# AN-1943 Understanding Serial Digital Video Bit Rates

**ABSTRACT**

The objective of this application report is to explain the basis for the bit rates used in serial digital interface (SDI). This leads to a deeper intuitive understanding of the nature of the SDI signal and will ultimately help the engineer design robust serial digital video systems.

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# 1 Introduction

The technical requirements for digital transport of video signals are described in standards issued by the Society of Motion Picture and Television Engineers (SMPTE). Transport of these signals over point-to-point serial links is referred to as SDI and is specified by, among others, SMPTE 259M (standard definition video signals), SMPTE 292M (high definition video signals), and SMPTE 424M (3 Gb/s high definition video signals). These standards originally envisioned only the transport of uncompressed digital video; since their publication they have been adapted to standardize the transport of other signals and other types of data. Because SDI was designed to apply to a very narrowly-defined class of signals the transport protocols are quite straightforward.

# 2 Elements of a Video Signal

For a full explanation of the generation and characteristics of an analog video signal the reader is referred to any of several excellent references on the subject [1], [2], and [3]. Encoding a moving image in the form of an electronic signal is actually quite complex due to the many ways in which it might be (and has been) accomplished. This application note focuses on just a few of these encoding schemes, but the reader should bear in mind that many other schemes exist. The general principles described in this application note can be applied to most of these schemes in a straightforward manner.

A color television picture can be encoded in any of a number of color spaces. The Red-Green-Blue (RGB) color space, for example is widely used. Three signals are required to encode a color television picture in this color space, each containing the instantaneous amplitude of one of the color components as a function of time.

The first television receivers did not display color pictures. When color television signal encoding became widespread it was defined so that black-and-white television receivers could display the color television pictures (albeit in black and white). So a color space was used that divides the color components between a luminance, or brightness, channel (which is all that black-and-white television receivers can display) and two chrominance, or color difference, channels. This is the YCbCr color space. Luminance is often designated by luma and chrominance by chroma.

For broadcast television, the video signal is modulated onto an RF carrier. This modulated carrier is what is transmitted by the television transmitter. The baseband signal imposed on this carrier consists of (1) the luminance signal encoding the brightness variation of each pixel in the video raster and (2) a color subcarrier centered at approximately 3.58 MHz onto which are modulated, using I/Q Modulation, both chrominance signals. A black-and-white television receiver removes the RF carrier, producing a baseband signal, and then filters out (or just ignores) the color subcarrier, producing the luminance signal which is all it can display.

The above descriptions hold for NTSC broadcast television, used in the United States until June, 2009. Other systems are used elsewhere, but the basic ideas are the same. The chrominance signals are easily separated from the luminance signal. The chrominance signal generally has a narrower bandwidth than the luminance signal because it encodes information for which the human eye has less spatial resolution.

Other elements of the television picture encoding scheme such as vertical and horizontal blanking, timing reference signals, color subcarrier reference signals, etc. are described in the references.

# 3 Digitizing a Video Signal

This section suggests some simple ways in which one might digitize a video signal. One possibility is to sample the baseband signal including the color subcarrier. This is called composite sampling. A second possibility is to digitize each of the components of the signal in turn and interleave the samples. This is called component sampling. One could also envision digitizing either the luminance and chrominance components described above or the underlying individual color signals.

Since the chrominance components carry less information than the luminance component it is possible to sample them at a lower sample frequency than the luminance component. This is not true if the RGB color space is used and the individual color components are digitized.

All of these methods are supported in SDI. This, in essence, is what an SDI signal is. It is a digitized video signal including very little extra information. The bit rate used to transmit this information is determined by the video content.

It is significant that so little extra information is required for SDI signals. Address headers are not necessary since transmission is from a single source to a single receiver (point-to-point) or from a single source to multiple receivers (multi-drop). Error correction overhead is minimal since the channel is well-controlled and single bit errors may not even be noticed in the displayed video signal. Timing reference signals, which are also present in the analog video signal, are always included. Error Detection and Handling information may be included [4]. Most of the signal, though, is just digitized video information. The sampling and serialization process is represented graphically in Figure 1.

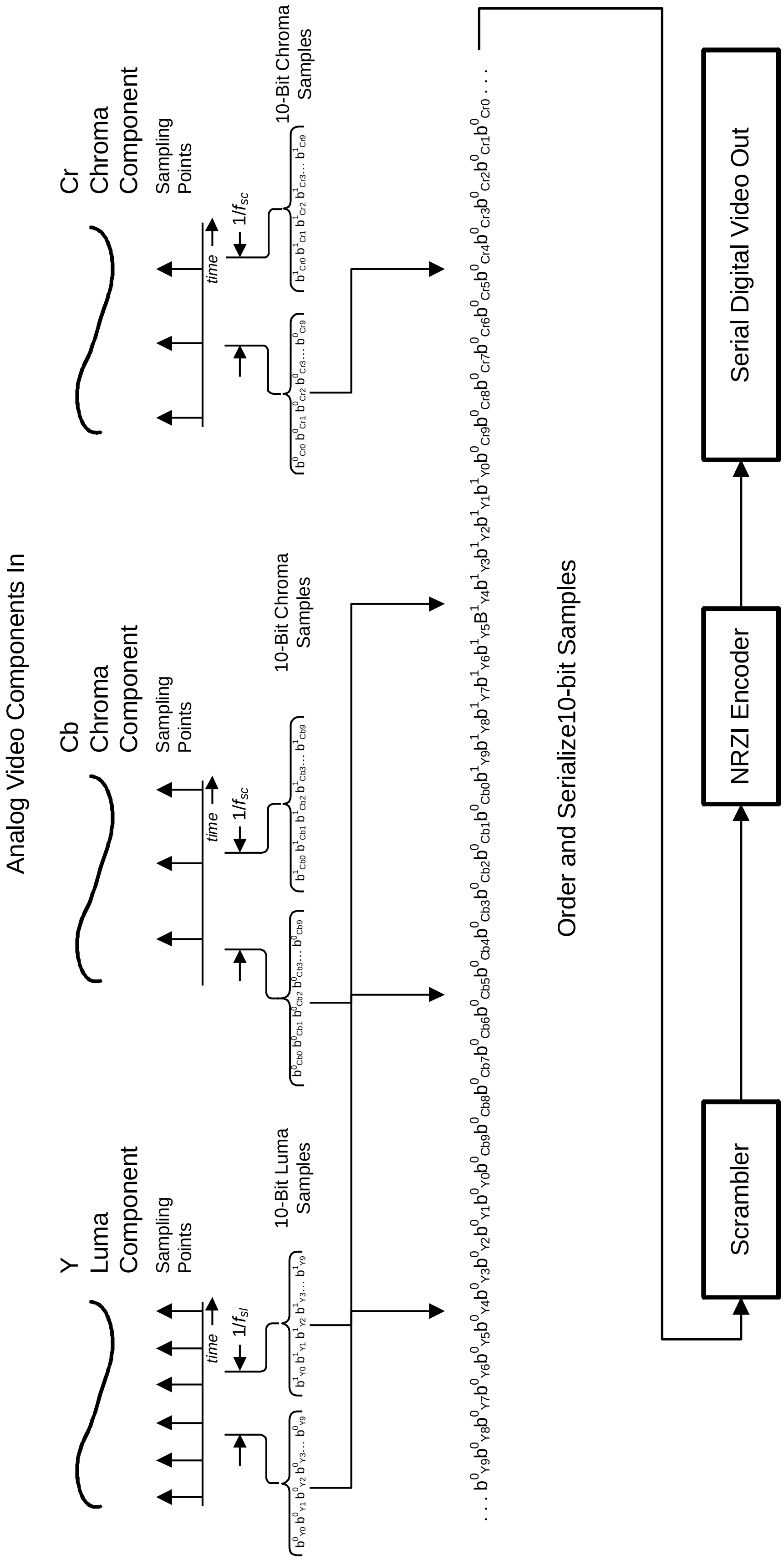


**Figure 1. Graphical Representation of the Sampling and Serialization Scheme for SDI Video**

## 4 Derivation of the SDI Bit Rate

An Excel spreadsheet showing example bit rate calculations is available from the Texas Instruments web site: http://www.ti.com/sdi. An example of the calculations from this spreadsheet is shown below in Figure 2.

The key elements to be considered when using the spreadsheet are as follows:

- Whether the signal is digitized as composite video or component video (there are standards for digitizing YCbCr and RGB components)
- Whether the signal is interlaced or progressive
- Whether the frame rate is 50 Hz, 60 Hz, or 60/1.001 Hz
- The number of lines per frame
- The sampling rate

Many serial video formats use 10-bit samples. SMPTE 425M and SMPTE 274M call out a 12-bit sample standard. One example of a video standard with 10-bit samples is 1080p60. When the signal is interlaced, two fields are transmitted for each frame of video. For a progressive signal, each frame of video is transmitted as a single field. The 1080p60 standard, for example, calls out a progressive video standard which transmits each frame of video as a single field, at 60 frames and 60 fields per second.

Notice that for video formats digitized as composite video there is only one sample rate – the composite video signal is digitized at that sample rate. For component video there are (sometimes) two sample rates – one for the luma component and one for the chroma components. Where the chroma components are sampled at half the sampling rate of the luma components this is called a 4:2:2 sampling structure for historical reasons. Where the sample rates are the same for the luma and chroma components this is called a 4:4:4 sampling structure. The standard 1080p60, for example, has a 4:2:2 sampling structure. The number of lines per frame is related to, but not identical to, familiar video standards – for example, 1080p60 has 1125 lines per frame. *Only 1080 of them are visible*.

The sampling rate for the signal is chosen so that the signal can be sampled without aliasing. The information content of each component determines the required bandwidth for each component. The information content is determined by the number of samples per video line, the number of video lines per frame, and the frame rate. For 1080p60, for example, the luma component is sampled at 148.5 MHz and each of the two chroma components at 74.25 MHz [5].

Using the elements above the bit rate can be calculated. The following symbols are used in the calculations.

$N_f$ = number of fields per frame — this is 2 for interlaced formats, 1 for progressive formats

$R_f$ = frame rate in Hz (frames/second)

$R_{field}$ = field rate in Hz (fields/seconds) = $R_f \times N_f$

$N_l$ = number of lines per frame

$N_s$ = number of samples per line

$f_s$ = sampling rate in number of samples/second for composite video signals

$f_{sl}$ = luma component sampling rate in number of samples/second

$f_{sc}$ = chroma component sampling rate in number of samples/second

$N_b$ = number of bits per sample (10 bits/sample for all the video formats in Figure 2)

$R_b$ = bit rate in bits/second

For composite sampled video, the bit rate is just the number of bits per sample times the number of samples per second.

$$R_b = N_b \times f_s \tag{1}$$

For component sampled video, the bit rate is just the number of bits per sample times the sum of the number of luma samples per second and twice the number of chroma samples per second (assuming 4:2:2 sampling structure).

$$R_b = N_b \times (f_{sl} + 2f_{sc}) \tag{2}$$

The number of samples per line, not all of which will be visible, is given by the following for component video signals (assuming a 4:2:2 sampling structure).

$$N_s = \frac{(f_{sl} + 2f_{sc})}{N_l \times R_f}$$

It is possible to have the number of samples per line available but not the sampling rate. In this case, the bit rate is given in Equation 3:

$$R_b = N_b \times N_l \times R_f \times N_s \quad (3)$$

**SDI Video Bit Rates**

| SMPTE Standard | Signal Type/Sampling Structure | Raster Standard | Video Signal Type | Fields/frame | Number of lines/frame | Field Rate | Frame Rate | Sample Rate | Luma or R'G'B' Sample Rate | Chroma Sample Rate | Samples per Line | Parallel Video Bits | Number Samples/Line | Bit Rate | Bit Rate (Mbps) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SMPTE 259M-1997<br>SMPTE 244M-2003 | NTSC Composite | 525i | 4fsc (composite) | 2.00 | 525 | 59.94 | 29.97003 | 1.43E+07 | | | 910 | 10 | 910 | 143181818.2 | 143.1818182 |
| SMPTE 259M-1997<br>IEC 1179 | PAL Composite | 625i50 | 4fsc (composite) | 2.00 | 625 | 50.00 | 25 | 1.77E+07 | | | 1133 | 10 | 1135 | 177343750 | 177.34375 |
| SMPTE 259M-1997 | 4:2:2 Component | 525i | YCrCb (component) | 2.00 | 525 | 59.94 | 29.97003 | | 1.35E+07 | 6.75E+06 | 1716 | 10 | 1716 | 270000000 | 270 |
| SMPTE 259M-1997 | 4:2:2 Component | 625i50 | YCrCb (component) | 2.00 | 625 | 50.00 | 25 | | 1.35E+07 | 6.75E+06 | 1728 | 10 | 1728 | 270000000 | 270 |
| SMPTE 259M-1997<br>SMPTE 267M-1995 | 4:2:2 Component | 525i | YCrCb (component) | 2.00 | 525 | 59.94 | 29.97003 | | 1.80E+07 | 9.00E+06 | 2288 | 10 | 2288 | 360000000 | 360 |
| SMPTE 344M-2000 | 4:2:2 Component | 525i | YCrCb (component) | 2.00 | 525 | 59.94 | 29.97003 | | 2.70E+07 | 1.35E+07 | 3432 | 10 | 3432 | 540000000 | 540 |
| SMPTE 292M-1998<br>SMPTE 274M-1998 | 4:2:2 Component | 1080i60 (1080i59.9) | YCrCb (component) | 2.00 | 1125 | 59.94 | 29.97003 | | 7.4176E+07 | 3.7088E+07 | 4400 | 10 | 4400 | 1483516484 | 1483.516484 |
| SMPTE 292M-1998<br>SMPTE 274M-1998 | 4:2:2 Component | 1080i60 | YCrCb (component) | 2.00 | 1125 | 60.00 | 30 | | 7.4250E+07 | 3.7125E+07 | 4400 | 10 | 4400 | 1485000000 | 1485 |
| SMPTE 292M-1998<br>SMPTE 274M-1998 | 4:2:2 Component | 1080i50 | YCrCb (component) | 2.00 | 1125 | 50.00 | 25 | | 7.4250E+07 | 3.7125E+07 | 5280 | 10 | 5280 | 1485000000 | 1485 |
| SMPTE 292M-1998<br>SMPTE 296M-2001 | 4:2:2 Component | 720p60 (720p59.9) | YCrCb (component) | 1.00 | 750 | 59.94 | 59.94006 | | 7.4176E+07 | 3.7088E+07 | 3300 | 10 | 3300 | 1483516484 | 1483.516484 |
| SMPTE 292M-1998<br>SMPTE 296M-2001 | 4:2:2 Component | 720p60 | YCrCb (component) | 1.00 | 750 | 60.00 | 60 | | 7.4250E+07 | 3.7125E+07 | 3300 | 10 | 3300 | 1485000000 | 1485 |
| SMPTE 292M-1998<br>SMPTE 296M-2001 | 4:2:2 Component | 720p50 | YCrCb (component) | 1.00 | 750 | 50.00 | 50 | | 7.4250E+07 | 3.7125E+07 | 3960 | 10 | 3960 | 1485000000 | 1485 |
| SMPTE 424M-2005<br>SMPTE 425M-2005 | 4:2:2 Component | 1080p60 (1080p59.9) | YCrCb (component) | 1.00 | 1125 | 59.94 | 59.94006 | | 1.4835E+08 | 7.4176E+07 | 4400 | 10 | 4400 | 2967032967 | 2967.032967 |
| SMPTE 424M-2005<br>SMPTE 425M-2005 | 4:2:2 Component | 1080p60 | YCrCb (component) | 1.00 | 1125 | 60.00 | 60 | | 1.4850E+08 | 7.4250E+07 | 4400 | 10 | 4400 | 2970000000 | 2970 |
| SMPTE 424M-2005<br>SMPTE 425M-2005 | 4:2:2 Component | 1080p50 | YCrCb (component) | 1.00 | 1125 | 50.00 | 50 | | 1.4850E+08 | 7.4250E+07 | 5280 | 10 | 5280 | 2970000000 | 2970 |
| SMPTE 424M-2005<br>SMPTE 296M-2001 | 4:4:4:4 Component | 720p60 | R'G'B'+A (component) | 1.00 | 750 | 60.00 | 60 | | 7.4250E+07 | 7.4250E+07 | 6600 | 10 | 6600 | 2970000000 | 2970 |
| SMPTE 424M-2005<br>SMPTE 274M-2005 | 4:4:4:4 Component | 1080i60 | R'G'B'+A (component) | 2.00 | 1125 | 60.00 | 30 | | 7.4250E+07 | 7.4250E+07 | 8800 | 10 | 8800 | 2970000000 | 2970 |

**Figure 2. Example Results for Bit Rate Calculation**

# 5 Conclusion

Serial digital interface bit rates can be computed in a simple manner from the characteristics of the video signals to be transmitted. This is a simple, but profound, characteristic of SDI signals. Understanding the basis for the bit rates of SDI signal provides valuable insight into how these signals are generated, transported, and displayed.

# 6 References


1. Bernard Grob and Charles E. Herndon, *Basic Television and Video Systems*, Sixth Edition (Westerville, OH: McGraw Hill, 1999).
2. Keith Jack, *Video Demystified* (San Diego, CA: HighText Interactive, Inc., 1996).
3. *Broadcast Video Owners Manual* (SNLA188)
4. Michael Robin and Michael Poulin, *Digital Television Fundamentals*, Second Edition (New York, NY: McGraw-Hill, 2000).
5. Society of Motion Picture and Television Engineers, *SMPTE274M-2005; for Television 1920 x 1080 Image Sample Structure, Digital Representation and Digital Timing Reference Sequences for Multiple Picture Rates* (Society of Motion Picture and Television Engineers, 2005).

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