White Paper

Supercharged ID: Image-based Barcode Readers Leap Forward With Breakthrough Technology

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Introduction: Manufacturers Rely on Laser Scanners and Conventional Image-based Readers

In the past, manufacturers have had two main categories to choose from when solving ID challenges: laser scanners and conventional image-based readers.

Laser scanners use a moving pinpoint of light to illuminate the barcode. A single photo cell receives the reflected light and converts the barcode into an electrical signal as it moves across a barcode (see Figure 1). The scanner then measures the relative widths of the bars and spaces, translates the different patterns into the barcode data, and sends them on to a computer or portable terminal.

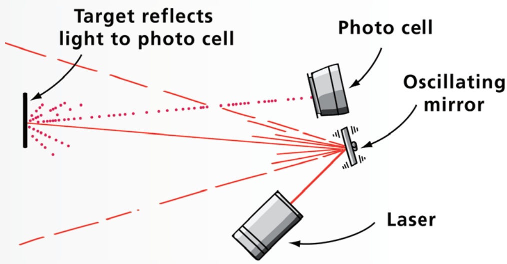

Figure 1. Laser Scanner technology. Most laser scanners sweep the laser beam horizontally using an electronically controlled oscillating mirror.

Laser scanners are able to read one-dimensional (1-D) barcodes in traditional high contrast applications, providing excellent performance for high-speed unidirectional scanning, offering large depth of field and a simple setup. Stitching several lasers together in an "X" or star pattern allows for omnidirectional scanning. However, less than ideal conditions—poor contrast codes, poor code quality, and perspective (angled) reading, for example—as well as the need to read the increasingly popular Data Matrix and other more complex two-dimensional (2-D) matrix codes—require a more robust approach.

Although laser-based systems are easy to set up, it can be a challenge to maximize read rates because users cannot see the images that the scanner is attempting to interpret. In addition, it is often difficult to determine the *reason* for an unsuccessful read, so optimizing the process proves next to impossible. Poorly printed codes, mistriggers, no code present, damaged codes, misaligned timing, etc. are all very difficult to debug with a laser scanner. Laser scanners also include moving parts (oscillating mirrors) which limit the equipment's mean-time-between-failures (MTBF) and useful life.

The other choice: conventional image-based readers (see Figure 2) generally connect commercially available components such as CCD or CMOS imagers and digital signal processors (DSPs) on a conventional printed circuit board (PCB). The reader captures an image, passes that image to the DSP to locate and decode any barcodes present, and then captures the next image in a pipeline fashion. A production environment with well formed high contrast 1-D barcodes can achieve reading speeds up to 45 decodes per second—suitable for many high speed applications that can benefit from the more robust reading capabilities of image-based systems.

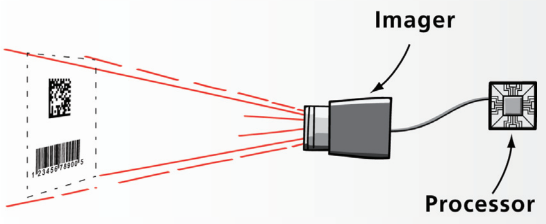

Figure 2. Conventional image-based reader technology. Note the horizontal width and a vertical height, which defines the scene the camera can see. The camera field of view gets wider as you move away from the lens but each pixel covers more area. At some distance the reader can no longer distinguish the cells or modules of a code.

Advantages and Limitations of Lasers and Imagers

Barcode quality, location, and orientation depend on a number of factors, including the supplier, the code printer, the amount that the product has been or will be handled, etc. Despite their speed, laser scanners' read rates fall off dramatically with inconsistent codes, and scanners typically cannot handle damaged codes or codes read at extreme perspectives. Image-based readers, on the other hand, which rely on solid-state camera technology, capture full-frame images in a single snapshot, avoiding the need to cross a barcode with scan lines from end to end the way lasers do. When an imager captures a frame containing a barcode, it can locate that code anywhere within the frame. Thus, in effect, each image contains thousands of scan lines in all directions making finding and reading barcodes more robust. Image analysis software algorithms can interpret a higher percentage of the captured codes than laser scanners can, and they can also manage the complexities of 2-D codes. In addition, the images themselves can be stored for training, historical analysis, or documentation.

Conventional image-based readers are typically designed for a single focal plane and offer only limited depth of field. System setup requires fixing variables such as the focus of the lens, aperture size, and target brightness. Changes in distance after setup cause images to be out of focus, overexposed, or otherwise misaligned. When a process provides consistent focus and lighting, however, conventional image-based readers offer clear benefits.

Some image-based readers make working within the requirements of focus and lighting easier. Cognex, for example, offers ID readers that incorporate liquid lens technology with autofocus, allowing users to change focal distances easily during line changeovers, thus reducing laser scanners' depth of field advantage. Also, software tools make optimizing a setup easier with features such as automatic target brightness and robust image analysis algorithms that are designed to handle some contrast variations and lighting changes. Nevertheless, until now a tradeoff has always existed between laser scanners and imagers depending on application priorities. While ease of use and well designed user interfaces can overcome some challenges, achieving the high speeds and throughput enjoyed by laser scanners presents a different kind of challenge.

Higher Levels of Chip Integration Never Seen Before

Until now, improvements in image-based readers have resulted primarily from improvements in individual hardware components. Third-party DSPs have increased in power and speed, image resolution has improved, and the introduction of multilayer PCBs has permitted optimizing component placement and reducing form factors. Improvements will continue to appear, however the system architecture limits any more fundamental changes.

Applications requiring speeds greater than 45 decodes per second require increasing image capture rates, processing speeds, and throughput. Decode speed—defined as the time required to capture an image and analyze it—is currently limited by the distance between the imager and the processor, the associated data transfer rates, and primarily the heavy analysis burden on the single DSP. Combining imager and processor on a single piece of silicon permits handling two tasks almost simultaneously, dramatically increasing decode speeds and overall frame rates. With its proprietary technology, called Cognex VSoC™ (vision system on a chip), Cognex has achieved this level of integration with the DataMan® 500 barcode reader (see Figure 3).

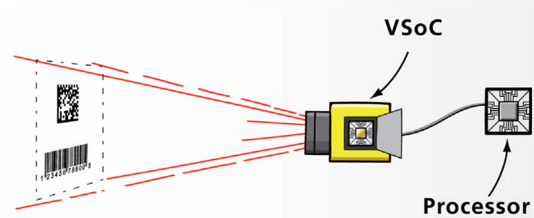

Figure 3. DataMan 500 image-based reader with Cognex VSoC technology

The VSoC includes a three-quarter-inch XGA CMOS active pixel image sensor that can capture high dynamic range (HDR) images and a single instruction multiple data machine called a linear array processor (LAP) optimized for real time image analysis. An external DSP provides additional processing for data decoding, formatting, and communication. Image-based readers built from this breakthrough technology can attain 1-D decoding speeds comparable to those of laser scanners while still enjoying the robust image analysis, 2-D code-reading capability, and other considerable advantages of the image capture technique as discussed above.

By capturing images and processing them in parallel, VSoC enables image capture speeds up to 1,000 frames per second and effectively *doubles* image-based 1-D barcode reading speeds to 90 decodes per second. A typical system (see Figure 4) with separate imager and processor operates in a serial pipeline fashion (one trigger, one image, one finder, one decoder, one output).

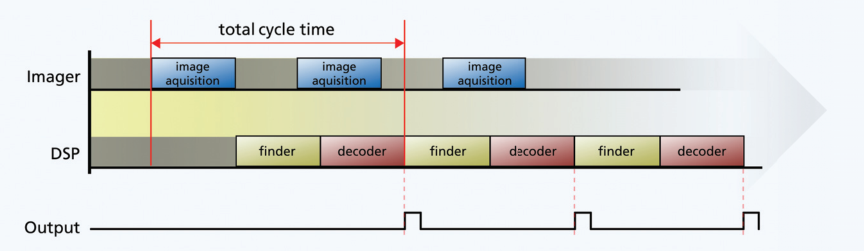

Figure 4. Conventional Serial Pipeline

For example, if a typical system runs at 60 frames per second, then an image capture occurs every 16 ms. That image proceeds to the processor, which must find and decode it in just 16 ms before it receives the next image. If the processor takes longer than 16 ms, then images must queue in a buffer and wait to be processed, reducing system throughput.

The VSoC on-chip processor captures multiple images through an autoexposure routine and determines in which image a barcode is present, locates it in the field of view, and reports its coordinates and orientation "on the fly" to the DSP (see Figure 5).

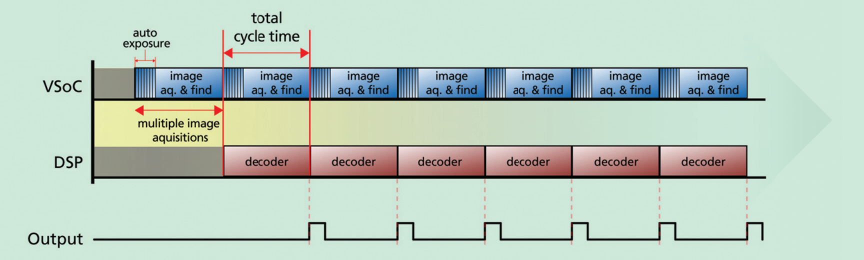

Figure 5. VSoC Optimized System. This system decodes at double the speed compared to the pipeline system above.

When the VSoC sends the images to the external DSP, it identifies which images to process and which to ignore. The external processor does not waste valuable time analyzing images that do not contain barcodes. For those that do, knowing the coordinates of the barcode means that the processor need only decode those small portions of the image, dramatically reducing the DSP's processing load. The VSoC effectively increases the image capture frame rates and the system throughput at the same time. "One trigger, one image, one finder, one decoder, one output", becomes "no trigger, multiple images with finding, one decoder, one output."

It All Adds Up to Simplicity, Easier Setup, and Cost Effective Operations

Increasing the frame rate without causing a huge buffer backup in the DSP offers other advantages as well. Higher frame rates combined with large pixels mean shorter exposure times. Shorter exposure times and large pixels mean the system can achieve higher speeds with less light than conventional imagers and can produce crisper, clearer images in high speed applications. The typical "one trigger, one image, one finder, one decoder, one output" scheme is particularly sensitive to variations in line speed or part location. The trigger must be well synchronized with the camera so that the barcode is in the same position in the image every time. On the other hand, the VSoC's high frame rate and its ability to discard images without codes as well as pinpoint the codes in the remaining images eliminate this need for a trigger.

Some conventional high speed imaging applications use an advanced triggering technique called "burst mode" to overcome positional uncertainty. For example, a Cognex DataMan 100 or 200 image-based reader can capture up to 22 images at a frame rate of up to 60 frames per second. Of the 22 images, perhaps only two or three that contain the barcode are buffered in the reader. Decode timeouts, set appropriately to decode those two or three images, would apply to all 22 images. Parts moving toward the reader would have to be spaced so that the reader finishes processing the buffered images before acquiring the next set of 22. Although this approach addresses positional uncertainty, the necessary part separation introduces an additional process complication.

In contrast, the VSoC's much higher frame rate allows capturing images without buffering them or requiring part separation. Also, the higher frame rate captures many more images containing the barcode, permitting more opportunities to read each code. In other words, less sensitivity to position uncertainty offers a more robust read result. Even with a damaged code or under less than ideal lighting conditions, at least one of the captured images will likely permit a relatively easy analysis. In addition, processing timeouts for images with codes can be set toward the average rather than the maximum, again improving total system throughput.

VSoC also handles target brightness and spontaneous lighting changes with a high speed auto-regulation routine. Ordinarily, these settings are fixed at setup, which makes imagers sensitive to changing conditions. The VSoC-optimized system performs these functions in real time at the chip level, giving it much greater tolerance for variations in lighting and depth of field. Based on "scene content", the routine specifically optimizes contrast between codes and background. For example, as parts move closer or farther away from image-based readers, the amount of light that they reflect changes. The high speed autoexposure routine handles these variations, especially those caused by differences in part height, glare, contrast levels from one part to the next, and part placement on the conveyor. The autoexposure routine combined with algorithms designed for difficult-to-read codes, results in a depth of field of up to ten inches with a fixed focus C-mounted lens with F-8 aperture. The high speed auto-regulation routine also works in conjunction with an optional liquid lens allowing an even greater depth of field.

Because of this automation, the VSoC technology within DataMan 500 makes the entire system simpler to use because position is not critical due to the large natural depth of field. By eliminating the additional setup of focus, exposure, special lighting, and triggers, downtime and changeover time are both reduced.

Summary

The challenges faced by imaging devices are not dissimilar to the challenges faced by PCs. As PCs must process and analyze ever larger images, microprocessors now include graphics coprocessors. A specialized DSP handles image-based tasks or a second DSP accelerates those tasks while a traditional DSP handles more typical processing. Cognex VSoC technology combines a dedicated imager and processor onto one chip that is highly optimized for accelerating vision related functions while relieving the sum of the burdens of the traditional DSP.

For straightforward applications that require only reading well-printed 1-D barcodes at high speeds at fixed positions, laser scanners will likely continue to provide a reliable, cost-effective solution. Traditional image-based readers will serve well in situations less concerned with high throughput than with detailed high reliability analysis of codes with varying quality, location, and orientation, when reading 2-D codes such as Data Matrix and QR, or when the line has indexed motion or stationary parts to provide a trigger. But when you need the most advanced capabilities of image-based scanning as well as high throughput, the VSoC-based DataMan 500 will offer you the best—if not the only—viable solution. This next generation system reduces downtime and changeover time, and will result in fewer parts rejected, less manual rework, and cost savings. And that’s an outcome that will be prized by many in the manufacturing sector.

About the Author

Michael C. Moed, Ph.D. has more than 20 years of professional experience in the machine vision industry. He has been an employee of Cognex since 1999, when he joined the company as a Principal Software Engineer. He is now Director of Engineering for Cognex’s Vision Sensors Business Unit. Dr. Moed holds a B.S.E. from the University of Pennsylvania, and an M.S.E. and Ph.D. from Rensselaer Polytechnic Institute.

About Cognex DataMan 500 Image-based ID Readers

The revolutionary DataMan 500 is a barcode reader powered by Cognex VSoC, a proprietary all-in-one vision technology developed by Cognex. VSoC enables a new level of performance for area-scan image-based readers never seen before.

DataMan 500 reads 1-D barcodes at twice the speed of other readers and is so easy to use, and reads codes so well, that it doesn't have to be positioned optimally to achieve high read rates.

POWERED BY VSoC

Speed, autoexposure, and trigger-free reading

- Acquires 1,000 frames per second
- Ultra fast autoexposure
- Decodes 90 1-D barcodes per second—two times the speed of conventional systems

Reduces overall setup costs, deployment time, and system complexity

- Increased depth of field
- Large pixel size
- High speed variable focus liquid lens

Reading robustness

- High read rates
- Minimal need for external lighting and precision alignment

COGNEX **Companies around the world rely on Cognex vision to optimize quality, drive down costs and control traceability.**

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