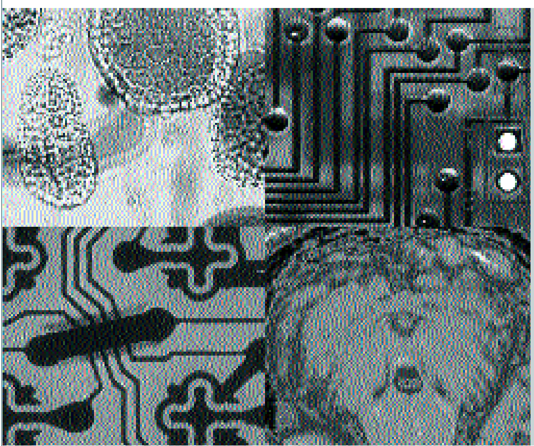
Matrox Imaging

Tutorial



Camera Interface Guide

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INTRODUCTION

This document serves as an introduction to video and interfacing a camera to Matrox hardware. It will help you to understand the descriptions and diagrams in your camera manual, and will enable you to get your system up and running more quickly. Depending on your level of knowledge, certain sections will meet your needs more than others. The sections at the beginning describe components and timings of standard and non-standard video. **Table 1** gives an example of some of the information required when building a digitizer configuration format (DCF) file using Matrox Intellicam camera interface software[1]. (A DCF provides the video description to the digitizer in order to enable grabbing). MODES OF OPERATION describes certain camera modes. MODE REFERENCE, located on the inside cover, summarizes the different modes in a quick reference table. The terminology used to describe video features may vary slightly from one camera manufacturer to another; the definitions found here are as Matrox uses them.

VIDEO FORMATS

There are standard and non-standard video formats. RS-170, RS-330 and RS-343 are the standard monochrome video signals used in the United States, Canada and Japan. The monochrome standard used mainly in Europe is CCIR. The three color standards used are NTSC (United States, Canada, Japan, and parts of South America), PAL (Europe), and SECAM (France, Russia and the republic states). NTSC is a 525 lines, 60 fields per second, 2:1 interlaced system that uses YIQ color space[2]. PAL (Phase Alternate Line) is a modification of the NTSC specifications. In order to prevent color distortion, PAL consists of a line by line reversal of the phase of one of the color signal components. PAL is a 625 lines, 50 fields per second, 2:1 interlaced system that uses the YUV color space[2]. SECAM (Sequentiel Couleur Avec Mémoire/Sequential Color with Memory) adds the hue and saturation to a monochrome signal by transmission on an alternative line to avoid any crosstalk of color information. SECAM is also a 625 line, 50 fields per second, 2:1 interlaced system.

Non-standard video formats usually differ from standard video by their timings and signal characteristics. Some examples of non-standard formats include high resolution, negative-going analog, and digital video. High resolution video includes those cameras with spatial resolution of 1024 pixels x 1024 lines or higher; requiring a higher sampling rate (MHz) by the frame grabber. Negative-going video is an analog video signal where white or bright pixel data is represented by a more negative electrical value than a black or dark pixel. Digital video is a digitized waveform of RS-170, NTSC, CCIR, PAL, or non-standard video signals where the sync, blanking, and saturation levels have been assigned a digital value. Additional discussion of non-standard video includes asynchronous reset, external exposure control and line scan.

STANDARD ANALOG VIDEO SIGNAL

Standard RS-170 cameras use a CCD (charged coupled device) array as an optical sensor which reads out frames in two fields. Even fields contain only even numbered lines and odd fields contain odd numbered lines. With non-interlaced video, also known as progressive scan mode, the sensor reads out the entire frame at one time, and the frame is not composed of fields.

The RS-170 is a standard monochrome composite video signal that contains both timing and image information in a single signal. This monochrome video signal is a 525 line system with a frame rate of 30 frames per second. RS-170 has a 1 volt video signal amplitude, is 2:1 interlaced scan and has a standard sampling field or digitizing frequency providing a 4:3 aspect ratio. Since the video signal ranges from -0.286V to +0.714V, it has an amplitude of 1V. The portion of the RS-170 signal that lies above +0.054V, called the black level, contains active video, while the portion of the RS-170 below +0.054V contains all sync information (blanking, horizontal and vertical). The saturation value of the RS-170 signal, called the reference white level, corresponds to a voltage of +0.714V.

[1] Matrox provides predefined DCFs for RS-170, CCIR, and many non-standard formats, which can be used as is or modified to meet specific requirements.

[2] YIQ is the color space used in the NTSC color system, where the Y component is the black and white portion of the image; and the I and Q parts are the color components. With YUV (used by the PAL color system) the Y component is the black and white portion of the image; and the U and V parts are the color components.

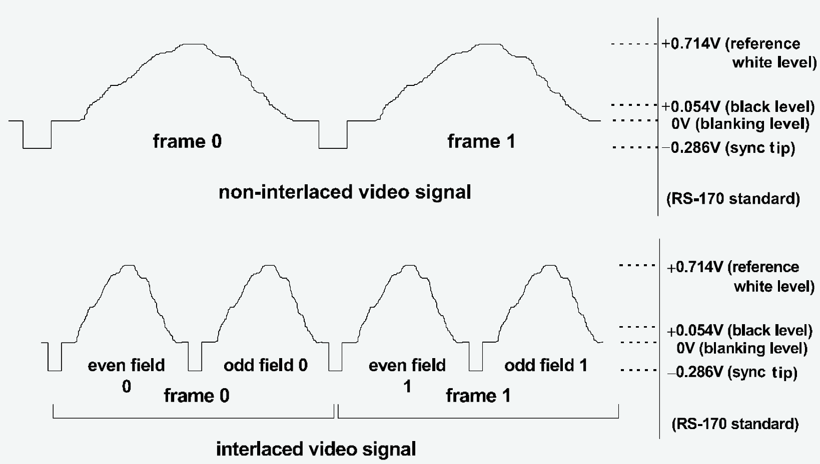

Figure 1: *Frames of non-interlaced, interlaced video and electrical voltage levels*

The reference black level corresponds to a voltage of +0.054V. The difference between an interlaced and non-interlaced video signal in terms of frames can be seen in **figure 1** along with their electrical representations.

BLANKING INTERVALS

A video signal has both vertical and horizontal blanking intervals. The vertical interval occurs between two frames; the horizontal blanking interval occurs between two lines.

VERTICAL BLANKING

Occurring between two frames, the vertical blanking interval is made up of a front and back porch **(see figure 2)**. Each porch consists of a series of pulses (equalization pulses). Between the porches is the sync portion of the blanking interval which, depending on the signal type, will either contain a series of pulses (serration pulses) or no pulse at all (block sync).

Serration pulses[3] are not used in conjunction with frame grabbers when a pixel clock is provided by the camera or frame grabber (see **PIXEL CLOCK** for more info).

HORIZONTAL BLANKING

The horizontal blanking interval occurs between two lines and consists of the front porch of the previous line, the horizontal sync (hsync) pulse and the back porch of the current line **(see figure 3)**. DC restoring of the signal, called clamping, usually occurs during the back porch of the hsync interval, though in some cameras it may occur during the sync pulse or even the front porch.

SYNC PULSES

Blanking intervals contain sync pulses: vertical sync (vsync) and horizontal sync (hsync) pulses. A vsync pulse separates the two frames (or fields) and indicates the top of the next frame. A hsync pulse separates each video line and indicates when the beginning of a new scan line occurs. During this period, the video signal drops below 0V to -0.286V (from the blanking level down to the sync tip). Individual lines and hsync pulse locations can be seen in **figure 4** for a non-interlaced and interlaced video signal.

COLOR CODING

Video line timing for color standards is similar to that of monochrome standards, except that color information must be included with the signal **(see figure 5)** by way of color phase and subcarriers. Color phase is the timing relationship in a video signal that assures correct color hues and is measured in degrees. Color subcarrier is a clock used to run the color decoder. This 3.58 MHz signal (for NTSC, 4.43 MHz for PAL) is superimposed on the luminance level and the subcarrier's amplitude represents the saturation while the phase angle represents hue. The color signal is also composed of horizontal and vertical blanking intervals, further made up of the front

[3] These pulses were used to ensure correct 2:1 interlacing in earlier television video signals.

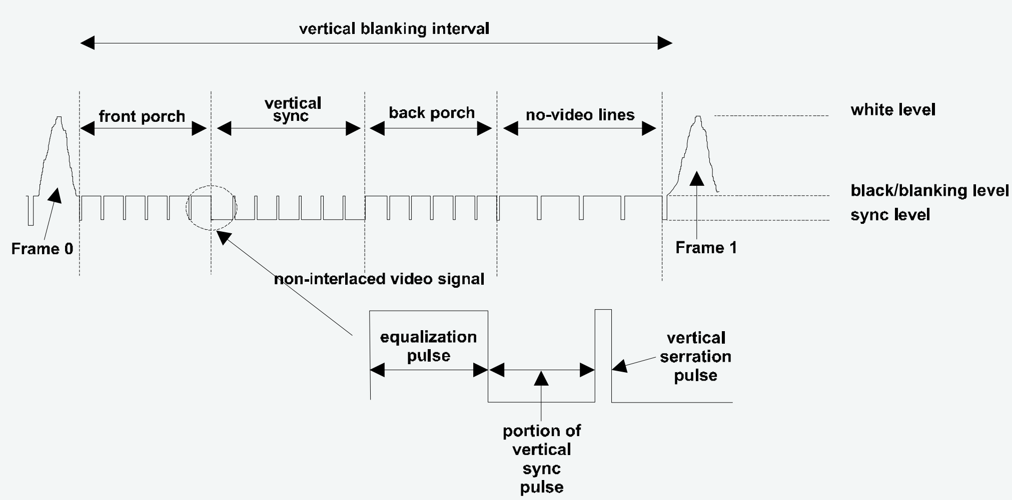

Figure 2: *Vertical blanking*

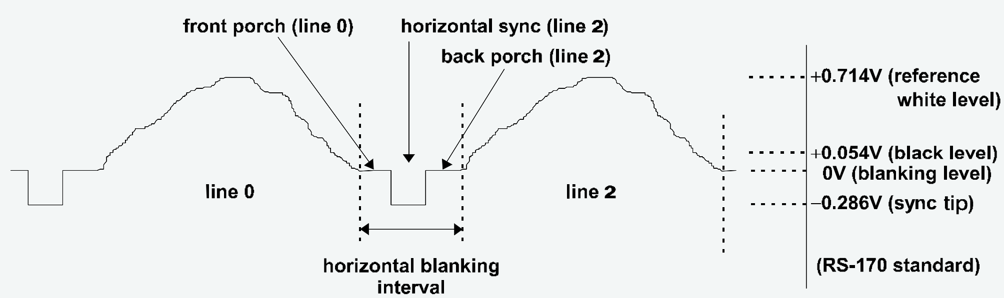

Figure 3: *Horizontal blanking*

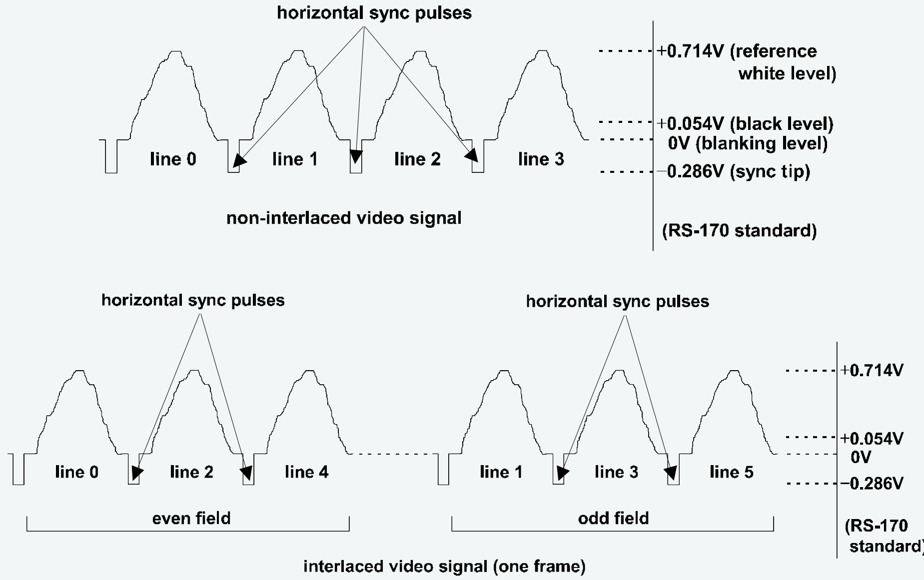

Figure 4: *Line timing and electrical voltage levels*

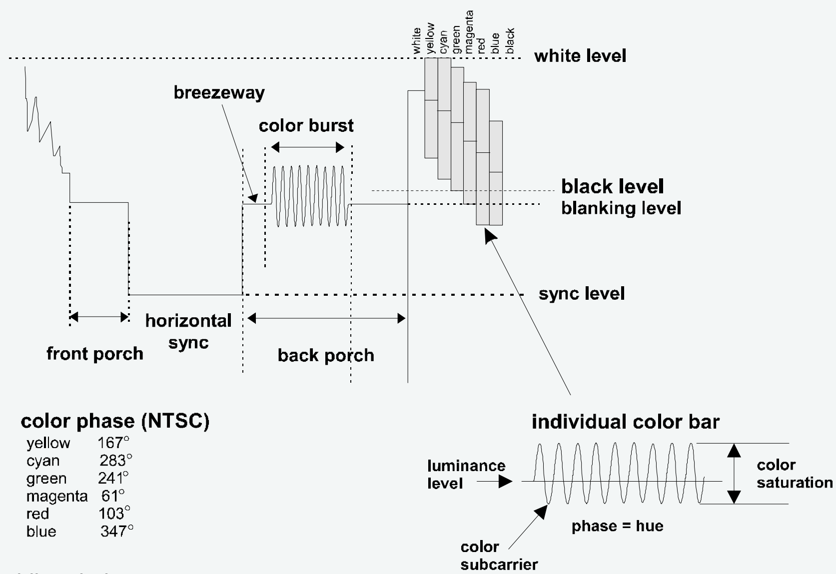

Figure 5: *Color horizontal line timing*

porch, the sync (horizontal and vertical), and the back porch. During horizontal blanking, the back porch is composed of a breezeway and color burst. The breezeway is the portion of the video signal between the rising edge of the hsync and the start of the color burst. The color burst informs the decoder how to decode the color information contained in the line of active video information that follows.

RS-330, RS-343A AND CCIR ANALOG VIDEO SIGNALS

RS-330 and RS-343A are monochrome video standards based on the RS-170 standard, that have additional signal characteristics by way of modified timing waveforms and tighter tolerances. With the RS-330 standard, the output is a composite analog signal without serration pulses during the sync period, known as block sync[3] **(see figure 6)**. The RS-343A is for high-resolution video signals containing between 675 and 1023 lines per image frame.

The CCIR (Comité Consultantife International des Radiocommunications) video standard is used generally in European countries. This monochrome video standard is a 625-line system with a frame rate of 25 frames per second. CCIR is similar to RS-170 in that it has a 1 volt video signal amplitude, is 2:1 interlaced scan and has a standard sampling field or digitizing frequency providing a 4:3 aspect ratio. The CCIR timing for the sync signals is similar to the RS-170.

[3] This characteristic of RS-330 video can prevent a frame grabber from locking onto a video source. Consult with Matrox to see if your camera is compatible with our frame grabbers.

VIDEO TIMINGS USED FOR BUILDING DCFs

The respective widths of the sync pulse, the back porch, the active video period and the front porch are known as the video timings of the camera. These timings are required when building a digitizer configuration file (DCF)[4] using Matrox Intellicam camera interface software, and can be read off of the timing diagrams in the camera manual. To be certain that you have a good understanding of the video characteristics (timings, etc.), complete the Video Specification Form found in the back of the Matrox Intellicam manual. **Table 1** provides an example of timings used to build DCFs for RS-170A and CCIR video signals.

PIXEL CLOCK

A pixel clock is a timing signal used to divide the incoming line of video into pixels. The pixel clock is derived from either the camera or the frame grabber (check your camera manual to determine if the camera provides a pixel clock). It may be necessary to generate a pixel clock using the frame grabber's phase-looked loop (PLL). To generate a pixel clock, the PLL uses a reference signal. The reference signal can be either the frame grabber's on-board crystal oscillator, or an external line sync (i.e. hsync) when periodic.

In some situations, a clock exchange will occur between the camera and the frame grabber. Initially the frame grabber will supply a pixel clock to the camera. The camera, in return, will generate a new pixel clock and return this pixel clock along with the video data to the frame grabber to insure that the incoming video data is in phase with the pixel clock used to digitize or sample this video data. A phase difference may result from internal delays created by digital circuitry in the camera.

Pixel jitter is the timing accuracy of the pixel clock, measured in nanoseconds by the variance in the rising edge of the pixel clock with respect to the falling edge of the hsync. Pixel jitter is introduced by either the camera (in the pixel clock or the hsync generated from the camera) or by the frame grabber's PLL (which can introduce additional pixel jitter). As a result of pixel jitter, the incoming video data may be digitized late or early resulting in inaccurate pixel representation **(see figure 7).** Generating the pixel clock from the frame grabber's PLL based on a stable reference will lower the pixel jitter to a value that will produce results well within a range of accuracy.

[4] Matrox provides predefined DCFs for RS-170, CCIR, and many non-standard formats, which can be used as is or modified to meet specific requirements.

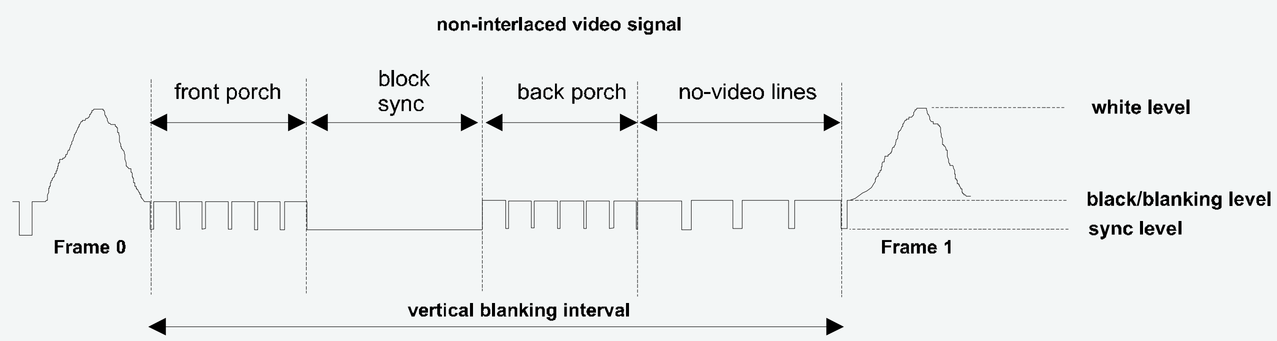

Figure 6: *Vertical blanking RS-330 video*

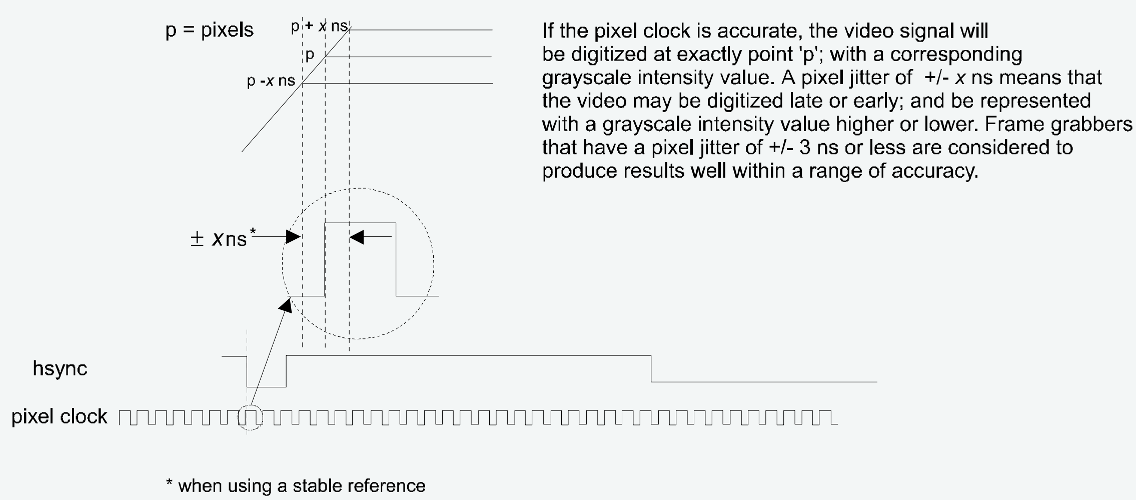

Figure 7: *Pixel Jitter*

TABLE 1: RS-170A AND CCIR TIMING

	RS-170A	CCIR	
# of raster lines/frame	525	625	Lines
# of raster lines/field	262.5	312.5	Lines
V total displayed lines/frame	485	575	Lines
V total displayed lines/field	242.5	282.5	Lines
V front porch/field	3.0	2.5	Lines
V sync/field	3.0	2.5	Lines
equalization pulse width	2.3± 1	2.35± 1	µs
V back porch/field	14	20	Lines
V blanking/field	20	25	Lines
line frequency	15.734	15.625	KHz
line duration	63.556	64.000	µs
line blanking	10.9 ± 0.2	12.00 ± 0.3	µs
front porch	1.5 ± 0.1	1.5 ± 0.3	µs
H sync pulse width	4.7 ± 0.1	4.7 ± 0.2	µs
back porch	4.7	5.8	µs
active horizontal	52.66	52	µs
nominal bandwidth	4.2	5.0, 5.5, 6.0	MHz
effective horizontal resolution	640	768	Pixels
output voltage	1.0	1.0	Vp-p
video voltage	0.7	0.7	Vp-p
sync voltage	0.3	0.3	Vp-p
impedance	75	75	ohm

NON-STANDARD VIDEO

HIGH RESOLUTION VIDEO

High resolution video includes any cameras with a spatial resolution of 1024 pixels x 1024 lines and higher. The difference between this video signal and standard video signals is the difference in the timing specifications and the signal period, along with the required increase in sampling rates by the frame grabber.

NEGATIVE-GOING VIDEO

Negative-going video is an analog video signal where white or bright pixel data is represented by a more negative electrical value than a black or dark pixel. **Figure 8** represents how negative-going video usually appears, however, other variations of negative-going video may exist.

DIGITAL VIDEO SIGNAL

Digital composite video is a video signal where data-carrying-signals are restricted to either one of two voltages levels, corresponding to logic 1 or 0 **(see figure 9)**. This type of representation of data is beneficial for it can be transmitted with a minimum of noise and distortion introduction. Each pixel, in digital video, is represented by a n-bit system **(see figure 10)**, where a value between 0 and 2^n represents the brightness value (e.g. an 8-bit system will have a value between 0 and 255 to represent the brightness value of a pixel). Each additional bit captured provides more information about the pixel. For monochrome images, this means that as one increases the number of bits captured, higher shades of gray are reproduced for a more accurate representation of the subject.

Digital video data is usually transmitted on a pixel by pixel basis in the form of several bits in parallel. Each bit is transmitted on an individual signal line (with TTL logic levels standard) or a pair of signal lines (Differential RS-422 standards). TTL (Transistor-Transistor Logic) is a medium/high speed family of logic integrated circuits, while RS-422 is a medium range differential signaling pair standard. With RS-422, digital information can travel over a longer distance without the introduction of as much noise (random image information known as snow or flecks) as with a TTL signal line.

MODES OF OPERATION

Cameras can typically be operated in one of several different modes. For area scan cameras, these modes include continuous, pseudo-continuous, trigger, asynchronous reset, control and long exposure (integration). Line scan cameras may be operated in fixed line scan rate, variable line scan rate mode and a combination of the two: variable line scan rate and triggered mode. The connections mentioned in the discussion of modes are general. Particular cameras may require additional connections for such things as auxiliary control signals, etc. All required connections should be specified in the camera manual. The use of “internal” in this discussion will refer to the camera’s end and “external” to the board’s end. Horizontal sync and vertical sync will be referred to as hsync and vsync respectively. Bi-directional signals represent those that can be supplied by either the frame grabber or the camera. Terminology varies from one manufacturer to another, so the definitions found here are as Matrox uses them.

AREA SCAN CAMERAS

1. **Continuous mode:** the camera continuously outputs images at a fixed frame rate, usually 30 frames per second (60 fields per second) or 25 frames per second (50 fields per second) being North American and European timings respectively. In general, the exposure time is the reciprocal of the frame rate. By using the adjustments on the camera, it may also be possible to change the exposure to a shorter time. The frame rate, however, does not change. Exposure of the current frame and transfer of the previous frame occur concurrently in continuous mode. Therefore, exposure time in this mode cannot exceed the reciprocal of the frame rate, or in others word, the frame transfer time.

   If the output of the camera is an analog video signal **(see figure 11)**, where both the hsync and the vsync are combined with video data to form a composite video signal, then that signal alone is required by the frame grabber for operation in continuous mode. While not typical, some cameras may output an analog video signal where only the hsync is composite; in this case, a separate digital vsync signal (e.g. a frame enable or a trigger signal) is required and supplied by the camera to the frame grabber or vice-versa.

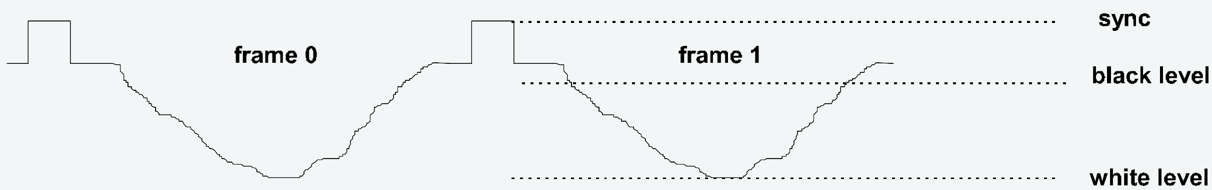

Figure 8: *Negative-going video*

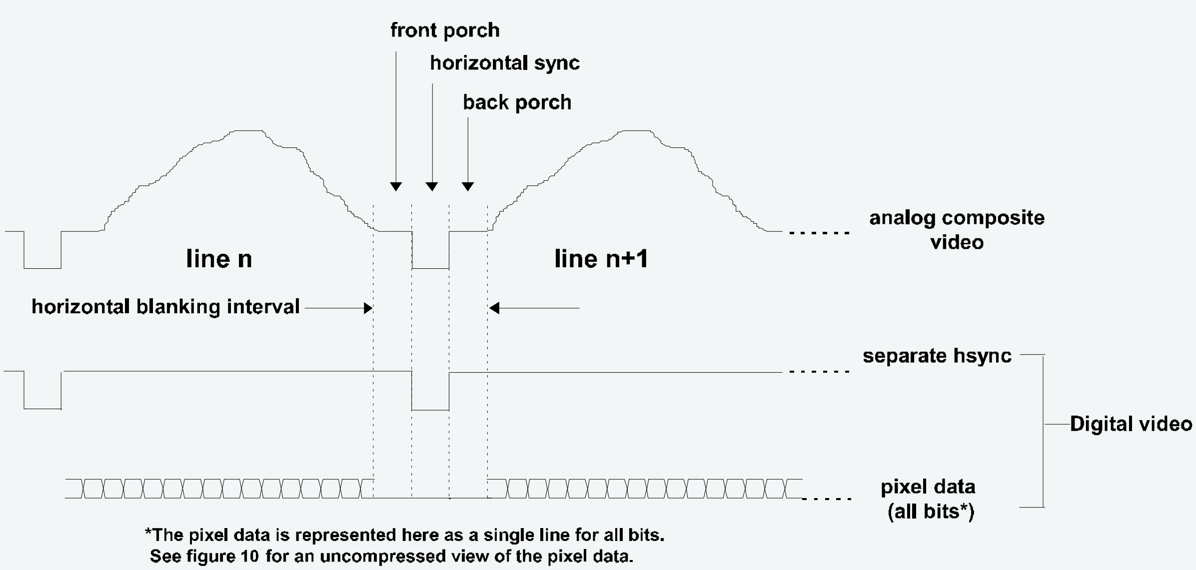

Figure 9: *Equivalence between analog composite video and digital video*

Separate digital syncs may also be employed when the output of the camera is a fully composite analog signal. The analog syncs included in the video signal are simply ignored.

If the output of the camera is a digital video signal, both the hsync and the vsync are usually separate digital signals provided by the camera or supplied by the frame grabber. There are some cameras that combine the hsync and the vsync into a single digital composite sync. Finally, a pixel clock may be provided by the camera or supplied by the frame grabber if required. They can be supplied by both in the case of clock exchange (see previous section, PIXEL CLOCK).

2. **Pseudo-continuous mode:** the camera continuously outputs images at a frame rate that is determined by the exposure time and the frame transfer time. The exposure time may be selected by adjusting the camera, however, the frame transfer time is fixed and is characteristic of the camera. Exposure and transfer of a frame occur sequentially **(see figure 12)**. Exposure of a new frame only starts once the previous frame has been fully transferred, therefore, the frame rate is the reciprocal of the sum of the exposure time and the frame transfer time. The camera sets an upper limit on the exposure time, but as opposed to continuous mode, the exposure time can be much longer than the frame transfer time. The signals involved in this mode are the video output (analog or digital) and syncs. As with continuous mode, these signals may be combined with video data (composite) or separate digital syncs can be used.

3. **Trigger mode:** the camera continuously outputs images at a fixed frame rate as in continuous mode, however, an external trigger signal is provided to the frame grabber **(see figure 13)**. The external trigger pulse causes the frame grabber to grab on the next vsync of the video signal, thereby acquiring the next

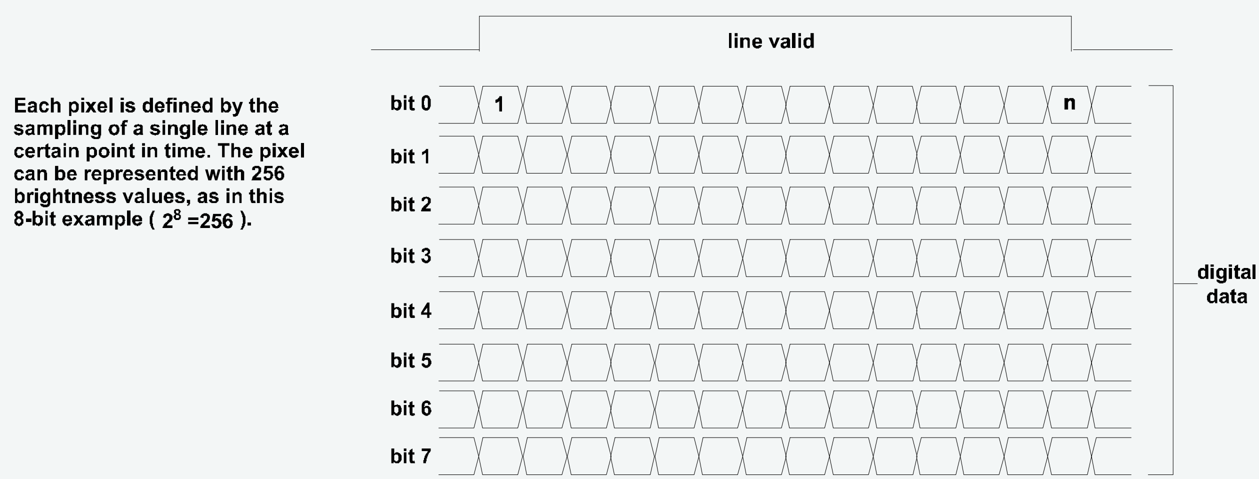

Figure 10: *8-bit digital video*

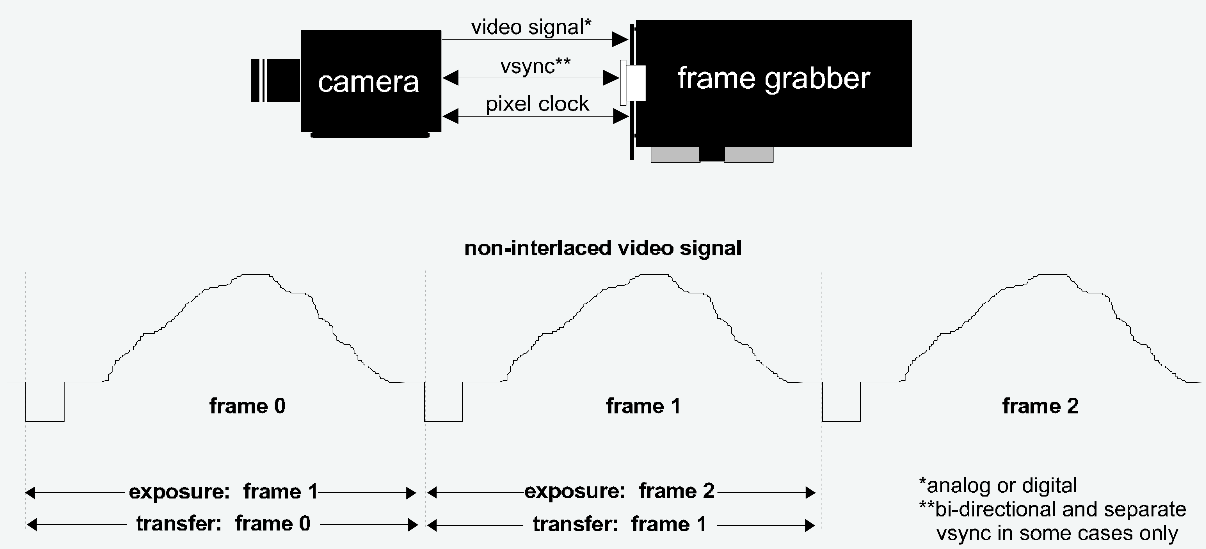

Figure 11: *Continuous mode*

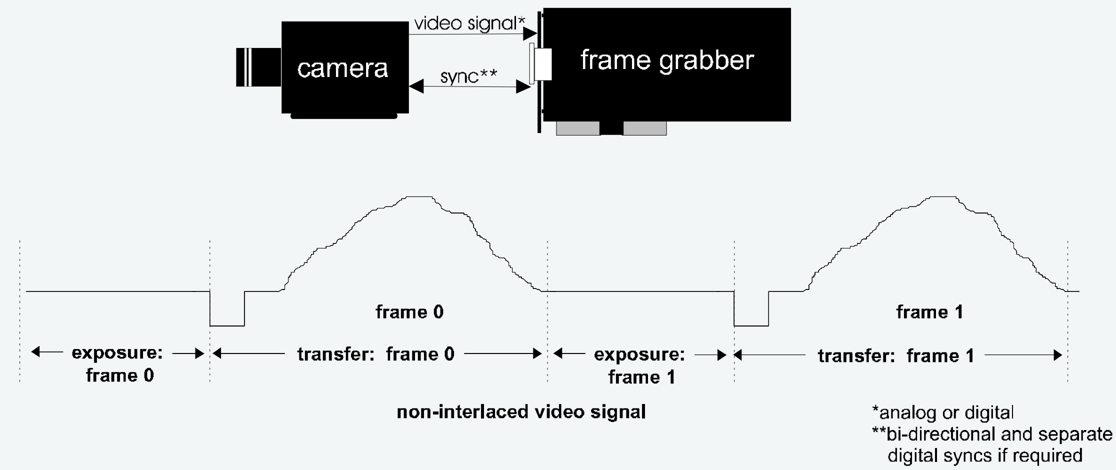

Figure 12: *Pseudo-continuous mode*

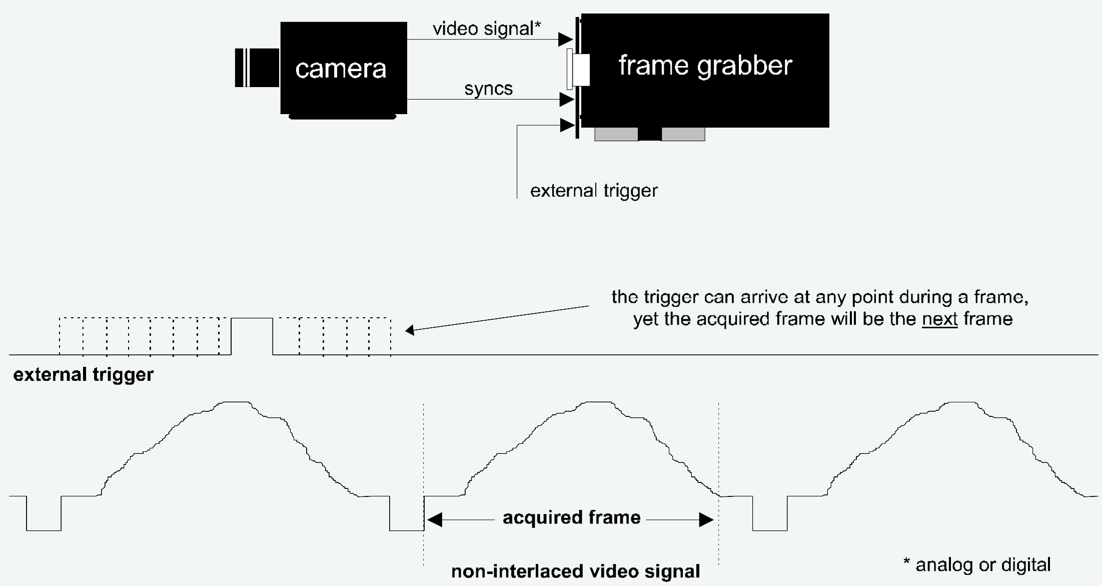

Figure 13: *Trigger mode*

frame. Any additional external trigger pulses will be ignored until the current frame period is over. To ensure the capture of an image, the shortest time between external trigger pulses should be greater than the sum of the exposure time and the frame transfer time. In addition to the external trigger signal, the video output and syncs are provided to the frame grabber. The trigger mode is used to capture a single image or a sequence of images.

4. **Asynchronous reset mode:** either an external trigger signal is provided to the frame grabber or the frame grabber has an internal trigger which can be periodic or aperiodic (software controlled). The frame grabber in turn triggers the asynchronously resettable camera to initiate exposure. The trigger signal from the frame grabber to the camera can be referred to as the exposure signal and is adjusted on the frame grabber through the use of Matrox Intellicam camera interface software. The camera is resynchronized on the arrival of the exposure signal. The delay from the time the frame grabber is triggered to the time it starts exposing is programmable **(see figure 14)**.

There are three versions of the asynchronous reset mode utilized by cameras; vertically asynchronously resettable, vertically and horizontally asynchronously resettable and fully asynchronously resettable. A camera can be identified as:

- vertically asynchronously resettable when only the vertical timings are reset on the exposure pulse;
- vertically and horizontally asynchronously resettable if both the vertical timings and the horizontal timings are reset on the exposure pulse;

- and, fully asynchronously resettable when the vsync, the hsync and the pixel clock are reset on the exposure pulse.

  Examine the timing diagrams that are found in the camera manual to determine which of the three cases corresponds to the asynchronous reset mode of your particular camera.

  In this mode the exposure time is set on the camera. Some cameras will ignore an exposure signal that arrives before the current frame period is over, while others will resynchronize on this new signal, discarding all current information. Generally, the shortest time between external trigger pulses should be greater than the sum of the exposure signal width, the exposure time and the frame transfer time in order to avoid loss of information. The signals utilized in this mode are an external trigger signal provided to the frame grabber, an exposure signal supplied from the frame grabber to the camera, the video output (analog or digital) and syncs.

5. **Control mode:** the exposure time is controlled externally, by way of the frame grabber. In most cases, the camera is triggered by an asynchronous reset pulse, provided by an external trigger source by way of the frame grabber. The asynchronous reset pulse can be referred to as the exposure signal. The delay from the time the camera is triggered to the time it starts exposing is programmable. The delay between exposure and frame transfer is fixed and a characteristic of the camera.

   In this mode **(see figure 15)**, the camera is resynchronized on the exposure signal. The width of the exposure signal determines the exposure time and is adjusted on the frame grabber through the use of Matrox Intellicam. Some cameras will ignore an exposure signal that arrives before the current frame period is over, while others will resynchronize on this new pulse, discarding all current information. To avoid loss of information, the shortest time between external trigger pulses should be greater than the sum of the exposure signal width and the frame transfer time. The signals utilized in this mode are an external trigger signal provided to the frame grabber, an exposure signal supplied by the frame grabber to the camera, the video output (analog or digital) and syncs. The control mode is employed for user control over the start and exposure time of an image.

6. **Long exposure or integration mode:** the exposure time can be controlled internally via switches on the camera, or externally by way of the frame grabber. In this mode, an external trigger signal is provided to the frame grabber, which in turn triggers the camera. The trigger signal from the frame grabber to the camera can be referred to the exposure signal and is adjusted on the frame grabber through the use of Matrox Intellicam camera interface software.

   With most cameras the exposure signal is latched on the horizontal sync and is used to initiate frame transfer on its next vertical sync. The exposure time must generally be specified in terms of an integer number of fields or frames, where one frame time (the frame transfer time) is equal to the reciprocal of the frame rate of the camera when operated in continuous mode; one field time is half of a frame time. This mode **(see figure 16)** is used when an exposure time greater than one frame time is desired. Most cameras will ignore the end of an exposure signal that arrives before the current frame period is over, while others will latch to the signal and initiate the next exposure directly afterward.

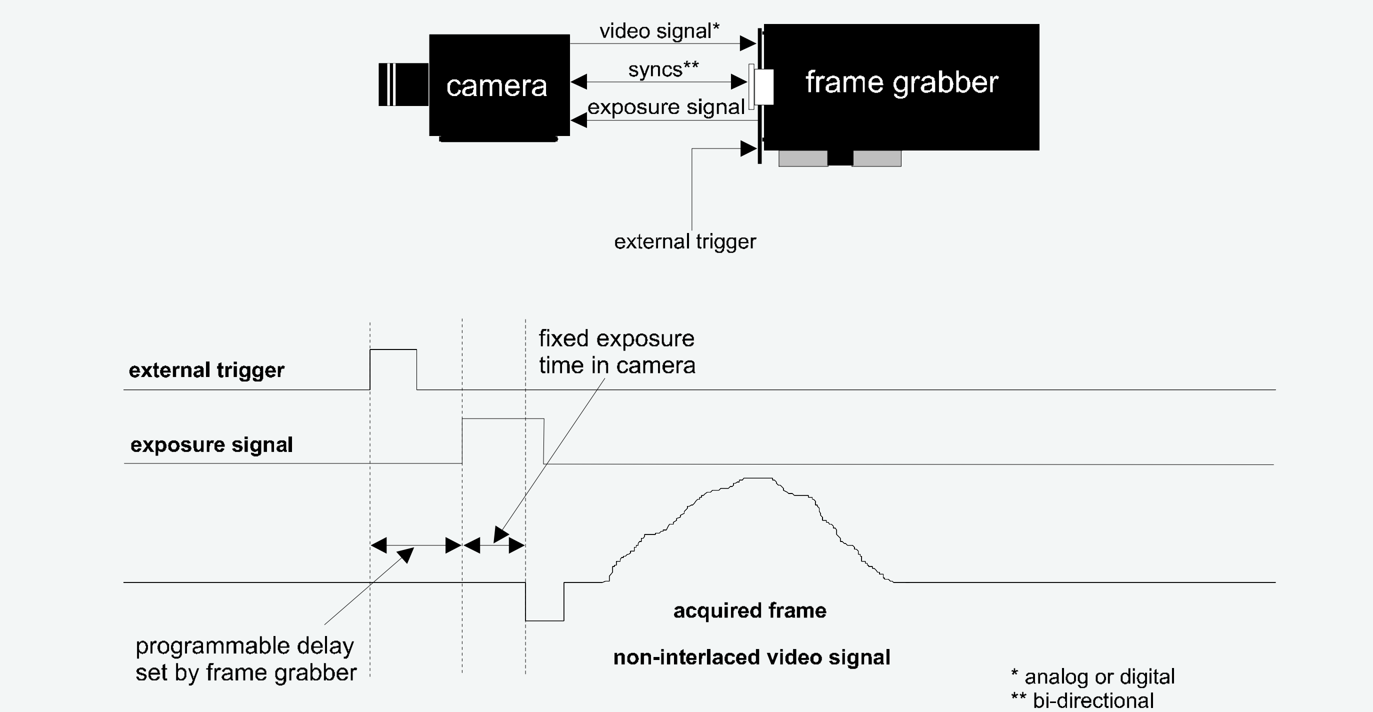

Figure 14: *Asynchronous reset mode*

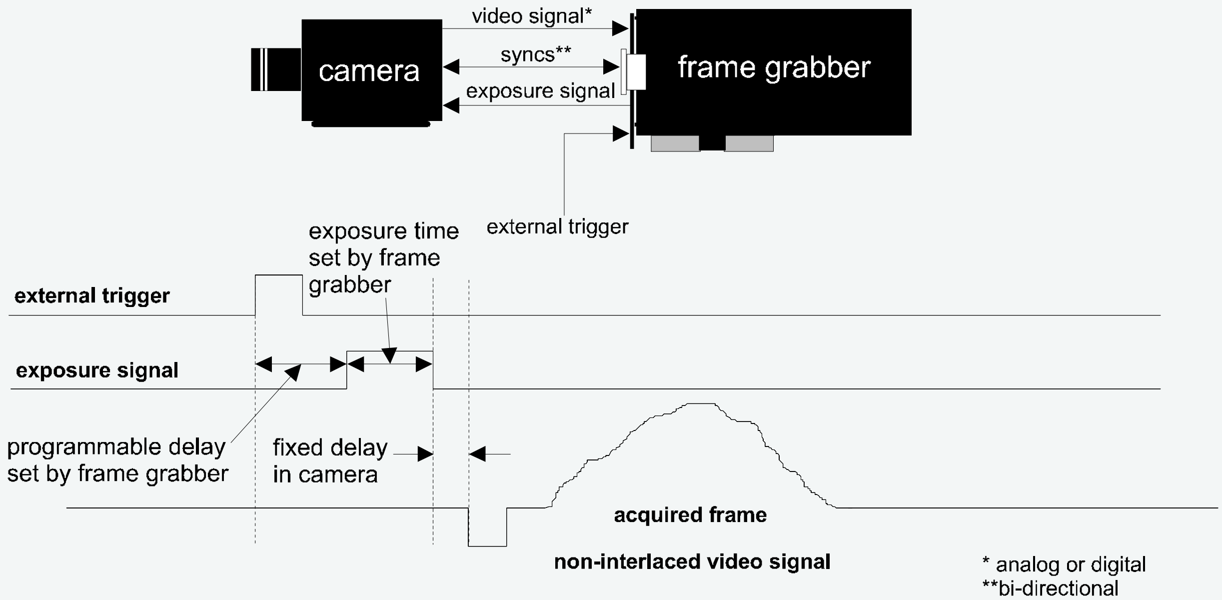

Figure 15: *Control mode*

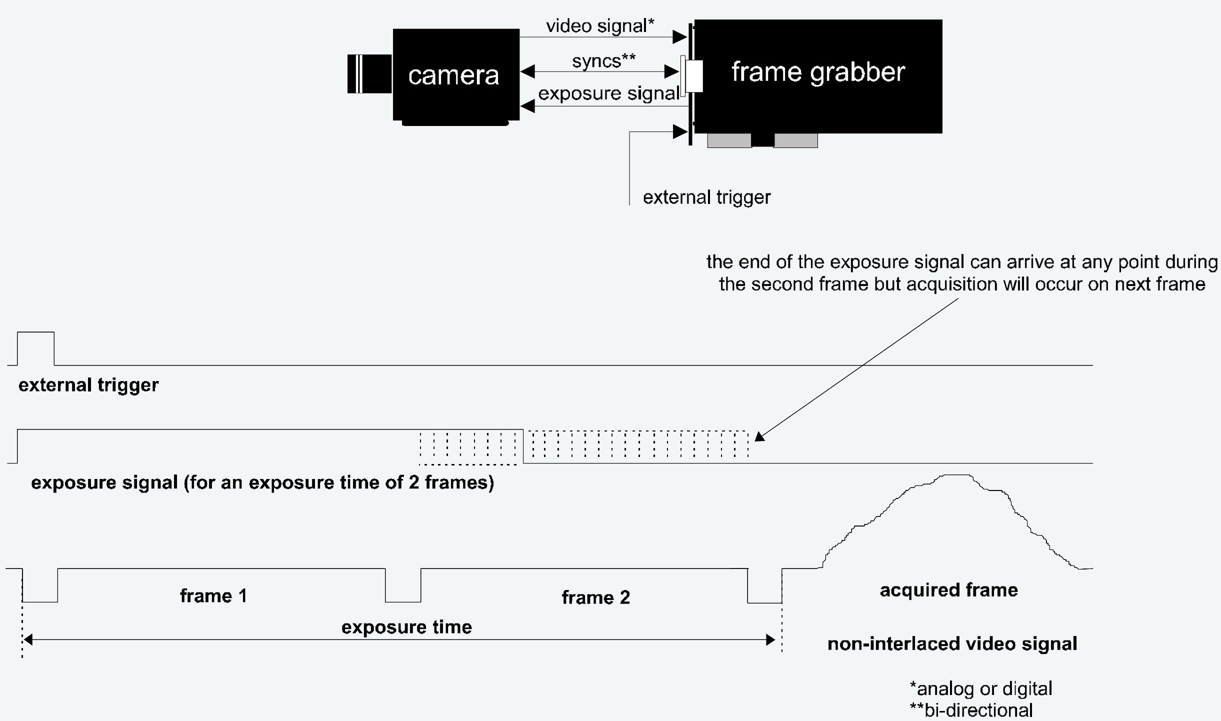

Figure 16: *Long exposure or integration mode*

To ensure the capture of an image:

- if the exposure is internally controlled, the shortest time between external trigger pulses should be greater than the sum of the exposure signal width, the exposure time and the frame transfer time;
- if the exposure is externally controlled, the shortest time between external trigger pulses should be greater than the sum of the exposure signal width and the frame transfer time.

The width of the exposure pulse determines the exposure time and is adjusted on the frame grabber through the use of Matrox Intellicam camera interface software.

The signals utilized in this mode are an external trigger signal provided to the frame grabber, an exposure signal supplied by the frame grabber to the camera, the video output (analog or digital) and syncs.

LINE SCAN CAMERAS

1. **Continuous line scan rate mode:** a hsync signal is supplied to the line scan camera by the frame grabber and the hsync frequency is what determines the line scan rate. Line transfer period is initiated upon the rising edge of the hsync and is followed by the line readout period. Unless the camera features exposure control, the exposure time is the reciprocal of or is inversely proportional to the line scan rate.

   A pixel clock is supplied to the camera by the frame grabber. There are some other cameras that return to the frame grabber an additional clock (strobe) that is derived from the first one, for use as the real pixel clock (clock exchange). The signals utilized in this mode are a pixel clock and hsync, a returned strobe signal (with some cameras), and a video output (analog or digital).

2. **Variable line scan rate mode:** an external trigger signal is provided to the frame grabber, which in turn triggers the camera to initiate line readout. The trigger from the frame grabber to the camera can be called the exposure signal. The time between external trigger pulses determines the line scan rate and must be greater than the exposure time and the line transfer time.

- With external exposure control, the length of the exposure signal will specify the exposure time.
- With internal exposure control, exposure time is set on the camera (through switches or control bits), and is specified by the exposure signal period plus line transfer delay.

   A pixel clock is usually supplied to the camera by the frame grabber. There are some cameras that return to the frame grabber an additional clock (strobe) that is derived from the first one, for use as the real pixel clock (clock exchange). The signals utilized in this mode **(see figure 18)** are an external trigger signal provided to the frame grabber, a pixel clock and exposure signal both supplied by the frame grabber to the camera, a returned strobe signal (in some cameras), and a video output, (analog or digital). Camera can also return a line valid signal.

3. **Variable line scan rate and triggered frame mode:** two external triggers (line and frame trigger) are provided to the frame grabber. The trigger from the frame grabber to the camera can be called the exposure signal. The line trigger is continuous yet with a variable rate. The line trigger provided to the frame grabber in turn triggers the camera to initiate the line readout. At the arrival of the frame trigger, (also may be variable), a specified number of lines are acquired.

   A pixel clock is usually supplied to the camera by the frame grabber. The signals utilized in this mode **(see figure 19)** are external line and frame trigger signals provided to the frame grabber, a pixel clock and exposure signal both supplied by the frame grabber to the camera, a returned strobe signal (in some cameras), and a video output, (analog or digital).

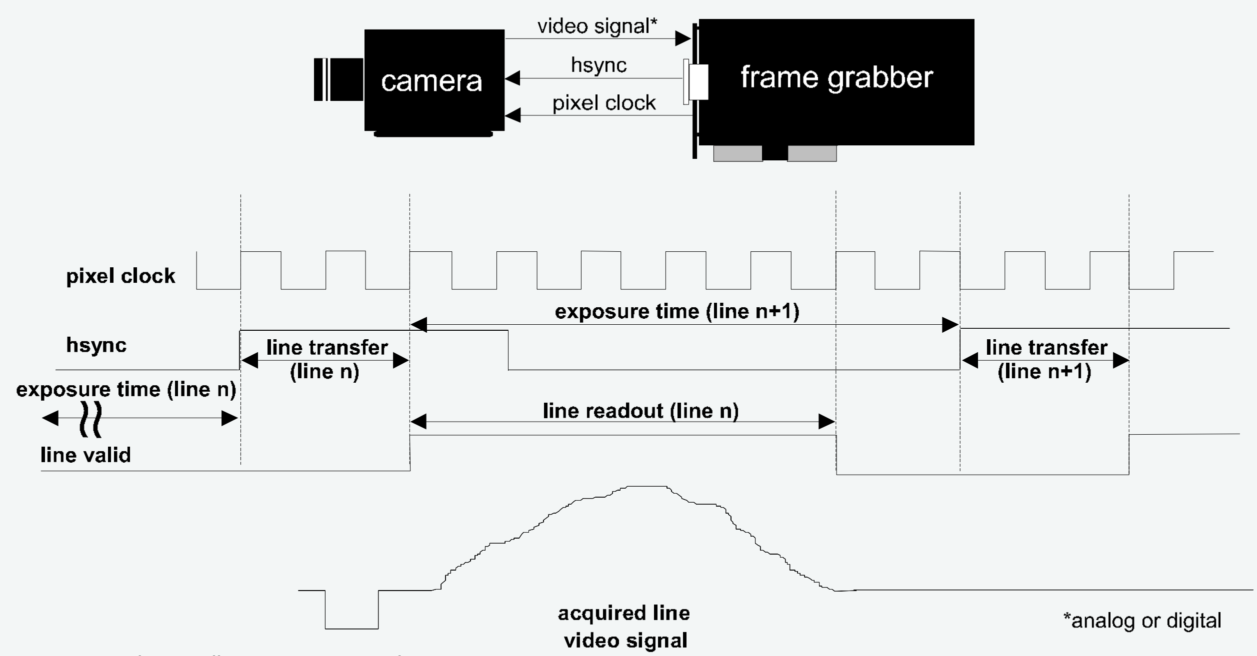

Figure 17: *Continuous line scan rate mode*

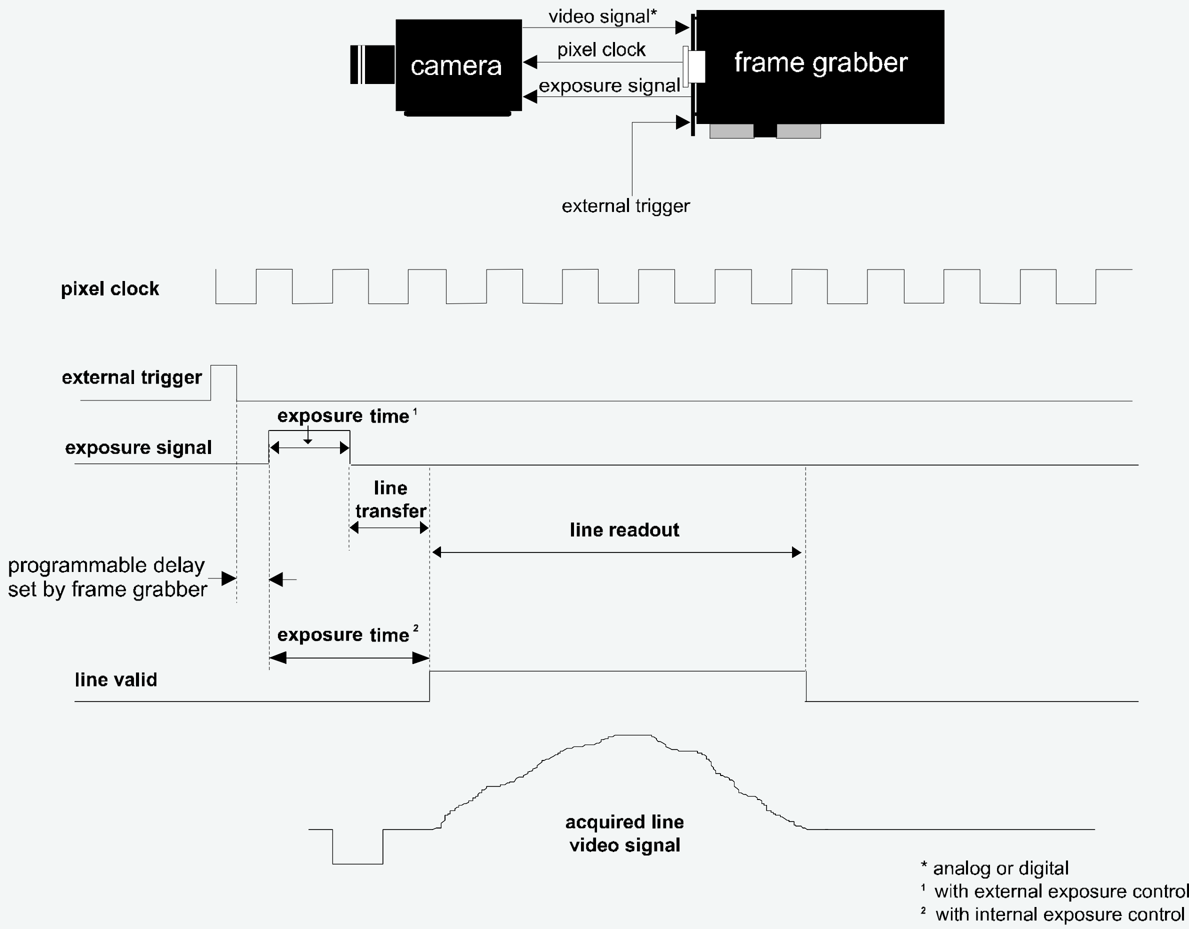

Figure 18: *Variable line scan rate mode*

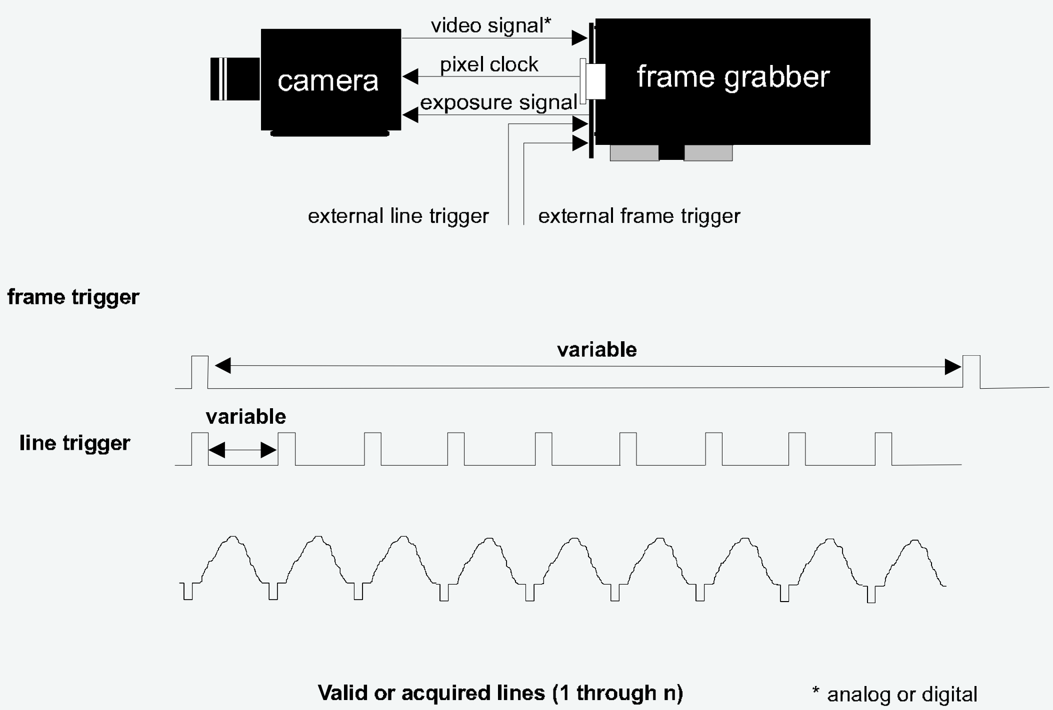

Figure 19: *Variable line scan rate and triggered mode*

TABLE 2: MODE REFERENCE

AREA SCAN CAMERAS

Camera Modes	Connections
1. Continuous mode: • continuous video • internal exposure control • exposure time cannot exceed frame transfer time • fixed frame rate is independent of exposure time	• video and sync signals between camera and frame grabber (syncs can be provided from frame grabber)
2. Pseudo-continuous mode: • continuous video • internal exposure control • exposure time can be much longer than frame transfer time • frame rate is a function of exposure time	• video and sync signals between camera and frame grabber
3. Trigger mode: • internal exposure control • external trigger	• video and sync signals connected between camera and frame grabber • external trigger signal connected to frame grabber
4. Asynchronous reset mode: • internal exposure control • external trigger	• video, sync and exposure (frame grabber acting has asynchronous reset) signals connected between camera and frame grabber • external trigger signal connected to frame grabber
5. Control mode: • external exposure control • external trigger	• video, sync and exposure (frame grabber acting has asynchronous reset plus actual exposure) signals connected between camera and frame grabber • external trigger signal connected to frame grabber
6. Long exposure or integration mode: • internal or external exposure control • exposure times longer than one frame • external trigger	• video, sync and exposure (trigger) signals connected between camera and frame grabber • external trigger signal connected to frame grabber

LINE SCAN CAMERAS

Camera Modes	Connections
1. Continuous line scan rate mode: • line scan rate determined by frequency of horizontal sync signal	• video and sync signals between camera and frame grabber (sync can be provided from frame grabber)
2. Variable line scan rate mode: • line scan rate determined by time between external trigger pulses • internal or external exposure time control	• video, sync and exposure (trigger) signals connected between camera and frame grabber • external trigger signal connected to frame grabber
3. Variable line scan rate and triggered mode: • line scan rate determined by time between external trigger pulses • internal or external exposure time control	• video, sync and exposure (trigger) signals connected between camera and frame grabber • external line and frame trigger signal connected to frame grabber

NOTE: The use of INTERNAL refers to the camera’s end and EXTERNAL to the board’s end.

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