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A Practical Guide to Using the In-Sight 5604 Line Scan Vision System

Integration Note

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IN-SIGHT
Vision Systems

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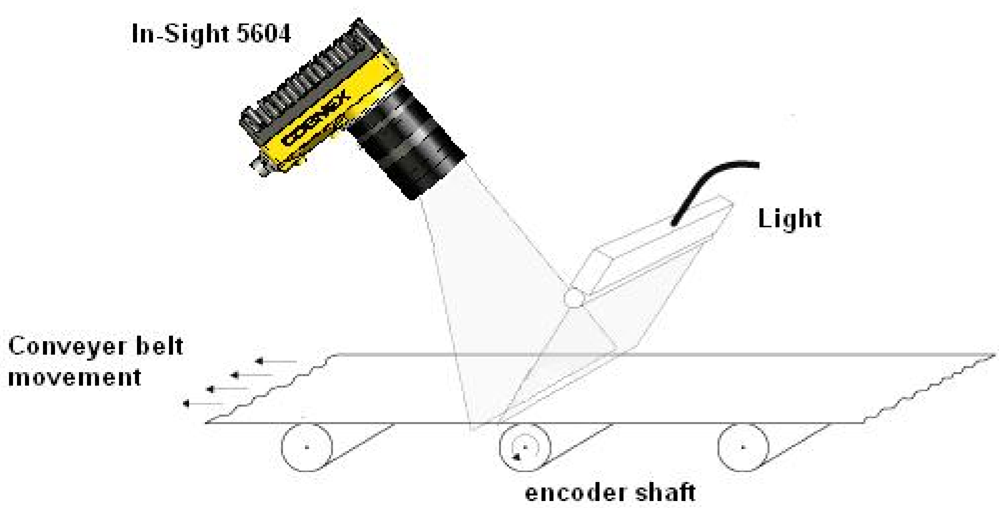
Introduction

The In-Sight® 5604 vision system uses line scan acquisition to build images for inspection. Line scan acquisition builds an image from a moving object, pixel line by pixel line, as it moves under the camera. Although line scan has many advantages over area scan cameras, it is generally viewed as difficult to set up because the part must be in motion (of known speed) in order image the part for inspection. Thus, the purpose of this document is to provide some practical information for getting started with the In-Sight 5604 line scan system. This Integration Note covers the following topics:

- *Line Scan Basics*: General introduction to line scan technology and applications suited to the In-Sight line scan system
- *In-Sight 5604 System Specifications*: Explains the hardware capabilities of the system and describes the accessories required, such as lenses and lighting, as well as an overview of the software capabilities of the system.
- *Setting up the In-Sight 5604 System*: Covers initial set-up of the system, including focusing and image acquisition, followed by an overview of software diagnostics available and some troubleshooting tips.
- *Appendices*: Appendix A provides a detailed description of the Line Clip Mode function, Appendix B provides notes for high speed applications, while Appendix C provides specific part number recommendations for appropriate lights and lenses to use with the In-Sight line scan system.

Line Scan Basics

Line scan acquisition is a method of building an image pixel line by pixel line of a moving object. Popular non-industrial line scan devices include fax machines and scanners. As the paper is fed into the machine, a digital image is made line by line as the paper moves past the scanner. The movement occurs at a set speed so the consumer needs only to feed the paper into the device. This is analogous to the image acquisition within the In-Sight 5604 system, except that the movement of the object is as variable as the user's application. Therefore, in order to how fast to acquire the lines of the image, the speed of the object must be known. This is accomplished through the use of an encoder (either a physical hardware encoder or a virtual, software encoder).



Encoders are devices that translate motion into electrical pulses. Typically encoders are installed on a conveyer belt and as the conveyer belt moves, the encoder shaft will rotate and output electrical pulses to indicate its angular rotation. The amount that the encoder rotates is directly proportional to the distance traveled by the conveyer belt. For example, if an encoder provides 360 pulses per 1 full revolution of its shaft (360 degrees of motion), and 1 revolution translates to 6 inches of conveyer belt movement, then a control system monitoring the conveyer can determine the speed of the line by counting the pulses it receives from the encoder per second. Similarly, the In-Sight 5604 system will count the encoder pulses to indicate when to acquire a new line in the image. For example, the In-Sight system can be set to count 10 encoder pulses per line. Then, each time 10 encoder pulses are detected by the In-Sight system, a new line is acquired. This continues line by line, until the total number of lines need to make the full image are acquired.

Applications for the In-Sight 5604

Since line scan acquisition builds an image line by line, only a sliver of the object you want to inspect needs to be visible at any given time to the line scan camera. As the product moves past the camera, new lines are acquired until the full image (total number of lines) is built to reveal the full product view. This presents a number of advantages over area scan camera, as illustrated in the following application descriptions.

- *Unwrapping a cylindrical object for inspection:* Line scan can be used to “un-wrap” a cylindrical objects by translating the curved surface into a two-dimensional image. Because the entire part cannot be seen without rotating it, this application is made possible through the use of line scan image acquisition. Line scan builds an image line by line as the cylindrical object rotates before the imager thereby creates a flat, uniform two-dimensional image of the object. This image is then easily inspected using common vision tools.
- *Working in a space-constrained environment:* Line scan only needs to see a sliver of the product (as it is passing by the camera) in order to build the entire image. This makes the required space on the manufacturing lines much smaller for line scan installations than area scan cameras require. Also, the lighting necessary for line scan is reduced to only a single pixel line, which can simplify the application lighting needs if lighting the entire part uniformly is difficult (or requires a large, expensive light). With the smaller space necessary for building the image, line scan is ideal for machine with limited real estate for additional vision inspections.
- *High speed applications:* The In-Sight 5604 system needs only 22 microseconds to acquire each line of the image. The highly light-sensitive CCD sensor used on the In-Sight 5604 is designed to collect as much light as possible which enables the exposure time to be set in the low microseconds range. The quickness of each line acquired means that strobing is not necessary to “slow” the motion of the product as it passes in front of the In-Sight 5604 system.
- *High resolution inspection needs:* Line scan cameras come in a variety of different resolutions ranging from 512 to 8k CCD sensors widths to satisfy a wide range of high resolution inspection needs. However, the higher the resolution, the more pixel data to process and the slower the system. This is why the majority of line scan system rely on the processing performance available in a computer, instead of a self-contained unit like the In-Sight system. The In-Sight system resolution is 1024 pixels wide by 8192* lines maximum, providing an 8-megapixel image. Relative to other self-contained vision systems, this is a relatively high resolution system.

* 8192 is supported in ISE 4.4. Previous ISE versions support a max of 2048 lines

In-Sight 5604 System Specifications

As is common to all machine vision systems, selecting the correct lens, lighting and trigger mechanism for the specific setup is crucial to the success of any line scan application. However, some additional parameters must be considered to acquire line scan images correctly. In the following section, both the new hardware and software considerations will be explained for the In-Sight 5604 system.

Lens

The In-Sight 5604 system supports a C-Mount type lens. It is recommended to use a 1 inch format lens to minimize lens distortion on the In-Sight 5604 system. The actual CCD size is approximately 14mm therefore a high performance 2/3 inch lens can be used as well however lens distortion maybe more prevalent than a 1 inch format. Since the width of the line scan sensor is the gating factor the field of view, determine the appropriate lens size using the below equation. The actual CCD width is: 14.336mm

Focal length of width = (Working distance × CCD Width) ÷ (Field of View width + CCD Width)

For example:

Focal length of width = (400mm x 14.336mm) ÷ (200mm + 14.336mm)

Focal Length of width = 26.7mm

Since this isn’t a common focal length, a more common 25mm lens would give you 215mm field of view width.

Once the lens is selected, the image resolution and pixel size can be determined. The In-Sight 5604 sensor width is 1024 pixels; use the following equation to determine the resolution of the acquired image:

Resolution of image in mm/pixel = Field of View Width in mm ÷ Width of sensor in pixels

For Example:

Resolution of image in mm/pixel = 215mm ÷ 1024 pixels

Resolution of image = .209mm per pixel

The pixel resolution value is also used to obtain the pixel length. Ideally pixel size should be in a 1:1 ratio (width = length) to maintain square pixels in the final image. Since line scan builds the image one pixel line at a time, each line that is captured is actually the ideal pixel length.

The field of view length can be determined from the resolution. For this example, assuming square pixels, your field of view length could be .209mm (length of pixel) x 8192 lines = 1712 mm.

Lighting

Because the In-Sight line scan imager is a single row of pixels, only a single line of light is needed. This not only minimizes the space needed to illuminate the part, but means the entire part does not need to be uniformly illuminated – just the single line being acquired.

In general, line scan cameras need higher intensity light than area scan systems due to the short acquisition speed. A line scan acquisition is typically the low microsecond range, as opposed to millisecond range of area scan cameras. It is important not only to expose high intensity light to the line scan imager, but to also make sure the line light is even. As long as the light is even across the part in one line field of view, the entire image (1024 x 8192) will have uniform lighting.

Line scan lights are typically high intensity LED bar lights that converge the light to a small width thereby increasing the intensity of the light in one line. The In-Sight 5604 system has been tested with three line lights which can be found in Appendix C.

Trigger

The same triggering methods exist in the In-Sight 5604 line scan system as the In-Sight area scan systems. Both systems need a trigger will indicate when the full image should START to be acquired.

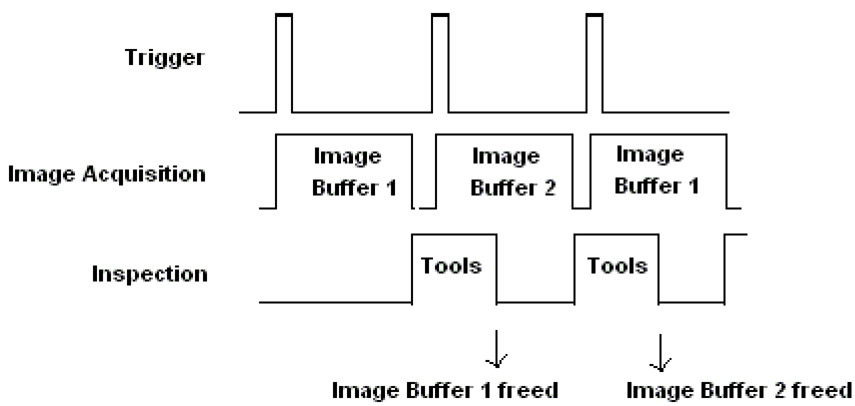
Re-arm time:

The In-Sight 5604 requires time between the last line acquired in the image to the trigger of the next image to prepare for the next image. This time is not an issue for most applications since the gap between last line and next trigger is sufficient to hide this time. The re-arm time varies but can be *at most* 1ms. Depending on the encoder period/steps per line, this could equate to 10 lines. If a trigger comes in during this gap, a missed acquisition will occur regardless if there are buffers available.

If this is a problem, the number of lines acquired can be decreased to allow for extra time between trigger and last line or Line Clip mode can be used. Line Clip mode guarantees the trigger will acquire a new image and not register as a missed acquisition. Missed acquisitions will still occur if the image buffers are full.

Image Buffering/Image acquisition

The Line scan image is built in one image buffer, when the image is complete tools run on this image while the system waits for another trigger. If the trigger frequency is high enough, the 5604 will use one image buffer to acquire the image while tools run on the previous image. In the caption below, the trigger frequency is such that it requires 2 image buffers to run the entire cycle: A trigger is received and the image is built in Image Buffer 1. Another trigger arrives and image buffer 2 is used to build the next image, while the tools run on Image Buffer 1. When the tools complete, image buffer 1 is freed and waiting for the next trigger.



Encoder

While the trigger signal will indicate when to start building the *entire image*, the encoder signal will indicate when to grab *each line* in that image. The encoder signal comes from either a hardware encoder (and the encoder signal is feed into In-Sight via the Encoder Input Signals A and B), or from a software encoder (and the encoder signal is time based and generated internally by software). Because of the need to know how quickly to build each line of the image, several new acquisition parameters have been added to the In-Sight software for the In-Sight 5604 system. Both encoder types and their relevant parameters are discussed below.

Hardware Encoder: The hardware encoder monitors for pulses on the Encoder A and/or Encoder B input lines. These lines are connected to the encoder device on a motion control system like a conveyer belt. As the encoder device moves with the conveyer belt, these output pulses are sent to In-Sight. In-Sight uses these pulses to build the image based on the conveyer belt movement therefore the movement of the belt is synchronized with the building of the image in the In-Sight system. As the speed of the conveyer belt increases, each pixel line is captured at the same, increasing rate. The same amount of pulses will be received if the conveyer belt moves 6 inches at 100ft per second, or 6 inches at 1000 ft per second. This is a benefit of the hardware encoder, during ramp up or ramp down of the belt, the same image, with the same size pixel line dimension will be acquired, regardless of speed.

The In-Sight 5604 input encoder signals have the following specifications:

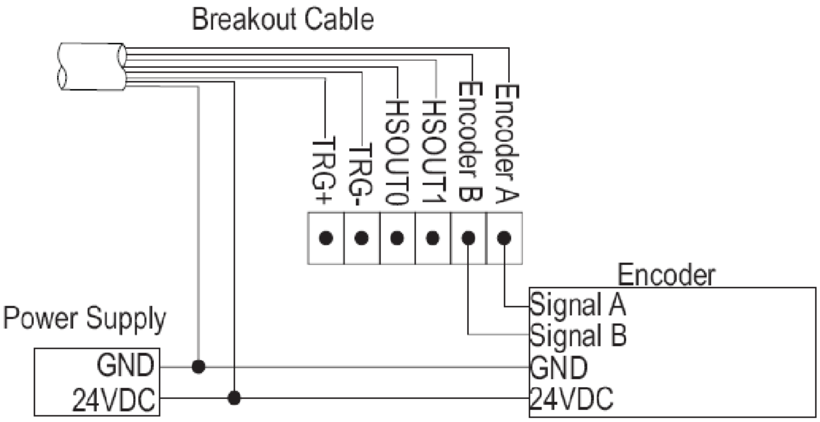
- Voltage at encoder inputs referenced to 24VDC- (ground))
- On state voltage is: 20-28V
- Off state is 0-3V (9.6V nominal threshold)
- Current on is 84 to 118uA
- Current off is < 11uA
- Input resistance is ~233K Ohms
- Max input encoder frequency: 99.2KHz with a 50/50 duty cycle
- Encoder inputs should be 50% duty cycle square waves

The In-Sight 5604 has a valid edge de-bounce time of 5us minimum and a 40ns edge detect time. To determine the max rate for a specific duty cycle, use the following equations:

50/50 duty cycle = 1/(5uS (for 50) + 40ns + 5uS (for 50) + 40nS) = 99.2KHz

40/60 duty cycle = 1/(5uS (for 40) + 40nS + 7.5uS (for 60) + 40nS) = 79.491KHz

The encoder signals are connected to In-Sight via the breakout cable (flying lead power/IO cable) as shown below:



Encoders come in a variety of different voltages and output signals. The following types will work with the In-Sight 5604 encoder inputs:

- Totem Pole Encoders: Source/sink (In-Sight needs source for on state voltage – minimum 20V)
- Push-Pull Encoders: Source/sink (In-Sight needs source for on state voltage – minimum 20V)
- Line Driver Encoders: As long as it has enough voltage behind it for “on” state voltage (minimum is 20 VDC), line driver signals are compatible.

The following types of encoders will work, but *are not desired* (because of potential noise issues):

- Open collector encoders: To use this type, an external pull up resister to voltage is needed. The voltage must be at least 20 VDC at the encoder input for the signal to be recognized as “on”. However, the resistor value choices and potential for noise makes these undesirable.

The following types of encoders are *not supported* for the In-Sight 5604 system:

- Differential signal encoders

Software Encoder: The software encoder parameter in the In-Sight 5604 system is time based. No external signals need to be connected to the In-Sight 5604 system because it uses an internal clock to provide this signal. The time base is set in software to the desired number of microseconds, and then a new line is acquired based on that time base, regardless of the physical motion of the machinery.

The software encoder is useful when the speed of the conveyer belt is consistent since no physical encoders must be installed and integrated. If it is a consistent speed, you can calculate how many microseconds the conveyer belt moves per 1 pixel line distance. However, if the conveyer belt speeds up or slows down, the image will compress or expand because the time to acquire each line remains constant and is independent of belt speed. The In-Sight line scan will accept changes to the speed parameter, but only at the beginning of each new image (not each new line) acquisition.

IO Module

The In-Sight 5604 supports the CIO-MICRO IO Module. The CIO-MICRO supplies 8 additional inputs /outputs and serial connection over Ethernet for the 5604. Selecting the CIO-MICRO IO Module is done in ISE. Once you are connected to the IO module, you can access the 8 inputs/outputs using the Read/WriteDiscrete functions and serial using the Read/WriteSerial functions.

The CIO-MICRO does not provide hardware encoder input pins**.** The hardware encoder signals are only supported by using the flying lead power/IO cable. The flying lead power/IO cable will supply access to power input, access to the 2 high speed outputs and the two input encoder signals. The CIO-MICRO will supply access to serial and the remaining 8 IO points over Ethernet (LAN port on CIO-MICRO)

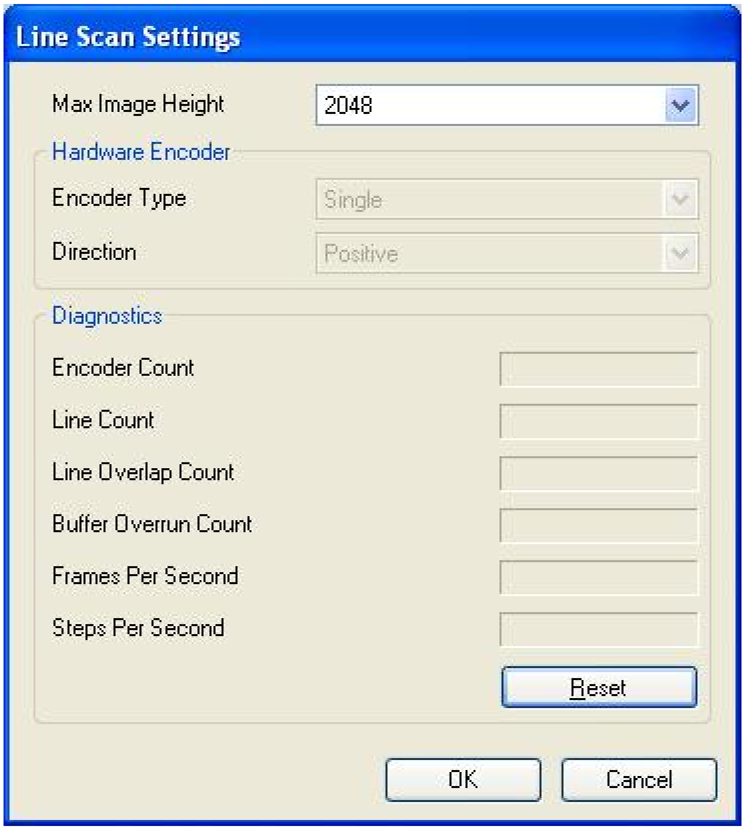
If you are using the software encoder, you can use the In-Sight M8 to DB15 power/IO cable to connect to the CIO-MICRO. This cable will supply the 5604 with power, trigger and high speed output pin connections directly on the CIO-MICRO. The remaining IO is accessed over Ethernet. (LAN port on CIO-MICRO)

Software Settings in A0

The following parameters have been added to the AcquireImage function cell in spreadsheet view and to the Acquisition Setup Step in EasyBuilder® view to support line scan acquisition.

Exposure: This is the exposure time for each individual line. The exposure for In-Sight 5604 system is set in microseconds. Due to the highly sensitive nature of the In-Sight 5604 system's imager, the exposure can be set very low (1.3 microseconds minimum).

Number of Lines: Since line scan builds the image one line at a time, this parameter specifies the total number of lines that is equal to one complete image. Once the total number of lines is acquired, the full image is complete and the system is ready to accept the next trigger signal. The maximum number of lines that the In-Sight 5604 system can build is 8192. To conserve memory space, you have the option of changing the max number of lines to 8192 (4 image buffers) to 2048 (6 image buffers). To do this, select the Encoder Setup button in A0 or the Sensor->Line Scan settings selection from the main ISE menu bar. The Line Scan Settings dialog box will appear as seen in the below caption.



Change the Max Image Height parameter, and then reboot the camera. The Max Image Height will allow you to acquire as many lines as needed, up to the max value of 2048 or 8192.

Delay: This parameter adds a delay in the start of acquisition. There are two different behaviors based on the acquisition trigger selected:

- *Camera Trigger:* This parameter will delay a camera trigger by a set number of lines. This is useful when the target product you want to inspect is triggered but you only want to capture a portion of the product starting from the trigger. Since each line represents a distance traveled, the time to start the acquisition is based on the encoder values set. For example, if each line represents 0.1 millimeter of movement, and the target inspection is 10 millimeters after the start of the product, then the delay would be set to 100 lines so the acquisition will starts after 10 millimeters.
- *Continuous Trigger:* This parameter will provide a continuous trigger at a set frequency. This frequency is set in milliseconds and provides a consistently timed acquisition trigger. This parameter, when combined with the software encoder, enables the line scan system to be up and run without hardware encoder signals.

Line Scan

Line Trigger Type: The In-Sight 5604 system supports either a hardware or software encoder. Below is a description of each:

- The hardware encoder is an external signal from an encoder device.

- The software encoder is a time based encoder signal which is generated internally by the In-Sight 5604 system.

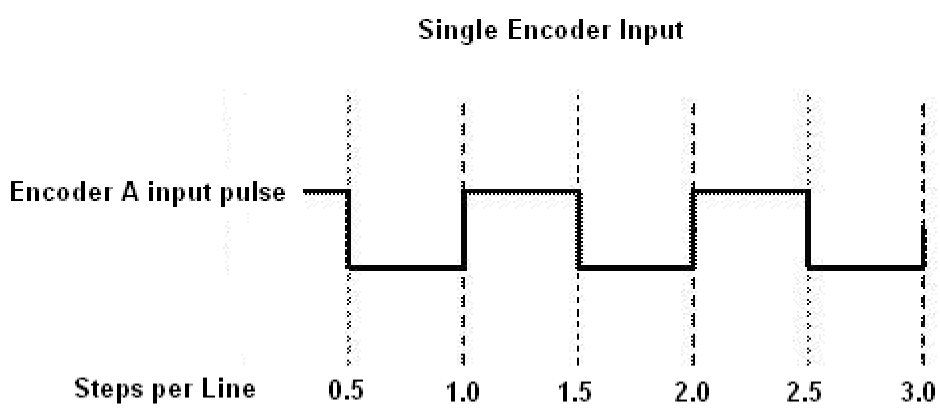
Line Period/Steps per Line: The parameter sets the timeline to acquire each line of the image. Steps per Line acquires lines based on number of encoder counts (pulses from the hardware encoder); whereas, the Line Period acquires lines based on time (microseconds) and is used by the software encoder. The In-Sight 5604 uses the Line Trigger Type parameter to determine whether Line Period or Steps per Line is the appropriate selection.

- If Software Encoder is selected under Line Trigger Type, then the Line Period is referenced in microseconds. This means every X microseconds, a new line is acquired. The calculation for the Line Period value is discussed in the "Acquiring an image" section of this document.
- If Hardware Encoder is selected under Line Trigger Type, then Steps per line is referenced as the number of steps (pulses) to count from the encoder input signals. This count is used to trigger a new line to be acquired. For example, a value of 10 means that for every 10 counts of the input encoder signal, a new line is acquired.

  The In-Sight 5604 supports both Single Encoder Input (using Encoder A only) and Quadrature Encoder Inputs (using both Encoder A and B).

  - For the Single Encoder input, each transition is interpreted in 0.5 increments for the steps per line parameter. For the Quadrature Encoder input, each transition is interpreted as 0.25 increments for the steps per line parameter.

    The In-Sight 5604 system interprets the input encoder signals according to the below diagram.

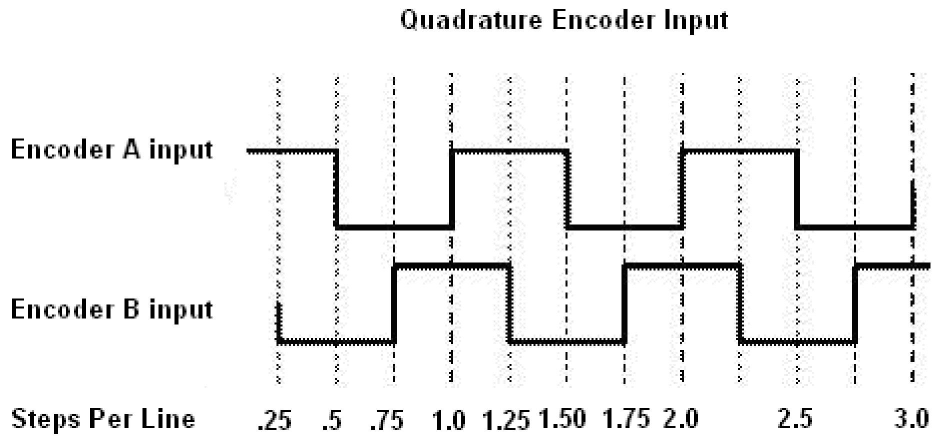


For a single encoder input (encoder signal on Encoder A input) each rising edge is counted. Meaning each pulse (low to high transition) is considered one full step. In-Sight will also allow additional encoder resolution by counting the falling edge (high to low) of the pulse. Steps per line are entered in as whole number values for rising edge only or .5 increments to count rising and falling edges.

Most encoders provide a Cycle per Revolution or Cycle per Shaft Turn as the encoder resolution value. This number is the number of counts per 1 revolution of the encoder disk or shaft. Each cycle by definition is only the rising edge of the pulse for single encoder inputs. It is recommended that you confirm with your encoder manufacturer the definition that they use for cycle.

– For quadrature encoder input, two signal inputs (encoder signal on both Encoder A and Encoder B inputs) are used. Each edge transition is now counted from both signals. The benefit for Quadrature Encoder signals is that you are counting more edge transitions per encoder rotation which gives you a higher degree of angular resolution. For example: If one encoder cycle(rising edge transition only) represented 1 inch of movement, you can only detect 1 inch of movement in 1 cycle. Quadrature encoder signals provide you 4x the signals per cycle. Now you can detect a fraction of movement (0.25 inches) in 1 cycle.

The In-Sight 5604 system interprets the input quadrature encoder signals according to the below diagram.



With quadrature encoder signals, most encoders will count every transition as a whole number. This is different how In-Sight 5604 interprets the quadrature input signal. The In-Sight 5604 counts Encoder A rising edge transitions as whole numbers, but other transitions are detected as fractions. In the above example, the total steps per line parameter is a value of 3 to In-Sight, but the encoder may give 12 as a cycle count (step per line x 4). Therefore In-Sight quadrature signals are _divided down_ by 4. For example: An encoder gives quadrature outputs capable of 8000 cycles per full revolution. If In-Sight acquires 1 line per revolution, this value in steps per line for In-Sight 5604 is 2000 (or 8000 cycles ÷ 4) because in-sight counts each transition as fractions. As a result, In-Sight will count each transition (1, 1.25,1.50,1.75,2, 2.25 etc) until the value of 2000 is reached. You receive the same resolution; it is interpreted differently in In-Sight.

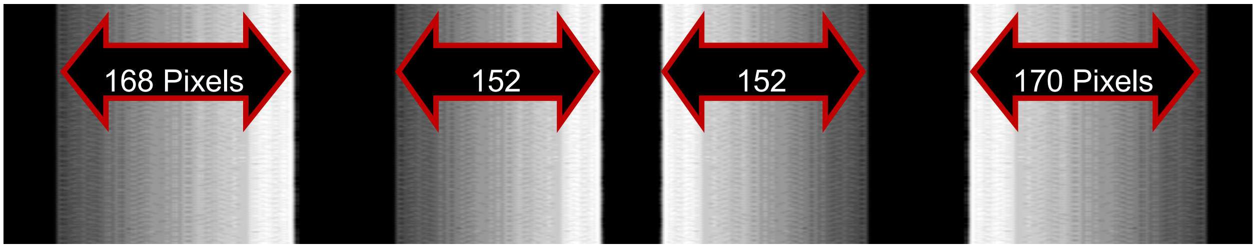
Line Clip Mode: Line Clip Mode is a new mode which is supported with the In-Sight 5604 system. This mode enables the user to decide what actions are taken when a new image trigger is received before the image has completed. Since line scan acquisition builds the image line by line, if a new trigger comes in before the image is complete, some part of the image is complete and could be used for inspections. Additional information can be found in Appendix A of this document.

Encoder Setup Button: This button opens the Line Scan Settings dialog box which allows you to select the type of encoder signals for In-Sight to expect. Single or quadrature encoder signals are supported. Additionally, a direction parameter is available for quadrature input signals. Quadrature signals provide direction of movement based on the sequence of the two input signals. Typically, the movement is positive; meaning Encoder Signal A is followed by Encoder Signal B. If reverse direction is detected, In-Sight will not acquire new lines until the movement is in the expected direction.

Software Functions specific to Line Scan

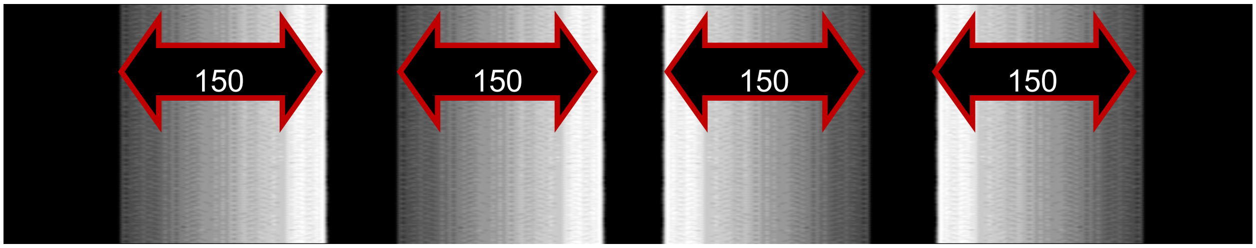
TrainLineScanDistortion and LineScanDistortion

Two functions have been created to remove horizontal distortion often seen in line scan images due to the lens and physical camera setup. For example: The following image should show equally sized white features in the field of view. But due to lens distortion, the features on the ends of the image appear stretched.



In order to remove this artifact, distortion correction is needed. Beginning in ISE 4.4, a calibration grid is available to correct this distortion on the IS5604. The grid is included with ISE in the Calibration Grids directory. Using the exact IS5604 physical setup, print out and place the grid in the field of view of the IS5604. No movement is necessary; however remember to set the encoder to software so the image can be built with no movement. Acquire a single image and use the *TrainLineScanDistortio*n function to train on the distortion of the physical setup. The *TrainLineScanDistortion* cell will be disabled so the distortion correction will remain when the grid is taken away. The region to apply the distortion correction is setup using the *LineScanDistortion* function. The *LineScanDistortion* function is then used as the input *image* to tools.

Below is the undistorted region from the original image:

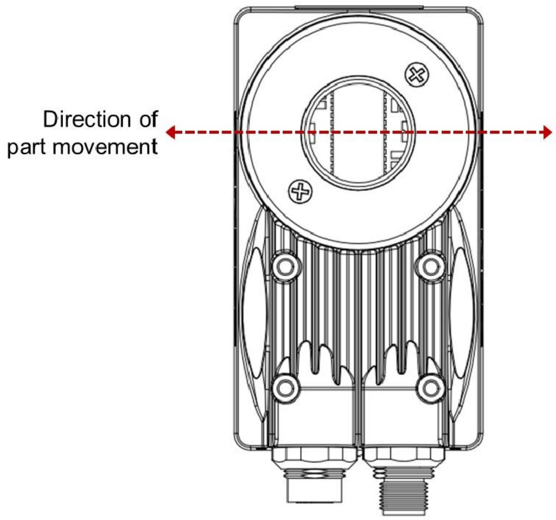


Setting up the In-Sight 5604 System

This final section covers initial set-up of the system, including acquiring a live image and image acquisition, followed by an overview of software diagnostics available and some troubleshooting tips.

Mounting the camera

When mounting the camera, note that the vertical axis of the 5604 line scan imager is aligned with the long axis of the camera body. This requires the 5604 to be mounted so that the long axis of the camera body is oriented 90-degrees relative to the direction of part movement.



Live Mode

In live mode, the 5604 will generate its own camera trigger to start the image acquisition process and uses the encoder settings in A0. If the encoder is set to Hardware, movement is necessary to complete each acquisition because the 5604 is expecting encoder signals from the encoder A and B inputs. If Software encoder is set, movement is not necessary. Keep in mind, if there is no movement, the same line will be repeated in the image. Often this is enough to focus the camera.

The acquisition trigger for live mode is not a consistent frequency trigger and does not rely on camera trigger, therefore if motion is introduced while in live mode, you will notice the image scrolling. This is expected.

Acquiring an image

Since the In-Sight 5604 system supports two different encoder options, this section will separately illustrate the calculations used to optimize acquisition using each of these options.

Software Encoder Example: Determine the correct Line Period, # of lines and exposure.

> On an assembly line, the speed of the conveyer belt is a consistent 5000mm/sec. Once the conveyer belt ramps up to the set speed, a product is dropped on the belt and travels to the vision system inspection area. The conveyer belt width is 200mm wide and the In-Sight 5604 vision system has been setup on the line to capture full width of the conveyer belt. The In-Sight 5604 is triggered based off of a photoelectric sensor (or "photo eye"). The entire product is 600mm and needs to be acquired for the inspection. We need to determine how to setup the encoder parameters and exposure in order to get as close to the 1:1 pixel ratio for this application.
>
> The following information is provided:

- Speed of line: 5000 mm/sec
- Line Trigger Type: Software Encoder (good for consistent speeds)
- Width: 200mm
- Length of product: 600mm

Determine the following parameters to enter in A0 to complete the set-up:

- Line Period
- # of lines
- Max Exposure

Step 1: Determine the Line Period

A) Determine resolution of image:

Resolution of image in mm/pixel = Width of object in mm ÷ Width of sensor in pixels

Resolution = 200mm ÷ 1024

Resolution = .195 mm per pixel. Your pixel width is .195 mm; next we need to get to a similar pixel height.

In order to maintain square pixels, we need to set the encoder up so that we capture the movement of the object and set the time per line equivalent to the pixel width.

B) Determine Line Rate

To determine the Line Rate (lines per second) for this setup, divide the velocity of the line by the size of the desired pixel. The mm unit cancels out to leave only pixels / second.

Line Rate = Speed of Line ÷ Pixel size or line size

Line Rate = 5000 mm/sec ÷ .195 mm/pixel

Line Rate = 25641 lines / second

This is how fast each line is moving past the In-Sight 5604. This line rate is well below the max limit of 44,000 lines per second line rate of the In-Sight 5604 system.

C) Determine Line Period

We need to know, how many seconds do we have per line. This will be our Line Period. To do this, invert the Line rate:

Line Period = 1 ÷ Line Rate

Line Period = 1÷ 25641

Line Period = 39us

Thus, 39 microseconds is the approximate value In-Sight 5604 system needs to maintain the square pixels for the setup.

Step 2: Determine Number of Lines

Using the above information, you can now determine the size of the image you will be acquiring. Since the In-Sight 5604 system has a 1:8 image ratio, the length of the image, assuming square pixels, will the 8x the width. For this example, assume the total number of lines is set to 8192.

Total Size of image = Number of lines × line size (or pixel length)

Total Size of image = 8192 × .195 mm

Total Size of image = 1597.44 mm

For this example, we need to acquire only 600mm.

Product Size = Number of lines × line size (pixel length)

600mm = Number of lines ×.195 mm

Number of lines = 3076.9 or 3077

To acquire the full product length, we will need at least 3077 lines. We can pad (add lines) the total number of lines to account for product movement relative to the trigger as necessary.

Step 3: Determine Exposure Limits

The exposure setting is variable depending on your lighting conditions. However, the exposure does have restrictions. In order to acquire a line every 39 micro seconds, the CCD must be exposed for less than this amount. If the exposure is to long, this will a conflict with the set Line Period and poor image will result.

Exposure Rule:

Exposure Max < Line Period – Line Integration Time

The line integration time for the IS5604 is approximately 22.2 microseconds per line. Following the max exposure rule, the maximum exposure time is:

Exposure max < 39 micro seconds – 22 micro seconds

Exposure max < 17 micro seconds

You can set the exposure as high as 17 microseconds (if necessary) for the line speed in this example.

Step 4: Extra Setup Information:

Determine Total Acquisition Time

Total Time for desired image size = Line Period x Number of Lines

Total Time = 39 us x 3077

Total Time =120 ms

If you know the time, you can determine the frames per second for you application.

Frames per second = 1 ÷ Total Time (convert to seconds)

Frames per second = 1÷ .120s

Frames per second = 8.3 fps

Keep in mind, if the length of the image is too large, or is not needed for the inspection; decrease the total number of lines. This will also decrease the total time to acquire the image.

For example, if the product is only 200mm:

Total Size of image = Number of lines × line size (or pixel length)

200mm = Number of lines x .195 mm

Number of lines = 1025.6 or 1026 lines

Total time = Line Period x Number of Lines

Total time = 39 us x 1026

Total time = 40 ms

Frames per second = 1 ÷ Total Time (convert to seconds)

Frames per second = 1 ÷.040014

Frames per second: 24.9 fps

Hardware Encoder Example 1: Determine the correct Steps per Line, # of lines and exposure max

A product label on each product on an assembly line is to be inspected. The conveyer belt width is 200mm wide and the In-Sight 5604 vision system has been setup on the line to capture full width of the conveyer belt. The In-Sight 5604 is triggered based off of a photoelectric sensor (or "photo eye"). The entire product is 500 mm, and needs to be acquired for the inspection. It is important to inspect every product regardless if the line is ramping up to full speed or slowing down to allow other stations to catch up in the assembly process. We need to determine how to setup the encoder parameters and exposure in order to get as close to the 1:1 pixel ratio for this application. The max speed of the line is 150 in/sec. The encoder used is 10000 counts (quadrature) per revolution. Each revolution is equivalent to 12 inches.

The following information is given:

- Speed of line: 150 in/sec (3810mm/sec)
- Line Trigger Type: Hardware Encoder (acquisition is in synch with speed of the line)
- Width: 200mm
- Length of product: 500mm
- Quadrature Encoder
- 10000 counts per 12 inches

Determine the following parameters to enter in A0 to complete the set-up:

- Steps Per Line
- # of lines
- Max Exposure

Step 1: Determine steps per line

A) Determine the pixel width for the line scan setup.

Resolution of image in mm/pixel = Width of object in mm ÷ Width of sensor in pixels

Resolution = 200mm ÷ 1024

Resolution = .195 mm per pixel.

In order to achieve square pixels, we need to set the encoder up so that we capture the movement of the object and set the steps per line equivalent to the pixel length (pixel width = pixel height for desired square pixels).

B) Determine encoder resolution

The encoder pulse per revolution is 10000 pulses per revolution. This is equivalent to machine movement which is 12 inches (304.8mm).

Encoder Resolution = 1 ÷ 10000 pulse per 304.8mm

Encoder Resolution = 1 ÷ 32.8pulse per mm

Encoder Resolution = .0305mm per pulse

The assembly line travels .0305mm for each detected edge transition (pulse)

C) Determine steps per line using target pixel height (line height) from Step 1A:

Steps per Line = Pixel height ÷ (Encoder Resolution x 4 pulses per step)*

*Each encoder pulse is equal to 4 edge transitions for In-Sight

Steps per Line = .195mm per line ÷ (.0305mm per pulse x 4 pulses per step)

Steps per Line = 1.59

D) Determine actual Steps per Line

In-Sight supports quarter increment steps, so the steps per line from step 1C is actually rounded to the nearest quarter increment. Entering 1.59 in A0 Steps per Line parameter will actually be 1.5 Steps per Line.

Step 2: Determine number of lines

A) Determine actual pixel height (line height)

Since the actual steps per line parameter is 1.5 (and not 1.59), this adjusts the actual line height. It is rare that the pixel width and height are exactly 1:1. We need to get as close as possible to the ratio.

Actual line height = Steps per Line x Encoder Resolution x 4 pulses per step

Actual line height = 1.5 steps per line x .0305mm per pulse x 4 pulses per step

Actual line height = .183 mm

B) Determine number of lines

Number of Lines = Product Length ÷ Line Height

Number of Lines = 500mm ÷ .183mm

Number of Lines = 2732.24 lines or 2733 lines

The full product can be acquired in 2733 lines. Pad the product length with extra lines as necessary to take care of positional uncertainty in reference to the trigger.

Step 3: Determine Maximum exposure

A) Determine Line Rate

Line Rate = Line Speed ÷Actual Line height

Line Rate = 3810 mm per sec ÷.183 mm per line

Line Rate = 20819 lines per sec

B) Determine Line Period

Line Period = 1 ÷Line Rate

Line Period = 48 us per line

C) Maximum Exposure

Exposure Value < Line Period – Line Integration Time

Exposure Value max < 48us – 22 us

Exposure Value < 26us

Step 4: Extra Setup Information:

Determine Total Acquisition Time

Total Time for desired image size = Line Period x Number of Lines

Total Time = 48us x 2733

Total Time =131.18ms

If you know the time, you can determine the frames per second for you application.

Frames per second = 1 ÷ Total Time (convert to seconds)

Frames per second = 1÷ .1312s

Frames per second = 7.6fps

Keep in mind, if the length of the image is too large, or is not needed for the inspection; decrease the total number of lines. This will also decrease the total time to acquire the image.

Hardware Encoder Example 2: Determine the correct Steps per Line, # of lines and exposure max

A product label on each product on an assembly line is to be inspected. The conveyer belt width is 200mm wide and the In-Sight 5604 vision system has been setup on the line to capture full width of the conveyer belt. The In-Sight 5604 is triggered based off of a photoelectric sensor (or "photo eye"). The entire product is 500 mm, and needs to be acquired for the inspection. It is important to inspect every product regardless if the line is ramping up to full speed or slowing down to allow other stations to catch up in the assembly process. We need to determine how to setup the encoder parameters and exposure in order to get as close to the 1:1 pixel ratio for this application. The max speed of the line is 150 in/sec. The encoder used is 4000 counts per revolution. Each revolution is equivalent to 12 inches.

The following information is given:

- Speed of line: 150 in/sec (3810 mm/sec)
- Line Trigger Type: Hardware Encoder (acquisition is in synch with speed of the line)

- Width: 200mm
- Length of product: 500mm
- Single Encoder
- 4000 counts per 12 inches

Determine the following parameters to enter in A0 to complete the set-up:

- Steps Per Line
- # of lines
- Max Exposure

Step 1: Determine steps per line

A) Determine the pixel width for the line scan setup.

Resolution of image in mm/pixel = Width of object in mm ÷ Width of sensor in pixels

Resolution = 200mm ÷ 1024

Resolution = .195 mm per pixel.

In order to achieve square pixels, we need to set the encoder up so that we capture the movement of the object and set the steps per line equivalent to the pixel length (pixel width = pixel height for desired square pixels).

B) Determine encoder resolution

The encoder pulse per revolution is 4000 pulses per revolution. This is equivalent to machine movement which is 12 inches (304.8mm). Need the encoder resolution which is in mm per encoder pulse.

Encoder Resolution = 1 ÷ 4000 pulse per 304.8mm

Encoder Resolution = 1 ÷ 13.12 pulse per mm

Encoder Resolution = .0762mm per pulse

The assembly line travels .0762mm for each detected edge transition (pulse)

C) Determine steps per line using target pixel height (line height) from Step 1A:

Steps per Line = Pixel height ÷ (Encoder Resolution x 2 pulses per step)*

*Each encoder pulse is equal to 2 edge transitions for In-Sight

Steps per Line = .195 mm per line ÷ (.0762mm per pulse x 2)

Steps per Line = 1.27 steps per line

D) Determine actual Steps per Line

In-Sight supports 1/2 increment steps in Single Encoder Mode, so the steps per line from step 1C is actually rounded to the nearest 1/2 increment. Entering 1.27 in A0 Steps per Line parameter will actually be 1.5 Steps per Line.

Step 2: Determine number of lines

A) Determine actual pixel height (line height)

Since the actual steps per line parameter is 1.5 (and not 1.27), this adjusts the actual line height. It is rare that the pixel width and height are exactly 1:1. We need to get as close as possible to the ratio.

Actual line height = Steps per Line x Encoder Resolution

Actual line height = 1.5 steps per line x .0762 mm per pulse x 2 pulses per step

Actual line height = .2286mm

B) Determine number of lines

Number of Lines = Product Length ÷ Line Height

Number of Lines = 500mm ÷ .2286mm

Number of Lines = 2187.22 or 2188 lines

The full product can be acquired in 2188 lines. Pad the product length with extra lines as necessary to take care of positional uncertainty in reference to the trigger.

Step 3: Determine Maximum exposure

A) Determine Line Rate

Line Rate = Line Speed ÷Actual Line height

Line Rate = 3810 mm per sec ÷.2286 mm

Line Rate = 16666 lines per sec

B) Determine Line Period

Line Period = 1 ÷Line Rate

Line Period = 60 us per line

C) Maximum Exposure

Exposure Value < Line Period – Line Integration Time

Exposure Value max < 60us – 22 us

Exposure Value < 38us

Step 4: Extra Setup Information:

Determine Total Acquisition Time

Total Time for desired image size = Line Period x Number of Lines

Total Time = 60us x 2188

Total Time =131.28

If you know the time, you can determine the frames per second for you application.

Frames per second = 1 ÷ Total Time (convert to seconds)

Frames per second = 1÷ .13128s

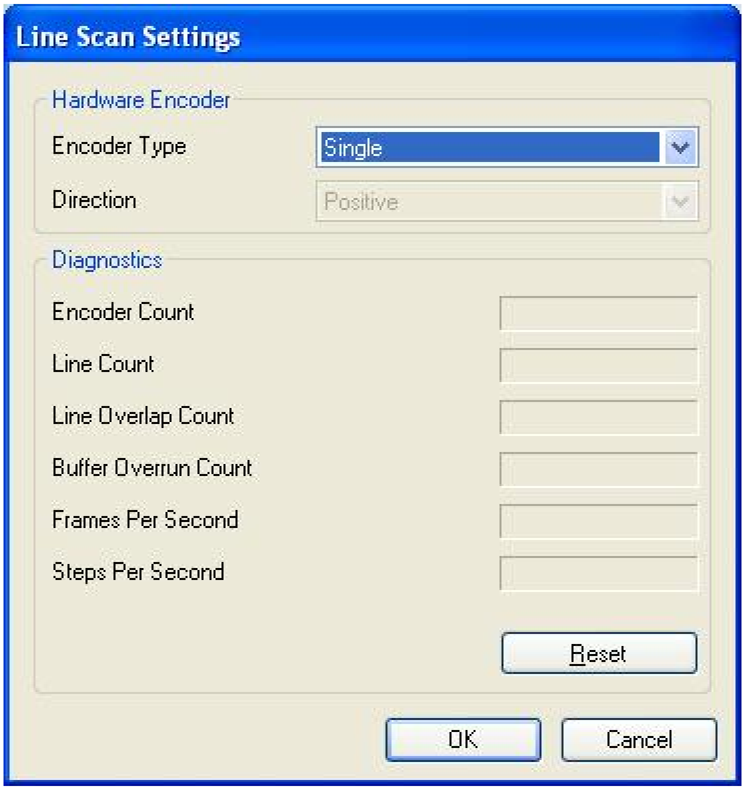
Frames per second = 7.6fps

Keep in mind, if the length of the image is too large, or is not needed for the inspection; decrease the total number of lines. This will also decrease the total time to acquire the image.

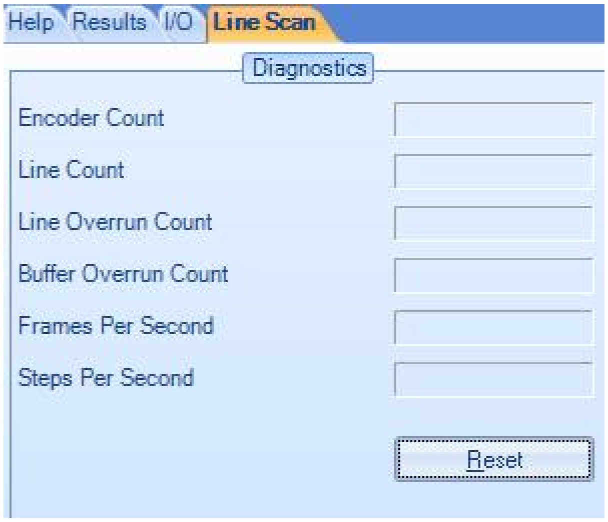
Diagnostics:

The In-Sight 5604 system has diagnostic information which is helpful during setup and runtime monitoring of the line scan vision system. The diagnostics are accessed via the spreadsheet functions or by dialog boxes in either EasyBuilder or spreadsheet view.

To access the diagnostic dialog box in the spreadsheet view, select Sensor from the ISE Main Menu bar, and then select Line Scan Settings. The Line Scan Setting dialog box will appear as shown in the caption below. This dialog box can be accesses on either online or offline mode.



To access the Diagnostics in EasyBuilder view, select Line Scan from the Tool Palette pane as shown in the below caption:



A description of each diagnostic is provided below:

- *Encoder Count:* Returns the number of steps for the current image. The spreadsheet function to access this data is GetLineScanAcqEncoderSteps(Event).
- *Line Count:* Returns the number of lines acquired for the current image. The spreadsheet function to access this data is GetLineScanAcqLineCount(Event)
- *Line Overrun Count:* Error flag which is set when the line rate is not set properly. Typically this is when the exposure is set greater than the Line Period - Integration Time. The next line is requested before the previous line is complete. The spreadsheet function to access this data is GetLineScanLineOverrunCount():
- *Buffer Overrun Count:* In-Sight 5604 has 3 buffers available in memory. This error flag is set when the buffers are full. Typically, this error is seen when the acquisition is to fast for the inspection to complete running. The spreadsheet function to access this data is GetImageBufferOverrunCount().
- *Frames per Second:* The frames per second are calculated based on the set Line Rate.
- *Steps Per Second:* Returns the number of steps since the last online/offline or after the Reset button is pressed or the LineScanStatResult(Event) is called. This value rolls over after about 4 billion steps.
- *Reset:* This button resets any cumulative line scan statistics. This is automatically called during an online or offline event. The spreadsheet function to access it is LineScanStatReset(Event).

Troubleshooting:

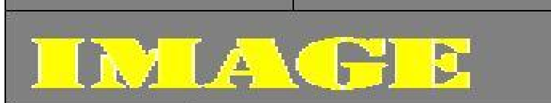
You may encounter images you did not expect. Below is a summary of what you may see and how to troubleshoot the problem.

Description **Acquired Image**

Correct Image

Scrolling/Moving part in field of view

Stretched



Compressed

Repeated part in single field of view

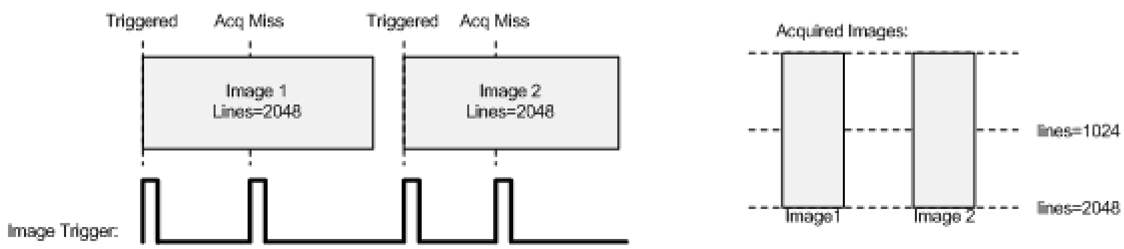
Truncated

- *Scrolling:* Image scrolling is a result of an acquisition trigger problem. The trigger is received at inconsistent times so the start of the image frame is varied. To stop image scrolling, make sure the image trigger is occurring at the correct expected time.
- *Stretched:* A stretched image is a result of too many lines in the image. This is caused by the line rate being to fast for the movement of the conveyer belt. Adjust the line rate (decrease Line Period or Steps per line depending on encoder type) to compensate.
- *Compressed:* A compressed image is a result of too few lines in the image. This is caused by the line rate being to slow for the movement of the conveyer belt. Adjust the line rate (increase Line Period or Steps per line depending on the encoder type) to compensate. The diagnostic Line Overrun Count will fire if you are missing lines.
- *Repeated part:* Repeated part in a single image is a result of an acquisition trigger is not being received when expected or building the image with too many lines. Adjust the acquisition trigger or the total number of lines to acquire.
- *Truncated:* A truncated part is a result of the number of lines for the total image is too small or an unexpected acquisition trigger was received. Adjust the acquisition trigger or the number of total lines in the image to compensate. A truncated image could be seen when Line Clip mode is set to Reduced Line Height. If this is the case, the truncated image is expected.

Appendix A: Line Clip Mode

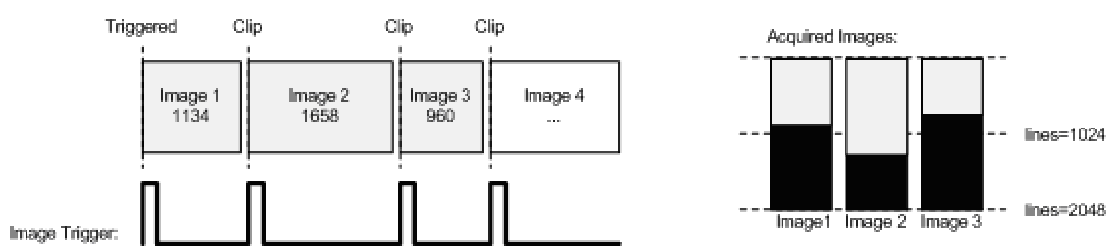
Line Clip Mode is a new mode which is supported with the In-Sight 5604 system. This mode enables the user to decide what actions are taken when a new image trigger is received before the image has completed. Since line scan builds the image line by line, if a new trigger comes in, some part of the image is complete and could be used for inspections. Line Clip Mode is often used in high speed applications which the trigger frequency does not allow the system time to re-arm between acquisitions. This occurs in a missed acquisition. However, with Line Clip Mode, each trigger is serviced even if the trigger occurs during the re-arm time. The new line clip mode supports 3 options:

- *No Clipping:* An image trigger is received before the total number of lines has been acquired. The image trigger is ignored, and a “Missed Acquisition” event is generated. This is the current functionality with In-Sight area scan cameras.



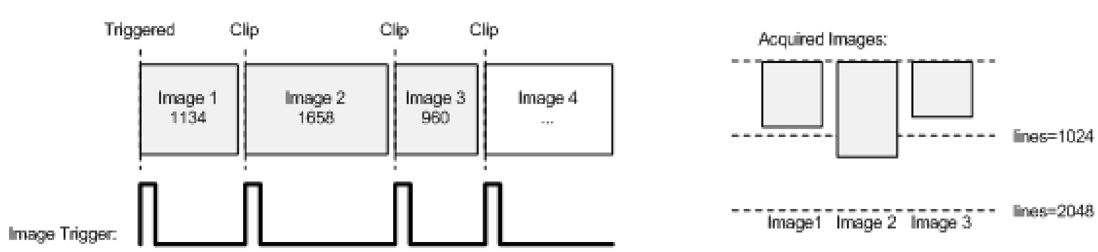
A0 Parameter “Number Of Lines” set to maximum (2048)

- *Fill Black:* An image trigger is received before the total number of lines has been acquired. The remaining lines in the current image are filled with black, and a new image is immediately started. No “Missed Acquisition” event is generated. The resulting image is still the 2048 lines.



A0 Parameter “Number Of Lines” set to maximum (2048)

- *Reduce Line Height:* The height of the current image is reduced to the number currently acquired and a new image is immediately started. No “Missed Acquisition” event is generated. This mode is useful when inspecting products of varying sizes.



A0 Parameter “Number Of Lines” set to maximum (2048)

Appendix B: Tips for High Speed Application Setup

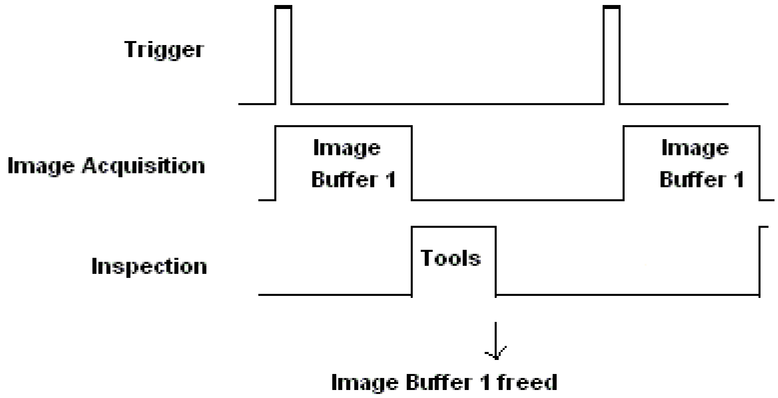
High speed applications push the vision system to the maximum speeds it can handle. This speed narrows down to two items: Speed of Vision System and trigger frequency. Below are points to be aware of when setting up the IS5604 vision application for high speed.

Important Notes on IS5604 speed:

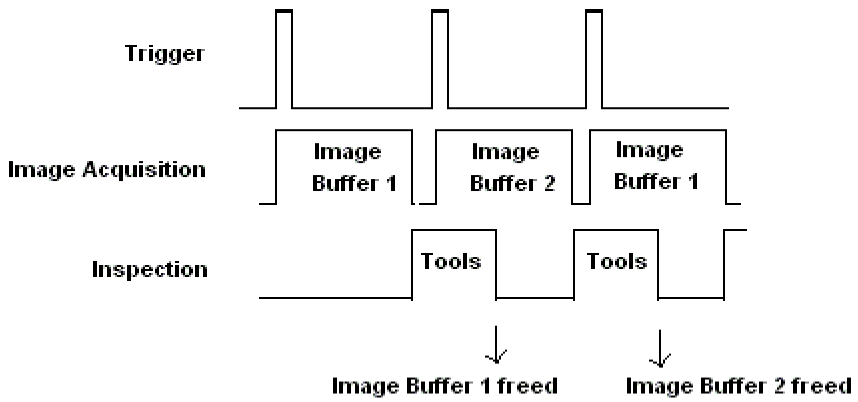
- The minimum exposure value for the 5604 is 1.33us. This puts the max line period the system can handle at approximately 23us. The same rules apply with line scan as they do with area scan, the faster (smaller) the exposure, the more intense light you will need.
- The 5604 is capable of 21.6 us integration time + exposure time. Therefore the maximum Line Period the 5604 can handle is approximately 23us. (Line Period > Integration time + Exposure time).
- Re-arm time varies depending on the Line Period, however, the worse case re-arm is 1 ms. This could equate to about 10 lines from last line acquired to next trigger.
- Choose the number of lines needed for inspection, not necessarily to view the entire product. Since line scan builds the image line by line, you can end the acquisition at any line. For example: Total product length is 400mm and the number of lines to acquire the entire product is 2000 lines. All of your inspection regions lie between 10mm – 250mm. Build the image to acquire only 300mm as opposed to 400mm. Less lines, less time spent on acquisition therefore increasing your frames per second.
- Missed Acquisitions will occur if there are no buffers available OR if a trigger is received before the re-arm time is complete (if not using Line Clip Mode).
- Trigger timing variations or jitter will occur on every system. This is more of an issue with line scan because if each line is .3mm, a slight delay or speed up on the assembly line due to vibrations, belt stretching, etc can cause the trigger to be tripped early or later than the ideal time. It is best to pad your total lines to accommodate this. +/- 2-3 lines is sufficient for more cases. Using Clip Mode will ensure a trigger is received every time.

Trigger Frequency:

Single Buffer Mode: If your trigger frequency is less than Acquisition time + Re-Arm Time + Total Tool Time, then you can exist in a single buffer mode.

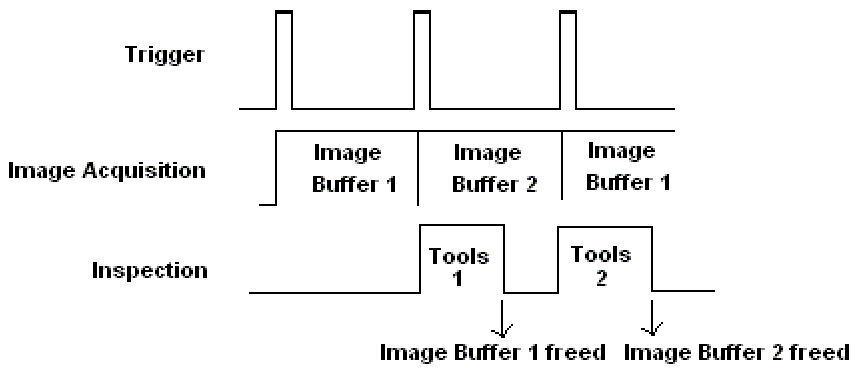


Overlapped Mode: If your trigger frequency is faster than the time needed, then you will be in a buffer mode. This means that your trigger frequency is faster than Acquisition time + Re-arm time, but less than Acquisition time + Re-Arm Time + Tool Time.



Line Clip Mode: If your trigger frequency is faster than Acquisition Time + Re-arm time, the system will return Missed Acquisition errors. Assuming there are buffers available, you have the following options to handle this error:

- Decrease your trigger frequency to allow for Acquisition time + Re-Arm time. Assuming your total tool time is less than Acquisition time.
- Decrease the number of lines needed for the image. This will decrease acquisition time and allow for re-arm time before the next trigger. Assuming your total tool time is less than acquisition time.
- Use Line Clip Mode. Line Clip mode will guarantee incoming triggers will be serviced even if they come in before Acquisition time or re-arm time. This assumes you have enough buffers to handle the image requests and your total tool time is less than acquisition time.



Appendix C: Accessories for the In-Sight 5604 System

The following lighting and lenses have been tested with the In-Sight 5604 vision system and are recommended with its use. The lens and lighting used for the In-Sight 5604 vision system is not limited to those listed in this appendix. The lens and lighting list is provided as a recommendation not a necessity.

Lighting

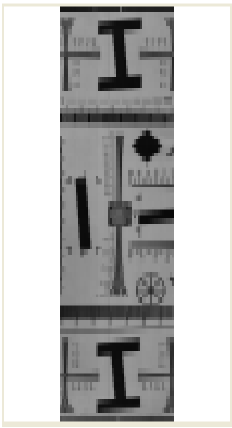
Three new line lights have also been qualified and are recommended for use with the In-Sight line scan vision system.

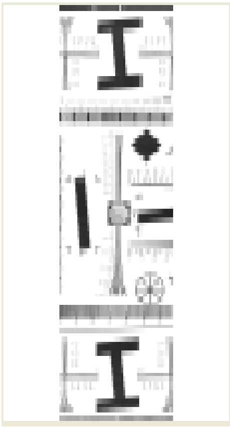
ICWL-200: High Intensity White LED Line Light with converging light lens. Light length = 200mm.

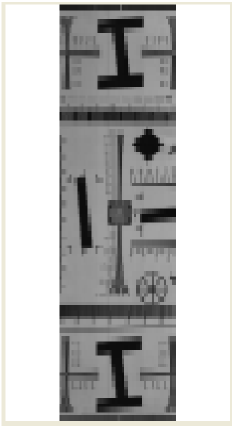
ICWL-200-HK-ST: Super Intensity White LED Line Light with converging light lens. Light length = 200mm.

IPWL-60025: High Intensity White Led Line Light with converging light lens. Light length = 425 mm (16.8 inches).

The In-Sight 5604 was used to capture an image of a target object using each light. Each image is displayed below to provide a comparison of each light intensity with identical acquisition setup on the In-Sight 5604 (exposure = 3 microseconds).







ICWL-200 ICWL-200-HK-STK IPWL-60025

The part numbers for the new line lights are listed below.

Part Number	Description
ICWL-200	High Intensity White LED Line Light, 200mm length
ICWL-200-HK-STK	Super Intensity White LED Line Light, 200mm length
IPWL-60052	High Intensity White LED Line Light, 425 mm (16.8 inches) length

Lenses

The part numbers for lenses tested with and recommended for the In-Sight 5604 vision system:

Part Number	Description
LFC-CF12.2	Fujinon 1” format, 12.5 mm lens
LFC-CF16	Fujinon 1” format, 16 mm lens
LFC-CF25	Fujinon 1” format, 25 mm lens
LFC-CF35	Fujinon 1” format, 35 mm lens
LFC-CF75	Fujinon 1” format, 75 mm lens
LEC-58000	Edmund Optics 2/3” TECHSPEC 8.5 mm lens
LEC-58001	Edmund Optics 2/3” TECHSPEC 12 mm lens
LEC-59870	Edmund Optics 2/3” TECHSPEC 16 mm lens
LEC-59871	Edmund Optics 2/3” TECHSPEC 25 mm lens
LEC-59872	Edmund Optics 2/3” TECHSPEC 35 mm lens

Revision History

23 March 2009 – Initial publication

19 April 2010 – Updated document:

# of lines increased to 8192

Added distortion correction, IO module, image buffering, re-arm topics

Added examples on lens selection

Corrected/reformatted acquisition examples

Added high speed tips appendix

Added Table of Contents

Corrected diagnostic descriptions

Removed focus topic, added live mode topic

12 August 2010 – Corrected document

Corrected max input frequency: 200KHz to 99.2KHz assuming a 50/50 duty cycle

10 October 2014 – Updated document

Added note on proper mounting orientation