DALSA

Line Scan/ TDI Line Scan Calculation Worksheet

In any line scan application the system designer must consider both the desired resolution perpendicular to the object's movement (Horizontal Resolution) and the resolution along the path of the object's movement (Vertical Resolution). See Figure 1.

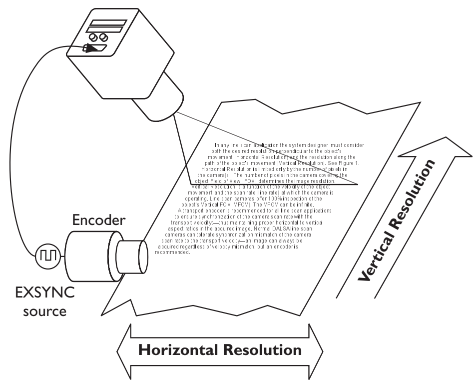
Horizontal Resolution is limited only by the number of pixels in the camera(s) and the object Field of View (FOV).

Vertical Resolution is a function of the velocity of the object movement and the scan rate (line rate) at which the camera is operating. Line scan cameras offer 100% inspection of the object's Vertical FOV (VFOV). The VFOV can be infinite.

A transport encoder is recommended for all line scan applications to ensure synchronization of the camera scan rate with the transport velocity—thus maintaining proper horizontal to vertical aspect ratios in the acquired image (i.e. square pixels). Line scan cameras can tolerate synchronization mismatch of the camera scan rate to the transport velocity; an image can always be acquired regardless of velocity mismatch, but an encoder is recommended. TDI applications will almost always require an encoder for proper synchronization.

The following examples demonstrate optical design. The formulas represent first order approximations and can be applied to most applications requiring wideband (polychromatic) lighting.

Figure 1. OCR Example



Example 1. OCR

A typical Optical Character Recognition (OCR) application requires 200 Dots per inch (DPI) image resolution. This means that each pixel of the camera must correspond to 0.005″ of object size. A high speed application may require 1000′/min which is 200″/sec. If the Horizontal Field of View (HFOV) required is 10″ including lateral tolerances then the required camera resolution is:

Resolution = HFOV x DPI
= 10″ x 200DPI
= 2000 pixels

The closest available sensor resolution of 2048 pixels:

Actual DPI = # pixels/HFOV
= 2048 pixels/10″
= 204DPI

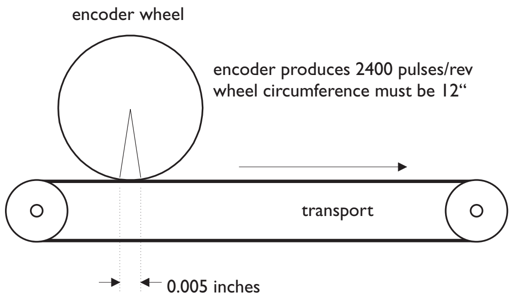
In this example, resolution would be increased to 204DPI across the 10″ HFOV. Each pixel on the camera (h') would then correspond to 0.005 inches (127µm) of Image size (h). If the pixel pitch is 10µm, the magnification ratio (m) equals:

Using m = pixel size/image size
= h'/h
= 10µm/127µm
= 0.079

Given a commercially available 55mm (f') lens, the distance from the object to the second principal point of the lens (OD) would be:

OD = f'/m
= 55mm/0.079
= 696mm
= 27.4″

Figure 2. OCR Encoder Wheel



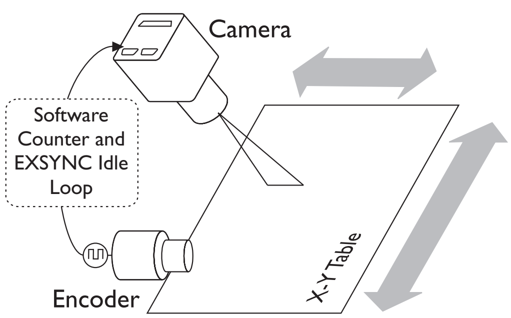
Synchronization of the camera scan rate to the object's movement is achieved by using an encoder. The encoder shaft is equipped with a wheel such that the linear velocity of the circumference of the encoder wheel is the same as the object transport velocity (see Figure 2). Vertical resolution is determined by the velocity of the object transport and the scan rate at which the camera must be clocked. Given a 200″/s transport speed, the camera line rate (scan rate) must be:

Line Rate	= transport speed x DPI
	= 200″/s x 204DPI
	= 40800s^{-1}
	= 40.8kHz

The scan rate control clock is derived from the resolution of an encoder and the circumference of the encoder wheel. Assuming a square aspect ratio (Horizontal object size vs. Vertical object size) each scan line of data must correspond to 0.005 inches of object movement. Given an encoder with 2400 pulses/revolution the circumference of the encoder wheel attached to the transport must be:

Wheel circumference	= object resolution x # pulses/rev
	= 0.005″ x 2400 rev^{-1}
	= 12.0″/rev

Figure 3. Flat Panel Example



Example 2. Flat Panel Inspection

Another typical application is defect inspection of LCD glass panels. This example uses a CL-P1-4096W line scan camera.

Assumptions

- LCD panel size = 100mm x 200mm
- Minimum size of defect which must be detected = 15µm
- X-Y table encoder resolution = 1 pulse per 1µm of travel.
- Inspection time target = 20 seconds per panel

1) Resolution Requirement

Experimentation with the application and camera has determined that a pixel size of 5µm at the object is sufficient to reliably detect all defects of size = 15µm.

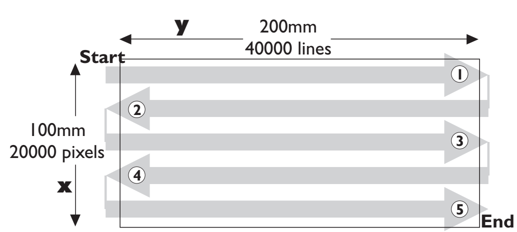
Number of pixels required in X direction	= 100mm/5µm = 20000 pixels
Number of lines required in the Y direction	= 200mm/5µm = 40000 lines

Since no camera exists with 20000 pixel resolution the inspection must be completed using multiple passes over the object with a high resolution line scan camera such as the CL-P1-4096W.

Number of passes required to completely inspect the glass surface	= 20,000 pixels/4096 = 4.88

Therefore 5 passes are required to inspect the entire surface.

Figure 4. Flat Panel Scan Pattern



2) Speed requirement

To complete the inspection in 20 seconds requires that each pass over the object be 4 seconds or less. The X-Y table requires 0.5 seconds to stop and reposition for the start of the next pass. This leaves 3.5 seconds to complete the 40,000 line scan of each pass.

Line scanning rate required	= 40,000 lines/3.5 seconds = approx. 11,500 lines/second.

The CL-P1-4096W maximum line scanning rate is 11.9KHz which is fast enough to meet this speed requirement.

3) Encoder Synchronization

To achieve a square pixel image requires that the pixel size in the Y direction be equal to the pixel size in the X direction. The pixel size in the X direction is 5µm. Therefore we must send EXSYNC to the camera every time the object moves by 5µm in the Y direction. The X-Y table encoder generates a pulse for every 1µm of object movement in the Y direction. A software counter may be used to generate a EXSYNC pulse to the camera every time the counter receives 5 encoder pulses.

Line scan and TDI line scan cameras require a minimum EXSYNC pulse frequency of approximately 300Hz for stable operation. In this application an EXSYNC idle loop or circuit must be used to prevent EXSYNC from stopping while the X-Y table reverses direction. For example a software loop may detect that EXSYNC has dropped below a threshold of 1000Hz at which time an idle EXSYNC frequency of 1000Hz is sent to the camera until the X-Y table begins scanning the next pass.