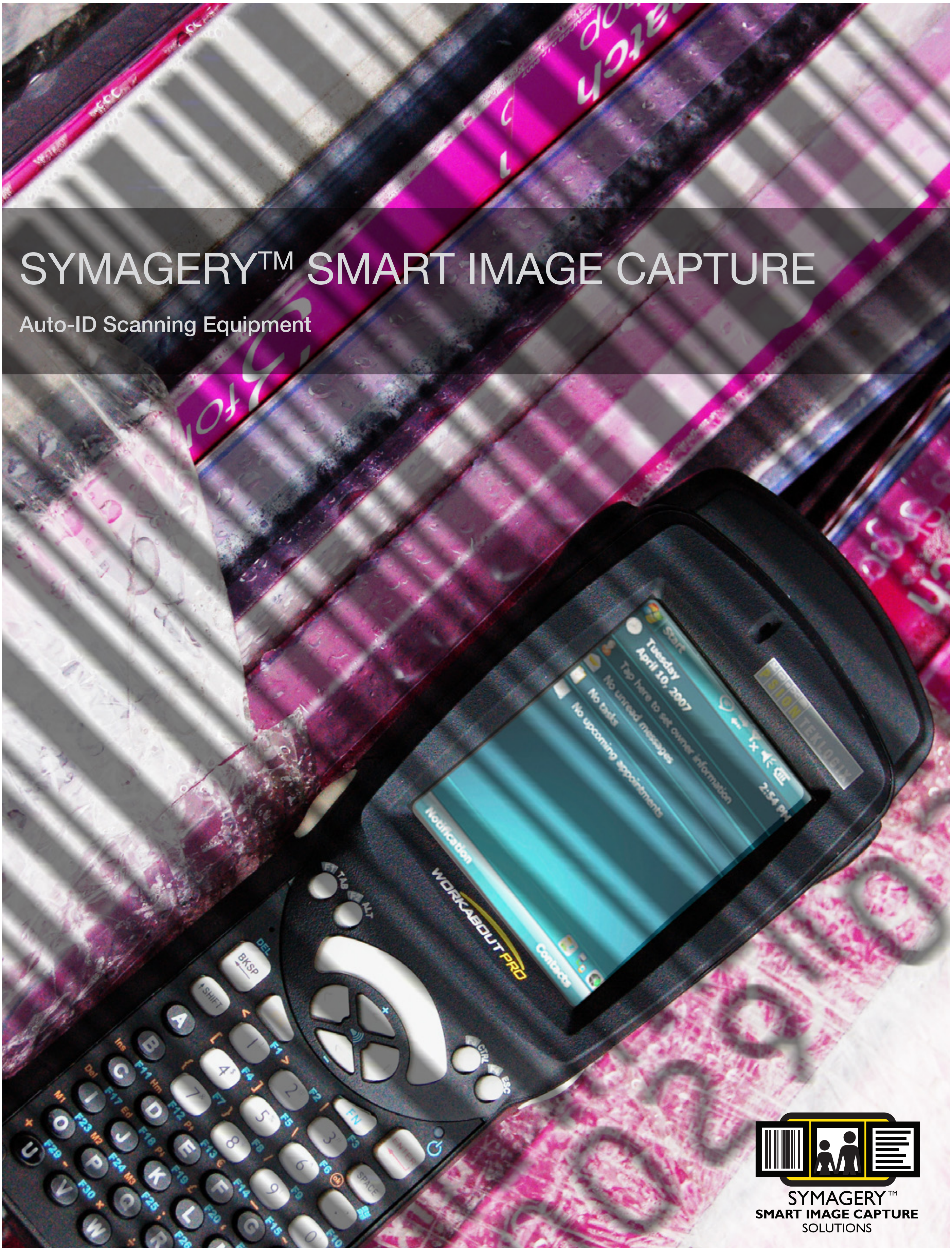
PSION TEKLOGIX

information in motion

WHITE PAPER

SYMAGERY™ SMART IMAGE CAPTURE

Auto-ID Scanning Equipment



SYMAGERY™
SMART IMAGE CAPTURE
SOLUTIONS

Auto-ID Symbol Scanning Equipment

Data Capture using Automatic Identification techniques is becoming more and more common both in business and everyday life. Much of the basic technology (abbreviated hereafter as AIDC) has been in existence in various forms for decades, but recent advances in electronics, optics, and miniaturization are fuelling the growth of a myriad of applications as capabilities increase at the same time that costs decrease.

Basic AIDC techniques include Bar Code, Radio Frequency Identification (RFID), Optical Character Recognition (OCR), Magnetic Stripe, and Machine Vision. If we expand the definition of AIDC to include technologies that involve an operator, we can also embrace other approaches such as Voice Recognition, Smart Cards, and Touch Memory.

FIGURE 1 Examples of different symbology types

The most prevalent AIDC technology today is Bar Code, which is inherently an optical technique. Originally developed in the 1930's, the beauty of Bar Code is that the information-bearing bar code symbol can be created directly on a variety of packaging, often as part of the existing printed labeling. When considering Bar Code, most people immediately think of an arrangement of varying width bars and spaces like the ubiquitous UPC symbol, however this is only one way to convey information in printed pattern of optical marks. "Conventional" bar code symbols (like UPC) encode information by varying the width of the bars and spaces in a pre-determined fashion (this is called "width modulation"), but it is also possible to vary the height of the bars. This is the approach taken in many large postal applications, and it is called "height modulation". If we broaden our definition of Bar Code still further to include tiered symbols and 2-D arrays of optical marks, the variety of possible symbol structures expands still further, as shown by the examples in Figure 1.

The term "symbology" is used to describe the set of standards and specifications that are used to create a particular symbol. Over the years, hundreds of different symbologies have been developed. The incentives to invent new symbologies were often application-specific, and included the desire to:

- encode more information in a given symbol
- minimize symbol size
- minimize errors
- decode poorly-printed or physically abused symbols
- decode symbols irrespective of their orientation
- minimize the cost of symbol creation (printing)
- decode symbols that are moving at high speed

Although the list of published symbologies can be intimidating at first, it soon becomes apparent that today's commonly encountered symbol types fit into general categories, as shown below.

This list is by no means exhaustive – the interested reader is encouraged to refer to "The Bar Code Book" for detailed information on these and many other machine-readable symbols.

Linear Width-Modulated Symbologies

UPC and EAN	Retail Point of Sale (POS) applications
Code 39, Code 128, I 2 of 5, Codabar	General industrial, logistics, and medical RSS

Linear Height-Modulated Symbologies

Postnet, Planet Code	U.S. Postal Service
Four State	Other Postal and services apps.

2D Stacked Symbologies

PDF417, Code 49	General industrial and logistics
MicroPDF	Small part labelling
PSS Stacked	
EAN.UCC Composite	

2D Matrix Symbologies

Maxicode	Logistics
DataMatrix	Electronics
QR Code, Code One, Aztec Code	General industrial

SCANNING

The process by which these optical symbols are "read" to extract the encoded information is commonly referred to as "scanning". The scanning equipment uses various approaches to examine different parts of the symbol in such a fashion that the symbology rules can be used to determine the embedded data. The actual decoding is performed by suitably-programmed processors: most of the equipment differences relate to the optical and packaging design.

Despite some early attempts to encode more information into symbols by using colours or "shades of gray", all of today's commonly encountered symbols use only two colours, Black and White. Note that the term "Black" is intended to include colored portions of a symbol that are intended to appear dark to the scanner. No matter how sophisticated, scanning equipment at its most basic level is trying to determine whether a particular part of a symbol is Dark or Light.

The most simple type of scanner involves a human operator dragging a wand (often called a "light pen") across a symbol. The scanning hardware is inexpensive, but the capabilities are limited, and the technique is only applicable to linear, width-modulated symbologies. This type of scanning is rapidly being replaced by more advanced techniques.

Laser Scanners

Laser scanning is probably the most common technique in use today. A laser beam is projected onto the symbol, and motor-driven mirrors cause the beam to follow a moving path through the symbol. The reflected light is then collected and converted to an electrical signal which is amplified and decoded. The mirror arrangement may cause the laser beam to simply trace out a single "line" on the symbol, or it may cause the line to move up and down (called "rastering"), or several different lines at varying angles may be projected. Fixed mount laser scanners employing a multitude of scan lines are commonly encountered in retail POS applications, where UPC symbols can be scanned omni-directionally because of the relatively tall symbol bar height. Hand-held devices projecting a single laser scan line are commonly used in a variety of general purpose applications. Rastering hand-held laser scanners are used to scan two-dimensional (2-D) stacked symbols, but some degree of operator care is needed to align the projected scan pattern with the symbol.

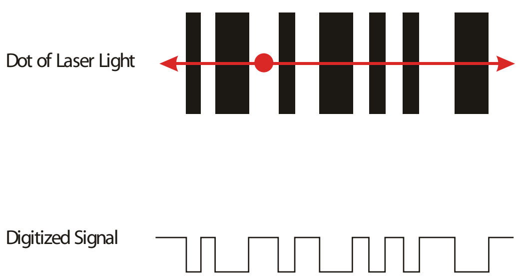


FIGURE 2 Laser scanning and the generated waveform.

Specialized high speed laser scanners have long been used to scan conventional linear width-modulated symbols on objects being transported on moving conveyor lines. Often several laser scanners are configured as an array, allowing them to scan symbols on any surface of a conveyed object. If a sufficient number of scan lines are used, it is possible to achieve omni-directional scanning of linear width-modulated symbols if the aspect ratio (the ratio of the symbol's bar height to the symbol length) is adequate. This type of equipment is generally not suitable for scanning height-modulated or randomly-oriented 2-D symbols.

Laser scanning equipment contain one or more lasers that are used as the light source. The majority of today's equipment uses solid state laser diodes, but some specialized equipment is still based on traditional gas laser tubes such as He-Ne (Helium neon). The laser diodes are rugged and reliable, whereas conventional gas laser tubes have a finite life, require high voltage power supplies, and need to be handled carefully.

Linear CCD Scanners

In the early 1980's, hand-held scanners became available that did not use lasers, and were more flexible and easy to use than wands. These were based on a semiconductor device known as a Charge Coupled Device (CCD), which is a linear arrangement of a large quantity of photosensitive elements which can be readily interfaced to electronic processing circuitry.

A linear CCD scanner is often packaged in a form factor reminiscent of a "windshield ice scraper". A row of LEDs projects red light onto the symbol to be scanned, and the reflected light is focussed onto the CCD. The contents of the CCD are electrically "scanned" to give a signal similar to that created by scanning a wand through a symbol. The device's internal microprocessor then analyzes the signal and decodes the symbol.

Linear CCD scanners need to be aligned with the symbol being scanned. These units are either used in contact with the symbol or in close proximity to it, although recent improvements in illumination technology have allowed for some improvement in working range. The operator typically moves the unit vertically through a symbol's bars until decoding occurs.

This type of scanning equipment was originally very popular in Asian retail POS applications because of cost and safety considerations. A linear CCD scanner is best suited for width-modulated linear symbols, but they can also be used for 2-D stacked symbols. These are relatively low cost scanners, and are a good choice for less sophisticated applications.

Imaging

"Imaging" is used to describe a form of scanner that "takes a picture" of a symbol, and then uses specialized image processing techniques to find the symbol and decode the contained information. There are usually no moving parts in an imaging system, and the symbol can be randomly oriented.

One of the first applications for this technology was in the postal sortation field. Large quantities of fixed mount equipment was deployed by the U.S. Postal Service in the early 1990's to scan randomly-oriented height-modulated symbols (Postnet) on rapidly-moving flat mail. In this particular application, conventional laser scanning equipment was unsuitable.

Fixed mount imaging systems found their way into a variety of conveyorized postal and logistics applications in the 1990's, based on the speed of the equipment, and the flexibility to work

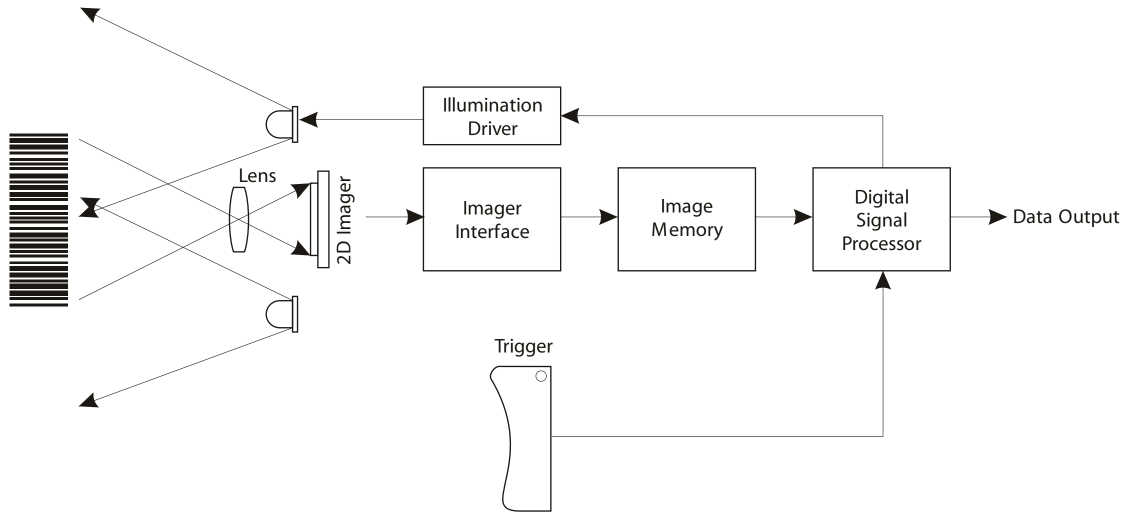


FIGURE 3 Block diagram of an imaging system

with a variety of different symbologies. It was possible to achieve omni-directional capability even on conventional width-modulated symbols with very short bar height, allowing imaging systems to compete very successfully against more traditional multi-laser arrays.

The rapid adoption of digital photography in the 1990's resulted in the ready availability of high resolution optical sensors. At the same time, the semiconductor industry was creating ever more powerful digital signal processing IC's and brighter solid state light sources (LEDs and lasers). It was inevitable that these two developments would be married together to create a hand-held imaging system for AIDC applications, and the first commercial product was introduced in the Fall of 1994. Since that introduction, a variety of imaging equipment has been developed by several different manufacturers. The early image-based systems tended to be somewhat large, and the decoding was noticeably slower than similar laser-based equipment, but the natural evolution of technology has overcome these drawbacks.

A general block diagram of an imaging system is show in Figure 3. The symbol is illuminated by some type of light source, and a lens system projects the scene's image onto a 2-D photosensitive array which is then interfaced to a powerful digital signal processor.

The signal processor is programmed with suitable algorithms that perform the following operations on the image data:

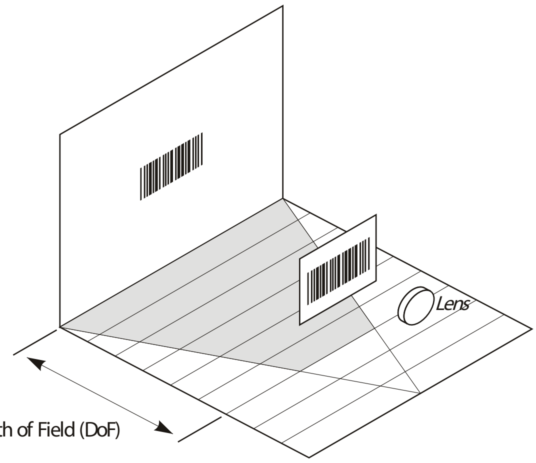
- Find the symbol. There may be lots of other optical information in the image that was captured (graphics, printing, packaging artifacts, etc), and it may not be immediately obvious where the symbol is located (or indeed, if there is a symbol at all). In order to perform this function effectively, an imaging system needs to incorporate a 2-D sensor and associated circuitry that can provide high resolution and dynamic range in order to accurately identify all dark/light transistions
- Determine the orientation. This is relatively easy to do for width-modulated linear symbols, but can be quite difficult with some of the more advanced 2-D symbols.
- Decode the symbol. Using the particular rules for the symbology, decode the information and perform any possible data checking. For some types of symbologies, this process includes an error-correcting step.
- Transmit or store the data.

All of this can get much more complicated if the imaging system is also configured to autodiscriminate between a number of different types of symbologies! Modern imaging systems usually incorporate powerful signal processors that are able to perform all of these functions without a noticeable delay to the operator.

Actual illumination of the symbol is usually performed by an array of LEDs. Recent developments have created LEDs that project white light at quite high intensity, making them ideal for this application. A fixed lens is usually used to focus the symbol on the photosensor array, but moveable lenses can also be employed if a greater Depth of Field (DoF) is called for.

One of the unique features of imaging systems is their ability to also capture graphical information, as well as decode symbols. They can be used to capture, compress, and store or transmit signatures, digital information, printed text, facial images, or even general photographic scenes.

As new ways are developed of encoding information into optical symbols, today's imaging systems can still be used for scanning: it is simply a matter or reprogramming the unit's processor – the hardware remains the same. This platform flexibility provides good insurance against future obsolescence.



COMPARING LASERS AND IMAGE-BASED SYSTEMS

When looking for suitable equipment to use in Auto-ID systems, the choice often comes down to either laser scanners or imaging systems. This is true both for fixed mount and hand-held applications, but the following comparison will focus on hand-held units.

Depth of Field

Both laser scanners and imaging systems are "non-contact" scanners. The range of distances over which they can successfully scan a symbol is referred to as the Depth of Field (DoF), and this parameter is highly dependent on the smallest element size in the symbol (the so-called "X dimension"). For traditional, linear symbols with a 10 mil (0.01 inch) X dimension, imaging systems will offer a DoF of about 8 inches, and laser scanners will provide slightly more. For symbols with smaller X dimensions, the DoF will be similar between the units. For symbols with X dimensions of greater than 40 mils, the laser scanner will offer greater DoF.

Resolution

The smallest symbol X dimension that can be resolved is a function of the scanners optical system. Both laser scanners and imaging systems are available with optional optical settings which allow them to resolve smaller X dimensions while sacrificing DoF for lower resolution symbols.

Working Range

Working range refers to the distance from the scanner to the middle of the DoF. For general purpose applications, this dimension is usually in the range of 6 to 8 inches in order to make it easy to aim at the desired symbol. There are some applications (such as scanning symbols on cartons at the top of racks in warehouses) where much greater working range (several feet or more) is desired these are typically best suited to laser scanners because of the intensity of their projected laser beam, however, progress is being made with imaging systems in this area as well.

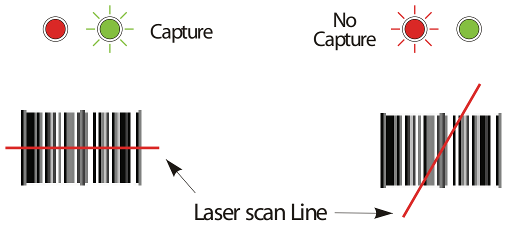
Types of Symbologies

Hand-held laser scanners project either a single scanning line or a "raster". This configuration works well for conventional width-modulated symbologies, but it is not suitable for decoding height-modulated symbologies (as commonly used in postal applications), or 2-D matrix symbologies. Imaging systems work equally well with all symbology types.

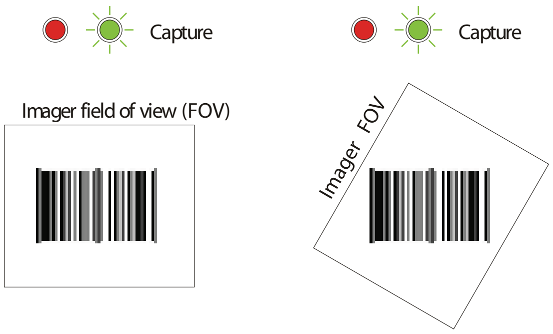
Omni-directional Scanning

A few types of hand held laser scanners have been developed with omni-directional capability for specific types of linear symbologies with high aspect ratios (such as UPC), but this capability is by no means general. Most laser scanners require that the operator align the scanner so that the projected laser line passes through the entire symbol at once. Imaging systems offer omni-directional scanning of all symbols.

Laser scanning

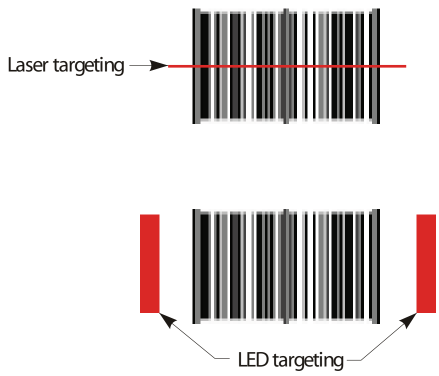


Omni directional scanning with an imager



Aiming

It is sometimes necessary to aim the scanner in a way to ensure that the correct symbol is read, and other nearby symbols are ignored. This is easily done with hand held laser scanners by pointing the projected laser line at the desired symbol. Likewise, imaging systems project "targeting marks" which define the area which is being imaged



Speed

Speed is a parameter which is very noticeable to an operator. When the trigger is pressed, the operator wants the symbol to be decoded and a "beep" to be heard as quickly as possible. This is an area where laser scanners used to have an advantage over imaging systems. Technology improvements have reduced the decoding time for Imaging systems, to the point where they are very comparable to laser scanners. However, the total time to scan a symbol should include the time to orient the scanner with the symbol, and when this time is included, the imaging system's omni-directional capability often gives it a slight edge.

Other Capabilities

Logistics applications often require the capture of signatures as well as the scanning of symbols. This capability is easily offered with imaging systems. In many applications, labels often contain several distinct bar code symbols which need to be read an imaging system with sufficient resolution can often capture all of the symbols simultaneously, whereas a laser scanner or CCD will require the operator to scan each symbol separately.

Upgradeability

Because they are built around a general purpose image-capture hardware platform, imaging systems can be adapted to a variety of new applications or symbology types by simply upgrading the firmware.

Size and Weight

Imaging systems and laser scanners are about the same size and weight.

Ruggedness

Today's laser scanners are very rugged, but imaging systems are inherently more reliable because they contain no moving components and are based on solid state technology with high Mean Time Between Failures (MTBF).

Safety

Laser scanners project a low-power beam of laser light, and are designed to comply with pertinent laser safety regulations. Imaging systems do not use lasers.

Cost

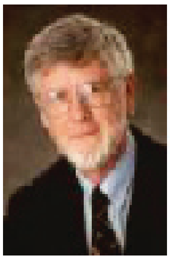
Imaging systems require more costly electronic components, but laser scanners require laser diodes and mechanical scanning elements. The material costs are roughly comparable between the two product types. There are a number of patents surrounding laser scanning technology, and many manufacturers are required to pay substantial royalties to the patent holders: this cost is then passed on to the end-user.

SUMMARY

There are still many applications where the low cost linear CCD scanner can provide adequate performance. The bulk of today's scanning applications use laser scanners, but imaging systems are starting to make inroads into applications based on modern 2-D matrix symbologies and new, emerging requirements for image capture. For the vast majority of applications, imaging systems provide similar (or better) performance to lasers, while providing an upgradeable hardware architecture that can provide future support for new symbologies or features.

About the author

A registered professional engineer in the province of British Columbia, Roger Palmer received an Electrical Engineering degree from McMaster University, and an Executive MBA from the University of Washington. Roger co-founded three successful companies, and currently he consults part-time through his company " Palmer Technologies" . In addition, he is the author of " The Bar Code Book" . a comprensive textbook on Automatic Identification, now in it's fourth edition.



Roger C. Palmer