MISB MOTION IMAGERY STANDARDS BOARD	**MISB ST 0403.3**
STANDARD	
Digital Representation and Source Interface Formats for Infrared Motion Imagery Mapped into 1280 x 720 Format Bit-Serial Digital Interface	**25 June 2015**

1 Scope

This document defines mapping digital infrared motion imagery parallel data from an IR source into a SMPTE ST 292-1 compatible serial digital interface (HD-SDI). Two methods are described: 1) pre-formatting the imagery such that it is pre-scaled, pseudo-colored, and prepared for display without further modification; 2) retaining the original image pixel values, and therefore, the full source dynamic range – up to 16 bits.

A number of progressive 60/50 Hz infrared image formats are mapped onto a 1280x720, progressive-scan, 60Hz/50Hz format image lattice. Infrared formats covered by this document include: 640x480, 640x512, 720x480, 1280x720, and 1024x1024 all at 60 Hz, and 720x576 and 1280x720 at 50 Hz. In the 1024x1024 image format case, clipping in the vertical frame dimension results in a 1024x720 format. The IR source format mapping for 1920x1080 is addressed in Annex A, and is beyond scope of this document.

2 References

2.1 Normative References

The following references and the references contained therein are normative.

[1] SMPTE ST 292-1:2012, 1.5 Gb/s Signal/Data Serial Interface
[2] MISB ST 0404.1 Compression for Infrared Motion Imagery, Feb 2014
[3] SMPTE ST 296:2012, 1280x720 Progressive Image 4:2:2 and 4:4:4 Sample Structure - Analog and Digital Representation and Analog Interface

2.2 Informative References

[4] SMPTE ST 372:2011, Dual Link 1.5 Gb/s Digital Interface for 1920x1080 Picture Formats
[5] SMPTE ST 352:2013, Payload Identification Codes for Serial Digital Interfaces
[6] SMPTE ST 291-1:2011, Ancillary Data Packet and Space Formatting
[7] SMPTE ST 259:2008, Television – SDTV Digital Signal/Data – Serial Digital Interface

3 Revision History

Revision	Date	Summary of Changes
ST 0403.3	06/25/2015	• Changed luminance to Luma consistent with SMPTE usage (Luma = gamma corrected signals)

4 Acronyms

EAV	End of Active Video
NTSC	National Television System Committee
SAV	Start of Active Video
SDI	Serial Data Interface
SMPTE	Society of Motion Pictures and Television Engineers
TRS	Timing and Reference Signal

5 Introduction

This document defines the use of SMPTE ST 292-1 [1] HD-SDI (High Definition, Serial Data Interface) interface for the transmission of high bit-depth infrared Motion Imagery. Infrared systems generally produce data with greater bit depths than found in commercial broadcast systems, and therefore, have relied on more specialized interfaces to transmit data. To leverage commodity broadcast equipment, such as recorders, displays, and image compression systems, many IR systems have used RS-170 and NTSC analog interfaces. While these legacy interfaces do provide connectivity, they do not maintain the high level of signal integrity and fidelity needed for IR. This document provides two data formatting methods that facilitate using HD-SDI; this affords use of standard commercial equipment, and also results in improved IR signal quality.

Although other high bit-depth interfaces exist, such as Firewire, GigE-Vision, and CameraLink, they are not widely found in commercial-off-the-shelf (COTS) broadcast equipment, which limits the use of such equipment.

Two methods are described for transmitting infrared imagery, up to 16-bits, through a SMPTE ST 291-1 HD-SDI interface:

- Method 1: In this method, the monochrome pixels are converted into a scaled and pseudo-colored format compatible with the SMPTE ST 292-1 10-bit $Y'C'_bC'_r$ color format. This allows images to be handled by standard equipment and then compressed, displayed, and/or recorded without further modification.
- Method 2: In this method, the monochrome infrared pixels are transmitted in full bit-depth, up to 16 bits. IR data is "packed" prior to transmission over SMPTE ST 291-1, and then "unpacked" at the receiving end prior to subsequent processing. For systems designed to operate with this method, the full dynamic range of the source infrared imagery can be retained. Thus, compression systems that support higher bit depths, such as 14-bit H.264 Fidelity Range Extensions and JPEG2000 can be used.

An important aspect in data delivery is the interface between different devices that implement various processing. A specific interface contains parameters that represent a "language" for connectivity between devices. Digital interfaces may be parallel, which use multi-conductor cables, or serial that might use only one or two wires. The advantage of a parallel interface is its simplicity; however, problems in cabling and signal propagation delay make this type of an interface relatively unreliable for long (several 10's of feet) distances. A parallel interface is often used in defining an image source, and so this document describes the infrared signal source based on a parallel interface.

The methods discussed in this document are expected to provide higher reliability, longer transmission distances, and a common equipment interface to existing commercial systems. Methods to convert an infrared signal from a 640x480, 640x512, 720x480, 720x576, 1024x1024 (with cropping to 1024x720) and 1280x720 line construct to a common parallel interface (1280x720 at 74.25 MHz) are discussed.

Before a parallel infrared signal can be converted into a serial digital stream, it is necessary to adapt the signal to a format used by the interface. This means that the sample rate of the IR signal needs to be equal to the sample rate of the receiving equipment, and that the IR signals information is mapped appropriately into the target signal interface space.

The process to convert a bit-parallel data infrared signal to a bit-serial SMPTE ST 292-1 compatible format is shown in Figure 1. An infrared signal format of 640x480, 640x512, 720x480, 720x576, 1024x1024 (with cropping to 1024x720) and 1280x720 line construct to a common parallel interface (1280x720 at 74.25 MHz) is first up-converted to match the timing and sampling of a 1280x720p60 image format in accordance with SMPTE ST 296 [3] (*Step 1*). The up-converted data stream is then processed using one of the two methods described using a parallel data stream model for a 1280x720p60 format signal (*Step 2*). Finally, parallel-to-serial conversion formats the stream into a compatible SMPTE 291-1 format (*Step 3*).

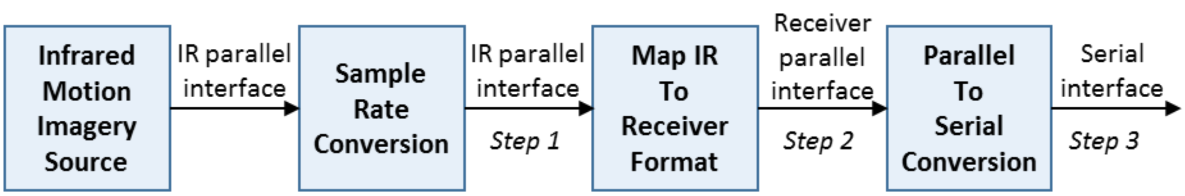

Figure 1: Processing steps for IR-SDI interface

6 Infrared Motion Imagery Source Characterization

The following sections outline array sizes and resolutions, and the timing and data characteristics for common infrared formats, and how these can be mapped into the 1280x720 image format.

6.1 IR formats

An IR digital signal provides a source of progressively scanned, infrared Motion Imagery data. The infrared signal may be in one of the formats given in Table 1.

Table 1: Infrared Motion Imagery Formats

IR System	Image lattice (pixels)	Frame rate (Hz)	Lines per frame	Total samples/words per line	Active samples/words per line	Pixel sampling clock (MHz)
1	640 x 480	60	525	858	640	27.027
2	640 x 512	60	525	858	640	27.027
3	720 x 480	60	525	858	720	27.027
4	720 x 576	50	625	864	720	27.0
5	1024 x 720	60	750	1650	1024	74.25
6	1280 x 720	60	750	1650	1280	74.25
7	1280 x 720	50	750	1980	1280	74.25

6.2 Parallel Interface Data for an IR Digital Signal Source

The timing and data properties of an IR signal are referenced to a parallel interface, which is a common output format supplied by an IR sensor.

Requirement	
ST 0403.2-01	All IR image digital formats identified in MISB ST 0403.3 Table 1 shall be in a parallel word format up to 16 bits wide.

6.2.1 Horizontal Timing of an IR Digital Source

Special timing sequences are inserted into the digital video stream to indicate the start of active video (SAV) and the end of active video (EAV). The SAV and EAV sequences indicate when horizontal and vertical blanking are present, and they have priority over active video data or ancillary data to ensure that correct video timing is always maintained. Figure 2 shows the code word mapping for one horizontal scan line. The designations a, d, e, etc. indicate which code word (pixel) on the line corresponds to a particular format given in Table 2.

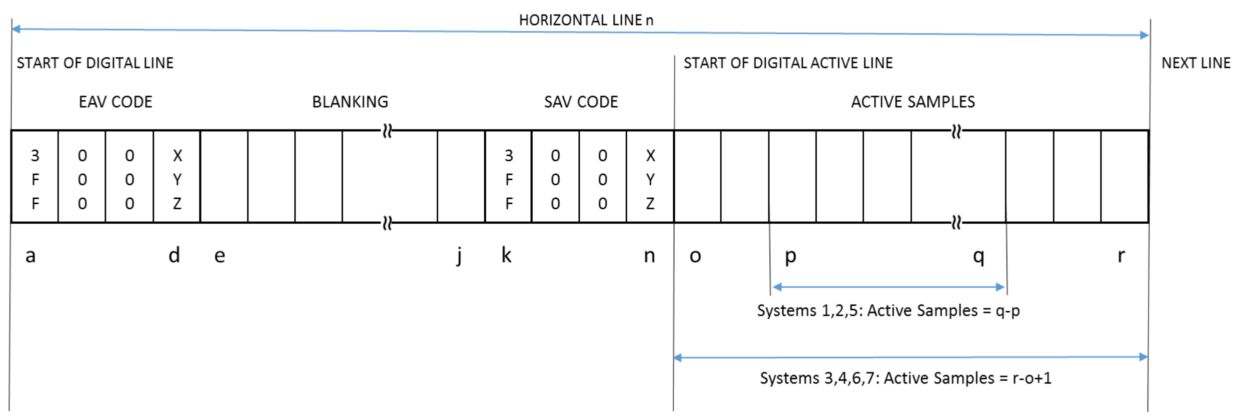

Figure 2: Code word structure for IR formats in Table 2

Table 2: Horizontal sample number for different IR image sources

System	Clock (MHz)	Format	a	d	e	j	k	n	o	p	q	r
1	27.027	640x480	720	723	724	853	854	857	0	39	679	719
2	27.027	640x512	720	723	724	853	854	857	0	39	679	719
3	27.027	720x480	720	723	724	853	854	857	0	n/a	n/a	719
4	27.0	720x576	720	723	724	859	860	863	0	n/a	n/a	719
5	74.25	1024x720	1280	1283	1284	1645	1646	1649	0	127	1151	1279
6	74.25	1280x720	1280	1283	1284	1645	1646	1649	0	n/a	n/a	1279
7	74.25	1280x720	1280	1283	1284	1975	1976	1979	0	n/a	n/a	1279

Requirement(s)	
ST 0403.2-02	For synchronization purposes a word sequence consisting of 3FFh, 000h, 000h, and XYZh called EAV (End of Active line) or SAV (Start of Active line) shall be used.
ST 0403.2-03	Code word logical values shall be referenced as positive logic.

A high voltage state will be an asserted signal representing logical 1. A low voltage state will be a negated signal representing logical 0.

6.2.2 Dynamic Range of an IR signal within a Parallel Interface

Within the full range available for a given data word length certain values are not allowed and others are set aside for subsequent processing that might cause underflow or overflow in arithmetic. Rather than clip these under/over flow values, a small percentage of the dynamic range is afforded to allow some additional signal amplitude growth. Figure 3 illustrates protected, headroom for processing, and safe operating ranges for IR signals. The protected range is intended for timing signals in the stream, so they are forbidden to use.

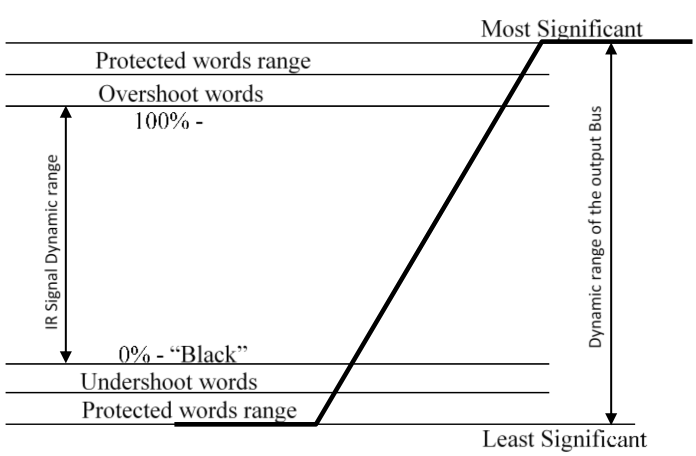

Figure 3: Dynamic range assignment

Figure 4 indicates the allowed data range for 8, 10, 12, 14 and 16 bit systems. Table 3 gives values for the ranges of protected, undershoot/overshoot, and the normal operating signal area. As an example, in an 8–bit system, the values 0x00 and 0xFF are protected (not allowed to be used for the signal itself). The undershoot range 0x10-0x1F and the overshoot range 0xEC-0xFE afford additional signal space of 15 values at the bottom and top of the signal range respectively. Finally, the signal should be limited to the operating range of 0x10 (black or 0% signal) to 0xEB (white or 100% signal).

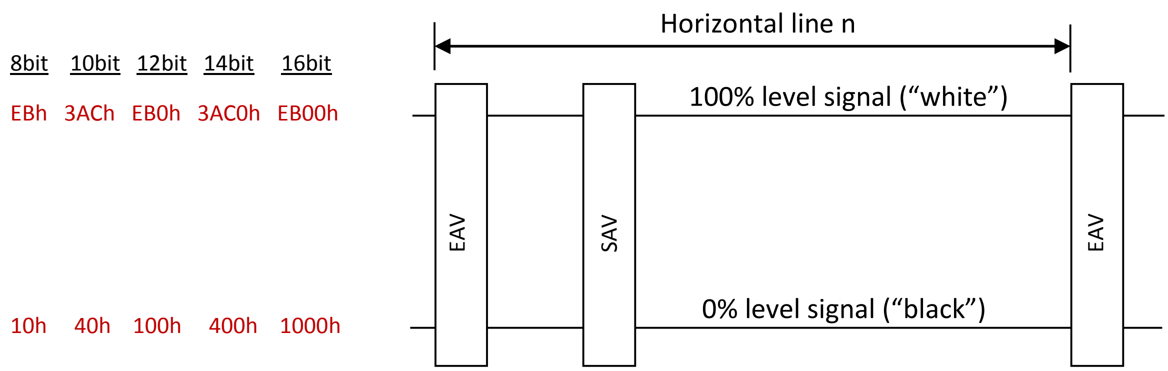

Figure 4: Digital code word range for 8, 10, 12, 14 and 16 bit systems

Table 3: Digital range assignment for different word sizes on a parallel signal bus

Bit range	8-bit (hex)	10-bit (hex)	12-bit (hex)	14-bit (hex)	16-bit (hex)
Most Significant	0xFF (255)	0x3FF (1023)	0xFFF (4095)	0x3FFF (16383)	0xFFFF (65535)
Protected words range	0xFF (255)	0x3FC-0x3FF (1020-1023)	0xFF0-0xFFF (4080-4095)	0x3FC0-0x3FFF (15041-16319)	0xFF00-0xFFFF (65280-65535)
Overshoot words range	0xEC-0xFE (236-254)	0x3AD-0x3FB (941-1019)	0xEB1-0xFEF (3761-4079)	0x3AC1-0x3FBF (15041-16319)	0xEB01-0xFEFF (60161-65279)
100% White signal level	0xEB (235)	0x3AC (940)	0xEB0 (3760)	0x3AC0 (15040)	0xEB00 (60160)
0% Black signal level	0x10 (16)	0x40 (64)	0x100 (256)	0x400 (1024)	0x1000 (4096)
Undershoot Words range	0x01-0x0F (1-15)	0x04-0x3F (4-63)	0x010-0x0FF (16-255)	0x40-0x3FF (64-1023)	0x100-0xFFF (256-4095)
Protected words range	0x00 (0)	0x000-0x003 (0-3)	0x000-0x00F (0-15)	0x0000-0x3F (0-63)	0x0000-0xFF (0-255)
Least Significant	0x00 (0)	0x000 (0)	0x0000 (0)	0x0000 (0)	0x0000 (0)

Note 1: The Protected word ranges shown in Table 3 are necessary to assure proper synchronization of the resulting IR image stream.

Note 2: The Undershoot and Overshoot words provide for dynamic range “headroom” in processing such as filtering.

Requirement	
ST 0403.2-04	The maximum digital signal code for nominal IR illumination ("100% white") and the minimum digital signal code for zero IR illumination ("0% signal = Black) shall be in accordance with MISB ST 0403.2 Table 3 for various output bus bit widths.

6.2.3 Output Interface Format

Requirement(s)	
ST 0403.2-05	Each data word shall represent a single pixel value.
ST 0403.2-06	The acquired infrared image signal shall be uniformly quantized Pulse Code Modulation (PCM) at a relevant pixel sampling clock as indicated in MISB ST 0403.2 Table 1.

Informative Note: Conversions for direct viewing of the digital infrared image from digital to analog domain presume that post-filters, which follow this conversion process, provide a sin x/x correction that is complementary to the original sin x/x filtering of the acquired image during the analog to digital conversion. This is most easily achieved if, in the design process, the pre and post filters are treated as a single unit.

7 Converting an IR digital signal to a 1280x720 parallel interface

Figure 5 shows one possible process for converting an IR source signal into an HD-SDI interface. In order to facilitate conversion the sample rate of the IR source should be matched to that of the destination interface, which is the video format for 1280x720 signals as specified in SMPTE ST 296.

7.1 Digital timing relationships of the 1280x720 signal

Details of digital timing for a 1280x720 signal at 60 and 50 Hz are found in the SMPTE ST 296[3] Table 1 and Sections 4, 6, 7, and 8.

The applicable systems from the SMPTE ST 296 Table 1 are System 1 and System 3. Individual paragraphs in SMPTE ST 296 that define color processing are excluded from the application defined in this document. IR systems 1-4 in Table 1 are up-converted in sample rate to meet the 74.25 MHz 1280x720 sampling format.

7.2 IR image sample rate up-conversion

Requirement(s)	
ST 0403.2-07	The clocked IR image sample rate (Systems 1, 2, 3 and 4 from MISB ST 0403.2 Table 1) shall be up-converted to the clock frequency of a parallel digital Interface at 74.25 MHz representing a 1280x720 system format.
ST 0403.2-08	Both the IR image clock and interface clock shall be synchronous.
ST 0403.2-09	The ratio of the parallel Interface clock divided by IR Image clock shall be (250/91) for 60 Hz frame frequency and (11/4) for 50 Hz frame frequency.

ST 0403.2-10	After up-conversion the number of IR image samples under the parallel interface system clock (74.25MHz) shall be identical to the number of acquired IR image samples under the image clock.
ST 0403.2-11	The word values of the acquired IR image and the word values of the IR up-converted samples shall be identical to each other.
ST 0403.2-12	The IR image samples of the acquired IR signal shall be located within the 1280x720 parallel interface system as shown in MISB ST 0403.2.
ST 0403.2-13	The parallel output signal shall conform to SMPTE ST 296[3] for System 1 and 3 as specified in MISB ST 0403.2 Table 2.

The only difference is that the up-converted interface samples are distributed in time differently during the active line period of the parallel interface than they are in the active line period of the original IR scanned image. The indicated up-conversion process provides only for clock rate up-conversion, and Table 4 indicates the location of the image samples on a horizontal line. In a practical sense, the displayed “rate up-converted’ image on a 16 x 9 high definition display device will be located in the center of the display, but not filling completely the screen of the display device.

Table 4: Location of IR source samples in the 1280x720 parallel interface system

System	IR Signal format	IR image system			Interface system (1280x720)		
		Number of total samples in each line	Number of active samples in each line	Location of IR samples in active line period	Number of total samples in each line	Number of active samples in each line	Location of IR samples in active line period
1	640x480	858	640	40 to 679	1650	1280	320 to 959
2	640x512	858	640	40 to 679	1650	1280	320 to 959
3	720x480	858	720	0 to 719	1650	1280	280 to 999
4	720x576	864	720	0 to 719	1980	1280	280 to 999
5	1024x720	1650	720	128 to 1151	1650	1280	128 to 1151
6	1280x720	1650	720	0 to 1279	1650	1280	0 to 1279
7	1280x720	1980	720	0 to 1279	1980	1280	0 to 1279

Note: The up-conversion process in the vertical direction is beyond the scope of this document. The mapping process and an up-conversion process are quite different from each other, and the purpose of this document is to map the IR image into the high definition interface. The up-conversion process commonly uses a sample buffer technique (several scanning lines long) with a dual clocking system and is beyond the scope of this document.

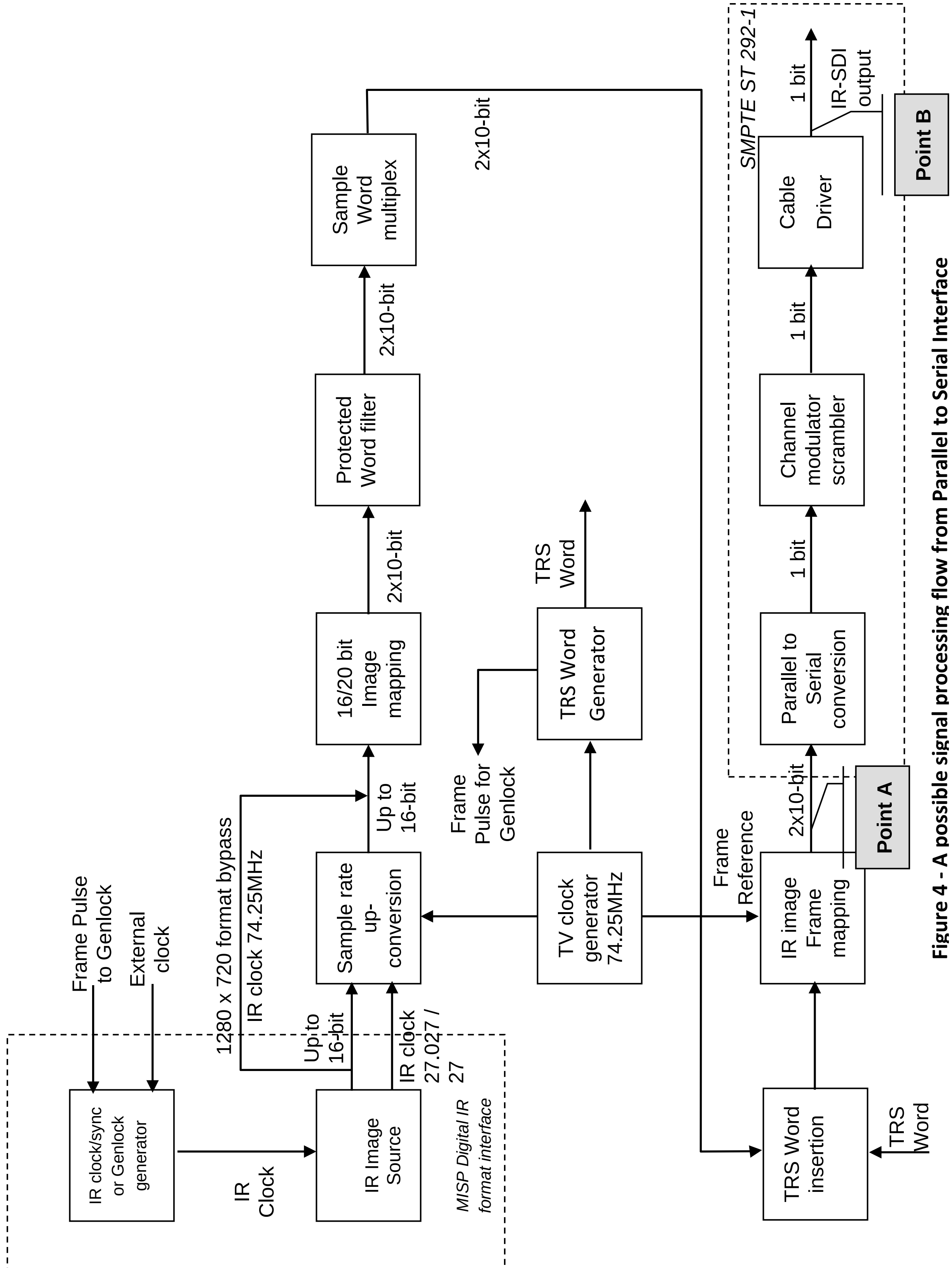

Figure 5: A possible signal processing flow from Parallel to Serial Interface

7.3 IR clock generation and gen-lock

Requirement(s)	
ST 0403.2-14	The IR source shall have two modes of operation: a self-sustaining mode and a gen-lock mode.
ST 0403.2-15	The IR source clock in self-sustaining mode shall attain a frequency value for each frame frequency as indicated in MISB ST 0403.2 Table 1 maintained to a tolerance of +/- 10ppm.
ST 0403.2-16	The number of total samples of each line in a frame for each system shall be as shown in MISB ST 0403.2 Table 1.
ST 0403.2-17	Other synchronization methods shall maintain the desired frequency lock within +/- 10ppm.

In the Gen-lock mode the IR clock may be synchronized periodically to an external stimulus consisting of:

1) Vertical reset pulse, or
2) An external clock and a vertical reset pulse.

7.3.1 IR source clock signal description

Requirement	
ST 0403.2-18	The clock signal shall be a square wave of relevant frequency for each system as indicated in MISB ST 0403.2 Table 1 and its waveform shown in Figure 6.

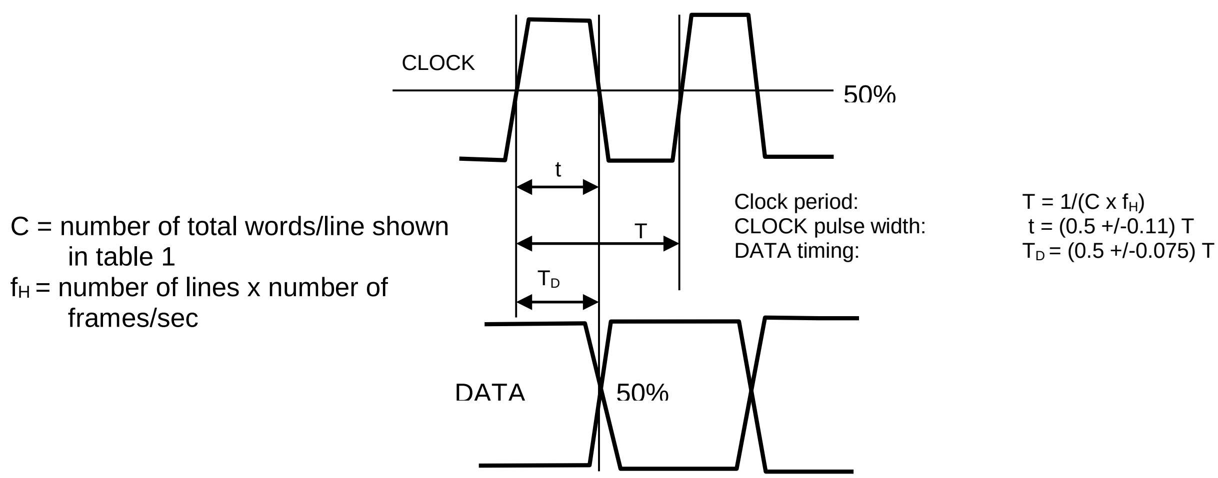

Figure 6: Clock to Data Timing

7.3.2 Clock jitter

Requirement	
ST 0403.2-19	The peak-to-peak jitter between rising clock edges shall be less than 0.08T measured over a period of one frame.

NOTE: This jitter specification, while appropriate for an effective parallel interface, is not suitable for clocking digital-to-analog conversion or parallel-to-serial conversion.

8 IR-SDI - Mapping of an IR source image word (8 thru 16-bit) into the SMPTE ST 292-1 interface channels

The SMPTE ST 292-1 HD-SDI serial digital interface is a synchronous interface, meaning that both a signal’s source digital clock and an interface’s digital clock are phase and frequency locked. While these clocks might have different frequencies, their relationship relative to each other is constant and time invariant. Based on this principle, the IR source clock should be synchronous with the IR serial digital interface (IR-SDI) clock.

A typical commercial serial digital interface (SDI) [7] interface supports three different signals; a signal representing the Luma of the image (Y) and two signals (C'_b, C'_r) representing color difference information. The typical bit depth of an image sample (pixel) is 10 bits for each of the signal components at a frame rate of 30 Hz. The color difference signals are each sampled at one half that of the Luma signal. As a result, the SDI interface bit rate (total bit throughput) is 270 Mb/sec for a 525-line interlaced scanned signal based on a 13.5 MHz source clock. The payload capacity of this interface is less.

In contrast, as indicated in Table 1, IR imagery is progressive scan, up to 16-bit wide words, at a frame rate of up to 60 Hz. This translates to an interface requirement bit throughput of 432.4 Mb/sec for the 16-bit signal case. Such a high bit rate demands the use of the SMPTE ST 292-1 High Definition Serial Digital Interface (HD-SDI), which has a total bit throughput of 1.485 Mb/s and payload capacity of about 1.1 Gb/sec.

HD-SDI uses a 20-bit word, where each word consists of two 10-bit datums, coming from two logical (and parallel) data channels. One channel ("Y") encodes Luma samples; the other ("C") encodes Chroma samples. The C channel is further time-multiplexed into two half-bandwidth channels, known as C'_b (the "blue color difference" gamma-corrected channel), and C'_r (the "red color difference" gamma-corrected channel).

An IR image may have up to 16-bits per pixel data; to accommodate this data in HD-SDI format, the IR signal is split into two streams. For Method 1, where the infrared imagery is pre-scaled and pseudo-colored to generate a displayable 4:2:2 format image, the infrared pixels are scaled to 10-bit intensity values, and pseudo-colored to generate the associated color information in the $C'_bC'_r$ channel. For Method 2, where the unmodified full bit-depth pixels are available on the back end of the interface, the upper 8 bits of the IR signal are placed in the Luma channel and the remaining lower IR bits are mapped into the color channel. The reason for transmitting only the upper eight bits in the Luma channel is to avoid the protected word ranges in the 10-bit interface.

Requirement	
ST 0403.2-20	When SMPTE ST 292-1[1] is used for IR digital motion imagery, it shall be based on the 1280x 720 pixels per frame progressive-scan image lattice for a total of 750 lines in each frame with an image parallel source clock of 74.25 MHz and frame frequency of 60Hz/50Hz.

8.1 High bit depth IR image mapping methods

Two methods are described for encoding 10 through 16-bit infrared image data into the two channel, 10-bit interface defined by SMPTE ST 292-1.

8.1.1 Method 1

Method 1 allows standard/legacy compression systems, without modification, the ability to compress, transmit, and display the encoded high bit-depth monochrome images, so that they will appear as properly scaled 8/10-bit monochrome or 24/30-bit pseudo-colored images. This limits the dynamic range to a maximum of 10 bits per monochrome or 30 bits pseudo-colored images, thereby compromising data that may have greater dynamic range. The method includes contrast stretching a source image before encoding and transmission through the SMPTE ST 292-1 interface. Simply transmitting the upper 8 or 10-bits of a high bit-depth infrared image will generally result in degraded image quality. Figure 7 shows the mapping, with clipping at the low and high ends to avoid the protected regions of the interface.

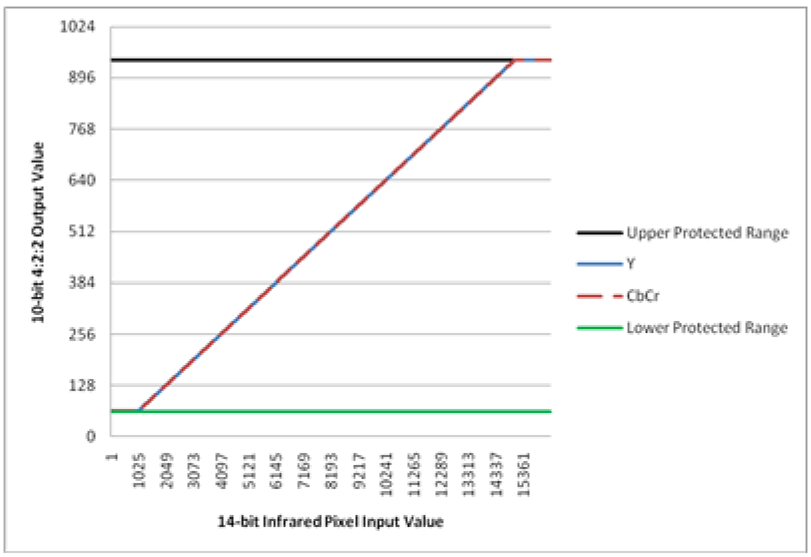

Figure 7: Encoding 14-bit IR pixels into SMPTE ST 292 luma and color channels for standard compression and display applications

Figure 8 shows the basic process of Method 1 for scaling and pseudo-coloring infrared pixels in preparation for transport through a SMPTE ST 292-1 interface when standard equipment is expected to be used on the back end of the interface. This method of operation constitutes the equivalent to how RS-170 and NTSC interfaces have been implemented on infrared cameras in the past.

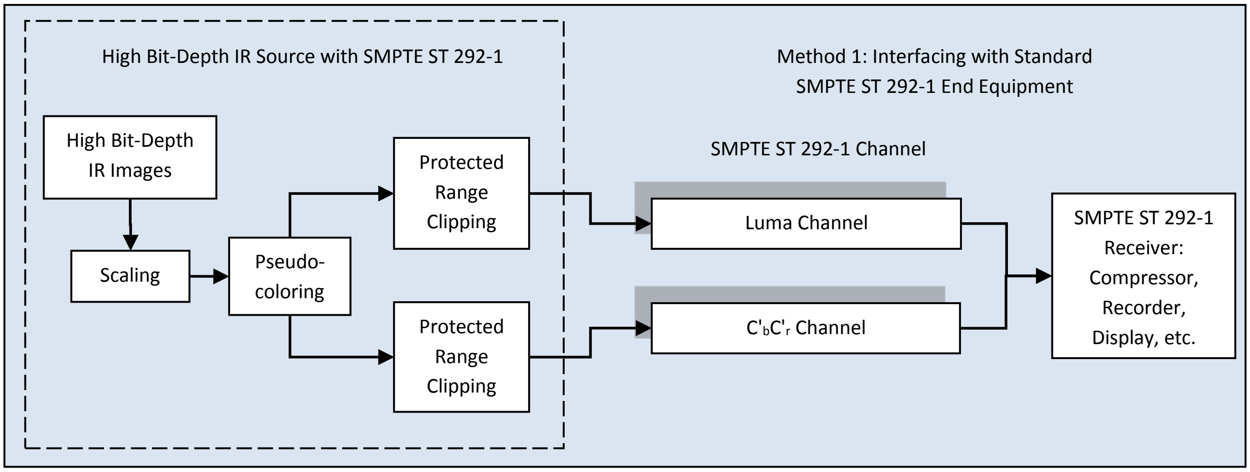

Figure 8: Method 1: 14-bit IR imagery encoded for a SMPTE ST 292-1 interface

Figure 9 shows how a legacy MPEG-2 or an 8-bit 4:2:0 H.264 compression system would receive, and convert the data from a SMPTE 292-1 interface prior to compression. In this case, the top eight bits of the luma and color channel data are processed in a manner consistent with any standard SMPTE ST 292-1 signal.

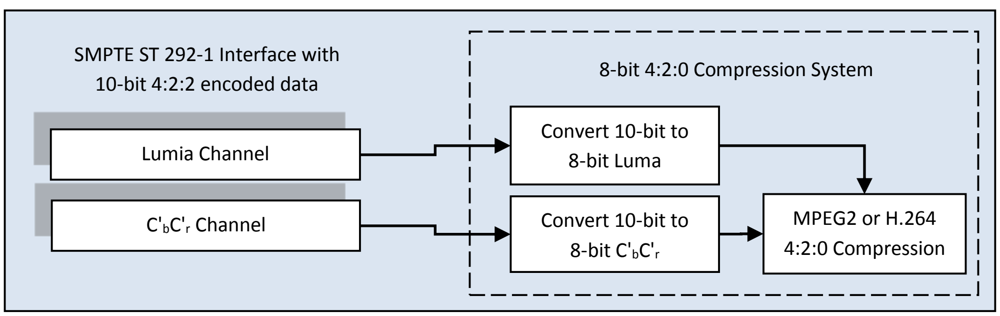

Figure 9: An MPEG2 4:2:0 compression system interfaced to a SMPTE ST 292-1 interface

8.1.2 Method 2

In Method 2, systems designed to take full advantage of high bit-depth pixels recombine the upper eight bits in the Luma channel with the remaining lower bits from the color difference channel on the receiving end to recreate the original high bit-depth pixels, without error. In this case, contrast stretching and pseudo-coloring are not performed before transmission through the interface. With the high dynamic range bits available after compression, the end user has the flexibility to apply a desired contrast stretch algorithm before display or compression. Transmission and reconstruction of high-bit depth levels allows for implementation of MISB ST 0404[2] compliant 14-bit H.264 or JPEG2000 compression using the interface.

Figure 10 shows the defined mapping for a 14-bit pixel input space into the two SMPTE ST 292-1 Y and $C'_bC'_r$ channels when the original 14-bit values are required to be retrievable on the back end of the interface.

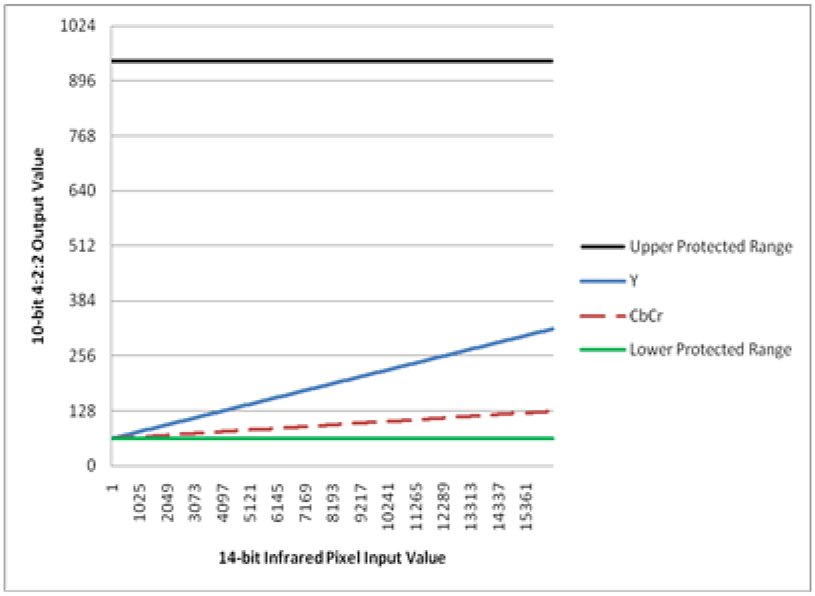

Figure 10: Encoding of 14-bit IR pixels into the SMPTE ST 292 luma and color channels when the original 14-bit values are to be retained

An offset value of 64 (0x40) is applied to the data in both channels to ensure that the transmitted values do not violate the lower protected word range (o to 63) of the SMPTE ST 292-1 interface. The receiving system subtracts this offset value of 64 from the data in each channel before re-merging the upper and lower portions of the original source pixel value. The clipping of the Luma channel on both the low and high ends is to meet the 10-bit code word requirements specified in SMPTE ST 296, which is discussed elsewhere in this document.

Figure 11 shows how this second method of transmitting high bit-depth infrared imagery is conceptually implemented.

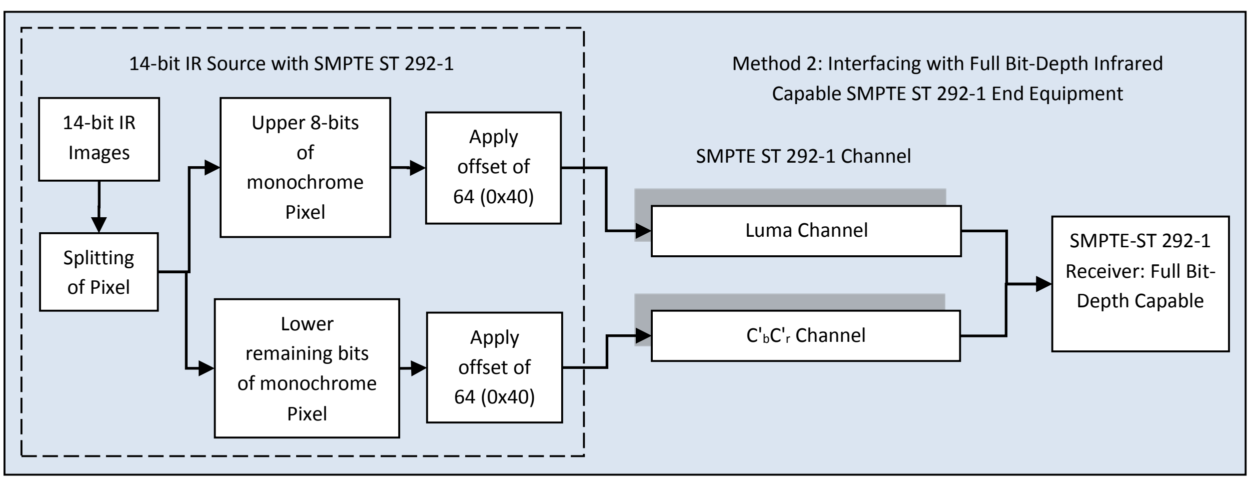

Figure 11: Encoding high bit-depth IR imagery for a SMPTE ST 292-1 interface when the original 14-bit values are to be retained

Figure 12 shows a corresponding high bit-depth receiver compliant with Method 2 for receiving and processing the infrared data from the SMPTE ST 292-1 interface. The offset value of 64 is first subtracted from each 10 bit value of the Luma and color channel. The lower eight bits of the Luma value is then shifted and placed “on top” of the lower eight bits of the 8-bit color channel value, resulting in a 16 bit value shifted to the MSB of the 16-bit word. This 16-bit pixel value can then be scaled and processed as desired.

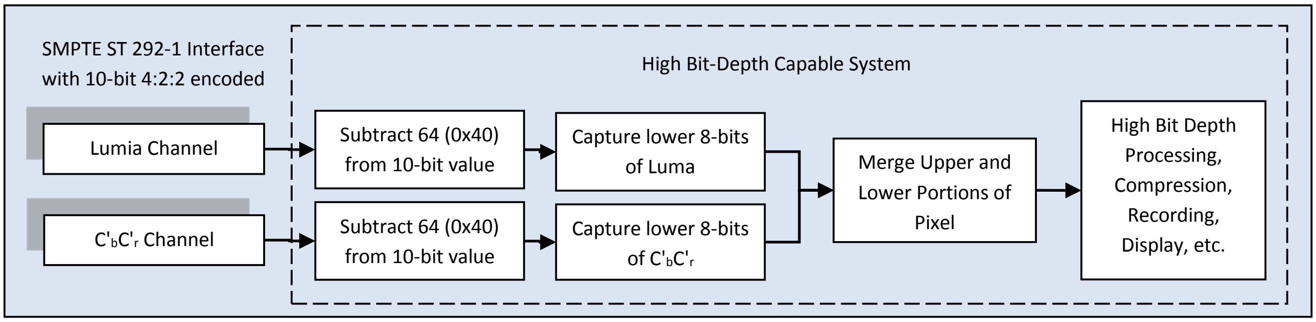

Figure 12: A high bit-depth handling compliant receiver system

8.1.3 Contrast Stretching

Various techniques exist for contrast stretching a 14-bit infrared image. These are typically based on algorithms such as plateau equalization, histogram projection, etc. The stretching is frequently performed on imagery before it is compressed or displayed to maximize the contrast of scene content. While contrast stretching is outside the scope of this document, the performance and utility of many systems will likely benefit by properly contrast stretching a high bit-depth IR image. In Method 1, contrast stretching occurs *before* the pixels are transmitted through the SMPTE ST 292-1 interface. In Method 2, if stretching is required, it will typically be performed *after* the high bit-depth pixels are received from the SMPTE ST 292-1 interface.

8.1.4 Protected words

The IR Serial Digital Interface (IR-SDI) uses some protected words during the horizontal and vertical blanking interval for synchronization purposes. Out of the total available word range combination, 000h and 3FFh data words are used for synchronization purposes in 10-bit and 8-bit image transport systems.

Requirement(s)	
ST 0403.2-21	Data word values 000h and 3FFFh are protected values and shall only be used for system timing purposes.
ST 0403.2-22	The IR bit-serial digital interface shall use the words 000h and 3FFh for synchronization purposes.
ST 0403.2-23	The words 000h and 3FFh shall be present on the 1280 x 720 parallel Interface.
ST 0403.2-24	The words 000h and 3FFh shall be inserted prior to the data word stream serialization process.

The filtering block indicated in Figure 5 suggests that word filtering is done after sample rate up-conversion. It is possible that filtering may be performed at a different stage of the process; perhaps on the original IR image signal itself prior to sample rate up-conversion.

Note: A suggested filtering method is to check for the presence of protected words, and when found, substitute a fixed value nearest the original in the data range.

8.2 Timing and reference signal (TRS) insertion

A detailed description of the TRS (Timing and Reference Signal) system can be found in SMPTE ST 292-1.

A synchronization pattern is based on TRS words where a combination of four data words describe important timing signals. These combinations are called Start of Active Video (SAV) and End of Active Video (EAV). Each SAV or EAV consists of the 3FFh, 000h, 000h word combination and an additional XYZh word that contains protection bits and other parameters such as the Vertical Blanking interval, Horizontal Blanking interval, Ancillary space and Active video space.

8.3 Vertical and horizontal timing relationships for the 1280x720 system

8.3.1 Vertical timing of a digital stream

Figure 13 shows the vertical timing relationship of the 1280x720 system, and the vertical blanking area and numbering scheme for line numbers as well.

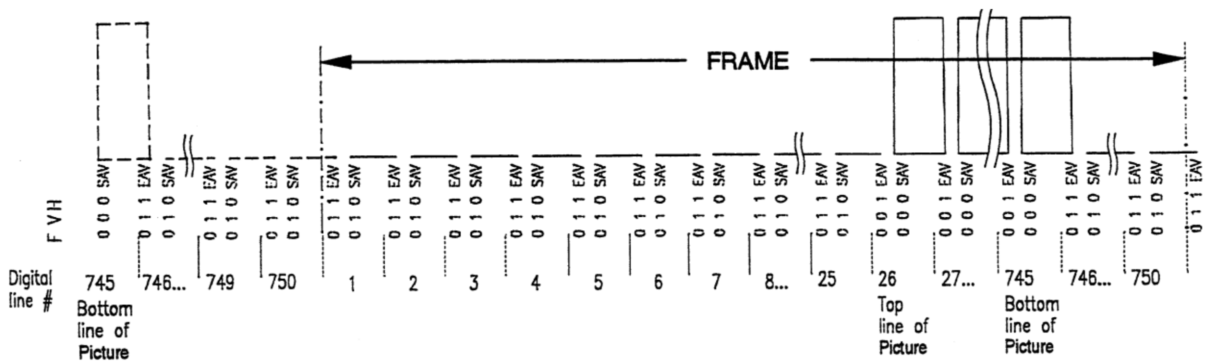

Figure 13: Vertical timing of a 1280x720 digital stream (SMPTE ST 296)

8.3.2 Horizontal timing of a digital stream (sample numbers) for 1280x720 system

A sample number identifies each horizontal sample in the 1280x720 system.

8.4 Timing reference signal description

Table 5 and Figure 14 show the position of the timing reference signals (EAV, SAV) in the parallel multiplexed data stream. The timing reference signals are contiguous with the video payload data, when present, and continue through the vertical blanking interval as shown in Figure 14.

Table 5: Sample numbering for a Horizontal line of a 1280x720 system

SMPTE ST 296 System	Frame freq. (HZ)	Sample number (Luma channel)											
		a	b	c	d	e	k	l	m	n	o	p	a
1	60	1280	1281	1282	1283	1284	1646	1647	1648	1649	0	1279	1280
3	50	1280	1281	1282	1283	1284	1976	1977	1978	1979	0	1279	1280
		EAV				ANC space	SAV				Active video line		
		A horizontal line											

Each EAV/SAV timing reference signal consists of a four-word sequence in the following format:

3FFh 000h 000h XYZh

Because of 8 and 10-bit equipment, all signal values in the range of 000h-003h and 3FCh-3FFh must be considered equivalent to 000h and 3FFh as indicated in Section 6.2.2. The first three words of the TRS are a fixed preamble.

Requirement	
ST 0403.2-25	The fourth XYZh word of the TRS shall contain information defining the state of vertical blanking and horizontal blanking.

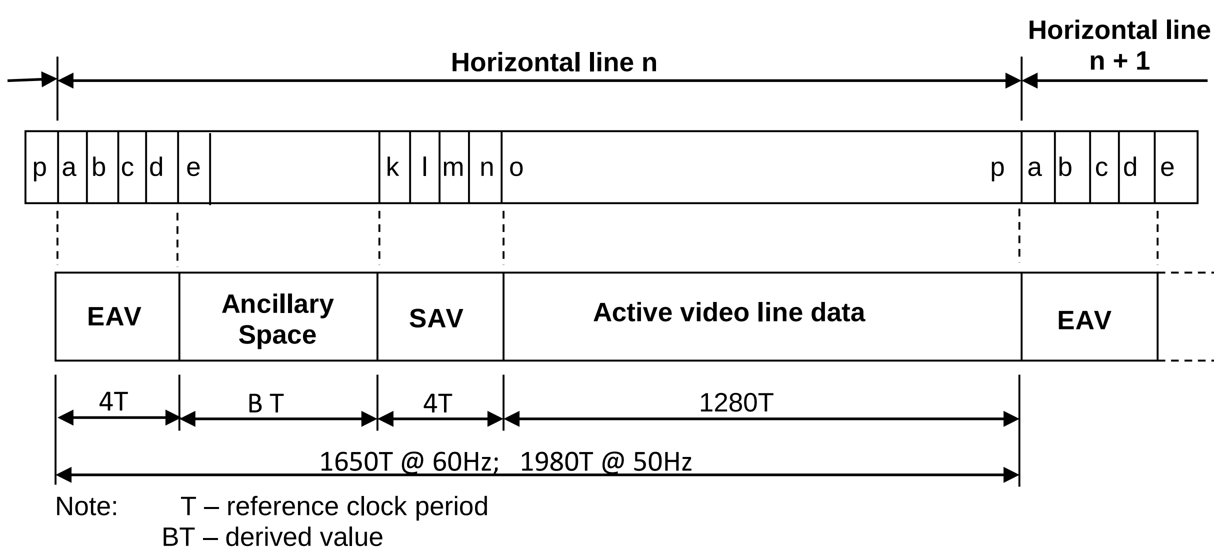

Figure 14: Horizontal timing of a digital stream for a 1280x720 system

The assignment of bits within the fourth word (word = 3) is shown in Table 6.

Table 6: Timing Reference codes and Protection bits for SAV and EAV

Bit number		b9 (MSB)	b8	b7	b6	b5	b4	b3	b2	b1	b0
Word	**Value**										
0	3FFh	1	1	1	1	1	1	1	1	1	1
1	000h	0	0	0	0	0	0	0	0	0	0
2	000h	0	0	0	0	0	0	0	0	0	0
3		**1**	**F**	**V**	**H**	**P3**	**P2**	**P1**	**P0**	**0**	**0**
	200h	1	0	0	0	0	0	0	0	0	0
	274h	1	0	0	1	1	1	0	1	0	0
	2ACh	1	0	1	0	1	0	1	1	0	0
	2D8h	1	0	1	1	0	1	1	0	0	0

Requirement(s)	
ST 0403.2-26	A SAV sequence shall be identified by H = 0.
ST 0403.2-27	An EAV sequence shall be identified by H = 1.
ST 0403.2-28	In a progressive scan system the F bit shall be always set to 0.

In a progressive scan system the V bit changes its state during vertical blanking (see Figure 13). P0, P1, P2, and P3 (parity bits) have states dependent on states of bits F, V, and H according to Table 6.

8.5 Frame mapping of various IR source images

8.5.1 Frame mapping of 640x480, 640x512, 720x480 and 720x576 IR source image

Requirement	
ST 0403.2-29	To achieve a centered position on a 1280x720 display screen the location of the IR image lines shall be mapped as indicated in MISB 0403.2 Figure 15.

The line numbers for a 720-line raster image contain active video from line 26 thru line 745 inclusive. A 480-line structure, operating at 60 Hz frame frequency, will have its lines located between line number 146 and line 626 inclusive, of the 720-line structure as shown in Figure 15. A 512-line structure, operating at 60 Hz frame frequency, will have its lines located between line number 130 and line 642 inclusive, of the 720-line structure.

A 576-line structure, operating at 50 Hz frame frequency, will have its lines located between line number 98 and line 674 inclusive, of the 720-line structure (see Figure 15).

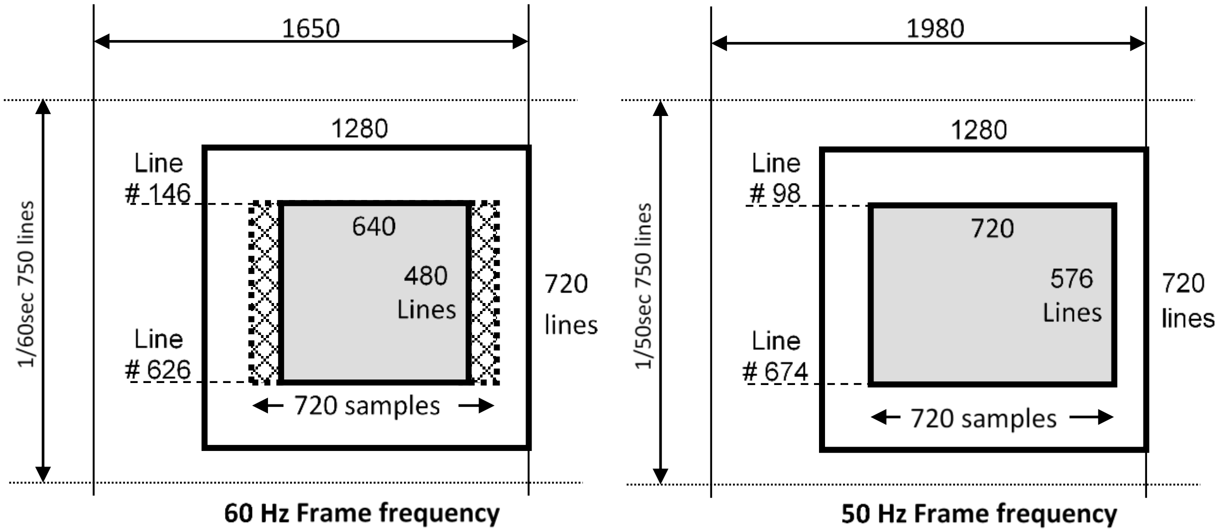

Figure 15: Positioning of IR image formats mapped into the 1280x720 lattice

8.5.2 Frame mapping of 1280x720 IR source image

Frame mapping of a 1280x720 IR Image source is not necessary because the IR source signal occupies the full 1280x720 system.

8.5.3 Frame mapping of 1024x1024 IR source image

Frame mapping of the IR image source requires clipping in the vertical direction because the IR image has more lines than is available within the 720p format. 304 horizontal lines are required to be clipped from the source image as part of the frame mapping to the 1280x720 format frame.

8.6 Parallel to Serial conversion, channel modulation, cable driver

Requirement(s)	
ST 0403.2-30	All parameters of the mapped IR parallel interface as indicated at point A in MISB ST 0403.2 Figure 5 shall be identical to parameters as defined in this document and conforming to SMPTE ST 296[3] Table 1 for 720 line progressive signal System 1 and 3.
ST 0403.2-31	Bit-Serial Digital interface output of an IR motion imagery interface shall be compliant to SMPTE ST 292-1[1], Table 1 System L as indicated at point B of MISB ST 0403.2 Figure 5.

9 Annex A – Informative

9.1 Mapping of IR motion imagery format 1024x1024 and 1920x1080 at 60 Hz

Mappings of IR motion imagery progressive formats 1024x1024, 1920x1080, at 60 Hz up to 16 bits, without windowing, into the SMPTE ST 292-1 bit-serial digital interface is beyond the capacity of the IR-SDI interface described in this document. A potential solution for these implementations is the dual SMPTE ST 292 link (SMPTE ST 372[4]), which is beyond the scope of this document.

10 Annex B - Informative

10.1 Identification of mapped IR image format

SMPTE ST 352[5] provides for identification of video payloads in a serial digital interface. While this document covers a very specific and unusual video payload mapping not found in SMPTE ST 352, it is possible to use SMPTE ST 352 to insert an ancillary packet into the serial digital stream identifying the IR imagery specific payload. The specific implementation of such an ancillary packet (SMPTE ST 291[6]) is beyond the scope of this document.