HDTV Fundamentals

A S3Graphics Technical Brief

S3 Graphics, Inc.
1045 Mission Court, Fremont, CA 94539 510.687.4900

The migration from analog to digital imaging is as significant a step in image quality as was the change from B&W to color

A DeltaChrome Feature Presentation

from

S3Graphics, Inc.

INTRODUCTION

Little has changed in television since its original introduction. The last major change in NTSC television standards occurred with the migration from B&W to color. The FCC's mandate to change our broadcast standards from NTSC analog to ATSC digital broadcasting was a big bold move, requiring changes in the way studios shoot video, in the format that video is transmitted, and in the equipment we use to watch television. Since the digital format is PC-friendly, this change in broadcast standards is welcomed by the PC industry and is of great benefit to the viewer. Display format will no longer be limited to only 525 interlaced lines and progressive digital images will not be prone to

the image artifacts common to interlacing, such as screen flickering, ghost-shadows, and blurring. Digital television does not require the traditional television (analog) encoding scheme to display images. Digital signals can produce a higher quality TV picture, displaying sharp and vivid images using up to 1080 lines instead of 525 lines.

This document provides a summary introduction to the Standards SMPTE 296M and SMPTE 274 developed by the Society of Motion Picture and Television Engineers (SMPTE), as well as a guide to the overall design choices made specifically for the S3 Graphics IC environment.

For further understanding and description of the standards, please refer to the SMPTE 296M Standard or SMPTE 274M Standard specifications issued by SMPTE.

BACKGROUND: HDTV KEY FEATURES

Few specifications existed for HDTV during its early development. It was not until the spring of 1994 that significant progress was made toward the final HDTV system proposal. Key features of the system specification include:

TWO BASIC PIXEL ARRAYS: 1920 X 1080 AND 1280 X 720

Both 1920x1080 and 1280x720 pixel formats support a wide-screen 16:9 aspect ratio. These formats also incorporate square pixels, important for computer interoperability. Frame rates of 60, 30 and 24 Hz are supported, yielding a total of six different possible scanning formats (two pixel arrays, each having three frame rates). The 60 and 30 Hz frame rates are important for video source material, while 24 Hz is important for film.

PROGRESSIVE SCANNING

The second key feature of the system is the Grand Alliance's commitment to the use of progressive scanning, which is also widely used in computer display.

Progressive scanning is used for five of the six video formats. All three 720-line formats and 1080-line formats at 30 and 24 Hz incorporate the progressive scan mode.

TABLE 1 – HDTV PICTURE DISPLAY FORMATS

	Format	Vertical Scan Lines	Horizontal Pixels	Aspect Ratio	Scan Mode	Frame Rate (fps)	Delta Chrome support
HDTV	1080p	1080	1920	16:9	Progressive	24	N
	1080p	1080	1920	16:9	Progressive	30	Y
	1080i	1080	1920	16:9	Interlaced	30	Y
	720p	720	1280	16:9	Progressive	24	N
	720p	720	1280	16:9	Progressive	30	Y
	720p	720	1280	16:9	Progressive	60	Y
DTV	483p	483	720	16:9	Progressive	60	Y

It is neither technically nor economically feasible to provide the sixth video format (1080-line, 60 Hz) as a progressive format, although it was a long-term goal for the Grand Alliance. The 1080-line, 60 Hz format is handled in the initial standard with interlaced instead of progressive scanning.

SMPTE SCANNING STANDARDS

After the ATSC standard for digital television was approved for implementation, the SMPTE defined a series of scanning formats and interfaces for the multiple picture rates accommodated by DTV. S3 Graphics is adopting the formats defined by **SMPTE 274M** (1920 x 1080) and **SMPTE 296M** (1280 x 720) using Y', C_B', C_R' color encoding and an analog interface.

SMPTE 274M-1998 STANDARD FOR 1920 X 1080

SMPTE 274M-1998 defines a series of raster-scanning systems for the representation of images sampled temporally at a constant frame rate and within the following parameters:

- An image format of 1920 x 1080 samples (pixels) inside a total raster of 1125-lines,
- An aspect ratio of 16:9,
- Y', C_B', C_R' color encoding and an analog interface.

System parameters for SMPTE 274M-1998 are listed in Table 2. Analog interface timing details are given in Figure 1.

TABLE 2 – SCANNING SYSTEM FOR SMPTE 274M-1998

System Description	Samples per active line (S/AL)	Active lines per frame	Frame rate (Hz)	Scanning format	Interface sampling frequency f_s (MHz)	Samples per total line (S/TL)	Total lines per frame
1: 1920 x 1080/60/1:1	1920	1080	60	Progressive	148.5	2200	1125
2: 1920 x 1080/59.94/1:1	1920	1080	60/1.001	Progressive	148.5/1.001	2200	1125
3: 1920 x 1080/50/1:1	1920	1080	50	Progressive	148.5	2640	1125
4: 1920 x 1080/60/2:1	1920	1080	30	2:1 interlace	74.25	2200	1125
5: 1920 x 1080/59.94/2:1	1920	1080	30/1.001	2:1 interlace	74.25/1.001	2200	1125
6: 1920 x 1080/50/2:1	1920	1080	25	2:1 interlace	74.25	2640	1125
7: 1920 x 1080/30/1:1	1920	1080	30	Progressive	74.25	2200	1125
8: 1920 x 1080/29.97/1:1	1920	1080	30/1.001	Progressive	74.25/1.001	2200	1125
9: 1920 x 1080/25/1:1	1920	1080	25	Progressive	74.25	2640	1125
10: 1920 x 1080/24/1:1	1920	1080	24	Progressive	74.25	2750	1125
11: 1920 x 1080/23.98/1:1	1920	1080	24/1.001	Progressive	74.25/1.001	2750	1125

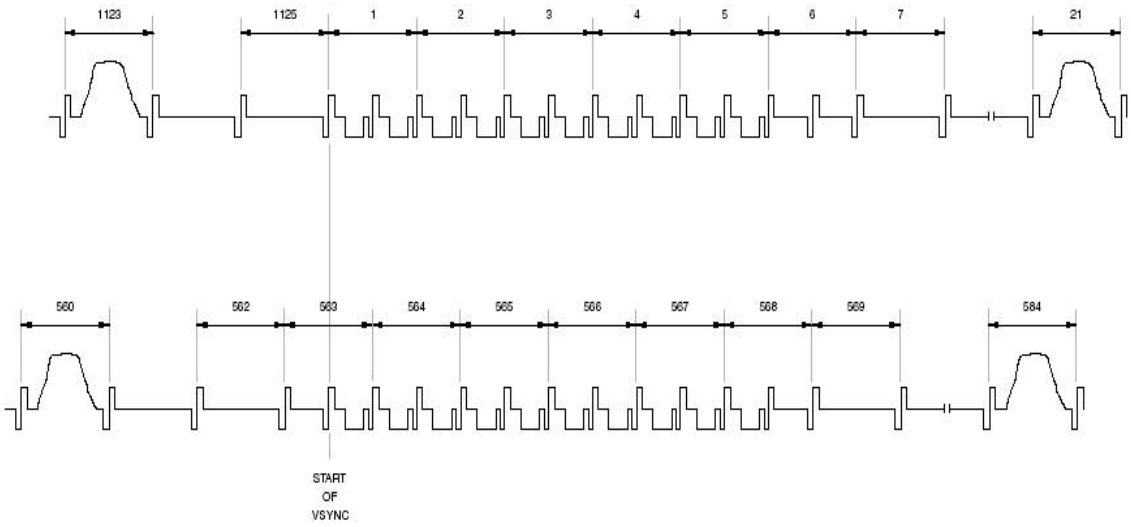

FIGURE 1 – SMPTE 274M- 1125-LINE INTERLACED VERTICAL INTERVAL TIMING

SMPTE 296M-2001 STANDARD FOR 1280 X 720

SMPTE 296M-2001 defines a series of raster-scanning systems for the representation of images sampled temporally at a constant frame rate and within the following parameters:

- An image format of 1280 x 720 samples (pixels) inside a total raster of 750-lines,
- An aspect ratio of 16:9,
- Y', C_B', C_R' color encoding and an analog interface.

System parameters for SMPTE 296M-2001 are listed in Table 3. Analog interface timing details are given in Figure 2.

TABLE 3 – SCANNING SYSTEM FOR SMPTE 296M-2001

System Description	Samples per active line (S/AL)	Active lines per frame	Frame rate (Hz)	Scanning format	Interface sampling frequency f_s (MHz)	Samples per total line (S/TL)	Total lines per frame
1: 1280 x 720/60	1280	720	60	Progressive	74.25	1650	750
2: 1280 x 720/59.94	1280	720	60/1.001	Progressive	74.25/1.001	1650	750
3: 1280 x 720/50	1280	720	50	Progressive	74.25	1980	750
4: 1280 x 720/30	1280	720	30	Progressive	74.25	3300	750
5: 1280 x 720/29.97	1280	720	30/1.001	Progressive	74.25/1.001	3300	750
6: 1280 x 720/25	1280	720	25	Progressive	74.25	3960	750
7: 1280 x 720/24	1280	720	324	Progressive	74.25	4125	750
8: 1280 x 720/23.98	1280	720	24/1.001	Progressive	74.25/1.001	4125	750

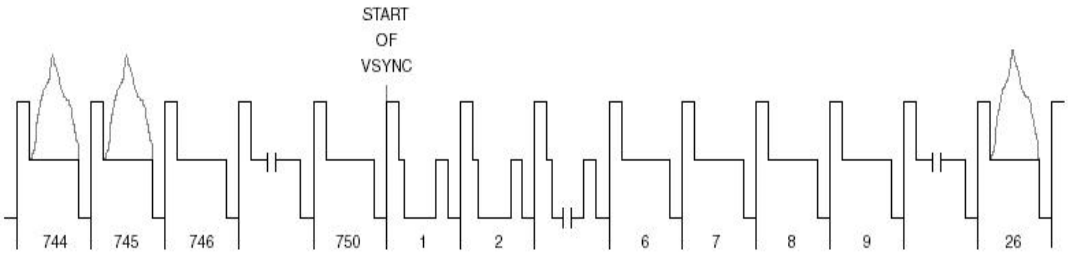

FIGURE 2 – SMPTE 296M- 750-LINE PROGRESSIVE VERTICAL INTERVAL TIMING

SCANNING

Scanning is based on a reference clock of the sampling frequency indicated in Tables 2 & 3, maintained to a tolerance of ±10 ppm. A frame consists of the indicated total lines per frame. Each line is of equal duration as determined by the sampling frequency and the samples per total number of lines (S/TL). Each line is uniformly scanned from left to right. Lines in a frame are uniformly scanned from top to bottom.

BENEFITS OF PROGRESSIVE SCANNING OVER INTERLACED

Interlacing was first introduced in the early days of television to reduce the amount of information that needed to be sent for each image. By transferring the odd-numbered lines first and then sending the even-numbered lines (as shown in Figure 3), the amount of information sent per frame was effectively halved.

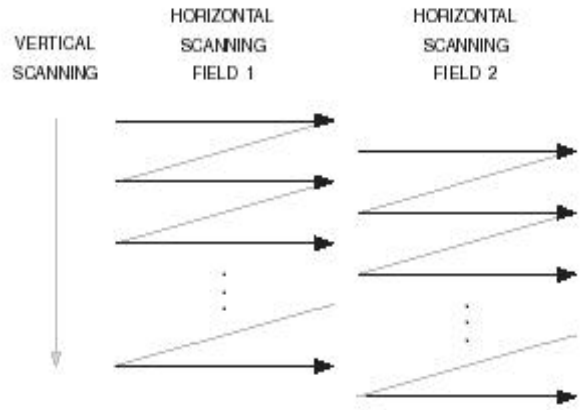

FIGURE 3 – INTERLACED SCAN PATTERN

Given this advantage of interlaced scanning, a common question is why should we bother to use progressive scanning instead?

With interlaced displays, each scan line is refreshed half as often as it would be if it were a progressive display. Line flicker can occur on sharp edges because the refresh rate is too low. To limit the number of line-to-line changes low-pass filtering of the vertical traces can be used.

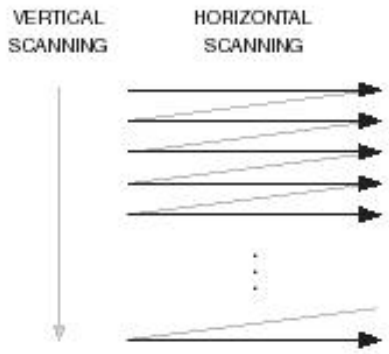

FIGURE 4 – PROGRESSIVE SCAN PATTERN

A progressive display, on the other hand, can make an unlimited number of line-to-line changes without sacrificing image quality. Progressive scanning is extremely capable of providing a high-resolution image (vertically) without flicker artifacts.

BENEFIT OF 720P FORMAT OVER 1080I

First generation interlace HDTV was called 1080 interlace, which actually should be characterized as 1920x540x60. Because progressive scan formats do not drop alternate lines in a given frame, they are capable of providing a higher quality image to the end user. Of the two recognized commercial technology formats for high definition television (HDTV), 720p yields the best quality images with minimal artifacts.

The following diagram simulates the differences between images in 720p or 1080i scanning format. Both images depict an object moving from one frame to another against a stationary background. The upper row of images demonstrates an image using 720 lines scanned progressing at 60 Hz. The lower row of images shows the lower quality provided by a 1080i image, which scans only 540 lines in 60 fps. Only half of the 1080 lines of information are being updated in any given frame:

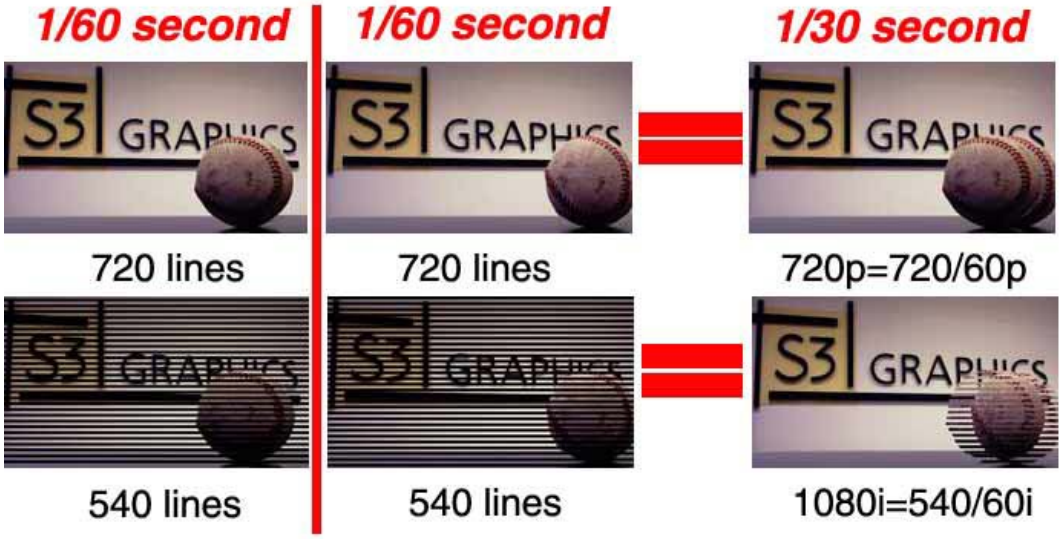

FIGURE 5 – IMPROVED QUALITY WITH 720/60P OVER 1080I (SIMULATED)

1920x1080 interlace raster scan utilizes 2:1 scanning, which means that the 1080 vertical lines are divided by 2: 1080/2= 540. A 1920x1080 resolution will take 2 fields to generate. 1080 interlace can thus be characterized as 1920x540x60. 1280x720 progressive raster provides a true frame scanning of 1280 horizontal pixels by 720 vertical pixels, 60 times every second. Thus 1280x720x60 delivers greater vertical resolution than 1920x540x60 (720 is better than 540).

Image quality is not always directly proportional to total available pixel count. An interlaced image may theoretically be generating more pixels per second, but quality is compromised if the output from those pixels produces a distorted image composed of compressed non-square pixels and missing pixels. 720 progressive delivers a distortion free high quality image:

> "720 progressive scan has virtually no distortion artifacts, whereas 540/60i has distortion artifacts throughout the image caused by the interlacing scan lines… What is called 1080 interlace does not appear to the human eye as 1080 lines, but rather as something more like 700 lines. This known phenomenon is the so-called "Kell Factor," which acknowledges degradation caused by receiver interline flicker and motion during the scanning process. Therefore, 720p is the optimum choice from both a temporal quality and distortion free spatial quality point of view." (source: http://www.atd.net/HDTV_faq.html)

APPLICATION INFORMATION

SMPTE 274M ANALOG INTERFACE

SMPTE 274M defines the position of the start of each line at the positive zero-crossing of a tri-level sync pulse. The sync pulse has a negative transition on a fixed number of clock cycles preceding this instant and another negative transition on a fixed number of clock cycles following this instant, as shown in Figure 6 & Figure 7. For both Y', P'_B and P'_R, the positive peak of sync is 300mV; the negative peak is -300mV.

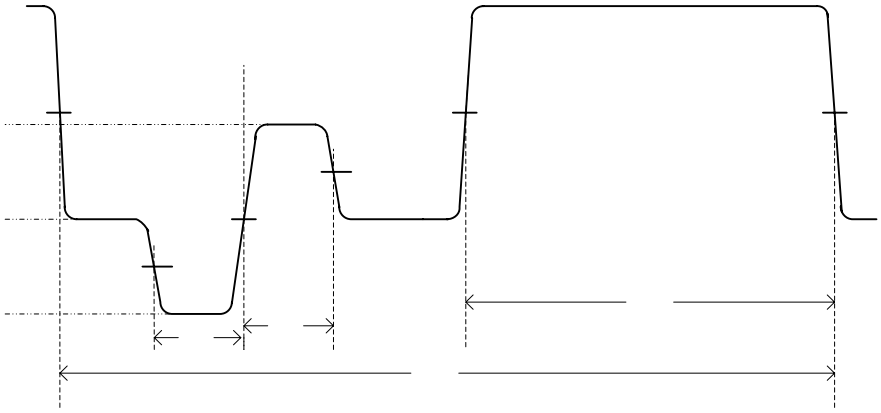

FIGURE 6 – SMPTE 274M LINE WAVEFORM (Y')

The tri-level horizontal sync is inserted on all analog outputs and has identical absolute amplitude levels in all cases. For Y', black corresponds to a level of 0V and peak white is 700mV (see Figure 6). P'_B and P'_R on the other hand have amplitudes between -350mV and 350mV (see Figure 7).

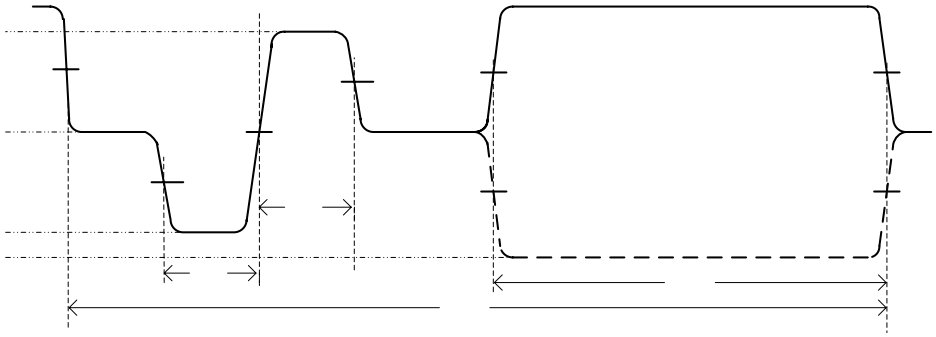

FIGURE 7 – SMPTE 274M LINE WAVEFORM (P'_B, P'_R)

PB'/P

SMPTE 296M ANALOG INTERFACE

350mV

The SMPTE 296M analog interface shares the same characteristic behavior as the SMPTE 274M, except for the following:

300mV

- The width of the tri-level horizontal is 40T instead of 44T
- Active samples are 1280T
- Total samples are 1650T

The amplitude levels of the sync and the amplitude levels of Y', P'_B or P'_R remain the same as for SMPTE 274M.

0mV

-300mV

-350mV

COPY PROTECTION TECHNOLOGY

DeltaChrome will continue the S3 Graphics tradition of providing support for Macrovision's copy protection and encryption technologies.

The technology will be implemented for 480p DTV resolution. This will allow users to display copy-protected material such as DVD movies using their standard PC display or using the component interface. At this writing, protection technology standards for 720p or 1080i modes are not finalized. For this reason, S3 Graphics device drivers will automatically switch the component display output to 480p for users who want to watch DVD with 720p or 1080i resolution.

S3 GRAPHICS MOBILE HDTV

As a leading provider in the PC mobile graphics industry, S3 Graphics is committed to delivering the best image quality to our customers. S3 Graphics is the first company to integrate advanced DTV/HDTV support technology into the graphics core. This integration eliminates the system requirement for an external dongle. DeltaChrome supports HDTV 720p and HDTV 1080i formats as well as the 480p DTV format using the component interface (YPbPr).

CONCLUSION

At S3 Graphics, we feel that providing standard DTV/HDTV solutions to our customers is not enough. We want to make sure our current solution will be able to drive tomorrow's technology, by providing the highest bandwidth for HDTV which is 1080 progressive at refresh rate of 60 Hz.

Currently, there are no HDTV Plasma/CRT displays available which take advantage of this resolution. However, since HDTV based on LCD technology is capable of displaying 1080p natively, we expect such displays to be available soon. We believe no one else can deliver the high bandwidth HDTV solution we offer in the cost effective integrated package we provide.

REFERENCES AND FURTHER READING

1. **SMPTE Standard: 274M-1998** Television - 1920 x 1080 Scanning and Analog and Parallel Digital Interfaces for Multiple Picture Rates. specification issued by Society of Motion Picture and Television Engineers (SMPTE, http://www.smpte.org)
2. **SMPTE Standard 296M-2001** Television - 1280 x 720 Progressive Image Sample Structure - Analog and Digital Representation and Analog Interface. Society of Motion Picture and Television Engineers (SMPTE. http://www.smpte.org)
3. **Advanced Television Systems Committee (ATSC)** Standard A/53B with Amendment 1: ATSC Digital Television Standard, Rev. B, 7 August 2001, (www.atsc.org/standards.html)
4. Frequently Asked Questions White Paper regarding DoD HDTV Formats (http://www.atd.net/HDTV_faq.html)
5. **Macrovision**: http://www.macrovision.com/solutions/video/copyprotect/