# MATRIX SERIES

## READING METHODS

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Matrix Series Reading Methods

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# CONTENTS

# 1 GENERAL DESCRIPTION

This manual provides a comprehensive description of the behavior of the Matrix family readers according to their operating mode programming and in relation to the type of application in which it is used.

It’s really important to understand how these operating modes work to better set the 2D reader depending on the specific application. Chapters 2 and 3 explain how to select the best parameter settings for your Matrix reader.

Furthermore, Chapter 4 explains how to improve the reading performance of your Matrix reader on difficult and damaged symbols, or when a large quantity of similar symbols must be processed.

Descriptions of parameter settings refer to selection through the VisiSet™ configuration program, although these parameters can also be set using other valid configuration methods (i.e. Host Mode Programming or Host Control Mode).

## 1.1 OPERATING MODES

Three different operating modes can be set according to application requirements:

- Continuous
- One Shot
- Phase Mode

A detailed description of all operating modes is provided in the following Paragraph.

Moreover, theoretical considerations about important operating mode features and related parameters are provided in Paragraphs 1.2 and 1.3.

## Continuous

Matrix reader repetitively acquires images as fast as possible.
The maximum frame rate mainly depends on the decoding time and on the exposure time. The theoretical limit is given by the maximum image sensor frame rate as described in Paragraph 2.2.

### Code Filter Depth

It is used to avoid multiple reads of the same code. The selected value (other than zero) defines the number of codes to memorize in a FIFO list.
When a code is read, it is compared to the list. If the list contains a code identical to the current code being read, the current code is discarded. If not, the current code is accepted and added to the list in either the last available position or by replacing the oldest code in the list.

### Good Read Threshold

Sets an N number of acquisitions with the same code in order to assure the code transmission.

### No Read Threshold

Sets an N number of acquisitions without the same code in order to assure the code transmission.

Example of the code acquisition when using the ***Code Filter Depth*** parameter:

***Code Filter Depth:*** *3*

| List | Code Read | Accepted |
|---|---|---|
| xxx (no code in list) | A | Yes |
| Axx | B | Yes |
| Bax | B | No |
| Bax | C | Yes |
| CBA | D | Yes |
| DCB | A | Yes |
| ADC | A | No |

**NOTE**

*To avoid several No Read strings trasmission when reading the same code, it is suggested to disable the **No Read Message** parameter.*

## One Shot

Matrix acquires a single image depending on the selected value for ***Acquisition Trigger*** parameter.

### Acquisition Trigger

Sets the trigger event(s) that cause Matrix to acquire one image. The possible selections are:

- *External Trigger Leading/Trailing Edge*: once the external event has occurred, the image capture is delayed depending on the selected values for ***Debouncing*** and ***Delay Time*** (if at least one ACQUISITION TRIGGER DELAY is enabled).
- *Serial Port String* from either Main or Auxiliary port: once the string is received, the image capture is delayed depending on the ***Delay Time*** value (if at least one ACQUISITION TRIGGER DELAY is enabled).
- *Ethernet String* from the Ethernet DATA SOCKET. Once the string is received, the image capture is delayed depending on the ***Delay Time*** value (if at least one ACQUISITION TRIGGER DELAY is enabled).
- *Ethernet IP Trigger Leading/Trailing Edge*: once the external event has occurred, the image capture is delayed depending on the selected values for ***Debouncing*** and ***Delay Time*** (if at least one ACQUISITION TRIGGER DELAY is enabled).

It is possible to select multiple trigger events so that any one of them will cause the reader to acquire an image. To do this, from the pull down menu, hold down the CTRL key, select the desired events with the mouse and press ENTER. The events will be listed separated by a comma.

To synchronize the image capture when the code is moving the specific ACQUISITION TRIGGER DELAY parameter is available. Obviously, the expected aim is to take pictures when the code is inside the Field of View (FOV).

## Phase Mode

Matrix acquires images during the reading phase depending on the selected value for the ***Acquisition Trigger*** and the ACQUISITION TRIGGER DELAY.
The ***Reading Phase ON*** and ***Reading Phase OFF*** events mark respectively the beginning and end of the reading phase.

### Reading Phase ON

Defines the event(s) starting the reading phase. The possible selections are:

- *External Trigger Leading/Trailing Edge*: Once the external event has occurred, the beginning of the reading phase is delayed depending on the ***Debounce Filter (ms)*** parameter value.
- *Input 2 Leading/Trailing Edge*: Once the external event has occurred, the beginning of the reading phase is delayed depending on the ***Debounce Filter (ms)*** parameter value.
- *Serial Port String* from either Main or Auxiliary port.
- *Ethernet String* from the Ethernet DATA SOCKET.
- *Ethernet IP Trigger Leading Edge/Trailing Edge*.

It is possible to select multiple events so that any one of them will start the reading phase. To do this, from the pull down menu, hold down the CTRL key, select the desired events with the mouse and press ENTER. The events will be listed separated by a comma.

### Acquisition Trigger

Sets the trigger event(s) that cause Matrix to acquire images. The possible selections are:

- *Continuous*: allows acquiring images continuously with a rate up to 60 frames per second depending on the decoding time. If at least one ACQUISITION TRIGGER DELAY is enabled the acquisition process starts after the selected delay.
- *Multi-Delay*: allows acquiring images at the exact time(s) selected for the ACQUISITION TRIGGER DELAY. The minimum gap allowed between two delays depends on the scanning rate.
- *Periodic*: allows a continuous acquisition of images with the defined frequency (*Acquisition Trigger Period* parameter). If at least one is enabled the acquisition process starts after the selected delay.
- *Input 2 Leading/Trailing Edge*: Once the external event has occurred, the image capture is delayed depending on the ***Debounce Filter (ms)*** parameter value.
- *Serial Port String* from either Main or Auxiliary port.

- *External Trigger Leading /Trailing Edge*: Once the external event has occurred, the image capture is delayed depending on the ***Debounce Filter (ms)*** parameter value.
- *Ethernet String* from the Ethernet DATA SOCKET.
- *Ethernet IP Trigger Leading Edge/Trailing Edge*.

It is possible to select multiple events so that any one of them will start the reading phase. To do this, from the pull down menu, hold down the CTRL key, select the desired events with the mouse and press ENTER. The events will be listed separated by a comma

## Reading Phase OFF

Defines the event(s) stopping the reading phase. The possible selections are:

- *External Trigger Leading/Trailing Edge*: Once the external event has occurred, the end of the reading phase is delayed depending on the ***Debounce Filter (ms)*** parameter value.
- *IN2 Leading/Trailing Edge*: Once the external event has occurred, the end of the reading phase is delayed depending on the ***Debounce Filter (ms)*** parameter value.
- *Serial Port String* from either Main or Auxiliary port.
- *Timeout*.
- *Complete Read*: Once the code collection is completed, the end of the reading phase is automatically generated.
- *Ethernet String*.
- *Ethernet IP Trigger Leading/Trailing Edge*.

## Acquisition Trigger Period (ms)

In Phase Mode when the ***Acquisition Trigger*** is *Periodic*, this parameter sets the cycle time (period) for acquiring a new image.

## Reading Phase Timeout (ms)

In Phase Mode when the ***Reading Phase OFF*** is set to *Timeout*, this parameter defines the Maximum duration of the Reading Phase.

## Timeout Counting From

This parameter determines whether the Timeout used to determine the reading phase will begin from the ***Reading Phase ON*** event (normal operation), or from the ***Reading Phase OFF*** event (effectively extending the reading phase duration).
The possible selections are:

- *Reading Phase ON.*
- *Reading Phase OFF*.

NOTE

*Timeout counting from the end of the Reading Phase requires to set at least one additional event to the **Reading Phase OFF** parameter.*

## First Acquisition Setting Used

Defines the IMAGE ACQUISITION SETTING used to capture the first image within the reading phase. The possible selections are:

- *First Enabled*, which indicates the first recipe enabled among those available.
- *Last Successful*, which indicates the last recipe allowing the capture of a decodable image.

## 1.2 RELATED OPERATING MODE PARAMETERS

### Acquisition Trigger Delay

ACQUISITION TRIGGER DELAY (1 to 10) allows delaying the image capture(s) after an external event.

- While working in One Shot mode the delay starts from the ***Acquisition Trigger***. Before any image capture a new delay, among those enabled, is set following a cyclical order.
- While working in Phase Mode the delay starts from the ***Reading Phase ON*** event. If the ***Acquisition Trigger*** value is *Continuous* or *Periodic* for any one of the reading phases a new delay, among those enabled, is set following a cyclical order. On the other hand, by selecting *Multi-delay* each enabled delayed trigger is activated at the beginning of the reading phase.

***Delay Time (x100µs)*** parameter defines the delay time value in hundreds of microseconds.

### Image Processing Timeout

This parameter sets a limited processing time for each captured image. It can be used in dynamic reading applications to avoid missing some acquisitions.

- If set to 0, the Image Processing Timeout is disabled.
- The Image Processing Timeout period does not include image acquisition time (depending on the image sensor frame rate).
- If a timeout occurs during processing, the image will be recorded as a No Read event. For this reason the Image Processing Timeout period must be evaluated according to the enabled symbologies to allow reliable decoding.

This time can be evaluated according to the “Mean Decoding Time” and “Maximum Decoding Time”’ values: you can get the value of these parameters using the VisiSet™ Statistics tool for the specific application.

By providing the decoding result following each image, the Host system will be able to track the decoding result trend. The Host system must expect a large amount of data (up to 60 Frames/s for Matrix-2000™ models).

## Image Acquisition Buffer Size

Defines the maximum number of queued images waiting for processing.

NOTE

*It is recommended to use this parameter only when:*

- *Lots of images must be acquired in a short time;*
- *Enough time is available after the acquisition to guarantee the processing of all images.*

This is an example of the image acquisition when using the ***Reading Phase ON***, ***Reading Phase OFF***, ***Acquisition Trigger*** and ***Image Acquisition Buffer Size*** parameters:

***Operating Mode***: *Phase Mode*
***Reading Phase ON***: *External Trigger Leading Edge*
***Reading Phase OFF***: *External Trigger Trailing Edge, Timeout*
***Acquisition Trigger***: *Continuous*
***Image Acquisition Buffer Size:*** 7

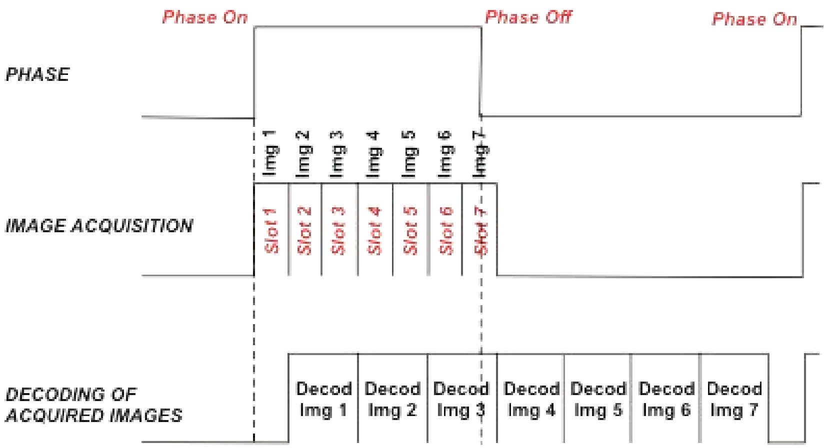



**Figure 1 – Image Acquisition Buffer**

## Reading Phase

When a synchronization source is available it is possible to operate in two different ways to define a Reading Phase:

- **External or Serial Reading Phase ON only**: a Leading/Trailing Edge on the reader inputs or a string on its serial ports starts the Reading Phase; when the configured Phase Timeout expires the reading phase is stopped (Figure 2).

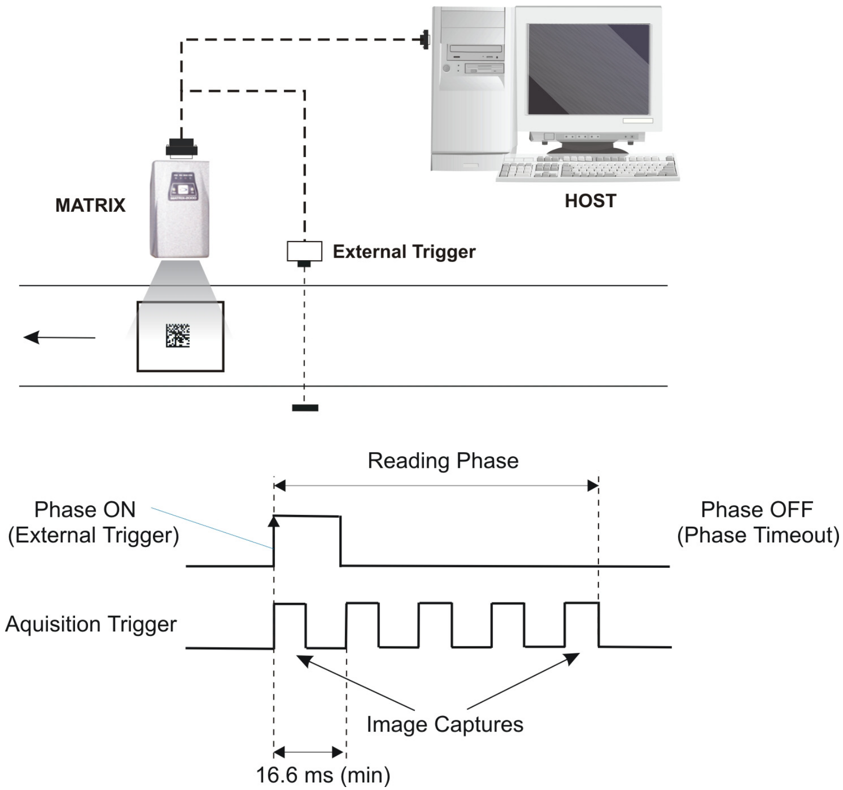



**Figure 2 – Reading Phase using Phase ON only and Phase Timeout**

- **Presence Sensor**: the presence sensor signal edges define the Reading Phase according to the values of the ***Reading Phase ON*** and ***Reading Phase OFF*** parameters (Figure 3).

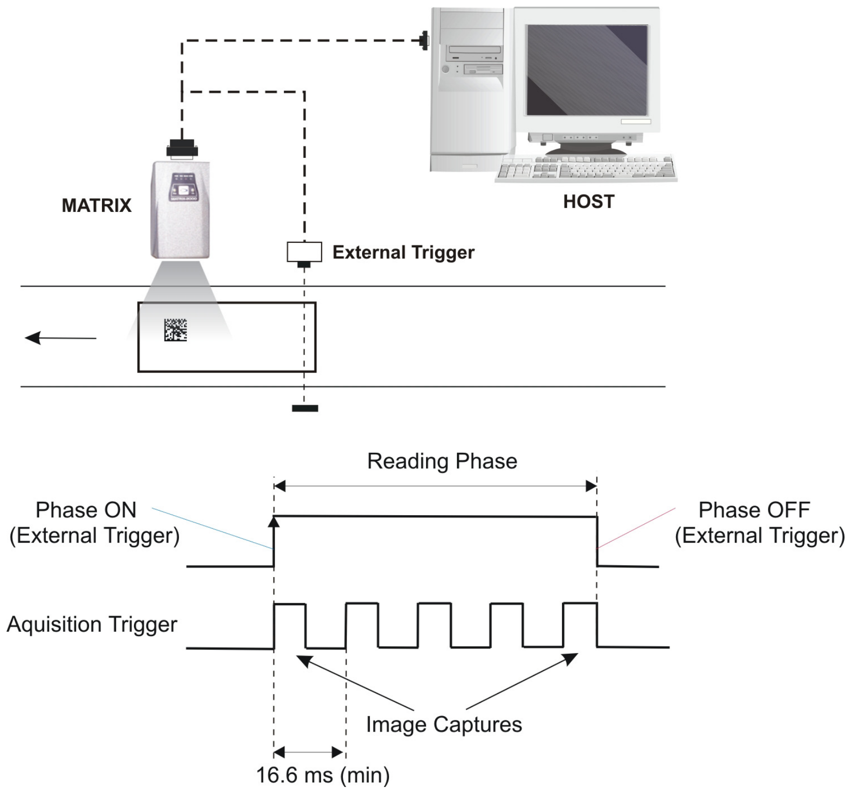



**Figure 3 – Reading Phase using external Presence Sensor signal**

***Message TX Trigger*** and ***Output Lines Activation*** parameters available in the DATA COLLECTION menu allow to select the transmission of the output message and the output lines activation as soon as the code collection is completed or after Reading Phase OFF event.

## 1.3 IMPORTANT OPERATING MODE FEATURES

### Run Time Self Tuning

This feature is available for all the operating modes and for both CALIBRATION and IMAGE PROCESSING parameter groups.

IMAGE ACQUISITION SETTING (CALIBRATION)

Self Tuning provides automatic adjustment in run time of acquisition parameters (Exposure Time and Gain) for each captured image based on calculations performed on the previous acquisitions. These dynamic settings will be used instead of the static settings saved in memory.

Reader automatically adjusts photometry parameters when the codes are presented with different backgrounds or with different colors or when the external light changes during the manufacturing process.

The Self Tuning function can be enabled for each IMAGE ACQUISITION SETTING (1 to 10) by means of the following parameters:

**Self Tuning**
Enables/disables the Self Tuning function for the Image Acquisition Setting parameters.

**Self Tuning Mode**
Defines the type of Self Tuning function to perform. The possible selections are:

- *Gain Only*: optimizes only the Gain parameter, maintaining the configured Exposure Time value (advised for dynamic reading applications).
- *Exposure Time Only*: optimizes only the Exposure Time parameter, maintaining the configured Gain value.
- *Exposure Time And Gain*: optimizes both parameter values in a balanced way.

**Self Tuning Timeout (ms)**
Sets a limited execution time for Self Tuning function.

- If set to 0, the Self Tuning Timeout is disabled.
- The Self Tuning Timeout period does not include image Exposure Time and Image Acquisition time (depending on the image sensor frame rate, refer to Paragraph 2.2 for further details).

## IMAGE PROCESSING SETUP

Self Tuning performs different processing attempts on the same captured image using different Image Processing and symbology related parameters.

Reader automatically tries different image processing or decoding options on the same captured image when codes are presented with different features during the manufacturing process.

The Self Tuning function can be enabled for IMAGE PROCESSING by means of the following parameters:

### Self Tuning

Enables/disables the Self Tuning function for Image Processing and Symbology related parameters.

### Self Tuning Mode

Defines the type of Image Processing Self Tuning to be performed. The possible selections are:

- *Symbologies Only*: attempts to process and decode the symbologies from all those available in software.
- *Processing Modes Only*: cycles the Processing Mode options on the symbologies already enabled.
- *Decoding Methods Only*: cycles the Decoding Methods options on the 2D symbologies already enabled.
- *Code Contrast Levels Only*: cycles the possible values for the Code Contrast parameter on the 2D symbologies already enabled.
- *Image Mirroring Only*: makes attempts with and without Mirroring on the symbologies already enabled.
- *General Purpose*: makes all possible attempts.

### Self Tuning Timeout (ms)

Sets a limited execution time for Self Tuning function.

- If set to 0, the Self Tuning Timeout is disabled.
- Since each processing attempt is based on the Image Processing Timeout parameter, this timeout must be longer than it.

## Multi Acquisition Setting

This feature is available for all the operating modes. It allows enabling up to 10 pre-defined IMAGE ACQUISITION SETTINGS (sets of CALIBRATION parameters) to deal with different code contrasts, printing techniques, target surface reflectance etc. without having to reconfigure the reader.

During any image capture a new recipe, among those enabled, is used following a cyclical order. While working in *Phase Mode* the first recipe used within the reading phase depends on the selection of the ***First Acquisition Setting Used*** parameter.

In specific applications, where the labels have very different characteristics, this can be very useful: you can optimize reader parameters for different reading conditions (at least the most important and repetitive) and collect them into different recipes.

## Multi Capture

This feature is available selecting ***Operating Mode***: *Phase Mode* and ***Code Collection***: *Within an Image* in Data Collection menu. It allows to acquire/decode up to 10 images of separate codes starting from a single ***Reading Phase ON*** event.

The ACQUISITION TRIGGER DELAY time values can be tuned using the VisiSet™ Calibration Tool so that any image is captured as soon as the whole code is inside the reader FOV. The reader will output a result after each image decoding.

## Multi Attempt

This feature is available by selecting ***Operating Mode***: *Phase Mode* and ***Code Collection***: *Within a Phase* in the Data Collection menu whenever the code remains in the reader FOV for at least two frame periods.

In most applications, the number of acquisitions necessary to obtain the requested reading percentage may depend on different non-optimal conditions (reading distance, angles, label contrast, printing technique etc.).

Generally it is advisable to increase the number of successive shots as much as possible for statistical reasons.

Assuming:

- **RSS**: Reading percentage using single shot mode (%)
- **N**: Number of successive shots.
- **RMA**: Reading percentage using "multi-attempt" mode (%)

The good reading percentage (RMA) when using more than one shot to read the same code is:

$$\mathbf{RMA = [1 - (1 - RSS / 100)^N ] \times 100}$$

The following table shows the method to increase the reading percentage.

| Reading Percentage in single shot mode | Number of successive shots | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1** | **3** | **6** | **8** | **10** | **12** | **14** | **20** |
| **5,00%** | 5,00% | 14,26% | 26,49% | 33,66% | 40,13% | 45,96% | 51,23% | 64,15% |
| **10,00%** | 10,00% | 27,10% | 46,86% | 56,95% | 65,13% | 71,76% | 77,12% | 87,84% |
| **15,00%** | 15,00% | 38,59% | 62,29% | 72,75% | 80,31% | 85,78% | 89,72% | 96,12% |
| **20,00%** | 20,00% | 48,80% | 73,79% | 83,22% | 89,26% | 93,13% | 95,60% | 98,85% |
| **25,00%** | 25,00% | 57,81% | 82,20% | 89,99% | 94,37% | 96,83% | 98,22% | 99,68% |
| **30,00%** | 30,00% | 65,70% | 88,24% | 94,24% | 97,18% | 98,62% | 99,32% | 99,92% |
| **35,00%** | 35,00% | 72,54% | 92,46% | 96,81% | 98,65% | 99,43% | 99,76% | 99,98% |
| **40,00%** | 40,00% | 78,40% | 95,33% | 98,32% | 99,40% | 99,78% | 99,92% | 100,00% |
| **45,00%** | 45,00% | 83,36% | 97,23% | 99,16% | 99,75% | 99,92% | 99,98% | 100,00% |
| **50,00%** | 50,00% | 87,50% | 98,44% | 99,61% | 99,90% | 99,98% | 99,99% | 100,00% |
| **55,00%** | 55,00% | 90,89% | 99,17% | 99,83% | 99,97% | 99,99% | 100,00% | 100,00% |
| **60,00%** | 60,00% | 93,60% | 99,59% | 99,93% | 99,99% | 100,00% | 100,00% | 100,00% |
| **65,00%** | 65,00% | 95,71% | 99,82% | 99,98% | 100,00% | 100,00% | 100,00% | 100,00% |
| **70,00%** | 70,00% | 97,30% | 99,93% | 99,99% | 100,00% | 100,00% | 100,00% | 100,00% |
| **75,00%** | 75,00% | 98,44% | 99,98% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% |
| **80,00%** | 80,00% | 99,20% | 99,99% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% |
| **85,00%** | 85,00% | 99,66% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% |
| **90,00%** | 90,00% | 99,90% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% |
| **95,00%** | 95,00% | 99,99% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% |
| **100,00%** | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% | 100,00% |

# 2 THEORETICAL CONSIDERATIONS

## 2.1 IMAGE SENSOR TECHNOLOGIES

**CCD** (acronym for Charge Coupled Device) and **CMOS** (acronym for Complementary Metal Oxide Semiconductor) image sensors are two different technologies for capturing images digitally.

Both types of sensors include an array of photo-sensitive diodes (each diode representing one pixel) to convert light into electric charge and process it into electronic signals:

- **CCD** image sensors create high-quality and low-noise images, and traditionally have very high light sensitivity. CCD sensors tend to be used in cameras that focus on high-quality images and excellent light sensitivity.
  The CCD image sensors are typically the choice for applications with high line speed and poor marking quality, or whenever a very high image quality is required.

- **CMOS** image sensors traditionally are more susceptible to noise and have lower light sensitivity. Nevertheless, CMOS sensors are usually less expensive and offer lower power dissipation (at the chip level).
  The CMOS image sensors are the preferred option when line speed and image quality are not critical (thermal transfer printing technology, static or slow moving reading applications).

Devices based on image sensors require typically some form of **Shutter** to control **Exposure**. This can be achieved either by incorporating an external mechanical shutter in front of the image sensor or using an electronic shutter integrated in the component.

For digital cameras equipped with a mechanical shutter, the photodiode integration time depends on the duration of the opening of the mechanical shutter.
For digital cameras based on image sensors equipped with an **electronic global shutter**, the photodiode integration time depends on the selected exposure time duration.

## 2.2 MATRIX SERIES IMAGE SENSORS

All Matrix readers mounts  progressive scan CCD or CMOS image sensors with a built-in **Electronic Global Shutter**.

The entire image sensor is reset before integration to remove any residual signal in the photodiodes; the photodiodes then accumulate charge during the exposure.
At the end of the integration period, all charges are simultaneously transferred to light shielded areas of the sensor.

All pixel rows and columns are exposed at the same time according to the selected integration time. Therefore, <u>all Matrix readers are suitable for static (stop and go) and dynamic reading applications</u>.

| Reader Models | Image Sensor | Image Format | Frame Rate |
|---|---|---|---|
| Matrix-1000™ | CCD | VGA (640x480) | 30 Frames/s |
| Matrix-2000™ | CCD | VGA (640x480) | 60 Frames/s |
| Matrix 200™ | CMOS | WVGA (752x480) | 60 Frames/s |
| Matrix 400™ 400-0x0 | CMOS | SXGA (1280x1024) | 27 Frames/s |
| Matrix 400™ 600-0x0 | CCD | UXGA (1600x1200) | 15 Frames/s |

In order to satisfy very high throughput applications, higher frame rates can be achieved using the ***Region Of Interest (ROI)*** windowing parameters in the CALIBRATION Parameter Setup menu.

**Region Of Interest** windowing function allows defining a region or window within the reader FOV. The Top, Bottom, Left and Right parameters allow to precisely define the image window to be processed, visualized and saved.

- In Matrix-1000™, Matrix-2000™ and Matrix 400™ 600-0x0 models equipped with CCD image sensors the frame rate is dependent on the number of lines (or rows) in the defined window.
- In Matrix 200™ and Matrix 400™ 400-0x0 models equipped with CMOS image sensor the frame rate is dependent on the number of rows and columns in the defined window.

The smaller the window, the lower the frame period and consequently the higher the frame rate. In general the overall Image Processing time can be reduced by reducing the window dimensions.

## 2.3 MAX LINE SPEED AND EXPOSURE TIME CALCULATION

The ***Exposure Time*** (or **Shutter**) parameter defines the time during which the image will be exposed to the reader sensor to be acquired. This parameter depends heavily on the environmental conditions (external lighting system, image contrast etc.).

In general, a longer time corresponds to a lighter image but is susceptible to blurring due to the code movement; a shorter exposure time corresponds to a darker image.

**NOTE**

*The following considerations must be applied only when the internal lighting system and **2D codes** are used. The Maximum line speed allowed for linear codes or postal code reading applications heavily depends on the direction of symbol movement. When the direction of movement is parallel to the elements of the code, the maximum speed is greater.*

Assuming:

- **X**: Code Resolution (mm)
- $\mathbf{T_{exp}}$: Exposure Time (s)
- **LS**: Line Speed (mm/s)

The essential condition to avoid blurring effects between two adjacent elements in a dynamic reading application is:

$$\mathbf{LS * T_{exp} \leq X}$$

The maximum (theoretical) line speed **LS** can be calculated as follows:

$$\mathbf{X / T_{exp\ (max)} = LS_{\ (max)}}$$

**Example:**

A Matrix 400™ 600-010 using:

*Internal Lighting Mode = Very High Power Strobe*
*Exposure Time (x10 $\mu$s) = 10 (100 $\mu$s)*
*Code Resolution (X) = 0.254 mm (10 mils)*

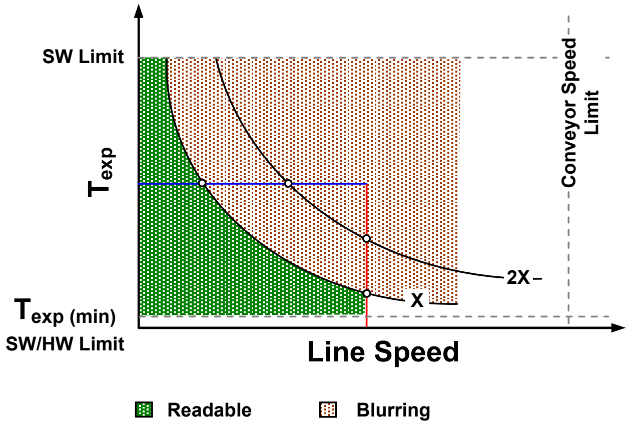
has a maximum line speed of:

0.254 (mm) / 0.0001 (s) = 2540 mm/s

Likewise, **$T_{exp\ (max)}$** is the maximum ***Exposure Time*** value that can be used without blurring for the given application line speed and code resolution. Therefore:

$$X / LS_{(max)} = T_{exp\ (max)}$$

**$T_{exp\ (max)}$** and **$LS_{(max)}$** are represented in the graph below as the curved line for **X** (code resolution). Values above the curve result in blurring. In practice, the application values are somewhere below the theoretical line, (in the green area), due to environmental and other conditions.




For example, the maximum target speed in the application is also affected by these conditions:

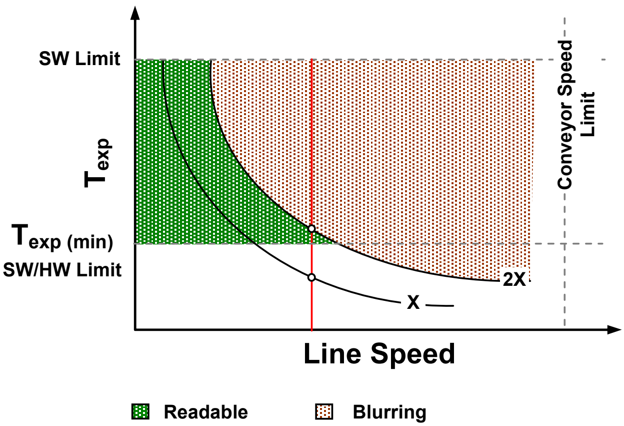
- **Code/Background Contrast**: maximum speed decreases when decreasing image contrast (poor quality codes, reflective transparent coverings, different supports and printing techniques).
- **Code Resolution**: maximum speed increases when decreasing code resolution, (i.e. **2X)**. There is a decrement of overlapping effects between two adjacent elements.
- **Tilt Angle**: maximum speed decreases when increasing Tilt angle (from 0 to 45 degrees).

The ***Internal Lighting Mode*** parameter allows setting the operating mode of the internal lighting system. The possible values are:

- *Disabled*: the built-in LED array is turned off all the time. This option can be useful if using an external lighting system;
- *Always ON*: the built-in LED array is turned on all the time at the lowest power level. This option is useful if the LED-array blinking (Strobed operating mode) disturbs the operator.
- *Very High/High/Medium/Low-Power Strobed*: the built-in LED array is on only during the image exposure time. Four different lighting levels can be set.

**NOTE**

*To avoid LED array overheating, for Power Strobed settings, the program automatically limits the range of allowed values for the* ***Exposure Time*** *parameter. Therefore, after changes to Internal Lighting Mode, recheck* ***Exposure Time****.*




**$T_{exp\ (min)}$** is the minimum ***Exposure Time*** value obtainable for the specific application. It can be evaluated in static reading conditions and depends on the Matrix reader model selected for the application (internal lighting system, optical lens, diaphragm aperture, reading distance) and on any external lighting system. It may also depend on code printing quality, and reader position.

# 3 OPERATING MODE SELECTION

Reading applications can be classified depending on the speed of the target moving in front of Matrix reader; the possible application types are:

- Static (stop and go) reading applications.
- Dynamic reading applications.

A detailed description of recommended operating modes for each case is provided in the following paragraphs.

Moreover, theoretical considerations about dynamic reading applications and related operating mode features are provided in Paragraph 1.3.

## 3.1 STATIC READING APPLICATIONS

Whenever the target can be stopped while the code is inside the Matrix reader field of view the following ***Operating Modes*** can be used:

### Continuous or Phase Mode

*Continuous* mode is suggested whenever there is no means available to signal the presence of the target in the reader field of view, otherwise it's better to use the *Phase Mode* with ***Acquisition Trigger****: Continuous* or *Periodic*. For further details about the Reading Phase definition refer to Paragraph 1.2).

In both cases the continuous acquisition/decoding of the same code helps to increase the readability of poor quality labels. For further details about the 'Multi Attempt' feature refer to Paragraph 1.3).

The 'Multi Acquisition Setting' feature should be used whenever some of the environmental conditions (reading distance or angle, label contrast, printing technique etc.) could change among the codes to be read (refer to paragraph 1.3).

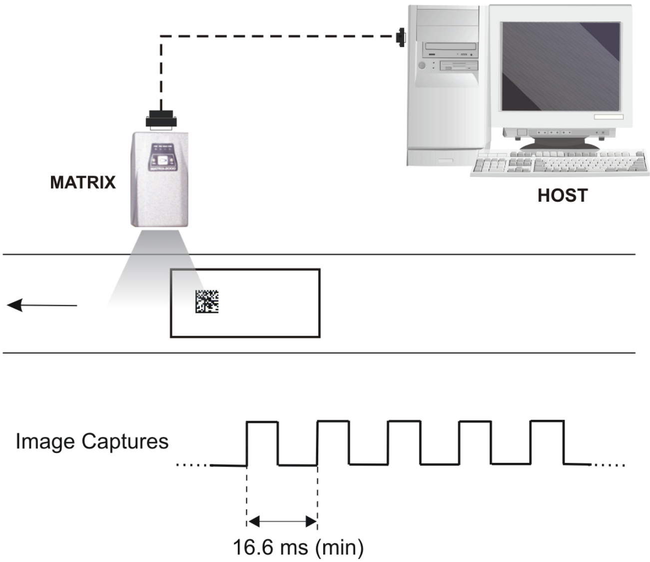



**Figure 4 - Continuous mode without External or Serial trigger signal**

## 3.2 DYNAMIC READING APPLICATIONS

In applications where the target cannot be stopped during the code reading, before defining the operating mode of the reader, it is necessary to know:

- Line speed: **LS** [mm/s]
- Reader FOV width in the code movement direction: **FW** [mm]
- Symbol Size in the code movement direction: **SS** [mm]
- Maximum reader Frame Rate: **FR** [Images/s]

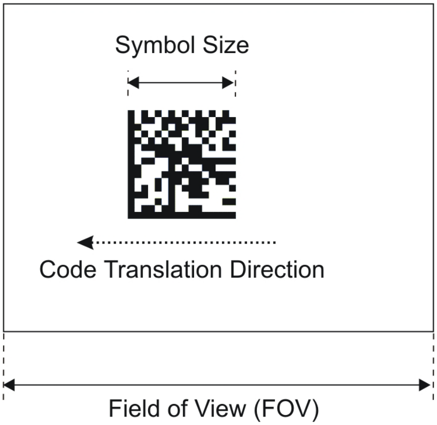



**Figure 5 - Reader Field of View**

These data and the following expression allow you to calculate the number of images (**NI**) that can be captured without using any external trigger (*Continuous* operating mode) while the whole code is inside the reader FOV:

**NI** = the largest integer not greater than **[(FW - SS) / LS] x FR**

Depending on the resultant **NI** value the following operating modes can be used:

### Continuous or Phase Mode/Continuous:

Whenever **NI** $\geq$ **1** it is possible to operate in *Continuous* mode (Figure 4), but if there is a means of external synchronization available, it is strongly suggested to select the *Phase Mode* with ***Acquisition Trigger***: *Continuous* or *Periodic* (Figure 6).

In this last case the ACQUISITION TRIGGER DELAY time must be calibrated to capture the image as soon as the entire code is inside the reader FOV.

We refer to the condition **NI** ≥ **3** as a quasi-static reading, where you can use the advantages of the Multi Attempt feature by selecting the ***Operating Mode***: *Phase Mode* and ***Code Collection***: *Within a Phase* (refer to paragraph 1.3).

Moreover the Multi Acquisition Setting feature should be used whenever some of the environmental conditions (reading distance or angle, label contrast, printing technique etc.) could change among the codes to be read (refer to paragraph 1.3).

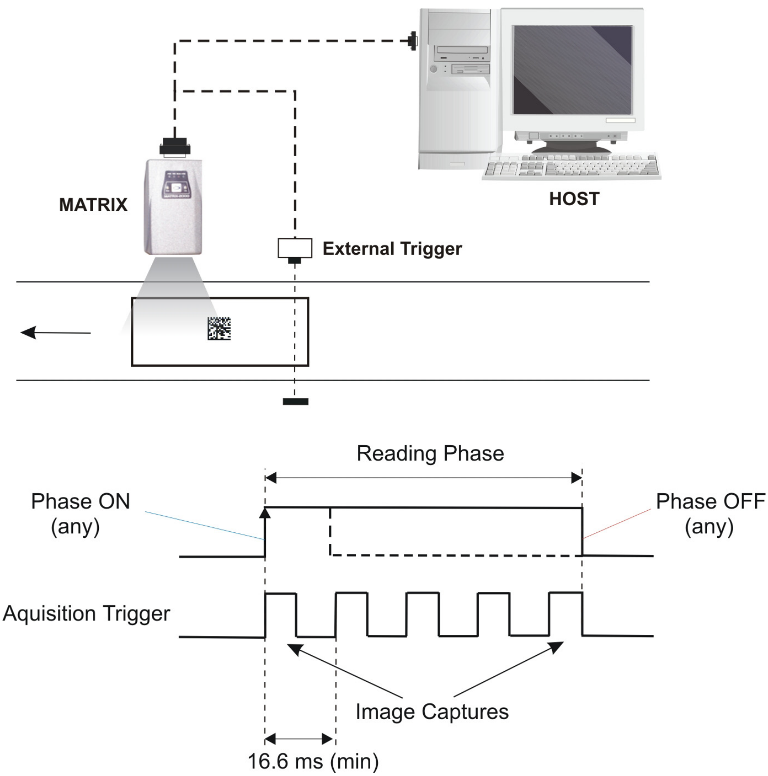



**Figure 6 - Phase Mode/Continuous or Phase Mode/Periodic (Multi-attempt)**

## One Shot
Whenever **NI = 0** the reader needs an external trigger. The only useful operating mode is *One Shot* and the ACQUISITION TRIGGER DELAY time must be calibrated to capture the image as soon as the whole code is inside the reader FOV.

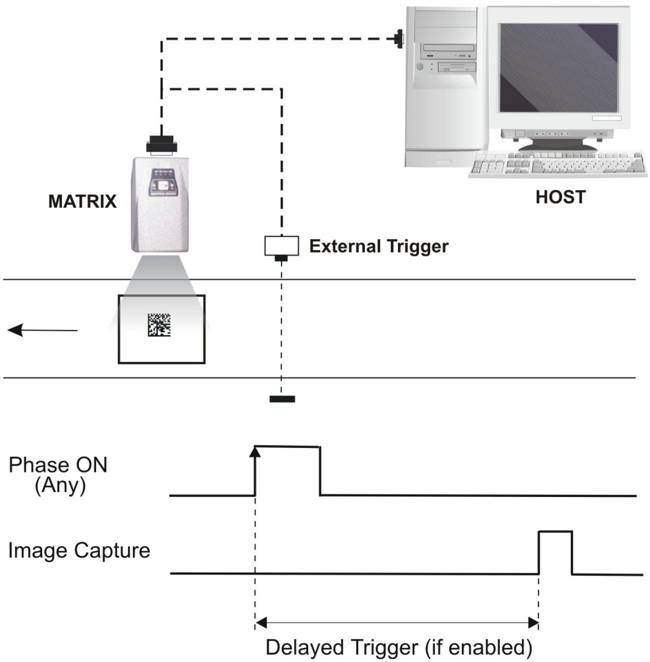



**Figure 7 - One Shot mode**

## Critical Condition:
Whenever **NI < 0** (the code width is larger than the FOV) check if it is possible to use a Matrix model with a larger FOV.

## Special case: Phase Mode/Multi-delay
In applications with a moving target where you have to read several codes so close together that the time elapsing between two adjacent captures approaches the frame rate, the Multi Capture feature can be used (see paragraph 1.3).
Figure 8 shows an example of a 'Multi Capture' application.

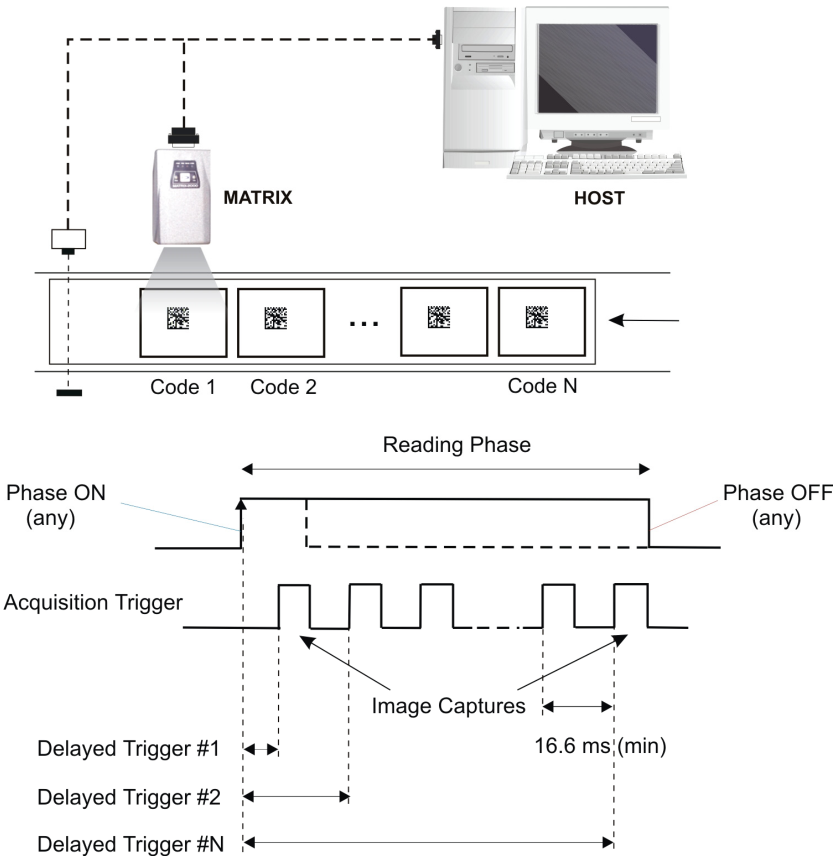



**Figure 8 - Phase Mode/Multi Delay (Multi-capture)**

| | |
|---|---|
| **NOTE** | *It's critical to have the delay(s) timing set correctly to guarantee that the code is in the reading field during image capture. Another essential condition is that the label speed has no significant fluctuations during the reading phase. Also, the Delay between two consecutive Reading Phases must be greater than the maximum Acquisition Time.* |

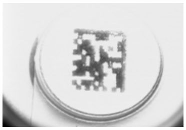
# 4 HOW TO IMPROVE READING PERFORMANCE

This chapter explains how to improve the reading performance of your Matrix reader on difficult and damaged symbols, or when a large quantity of similar symbols must be processed.

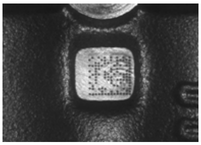
## 4.1 CHANGING DECODING METHOD

For **Data Matrix ECC200** and **QR Code** symbologies the ***Decoding Method*** parameter allows selecting the decoding algorithm according to the printing/marking technique used to create the symbol and on the overall printing/marking quality. The possible selections are:

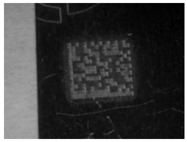
- *Standard*: this selection allows fast and high-performance reading of high quality codes or low contrast codes on uniform backgrounds.
- *Direct Marking*: the Direct Marking selection improves the decode rate for low quality Direct Part Mark codes and in general for Direct Part Mark codes with dot peening type module shapes.



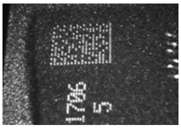
Washed out and Axial Distortion



Dot Peening On Scratched Surface

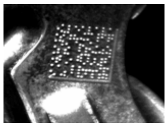


Low Contrast Problem

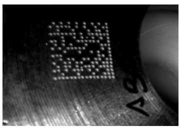


Background Problems

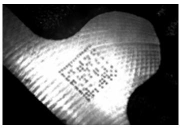
Marked On Curved Shiny Surface



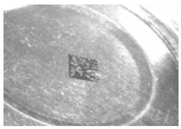
Axial distortion



Half moon effects



Shiny surface, noisy background



Low contrast, noisy background

All the previous examples can be successfully managed selecting the *Direct Marking* ***Decoding Method*** option.

## 4.2 MODIFYING IMAGE PROCESSING PARAMETERS

Although the Matrix reader with default decoding parameters is able to read a variety of different symbols, for applications that involve only one type of symbol or difficult symbols, a different decoding mode can be used.

The ***Processing Mode*** parameter is included in the IMAGE PROCESSING menu for all Matrix models. The possible selections are:

- *Standard*: it is used for applications where the magnification is generally highly variable, and the position and orientation of the symbol is generally unpredictable (e.g. manually presenting a symbol to the reader).
- *Low Height Codes*: can be used to increase decode rate when the symbol images have generally low height or low aspect ratio.
- *Advanced Code Setting*: can be used to increase decode rate on very small or difficult codes when the symbol is presented at a fixed magnification and may have known properties such as resolution, number of modules, orientation, minimum code height, etc..

Using *Low Height Codes* or *Advanced Code Setting* options allows (or, in many cases, requires) setting additional properties describing the symbol image.
As with a learn, this results in a more reliable decode of the same type of symbol. In most cases, it also speeds up the decoding time.

When various properties of the image are predictable, you should consider using this mode, which normally produce decode rate gains and often significantly reduces decoding time.

**NOTE**

*In order to use Low Height Codes or Advanced Code Setting options the Matrix 400™ reader models must acquire information regarding image density or PPI (pixels per inch) through the **Image Density Calibration** Procedure.*

*Low Height Codes* and *Advanced Code Setting* Processing Modes are necessary to decode:

- 2D codes having one or both dimensions lower than 64 pixels in the image;
- 1D codes having minimum height lower than 16 pixels in the image or very low aspect ratio.

*Advanced Code Setting* Processing Mode is necessary to decode:

- Poor printing quality or damaged 1D and 2D codes;
- Very low contrast 1D codes;
- Pharmacode symbology.

Moreover, *Advanced Code Setting* Processing Mode is necessary to perform code quality assessment according to the following Standards:

- ISO/IEC 15415 - 2D Symbols - Print Quality Test Specification
- ISO/IEC 15416 - Linear Symbols - Print Quality Test Specification
- AS9132A - Data Matrix Quality Requirements for Parts Marking
- AIM DPM - Direct Part Marking Quality Guideline

**NOTE**

*For Symbol Verification according to the ISO/IEC 15415, ISO/IEC 15416, AS9132A and AIM DPM Standards, the Advanced Code Setting **Processing Mode** is automatically configured.*

*Advanced Code Setting* Processing Mode is recommended:

- When Data Matrix or Postal codes to be read always have the same properties (number of modules or bars, size of modules, orientation);
- Whenever an improvement of reading performance is necessary (both decode rate and decoding time repetitiveness).

## 2D Codes

By constricting the code properties like Symbol Contrast, Number of Modules, Module Size and Orientation to a specific value, the decoding libraries will quickly reject any symbol that doesn't match the description.

### Code Contrast

Defines the symbol contrast threshold to be used during the decoding process.

By setting low contrast values for very low contrast symbols the decoding time may increase. By setting high contrast values for very high contrast symbols the decoding time may decrease.

The following parameters are included in the 2D CODES menu and valid only when the ***Processing Mode*** is set to *Advanced Code Setting*.

### Code Orientation

Allows selecting the orientation at which the symbols can be decoded. The possible selections are:

- *Aligned*: decodes Data Matrix symbols only if its finder pattern is aligned with the x and y axes of the image, with a tolerance of ± 20°.
- *Omnidirectional*: decodes Data Matrix symbols regardless of orientation.

### Code Size

Allows either reading codes with any module number (*Free*) or setting correctly the number of rows and columns of codes to be read (*Defined*).

### Number of Modules

Allows specifying one or more defined number of modules (Rows x Columns) of the codes to be read when ***Code Size*** parameter is set to *Defined*.

It is possible to select multiple *Number Of Modules* so that any one of them will cause the code to be decoded. To do this, from the pull down menu, hold down the CTRL key, select the desired events with the mouse and press ENTER. The events will be listed separated by a comma.

The following parameter is included in the 2D CODES menu and valid only when the ***Processing Mode*** is set to *Low Height Codes* or *Advanced Code Setting*.

### Module Size (mils)

It defines in mils the typical resolution of codes to be read. Typically, the decode algorithm operates with maximum robustness when this parameter is set to the estimated cell size.

## 1D Codes

By constricting the code properties like Minimum Height, Contrast and Aspect Ratio to a specific value, the decoding library will be able to make the reading process more reliable.

The following parameter is included in the 1D CODES menu and valid only when the ***Processing Mode*** is set to *Low Height Codes* or *Advanced Code Setting*.

### Minimum Code Height (mm)

Allows specifying the minimum height of 1D barcodes (including PDF417) in units of millimeters. When any symbology in the 1D Codes group is enabled, this property must be set appropriately.

A symbology with a code height less than this value may sometimes be decoded. Typically, the decode algorithm operates with maximum robustness when this parameter is set to the estimated code height.

The following parameters are included in the 1D CODES menu and valid only when the ***Processing Mode*** is set to *Advanced Code Setting*.

### Aspect Ratio

When selecting the *Low* value a special algorithm is enabled for locating low aspect ratio symbols.

Enabling this algorithm can substantially increases the time needed to decode symbols.

### Code Contrast

Enables special algorithms for the decoding of low contrast 1D symbols.
Low contrast images may occur for many reasons such as printing or lighting problems, motion blur, oblique reader angles, etc

By setting Low contrast value for very low contrast symbols the decoding time may increase.

## Postal Codes

By constricting the code properties like Minimum Number of Bars, Maximum Number of bars, Orientation and Bar Edge Spacing to a specific value, the decoding library will quickly discard any symbol that doesn't match the description.

The following parameters are included in the POSTAL CODES menu and valid only when the **Processing Mode** is set to *Advanced Code Setting*.

### Min Bar Count and Max Bar Count

Allows setting the minimum and maximum number of bars to expect in a postal symbology.

### Code Orientation

Allows selecting the orientations at which the symbols can be decoded. The possible selections are:

- *Omnidirectional*: decodes postal symbologies regardless of orientation.
- *Horizontal*: the symbology is aligned to the x axis with a tolerance of ± 20°.
- *Vertical*: the symbology is aligned to the y axis with a tolerance of ± 20°.
- *Horizontal and Vertical*: the symbology is aligned to the x or y axes with a tolerance of ± 20°.

### Bar Edge Spacing

Allows setting the typical value of the sum of the Bar Width + Space Width in mils


**Figure 9 - Bar Edge Spacing measurement**

Typically, the decode algorithm operates with maximum robustness when this parameter is set to the estimated bar edge spacing.

## 4.3 APPLYING PRE-PROCESSING IMAGE FILTERS

For poor quality codes it is possible to apply pre-processing filters to improve the image quality and make the reading performance more reliable.

The CALIBRATION menu allows selecting the proper pre-processing ***Image Filter*** and the number of iterations for the filter (***Image Filter Reiterations*** parameter). The possible filters are:

- *None*: no filter is applied (default value).
- *Erode*: this filter increases the size of the dark elements on the light background.
- *Dilate*: this filter increases the size of the white elements on the dark background.
- *Open*: this filter removes minor light defects of dark cells.
- *Close*: this filter removes minor dark defects of light cells.

Erode and Dilate filters can help to balance the size between the dark and light modules in a poor quality 2D symbol, or to decode particular ink-spread printed 1D symbols.

**NOTE**

*When setting a high number of reiterations for the **Image Filter Reiterations** parameter, the overall code processing time increases*

In specific applications, where the codes to read have very different characteristics, the Multi Acquisition Setting feature should be used: you can optimize pre-processing Image Filters and other CALIBRATION parameters for different reading conditions (at least the most important and repetitive) and collect them into different recipes.

The reader will try to decode the acquired images with the parameters stored in the IMAGE ACQUISITION SETTINGS, one at a time, until a successful decode is achieved.

Figure 10 shows a direct marked Data Matrix ECC200 code before **Erode** filter is applied. Figure 11 shows the same code after Erode filter is applied with 3 reiterations.

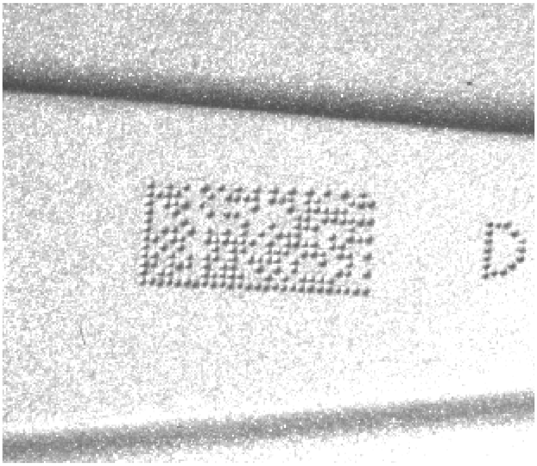


**Figure 10 - Image not decodable without applying Erode filter**

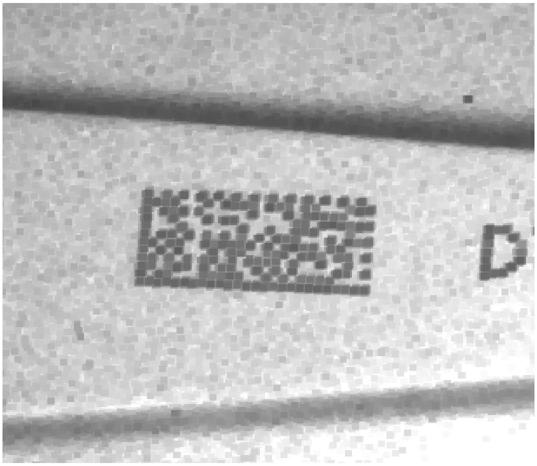


**Figure 11 - Image decodable applying Erode filter**

Figure 12 shows a direct marked Data Matrix ECC200 code before **Dilate** filter is applied. Figure 13 shows the same code after Dilate filter is applied with 4 reiterations.

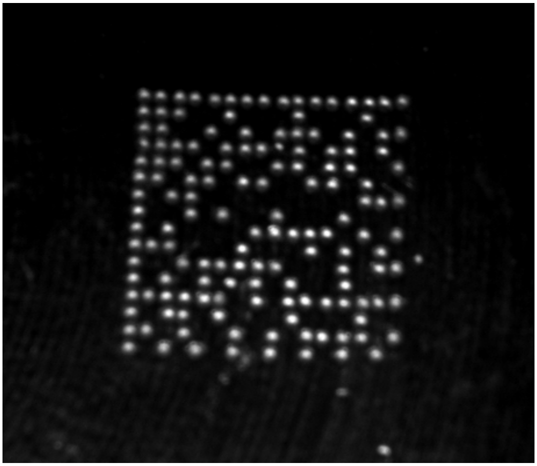


**Figure 12 - Image not decodable without applying Dilate filter**

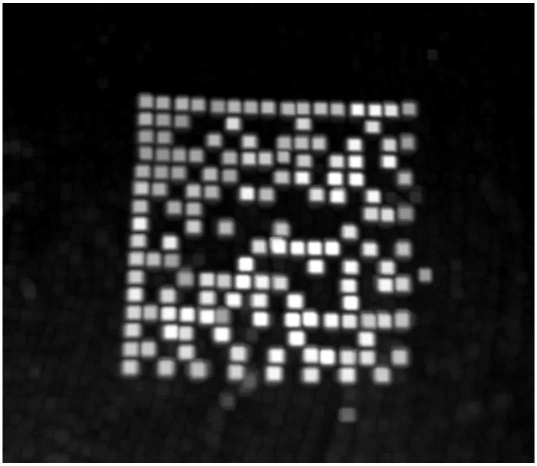


**Figure 13 - Image decodable applying Dilate filter**

# GLOSSARY

**AS9132**
Standard defining uniform quality and technical requirements for direct part marking (DPM) using Data Matrix symbologies.

**AIM**
(Association for Automatic Identification and Mobility): AIM Global is the international trade association representing automatic identification and mobility technology solution providers.

**AIM DPM Quality Guideline**
Standard applicable to the symbol quality assessment of direct part marking (DPM) performed in using two-dimensional bar code symbols. It defines modifications to the measurement and grading of several symbol quality parameters.

**Barcodes (1D Codes)**
A pattern of variable-width bars and spaces which represents numeric or alphanumeric data in machine-readable form. The general format of a barcode symbol consists of a leading margin, start character, data or message character, check character (if any), stop character, and trailing margin. Within this framework, each recognizable symbology uses its own unique format.

**Composite Symbologies**
Consist of a linear component, which encodes the item's primary data, and an adjacent 2D composite component, which encodes supplementary data to the linear component.

**Dark Field Illumination**
Lighting of surfaces at low angles used to avoid direct reflection of the light in the reader's lens.

**Decode**
To recognize a barcode symbology (e.g., Data Matrix ECC200, Codabar, Code 128, Code 39, UPC/EAN, etc.) and analyze the content of the barcode scanned.

**Depth of Field (DOF)**
The difference between the minimum and the maximum distance of the object in the field of view that appears to be in focus.

**Diffused Illumination**
Distributed soft lighting from a wide variety of angles used to eliminate shadows and direct reflection effects from highly reflective surfaces.

**Direct Part Mark (DPM)**
A symbol marked on an object using specific techniques like dot peening, laser etching, chemical etching, etc.

**Element**
The basic unit of data encoding in a 1D or 2D symbol. A single bar, space, cell, dot.

**Exposure Time**
For digital cameras based on image sensors equipped with an electronic shutter, it defines the time during which the image will be exposed to the sensor to be acquired.

**Image Processing**
Any form of information processing for which the input is an image and the output is for instance a set of features of the image.

**Image Resolution**
The number of rows and columns of pixels in an image, or the total number of pixels of an image sensor.

**Image Sensor**
Device converting a visual image to an electric signal. It is usually an array of CCD (Charge Coupled Devices) or CMOS (Complementary Metal Oxide Semiconductor) pixel sensors.

**IEC**
(International Electrotechnical Commission): Global organization that publishes international standards for electrical, electronic, and other technologies.

**ISO**
(International Organization for Standardization): A network of the national standards institutes of several countries producing world-wide industrial and commercial standards.

**LED (Light Emitting Diode)**
A low power electronic light source commonly used as an indicator light. It uses less power than an incandescent light bulb but more than a Liquid Crystal Display (LCD).

**LED Illuminator**
Light Emitting Diode technology used as an extended lighting source in which extra optics added to the chip allow it to emit a complex radiated light pattern.

**Matrix Symbologies (2D Codes)**
An arrangement of regular polygon shaped cells where the center-to-center distance of adjacent elements is uniform. Matrix symbols may include recognition patterns which do not follow the same rules as the other elements within the symbol.

**Multi-row (or Stacked) Symbologies**
Symbologies where a long symbol is broken into sections and stacked one upon another similar to sentences in a paragraph.

**Symbol Verification**
The act of processing a code to determine whether or not it meets specific requirements.