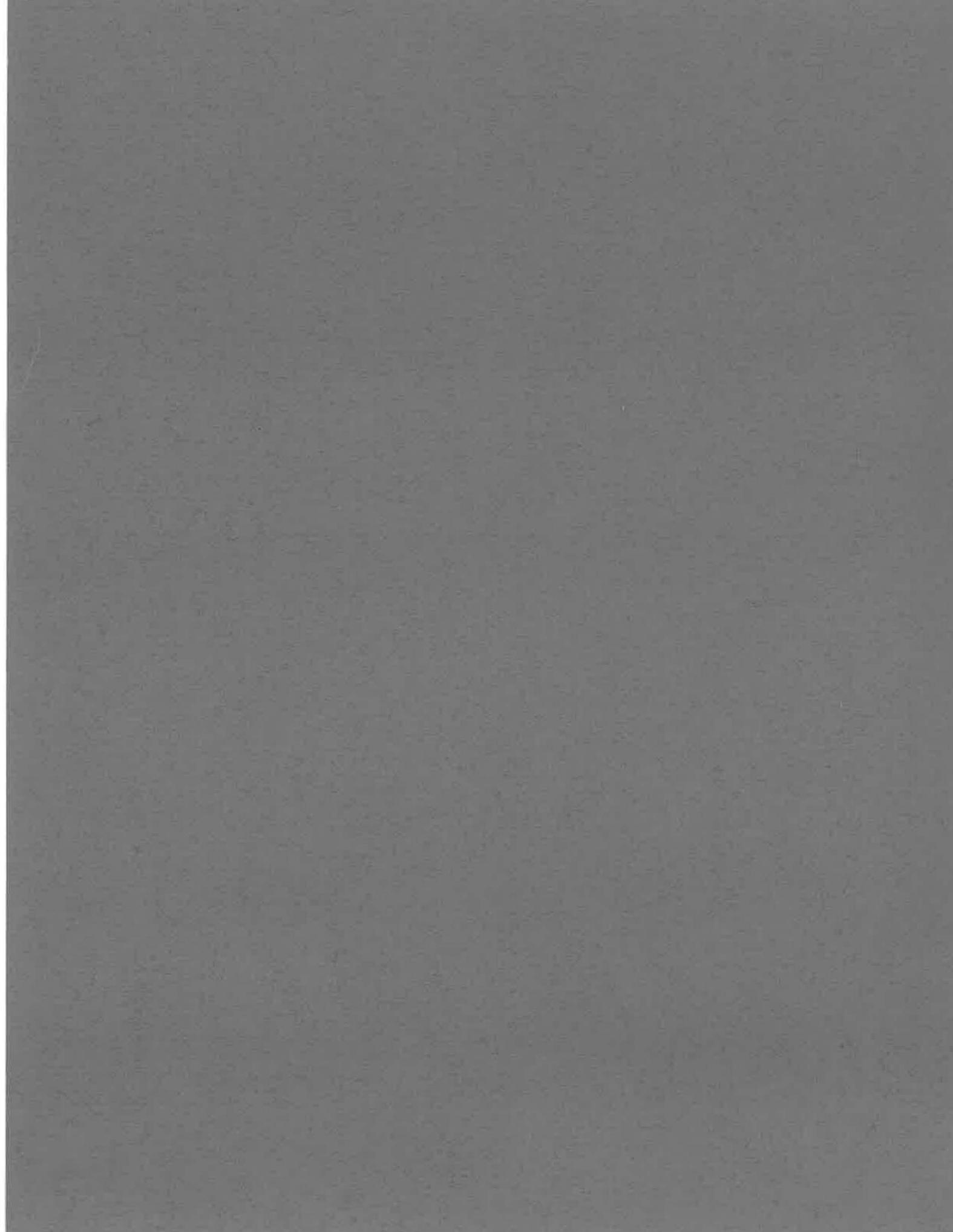


***Fixed-Mount  
Bar Code  
Scanning***  
*An Introduction*

***Mike Mertel***



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### **About the Author**

Mike Mertel is internationally recognized for his technological innovation in the field of bar code scanning. In 1982 he constructed the first laser diode bar code scanner. As the founder and Chief Engineer of Microscan Systems, Inc. he has been involved in thousands of fixed laser scanner applications and installations.

# ***Introduction — The Purpose of this Booklet***

The rapid growth and expansion that we've seen in other advanced technologies are now happening in the field of bar code scanners. It's an exciting time for users and developers alike, as new technologies find real-world applications on an almost daily basis.

Right now, the practical, reliable, economical uses of bar code scanners are greater than most people imagine — greater, in fact, than many of us in the industry had foreseen just a few years ago.

This booklet is intended to give you an introductory overview of fixed-mount bar code scanners: how they work, what they can and can't do, and how they can meet your specific requirements. I have not attempted to make a case for any particular technology or product, nor have I gone into extreme detail about such issues as bar code label production, interface with a host computer, etc.

Through the years, I have found that a little up-front planning and a few simple questions can ensure a successful fixed scanner application. In contrast to hand-held scanners that have the advantage of a human operator to trigger and aim the scanner, fixed mount scanners require a well thought-out plan.

Even so, the issues and criteria involved are relatively simple. Familiarize yourself with the basics, know the right questions to ask ... and don't stop asking questions until the answers make sense.

I hope this booklet provides a good point of departure for you. If you have any questions or comments along the way, we at Microscan would enjoy hearing from you.

*Mike Mertel*

# ***Fixed-Mount Bar Code Scanners: Background and Applications***

The earliest bar code scanners were capable of little more than rudimentary identification and counting tasks. By today's standards, they were quite cumbersome and required a great deal of human attention (and patience).

The fixed-mount scanner application which comes most readily to mind is the scanning of items on a conveyor. This type of system is very common and straightforward, which is why most of the examples and illustrations in this book deal with this type of system. However, this is by no means the only application of fixed mount scanning.

As in any rapidly evolving industry, more sophisticated technologies have proliferated as users demanded increased capability, more power and greater flexibility to adapt to their specific requirements. Today's scanner marketplace offers a broad (and, perhaps, confusing) variety of products, prices, capabilities, and levels of complexity.

During this period of rapid research, development and deployment, fixed-mount scanners (as opposed to the hand-held variety) have emerged as superior solutions in a wide range of installations. For a growing number of companies and applications, fixed scanners have proven themselves flexible, reliable and economical in both the short and long term. And as the technology continues to progress, these advantages are becoming even stronger.

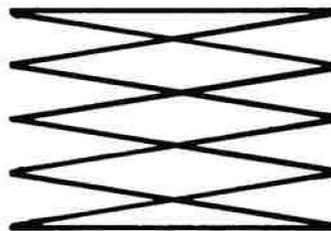
## ***Types of Fixed-Mount Scanners***

When one considers bar code reader applications, fixed-mount scanners definitely belong in a class by themselves. As you look more closely at this group, however, you'll find some striking differences. One of the most noticeable differences is in the scan patterns emitted. Although this booklet focuses on **line scanners** (unidirectional), other available types include raster and omnidirectional scanners.

### ***Types of Fixed-Mount Bar Code Scanners***

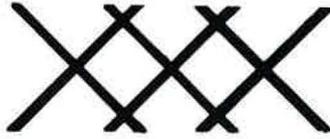


*Line Scanner*

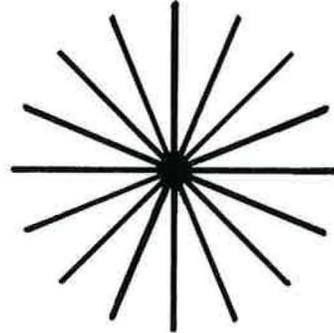


*Raster*

## *Types of Fixed-Mount Bar Code Scanners (cont.)*



*Omnidirectional (multi-line)*



*Omnidirectional (star pattern)*

At first, many applications may seem to require a raster or omnidirectional type of scanner. While these scanners do have their own niche in the industry, they are most often very cost-prohibitive. Line scanners are by far the most economical and, as you will see in the following pages, the most flexible and least complex of all fixed-mount scanners available today.

### ***Moving On . . .***

#### **The prospective user of a fixed scanner system is in an enviable position.**

In most cases it is quite reasonable to insist on a system that exactly meets your present and foreseeable needs at an affordable price. The first step, then, is to figure out exactly what you expect the scanner system to do. Be specific and be demanding. Remember, the scanner is working for you (not the other way around).

Once you've defined your needs in your own terms, you can begin to define solutions in terms of the scanner. The following sections should help you to plan your own installation, by considering such criteria as:

- How fast is the label moving past the scanner?
- How far away is the label and how much will that distance vary?
- Can the scanner read your label at the desired distance?
- How does the scanner know when to read and output the label data?

# How Fixed-Mount Scanners Work

Most people who have worked in a data collection environment have seen or used some kind of hand-held bar code scanner. Because of this familiarity, a good place to begin discussing fixed-mount scanners is to talk about how they differ from bar code "guns."

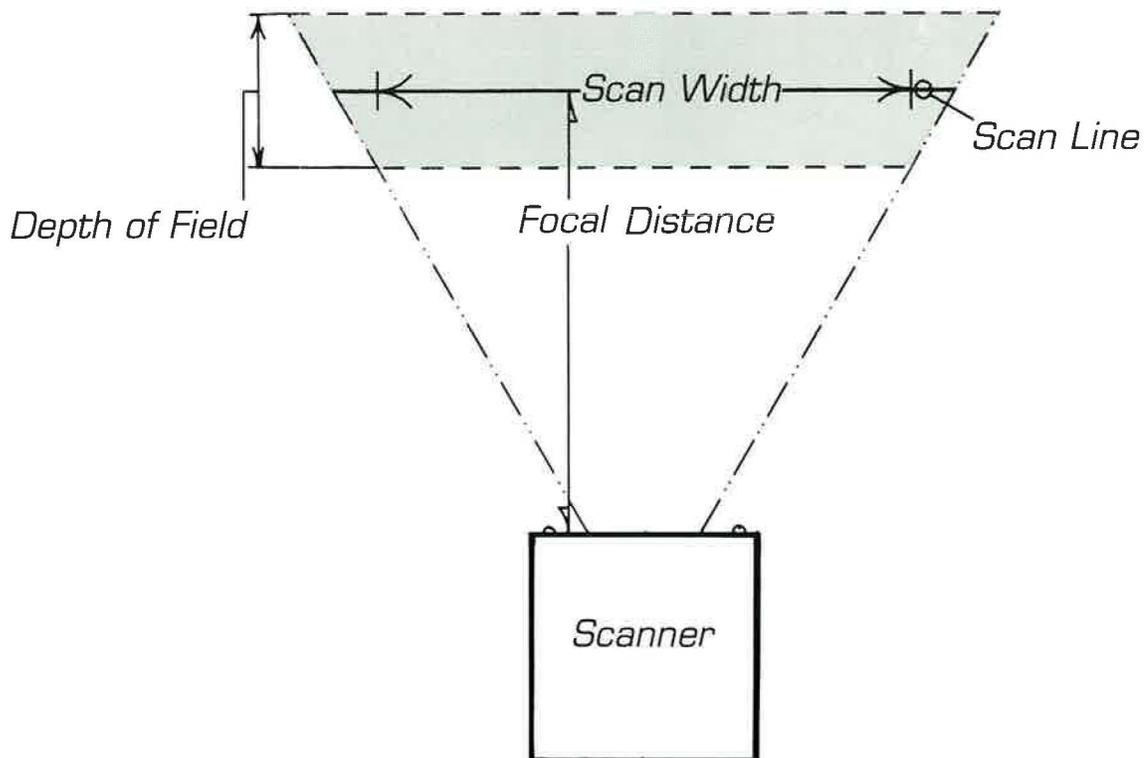
If you've ever used a hand-held scanner, you recall how easy it is. You aimed the gun at the bar code, pulled the trigger, and —"beep!" — the read was successful.

Actually, there was much more going on. First, even though you approximated an aim at the bar code before pulling the trigger, once the red scan line appeared, you moved it until it hit the bar code. Second, once the scan line was on the bar code, if no read occurred, you manually moved the scanner either toward or away from the bar code until a good read occurred. In other words, you moved the scanner's field of vision into the area of the bar code label.

In fixed mount scanning, there's no operator to assist the scanner, which brings us to a very important consideration: **Fixed mount scanners must be positioned so that all labels passing by will appear within the "read window."**

"Read window" refers to the region within which the scanner is capable of reading bar code. The read window is defined by the scanner's **scan width, focal point and depth of field.**

## The "Read Window"



The **scan width** is simply the distance along the scan line over which the scanner will read. This is usually less than the overall length of the scan line due to decreased signal strength at each end of the scan line. The **focal distance** (also called focal point, focus, or optical throw) is the distance between the scanner and the point upon which it is focused. **Depth of field** is the region in front of and behind the focal distance within which the scanner can still read bar code.

The focal point of a fixed mount scanner is usually specified by the manufacturer. The depth of field, however, depends on both the focal point and the bar code density being used. As in photography, the greater the focal distance, the greater the depth of field. Depth of field also depends on the density of bar code being read. For example, a label with narrow bars of .020 inch (low density) may be read over a greater depth of field than one with .0075-inch narrow bars (high density).

Finally, not all bar code densities may be read at all focal points (just as a newspaper and a highway sign have very different optimal reading distances). High-density bar code labels require short focal distances and lower-density bar codes allow longer focal distances.

This brings up another key point about fixed mount scanning: **The distance at which a scanner is required to read must be compatible with the density of the bar code being read.**

This is a very important consideration when choosing a bar code label and scanner. It is very difficult to match a fixed mount scanner with a high-density bar code unless the focal distance is relatively short. If longer focal distances will be required, a medium or low density label will provide much greater flexibility.

# ***The Bar Code Label***

The label itself is the most critical element in any bar code system—and the most often overlooked. Choosing the right symbology, density and printing method for your application will keep you from falling prey to the classic G.I.G.O. (garbage in, garbage out) syndrome.

The first step is to determine which symbology is appropriate for your application. There are many fine publications (such as the AIM Auto ID Manual) which address the attributes and disadvantages of various bar code symbologies, so I won't exhaustively duplicate that information here. However, here are a few points to consider which should give you a good start:

- What type of bar code and printing methods are your competitors using? For strategic reasons, should you conform to a standard (or pseudo-standard) used in your industry?
- Would anything in your installation be likely to degrade the label (cleaning solvents, heat, abrasion, airborne contaminants, etc.)?
- Be realistic about long-term label quality. For example, dot matrix label printers require periodic ribbon changes. Could the temptation to extend the time between changes jeopardize system integrity? In some installations the labels will need to be replaced occasionally because of wear and tear, so choose labels durable enough for your application.
- If space is not at a premium, use a lower density code and a 3:1 wide-to-narrow bar ratio (the large bar is three times the width of the narrow bar). A 3:1 ratio allows a greater margin of error in the label printing process.
- Choose labels of the right size and density.

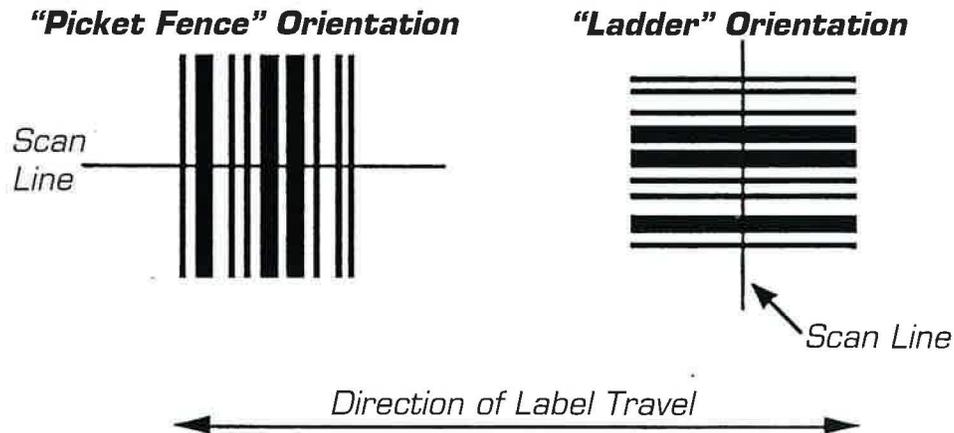
## ***Sizing and Orienting the Label***

**One of the most commonly asked questions concerning fixed-mount scanning is, "How fast can the bar code label travel?"** While scan speed is an important factor in determining this, the size and orientation of the label can be equally important. In some applications, size and orientation are dictated by the space available on the bar coded item (or simply by having no control over label placement). In these cases you must simply work around the constraints, compromising where necessary.

Of course, in some applications the label will be stationary when read, so the label need only be large enough to insure that it is under the read window in its stationary position. However, even when the label comes to a stop when being read, it is advisable to set up the scanner so it has a chance to read a portion of the label while

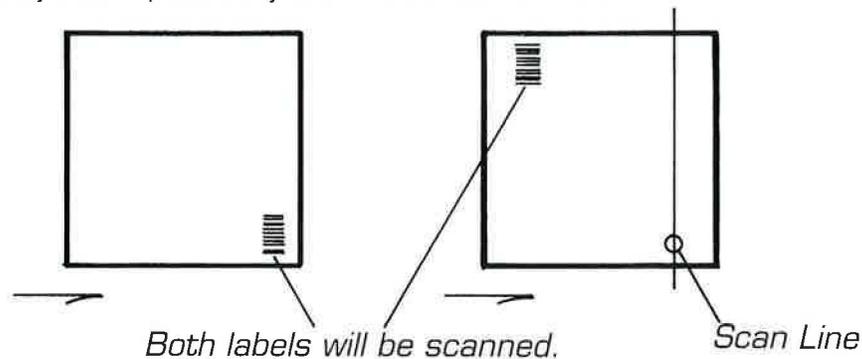
it is moving. This way, even if the label is damaged, the chances of "finding" a readable scan are much greater.

A label's orientation is commonly referred to as either "ladder" or "picket fence." This is a case where a picture is worth a thousand words:

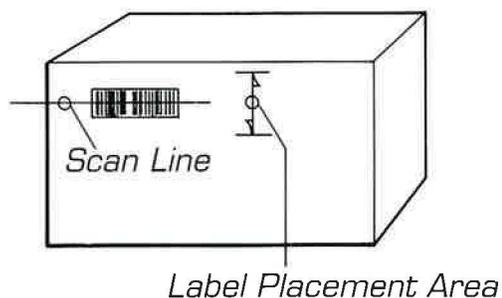


### **Ladder Orientation**

In general, if the label size and speed allow it, the ladder orientation is preferable since the scanner will be scanning different portions of the label as it goes by. Also, label placement is not as critical. As the illustration shows, a ladder-oriented label may be successfully read if placed anywhere within the "scan line."

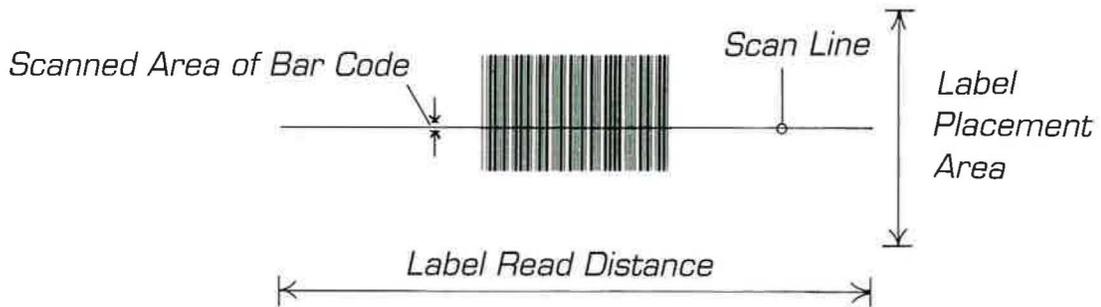


### **Picket Fence Orientation**

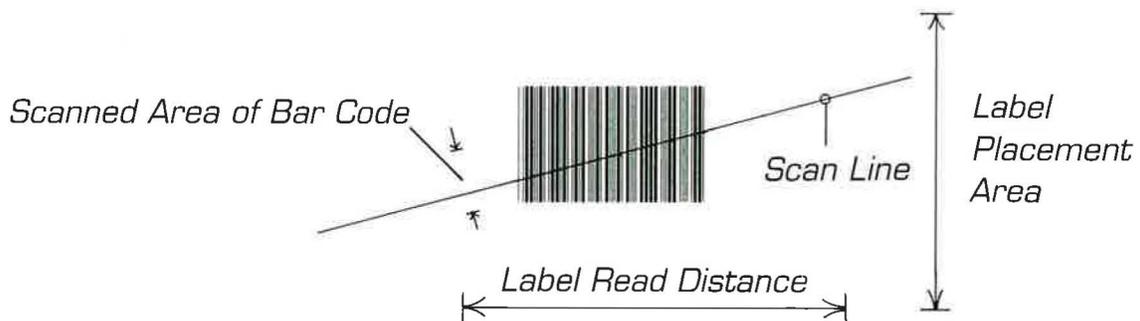


Unlike ladder orientation, the picket fence orientation usually has the disadvantage of only allowing a small portion of the entire label to be scanned. If the label is of questionable quality, or if an ink spot or void is present at the scanned portion of the label, the scanner may not read it. In addition, label placement is critical, especially when using very narrow bar codes.

### **"True" Picket Fence**



### **"Angled" Picket Fence**



If you must use the picket fence orientation, you can minimize these problems by slightly tilting the scan line. Thus you can scan a larger portion of the label and increase the label placement area by "simulating" the ladder orientation. Of course, with a short bar code height, an angled scan line is impractical. This angled picket fence approach is recommended only where the bar code is reasonably tall and the label speed is not too fast in relation to the scan field width, as angling the label will reduce the number of scans on the label.

One advantage of picket fence orientation can be in the area of label speed. In ladder mode, the label travel distance is the height of the bar code. In picket fence mode, the label can be read while it travels the entire scan field width. The scanner thus gets a longer look at the bar code. The examples in the following section help to illustrate this.

# ***Label Speed and Scanner Speed***

Probably the most complicated part of a moving-beam scanner application is determining whether the scanner is fast enough to scan a particular label reliably. Although a scanner can successfully read a bar code in two scans, experts generally recommend a minimum of five scans to read a well-printed label reliably.

The following formulas are useful for calculating how many actual guaranteed scans will occur given any combination of label size, speed and orientation.

The number of effective scans from a passing label is determined by:

- Scan rate
- Direction of label travel
- Speed at which the label passes
- Bar code label dimensions

Whether the bar codes are presented to the scanner in ladder or picket fence orientation, the number of complete scans per each pass of a label can be determined.

## ***Ladder Orientation***

If bar code labels are presented to the scanner in a ladder orientation, the number of scans per each pass of a label can be determined from the following parameters:

LH = Label height (inches)

LS = Label speed (inches/second)

Scan rate = scans/second (specified by manufacturer)

The following equation is used:

$$\left( \frac{LH}{LS} \times \text{Scan Rate} \right) - 2 = \text{Number of Complete Scans}$$

The “— 2” factor in this equation is to compensate for incomplete first and last scans.

Note: If the result of the calculations in the brackets is 3 or more, — 2 applies. However, if it is 2, subtract only 1, giving one good scan.

### ***Examples***

- #1** LH = 0.5 inches  
LS = 10 inches per second  
Scan Rate = 200 scans per second

$$\left( \frac{0.5}{10} \times 200 \right) - 2 = 8 \text{ Complete Scans}$$

**#2** Same example except with scan rate = 400 scans per second

$$\left( \frac{0.5}{10} \times 400 \right) - 2 = 18 \text{ Complete Scans}$$

### **Picket Fence Orientation**

If bar code labels are presented to the scanner in a picket fence orientation, the number of scans per each pass of a label can be determined from the following parameters:

LL = Label length (inches)

SW = Scan width (inches)

LS = Label speed (inches/second)

Scan rate = scans/second (specified by manufacturer)

$$\left( \frac{SW - LL}{LS} \times \text{Scan Rate} \right) - 2 = \text{Number of Complete Scans}$$

The “-2” factor in this equation is to compensate for incomplete first and last scans. Note: If the result of the calculations in the brackets is 3 or more, - 2 applies. However, if it is 2, subtract only 1, giving one good scan.

### **Examples**

- #1** LL = 1.5 inches  
SW = 3 inches  
LS = 10 inches per second  
Scan Rate = 200 scans per second

$$\left( \frac{3 - 1.5}{10} \times 200 \right) - 2 = 28 \text{ Complete Scans}$$

- #2** Same example except with scan rate = 400 scans per second

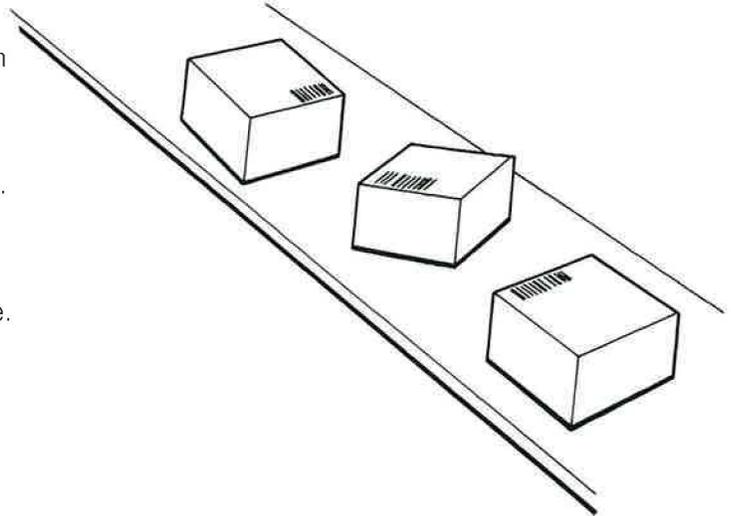
$$\left( \frac{3 - 1.5}{10} \times 400 \right) - 2 = 58 \text{ Complete Scans}$$

It is recommended that adjustment to the line speed or label dimension be done if the total number of complete scans is less than five. However, with bar code of consistently good quality, a high success is possible with as few as two scans.

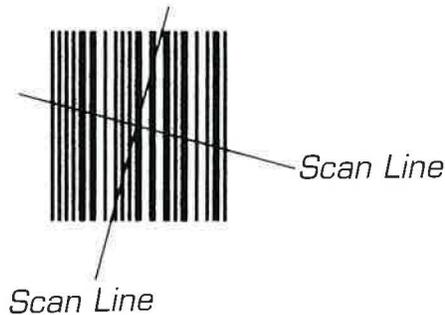
Note: These calculations must use consistent units of measurement ( i.e., inches and inches/second; mm and mm/second, etc.).

## Special Cases

In some cases, the application defines whether the label orientation will be ladder or picket fence. In other cases, however, the label may not appear in *any* defined orientation. If labels are hand-applied or if the package orientation is random, the label may pass the scanner in any orientation within a 360-degree circle.



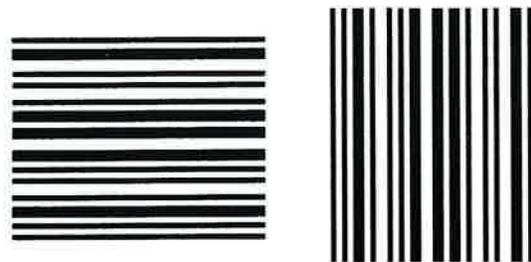
### Oversquare label



This type of application can be almost impossible to handle with a unidirectional scanner. However, with some flexibility in the label size, a solution can be found. If the label is **oversquare**, (in which the height of the bar code is greater than the length of the bar code, including "quiet zones"), two perpendicular scan lines (forming an "X" pattern) will read it in any orientation.

A similar solution is the omnidirectional airline baggage label of two perpendicular, oversquare bar codes. A single scan line will read this label in any orientation.

If label orientation cannot be controlled and the bar codes cannot be oversquare, a very complex and expensive scanner may be needed.

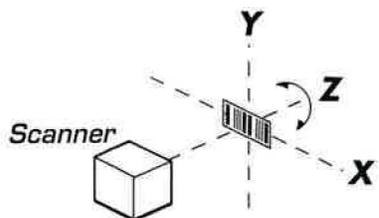


### Omnidirectional label

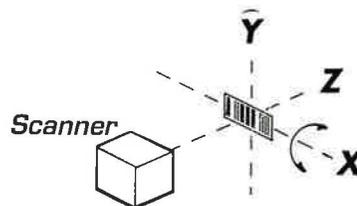
# Planning Your Installation

Having dealt with the bar code label, its size and its orientation, we're now ready to consider it as part of the total fixed-mount bar code scanner installation. In doing so, keep the following in mind:

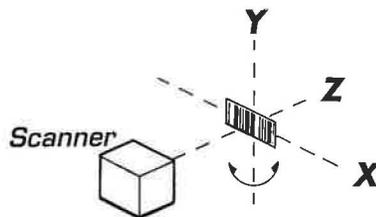
- Can you place the label in the ladder orientation? This orientation affords more chances to read a damaged label, and label placement is not as critical as in a picket fence orientation. In general, resort to a picket fence setup only if the ladder mode won't work in your installation.
- Have you avoided tilt, pitch and skew of the label as much as possible?



*Tilt is label rotation around the Z axis  
(Label dependent)*



*Pitch is label rotation around the X axis  
(60% typical)*



*Skew is label rotation around the Y axis  
(45% typical)*

## Optical Throw and Depth of Field

Next you must determine if the scanner can read your label at the distance you've chosen. Every scanner manufacturer publishes specifications describing these capabilities. The optimum distance (optical throw) and the difference between the nearest distance and the farthest (depth of field) are detailed for several different minimum-bar-width bar codes. As we discussed earlier, bar codes printed with narrow bars and spaces will have shorter optical throws and smaller depths of field.

The manufacturer will also specify the maximum angles of tilt, pitch and skew allowed. Pay close attention to these specifications and be aware that they apply only to well printed, high-contrast labels. Eighty percent of the scanning equipment on the market today requires at least forty percent contrast between absolute white and black.

Finally, in any new bar code system, always try your chosen labels with the scanner you intend to use — before you install 500 scanners or print 10,000 labels!

## ***System Considerations***

Fixed-mount bar code scanners collect data (usually on command), then either send the data to a host computer or activate an electronic signal line that causes something to happen. For accurate code/object detection, the scanner needs to be told when a label is supposed to be read. This is accomplished when either (1) a sensor sends a signal to the scanner, or (2) the host computer sends a "read" command.

Some kind of triggering is advised because it gives the scanner an indication that it should see a bar code. Then, if no bar code is read after a reasonable length of time (or after the bar coded item has gone away), a "No Read" message is sent to the host, prompting appropriate action for a mislabeled, unreadable or unlabeled package.

In cases where no trigger is available, the scanner can operate in a "continuous-read" mode, in which any label will be read repeatedly. However, in a continuous-read mode, a label could pass by without the scanner's detecting it if it were out of the read position or unreadable for whatever reason.

You can also choose to read continuously but only output different labels, thus getting only one output for each distinct label. You may also incorporate timeouts with some scanners. As you can see, this can get a little complicated, so be certain to think the application through completely (including the unexpected) before charging ahead.

## ***Scanner Mounting and Environment***

A number of factors should be taken into account when mounting fixed bar code scanners. One often overlooked item is the laser beam path itself. Some laser scanners are rated Class II visible light. This means that they have a very bright, intense beam and should not be mounted where a worker's eyes could encounter chronic exposure to the beam or its direct specular reflection. Most infrared scanners are rated Class I and there is no need for such precautions, although continuous eye-beam contact is not recommended.

The bracket for mounting the scanner should be made adjustable if possible, especially if the bar code label is small or its location may change over time. Scanner mounting presents a number of other considerations. For example:

- Is there power available for the scanner?
- Does mounting hardware or any other object obstruct the scanner window?
- If the scanner consists of two separate units (scanhead and decoder), is the distance between them within specification?
- Has room been left for the communication cable and connector?
- Is there reflective material or hardware around the scanner?

The environment in which the scanner will be mounted can also affect its performance. Consider the following:

- What are the shock and vibration levels, if any?
- Are there any sources of electromagnetic interference?
- Does the ambient temperature exceed the scanner rating?
- Does the ambient light exceed the scanner rating? Some pulsed infrared photo sensors can also disrupt scanner operation.

## ***Summary and Conclusions***

By no means have I covered every question that must be answered in every installation. However, if you combine this basic information with a clear definition of what the system must do to justify your investment, you should have a successful installation and happy users. This can be an exciting and challenging process.

But the most exciting part of all is yet to come — when you finally put your system to work and watch it collect data with tireless reliability while workers are free to perform other important tasks. There's nothing like seeing your own planning and work and investment pay off (and when a fixed scanner installation is done right, there's no doubt about the payoff).

I hope that you've found this booklet useful, and that your scanner installation is a complete success.

— *Mike Mertel*

## ***Terminology***

**Density** — The number of narrow bars and spaces represented in the symbol divided by the total width of the symbol, usually expressed as characters per inch.

**Depth of field** — The region in front of and behind the focal distance within which the scanner can still read bar codes.

**Focal point** — The specific measured distance between the scanner and the label at which a bar code can be optimally read.

**"Ladder" label orientation** — Orientation of the bar code label so that the direction of label travel is parallel to the bars and perpendicular to the scan line.

**Omnidirectional** — A scanner that can read in both horizontal and vertical label positions, or any position between horizontal and vertical.

**Optical throw** — The region between the scanner and the readable depth of field.

**Oversquare** — A label in which the height is greater than the length.

**"Picket fence" label orientation** — Orientation of the bar code label so that the direction of label travel is perpendicular to the bars and parallel to the scan line.

**Pitch** — The rotation of a bar code symbol about an axis perpendicular to the bars.

**Raster** — More than one scan line in two or more horizontal dimensions to allow reading of bar codes in different positions.

**Read window** — The region within which the scanner is capable of reading bar code. The read window is defined by the scanner's scan width, focal point and depth of field.

**Scan line** — The beam of light that reads across the bar code for information.

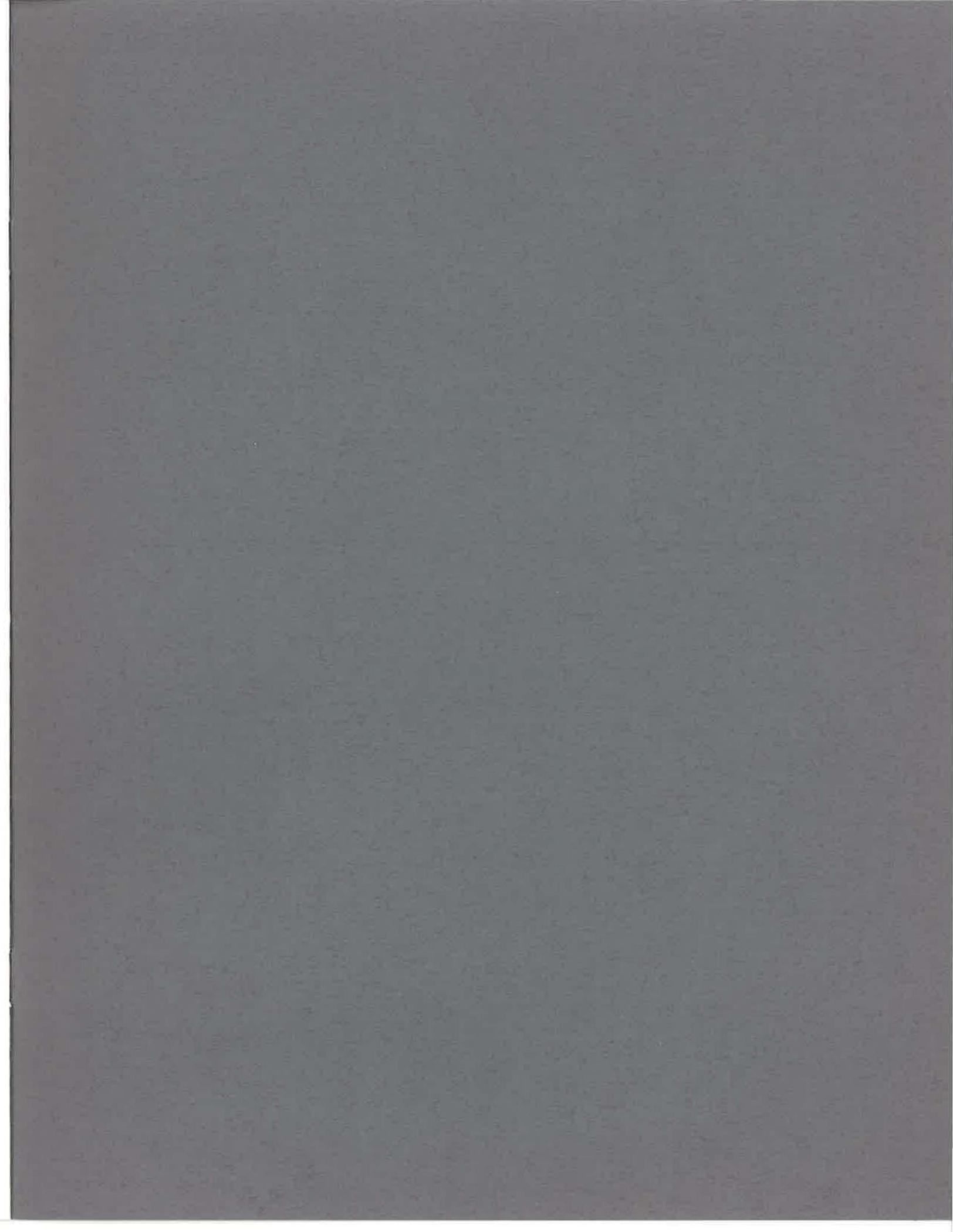
**Scan rate** — Scanner speed, in scans per second.

**Skew** — The rotation of a bar code symbol about an axis parallel to the bars.

**Symbology** — The combination of bar code characters and spaces which provide information processing for a variety of applications and specifications.

**Tilt** — Rotation of a bar code symbol about an axis perpendicular to the substrate.

**Trigger** — A method for informing the scanner/decoder of when to look for bar codes. This can be an external sensor device or a host-generated signal.



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