# SDI Video Bit Rate Calculation

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**ABSTRACT**

This document provides a reference for calculating Serial Digital Interface (SDI) bit rates. SMPTE Specifications or proposed specifications are used to calculate different SDI video bit rates. Also, length of the stressful video pattern - pathological - is calculated. This report contains detailed information relating to programming and different configuration options. Readers are expected to be familiar with different SMPTE standards or may refer to the specifications noted in this document.

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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 Serial Digital Interface (SDI). For a full explanation of different SMPTE specifications, the reader should refer to any of the several references on the subject [1] [2] [3]. SDI ease of use, single-ended electrical interface, digital implementation, and un-compressed video all have enabled an industry-wide acceptance. The SMPTE body has standardized a set of specifications to enable interoperability among different equipment manufacturers. These are 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). In order to accommodate higher resolution and higher frame rate further, the SMPTE standard working group has proposed new standards to keep pace with the ever increasing higher frame rates. The proposed ST-2081 and ST-2082 outline the serial interface electrical specification while the proposed ST-2082-10 provides the guideline for source image and ancillary data mapping.

## *1.1 Overview of Digital Interface*

It is beneficial to review the signal path from the analog RGB to different SMPTE specifications. Analog RGB signals are gamma-corrected and converted to luma and two scaled chroma components. Normally the luma is sampled at higher frequency versus chroma since the eye is more sensitive to brightness versus changes in hue. These signals are low pass filtered to remove high frequency content that might cause aliasing. The filtered signals are then digitized in a 10-bit data stream. BT.601 and BT.656 govern component analog RGB video signal-to-digital parallel and serial interface operating at SMPTE259M video rate. Similarly, SMPTE291M, SMPTE272M, and AES3 define how audio will be mapped into the SMPTE259M ancillary data channel.

High definition format has a similar architecture as well. In high-definition formats, data rates will be faster and separate parallel interfaces are used for brightness and color channels. BT.709 specifies how luminance and chrominance are mapped to convert from RGB video to digital representation. To support different spatial resolutions, different SMPTE standards were developed, namely SMPTE274 1920X1080, SMPTE296 1280X720, and SMPTE240 to transport analog video.

Ancillary data formatting structure of the digital video is described in SMPTE291M. This standard defines transport of video and audio in the form of 10-bit words.

For digital audio mapping, SMPTE299M specifies how digital audio is transmitted and embedded within the ancillary data packet. Signals defined by these standards are transmitted using SMPTE292 in a serial fashion. This standard specifies the electrical interface operating at 1.5 Gbps over a single-ended 75-Ω coax. SMPTE292M is used to transport either 720P or 1080i spatial resolution. To transport higher resolution such as 1080p60 or 1080p50, SMPTE425 is used to transport two 1080i or a native 1080p60 video frame over a single 75-Ω coax.

## 2 Derivation of the SDI Bit Rate

An Excel® spreadsheet was used to calculate bit rates for different video frame formats. For higher spatial resolution, proposed ST-2082-10 defines mapping of different source images into a single 12 Gbps serial interface. The different image format is divided into sub images and then mapped onto an 80-bit virtual interface operating at 148.5 MHz to create a serial 12G data stream.

The key considerations are:

1. Sampling structure
2. Whether video is interlaced or progressive
3. Video frame rate
4. Number of lines per frame
5. Sampling rate
6. Number of samples per line

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.

For component video there are typically two sample rates – one for the luma component and one for the chroma components. When 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. When the sample rates are the same for the luma and chroma components, this is called a 4:4:4 sampling structure.

Note 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 active video lines.

The sampling rate for the signal is chosen so that the signal can be sampled without aliasing. The information content of each component video 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.

Using the elements above, the bit rate can be calculated. The following symbols are used in the calculations (assuming 4:2:2 sampling):

$$BIT_{RATE} = 20*F_R*LUMA_{SAMPLE}*LNS_{FRAME} \quad (1)$$

$$PATH_{LENGTH} = 2*10*LUMA_{ACTIVE}*(1/BIT_{RATE}) \quad (2)$$

**$F_R$ —** Frame Rate in Hz (Frames/second)

**$LUMA_{SAMPLE}$ —** Number of Luma Samples per line

**$LNS_{FRAME}$ —** Number of lines per frame

**$BIT_{RATE}$ —** Bit Rate in bits/second

**$LUMA_{ACTIVE}$ —** Number of Active Samples per Line

**$PATH_{LENGTH}$ —** Pathological Pattern Duration in seconds

Note:

1. It is assumed that the number of luma and chroma samples are the same – 4:2:2 Resolution.
2. There are 10 bits per sample.

Table 1 shows video bit rates for 3 Gbps and below.

## Table 1. Video Bit Rates for 3 Gbps and Below

| SPECIFICATION | SYSTEM NO. | SYSTEM NOMENCLATURE | LUMINANCE or R'G'B' SAMPLES per ACTIVE LINE ($LUMA_{ACTIVE}$) | ACTIVE LINES per FRAME | FRAME RATE ($F_R$) (Hz) | INTERFACE SAMPLING FREQUENCY fs (MHz) | LUMINANCE SAMPLE PERIODS per TOTAL LINE ($LUMA_{SAMPLE}$) | TOTAL LINES per FRAME ($LNS_{FRAME}$) | BIT RATE($BIT_{RATE}$) | PATHOLOGICAL LENGTH ($PATH_{LENGTH}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| SMPTE274M | 1 | 1920 X 1080/60/P | 1920 | 1080 | 60 | 148.5 | 2200 | 1125 | 2970000000 | 1.29E-05 |
| | 2 | 1920 X 1080/59.94/P | 1920 | 1080 | 59.94 | 148.35 | 2200 | 1125 | 2967030000 | 1.29E-05 |
| | 3 | 1920 X 1080/50/P | 1920 | 1080 | 50 | 148.5 | 2640 | 1125 | 2970000000 | 1.29E-05 |
| | 4 | 1920 X 1080/60/I | 1920 | 1080 | 30 | 74.25 | 2200 | 1125 | 1485000000 | 2.59E-05 |
| | 5 | 1920 X 1080/59.94/I | 1920 | 1080 | 29.97 | 74.18 | 2200 | 1125 | 1483515000 | 2.59E-05 |
| | 6 | 1920 X 1080/50/I | 1920 | 1080 | 25 | 74.25 | 2640 | 1125 | 1485000000 | 2.59E-05 |
| | 7 | 1920 X 1080/30/P | 1920 | 1080 | 30 | 74.25 | 2200 | 1125 | 1485000000 | 2.59E-05 |
| | 8 | 1920 X 1080/29.97/P | 1920 | 1080 | 29.97 | 74.18 | 2200 | 1125 | 1483515000 | 2.59E-05 |
| | 9 | 1920 X 1080/25/P | 1920 | 1080 | 25 | 74.25 | 2640 | 1125 | 1485000000 | 2.59E-05 |
| | 10 | 1920 X 1080/24/P | 1920 | 1080 | 24 | 74.25 | 2750 | 1125 | 1485000000 | 2.59E-05 |
| | 11 | 1920 X 1080/23.98/P | 1920 | 1080 | 23.98 | 74.18 | 2750 | 1125 | 1483762500 | 2.59E-05 |
| SMPTE296M | 1 | 1280 X 720/60 | 1280 | 720 | 60 | 74.25 | 1650 | 750 | 1485000000 | 1.72E-05 |
| | 2 | 1280 X 720/59.94 | 1280 | 720 | 59.94 | 74.18 | 1650 | 750 | 1483515000 | 1.73E-05 |
| | 3 | 1280 X 720/50 | 1280 | 720 | 50 | 74.25 | 1980 | 750 | 1485000000 | 1.72E-05 |
| | 4 | 1280 X 720/30 | 1280 | 720 | 30 | 74.25 | 3300 | 750 | 1485000000 | 1.72E-05 |
| | 5 | 1280 X 720/29.97 | 1280 | 720 | 29.97 | 74.18 | 3300 | 750 | 1483515000 | 1.73E-05 |
| | 6 | 1280 X 720/25 | 1280 | 720 | 25 | 74.25 | 3960 | 750 | 1485000000 | 1.72E-05 |
| | 7 | 1280 X 720/24 | 1280 | 720 | 24 | 74.25 | 4125 | 750 | 1485000000 | 1.72E-05 |
| | 8 | 1280 X 720/23.98 | 1280 | 720 | 23.98 | 74.18 | 4125 | 750 | 1483762500 | 1.73E-05 |

## 3 UHD Video Bit Rate Calculation

The proposed ST 2082-10 calls for the mapping of different source image format and ancillary data into a single 12 Gbps SDI coax cable. The source image is divided into two or four sub images. The sub images are then mapped into eight 10-bit streams to build an 80-bit virtual interface operating at 148.5 MHz clock rate. There are two methods of mapping: In one case, a 2160-line source image is mapped into a 12 Gbps NRZ serial interface. In the second case, the gamma-corrected $Y'C'_BC'_R$ 1080 image is mapped into the 12G SDI serial interface.

Using the proposed ST 2082-10, bit rate and pathological length can be calculated (assuming 4:2:2 sampling):

**$L_{LENGTH}$ —** Overall Line Length

**$F_R$ —** Frame Rate

**$N_{SUB}$ —** Number of Sub-Image

**$N_I$ —** Total number of lines per sub image

**$DATA_{STREAM}$ —** Data Stream per Sub Image

**$N_{ACTIVE}$ —** Number of active samples per line

$$BIT_{RATE} = N_I * L_{LENGTH} * 20 * F_R * N_{SUB} \quad (3)$$

$$P_{LENGTH} = 20 * DATA_{STREAM} * (1/BIT_{RATE}) \quad (4)$$

**Table 2. Proposed UHD Video Bit Rates**

| MAPPING MODE | SMPTE PROPOSED STANDARD | SIGNAL TYPE/ SAMPLING STRUCTURE | TOTAL NUMBER of LINES/FRAME/ SUB IMAGE ($N_I$) | OVERALL LINE LENGTH ($L_{LENGTH}$) TOTAL SAMPLES per LINE | $N_{SUB}$ | $F_R$ | ACTIVE SAMPLES per LINE ($N_{ACTIVE}$) | DATA STREAM per SUB IMAGE ($DATA_{STREAM}$) | $P_{LENGTH}$ | $BIT_{RATE}$ | $BIT_{RATE}$ (Mbps) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ST 2036-1 | 4:2:2 Component | 1125 | 2200 | 4 | 60 | 1920 | 2 | 6.46E-06 | 1.188E+10 | 11880 |
| | 3840X2160 | | | | | | | | | | |
| | ST 2048-1 | 4:2:2 Component | 1125 | 2200 | 4 | 60 | 1920 | 2 | 6.46E-06 | 1.188E+10 | 11880 |
| | 4096X2160 | | | | | | | | | | |
| | ST 2036-1 | 4:4:4 Component | 1125 | 2200 | 4 | 30 | 1920 | 2 | 1.29E-05 | 1.188E+10 | 11880 |
| | 3840X2160 | | | | | | | | | | |
| | ST 2048-1 | 4:4:4:4 Component | 1125 | 2200 | 4 | 30 | 1920 | 2 | 1.29E-05 | 1.188E+10 | 11880 |
| | 4096X2160 | | | | | | | | | | |
| 2 | ST 274 | 4:4:4 Component | 1125 | 1100 | 2 | 120 | 1024 | 4 | 1.38E-05 | 1.188E+10 | 11880 |
| | 1920X1080 | | | | | | | | | | |
| | ST 2048-2 | 4:4:4 Component | 1125 | 1320 | 2 | 100 | 1024 | 4 | 1.38E-05 | 1.188E+10 | 11880 |
| | 2048x1080 | | | | | | | | | | |
| | ST 274 | 4:4:4 Component | 1125 | 1375 | 2 | 96 | 1024 | 4 | 1.38E-05 | 1.188E+10 | 11880 |
| | 1920X1080 | | | | | | | | | | |
| | ST 274 | 4:2:2:4 Component | 1125 | 1375 | 2 | 96 | 1024 | 4 | 1.38E-05 | 1.188E+10 | 11880 |
| | 2048X1080 | | | | | | | | | | |
| | ST 274 | 4:2:2:4 Component | 1125 | 1375 | 2 | 96 | 960 | 4 | 1.129E-05 | 1.188E+10 | 11880 |
| | 2048X1080 | | | | | | | | | | |

## 4 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.

## 5 References

1. Bernard Grob and Charles E. Herndon, *Basic Television and Video Systems*, 6th ed. Westerville, OH: McGraw Hill, 1999.
2. Keith Jack, *Video Demystified*. San Diego, CA: HighText Interactive, Inc., 1996.
3. National Semiconductor Corp., *Broadcast Video Owner's Manual*, 2nd ed. Santa Clara, CA: National Semiconductor Corp., 2008
4. 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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