.

"Raw" VBI Data Capture

"Raw" VBI data capture simply digitizes the VBI data, and outputs it onto the pixel outputs. Two applications for this are multimedia PCs (software decoding of VBI data) and settop boxes (pass the VBI data on to the NTSC/PAL encoder).

One requirement while generating oversampled VBI data is that the "active line time" be a constant, independent on the horizontal timing of the $\overline{\text{BLANK}}$ output signal. Thus, all the VBI data is assured to be captured, regardless of the output resolution of the active video data.

Summary

This Application Note has reviewed the basic architecture and features of the Intersil NTSC/PAL decoders. By adopting various output interfaces, such as VMI (Video Module Interface), BT.656, VIP (Video Interface Port), PCI, and AGP, a high-performance NTSC/PAL decoder is easily designed for a wide variety of applications.

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