SENSORS INTEGRATION

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Design for Inspection

By David Kotula

PACKAGING DETAILS TO CONSIDER FOR MACHINE READABILITY AND VALIDATION

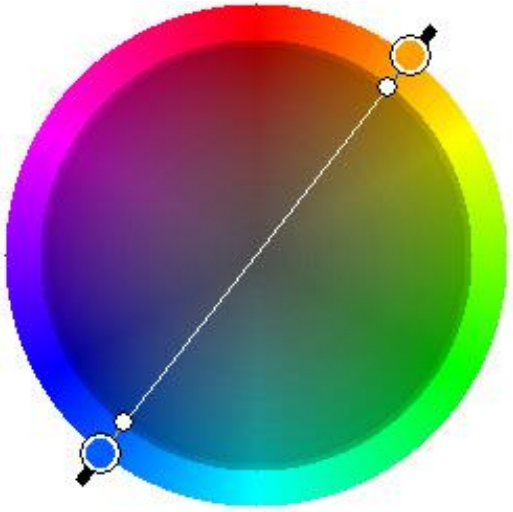
- **COLORS- How package colors look in Grey Scale**
- **Are PATTERNS like logos and shapes separated by space?**
- **Are 1D and 2D BARCODES printed to GS1 specifications and free of infringements?**
- **Is the TEXT for Date Code/ Lot Code/ Best if Used By an “OCR A” or “OCR B” machine readable font?**

COLORS- HUMAN VISION VS. MACHINE VISION

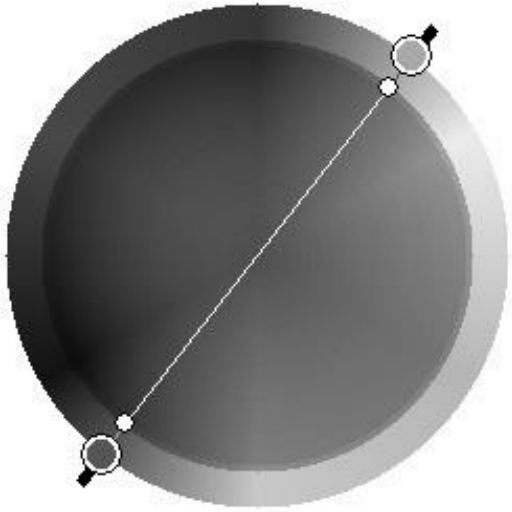
- **Humans process huge amounts of data almost instantly and filter out unnecessary data**
- **Machine vision systems are roughly equivalent to color blind 3 year old**
- **Machine vision is color blind**
  - Even with a color camera, they convert separate channels to grayscale (Red-Green-Blue with levels of Hue-Saturation and Intensity) and run the inspection tools on the grey scale image
- **Machines don’t have ‘context clues’**

MACHINE VISION THRIVES ON CONTRAST

- **The goal of DFI is to create the highest contrast for machine vision while creating aesthetic designs for human vision**
- **Contrasting colors to the human eye may not be contrasting to machine vision**



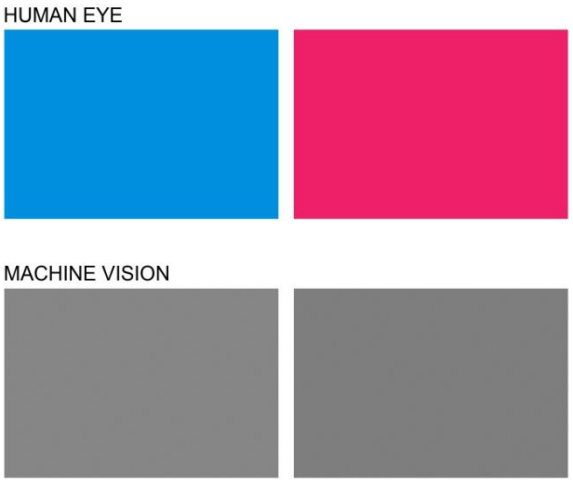
Human Perception

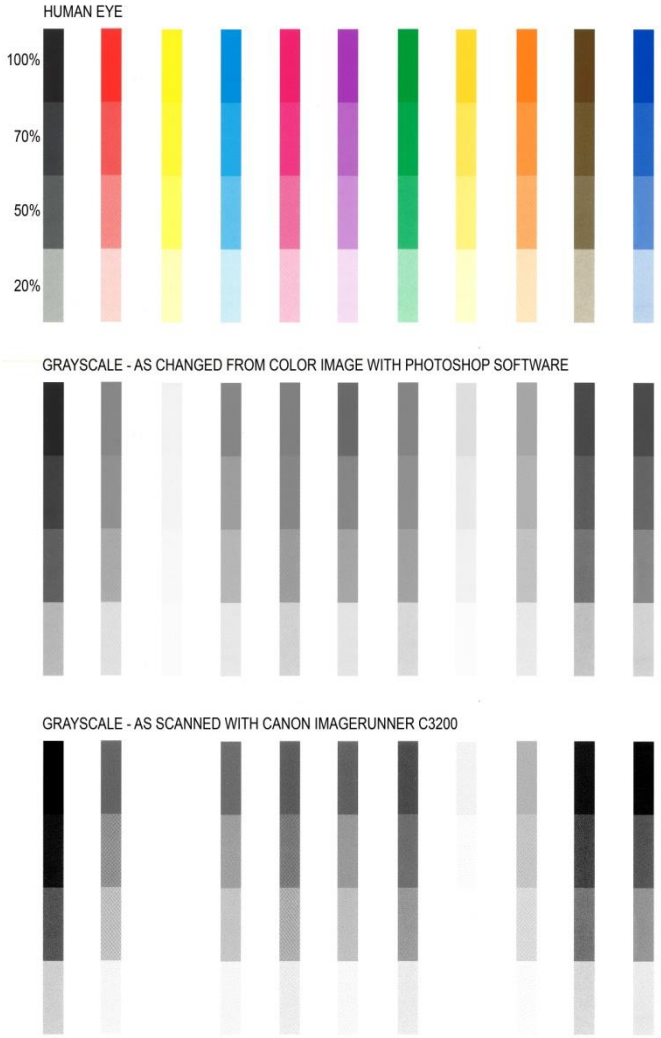


Machine Perception

COLOR CONTRAST VS. GRAYSCALE CONTRAST

- **Ideal contrast is black and white**
- **Lower contrast can work but causes increased camera decoding times**





COLOR BY THE NUMBERS

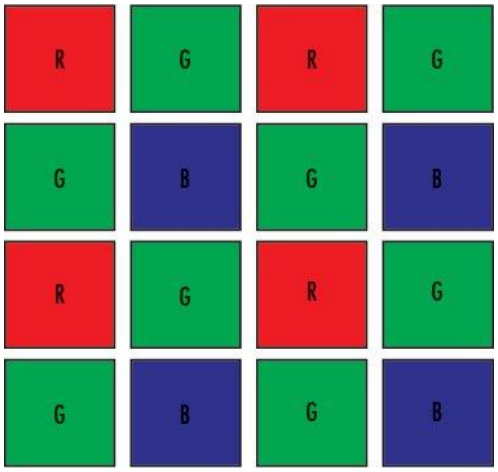
- **Humans have approximately 65,000,000 colors**
- **Machine vision corresponds to 255 shades of gray**
  - Must be at least 10 shades apart to see difference
- **Effectively about 26 shades of gray (including white + black)**
  - The further apart the two colors are, the faster the machines will read

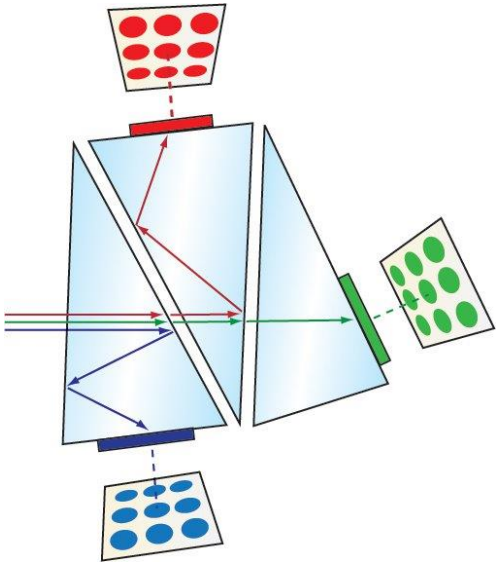
26 Shades of Gray

MACHINE VISION

COLOR CAMERAS VS MONOCHROME (GREY SCALE) CAMERAS

There are two types of color CCD cameras: single chip and three-chip. Single chip color CCD cameras offer a common, low-cost imaging solution and use a mosaic (e.g. Bayer) optical filter to separate incoming light into a series of colors. Each color is, then, directed to a different set of pixels. The precise layout of the mosaic pattern varies between manufacturers. Since more pixels are required to recognize color, single chip color cameras inherently have lower resolution than their monochrome counterparts; the extent of this issue is dependent upon the manufacturer-specific color interpolation algorithm.

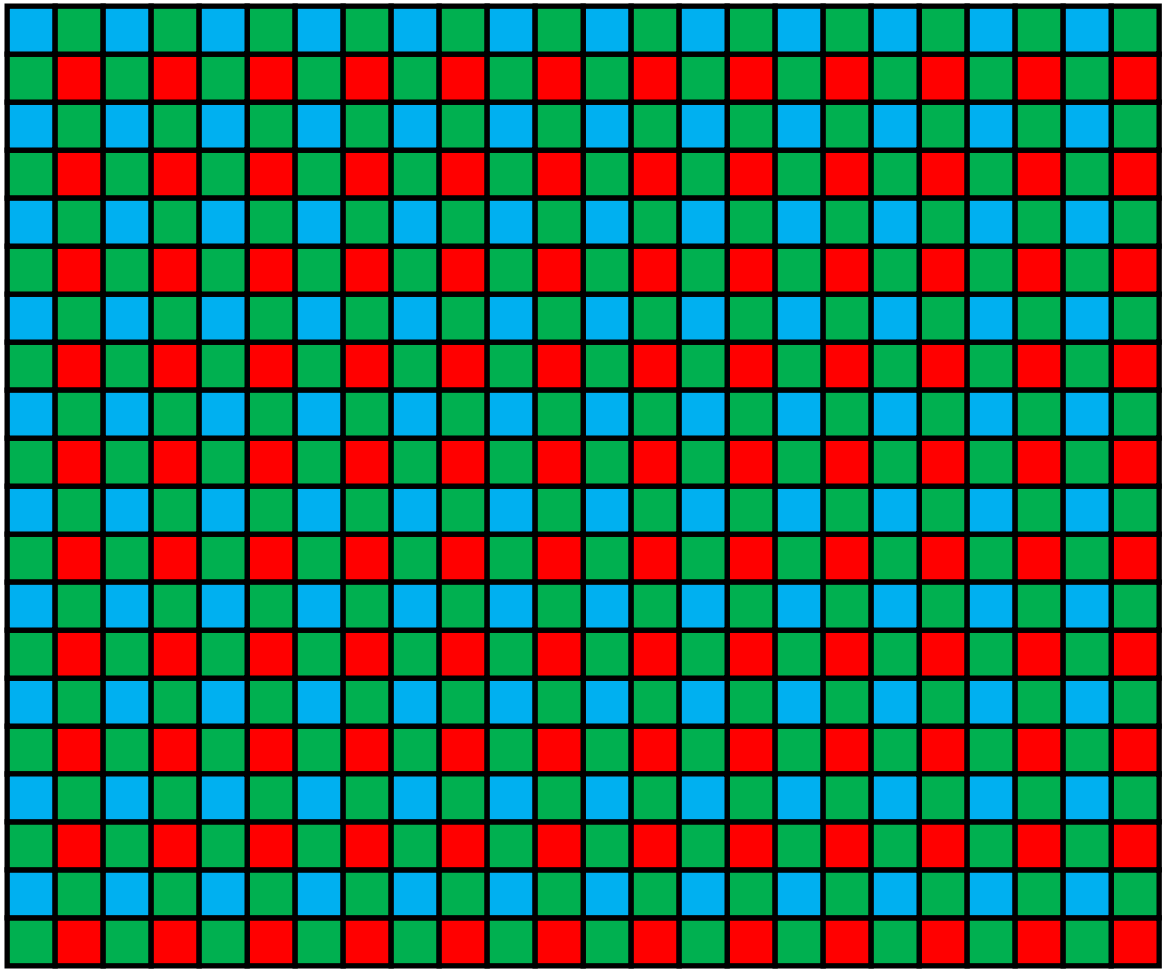




MACHINE VISION

BAYER FILTER

20x24 Pixel Resolution “Color Camera” example of a Bayer Filter Array
The Bayer array is 50% green pixels, 25% red pixels and 25% blue pixels.

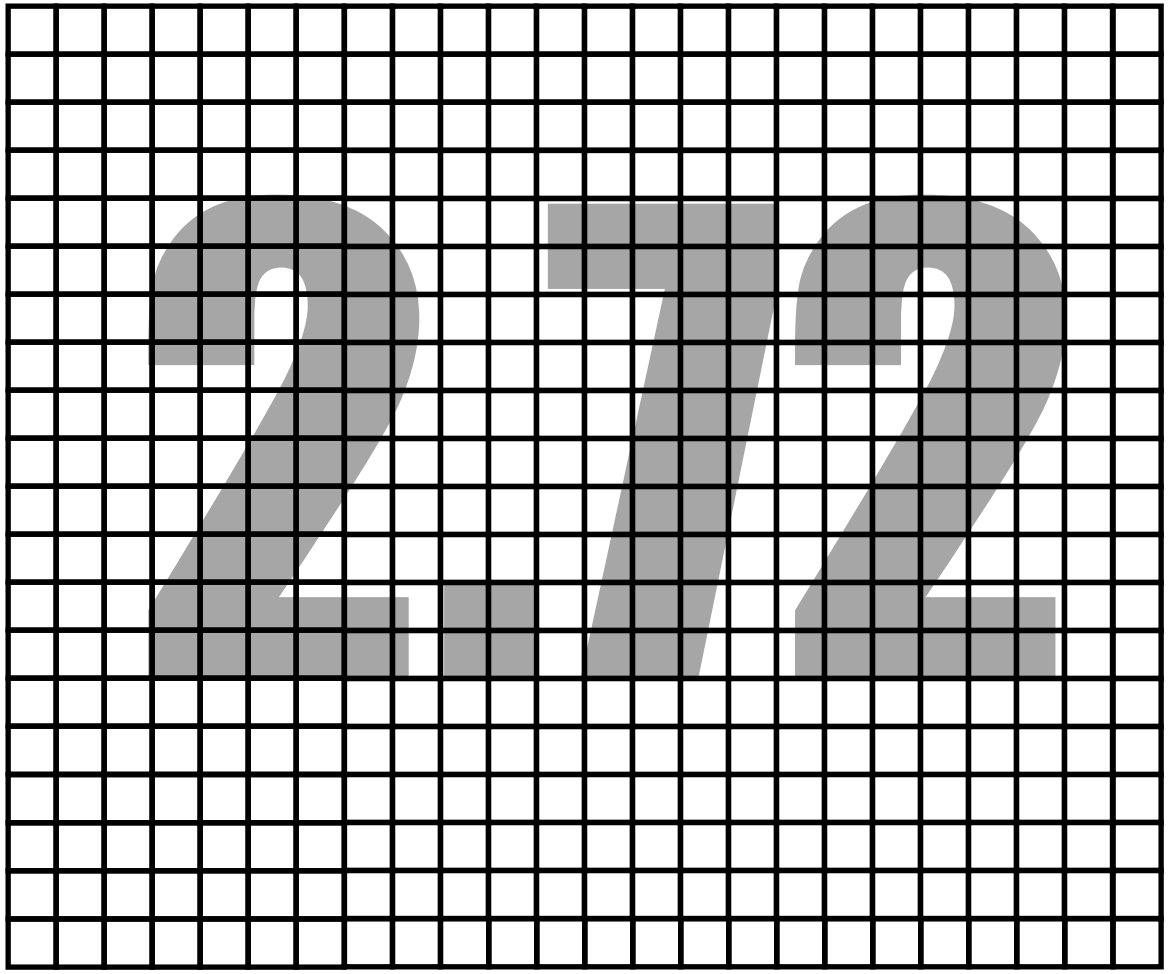


MACHINE VISION

MONOCHROME CAMERA

20x24 Pixel Resolution “Monochrome Camera” example:

Font size needs to be “225point font” to be read with 2 pixels wide on the decimal

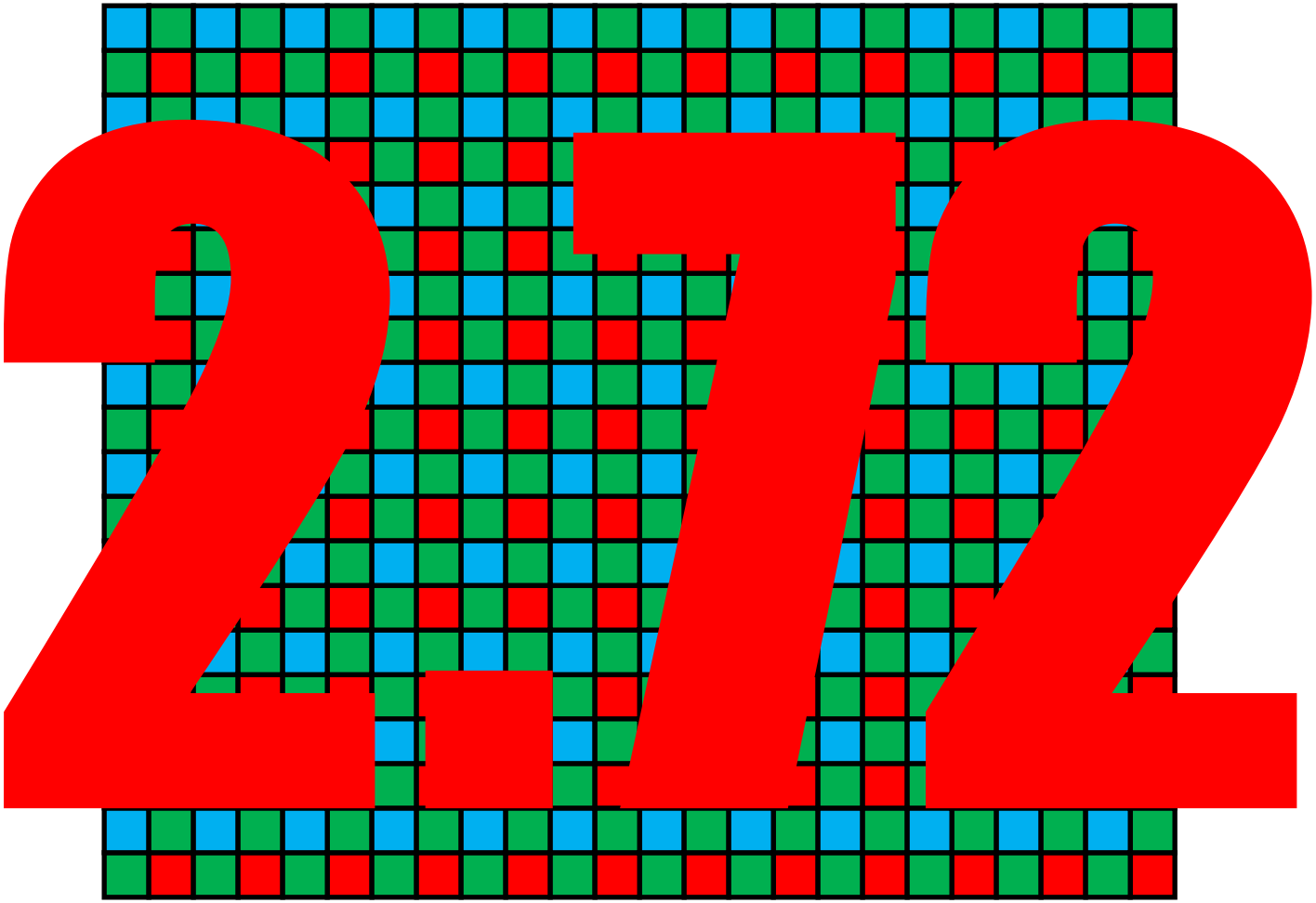


MACHINE VISION

BAYER FILTER

20x24 Pixel Resolution “Color Camera” example

Font size needs to be “350 point font” to be read with 2 pixels wide on the decimal

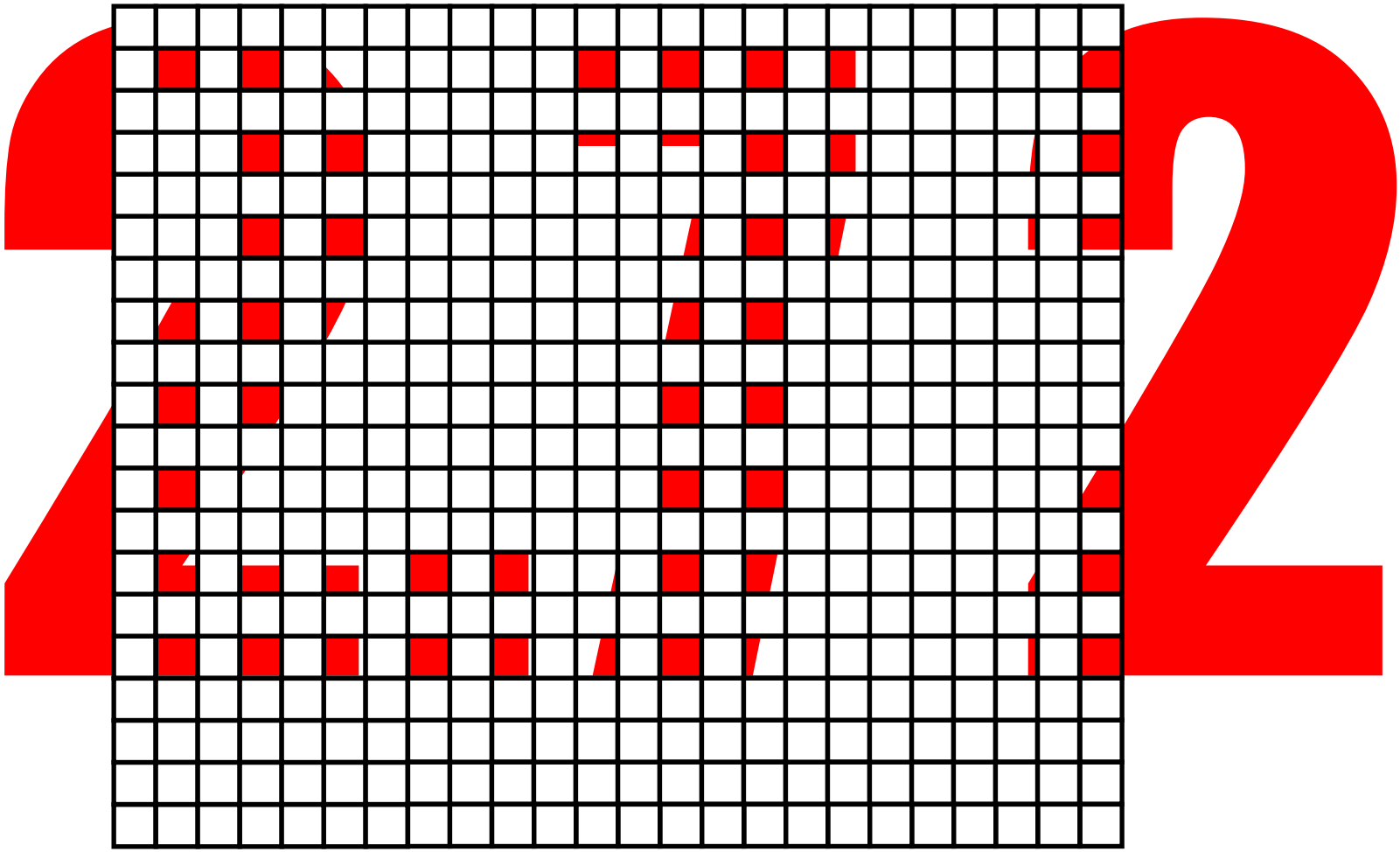


MACHINE VISION

BAYER FILTER

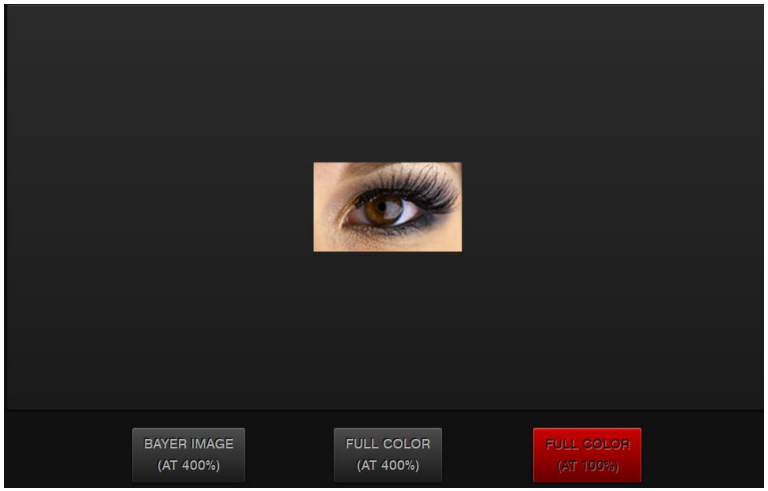
Color “Camera” example

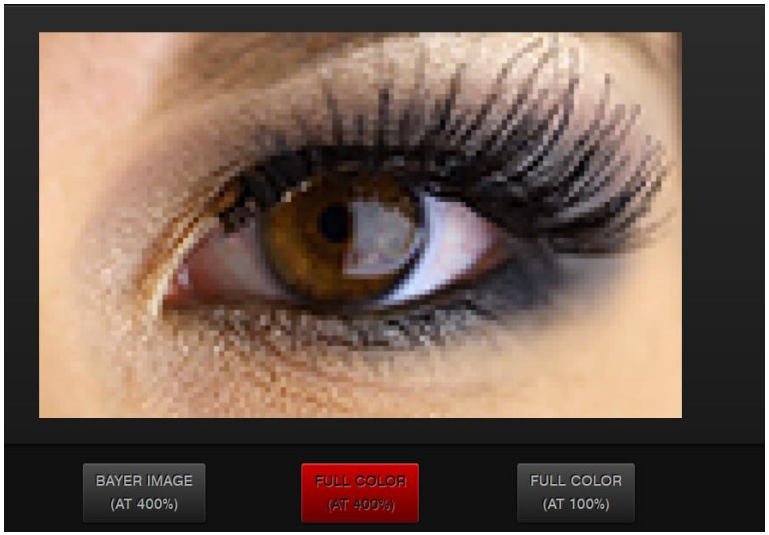
Font size needs to be “350 point font” to be read with 2 pixels wide on the decimal. This is what the ***Red*** camera pixels as seen through the Bayer filter

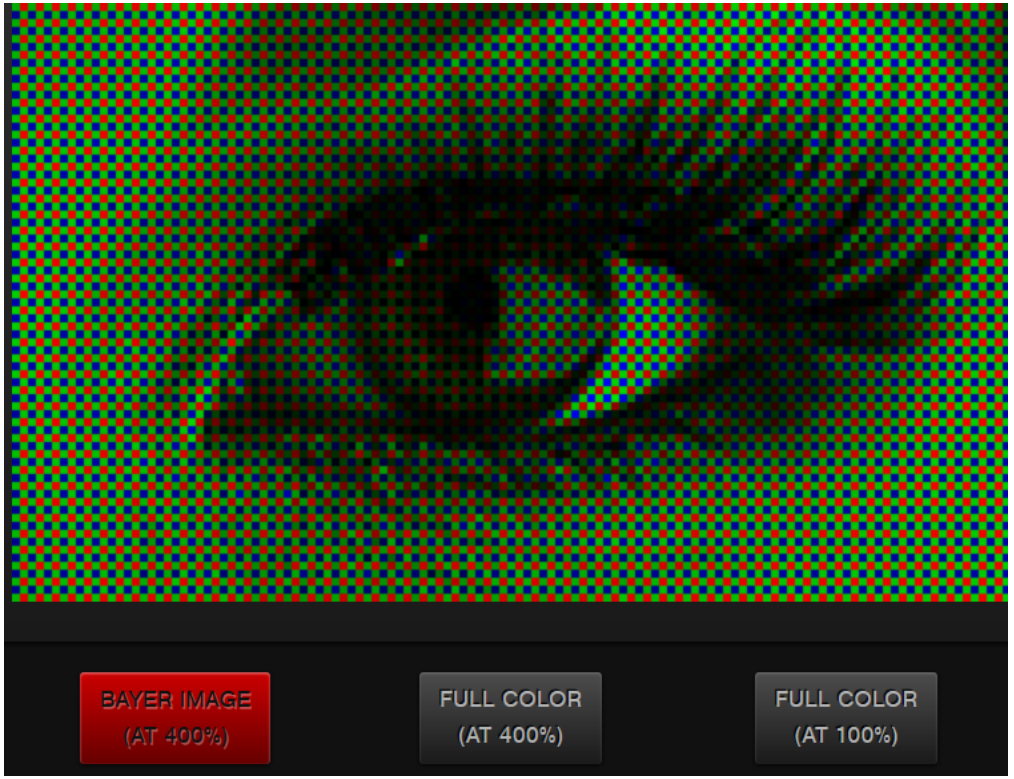


MACHINE VISION

COLOR CAMERAS VS MONOCHROME (GREY SCALE) CAMERAS

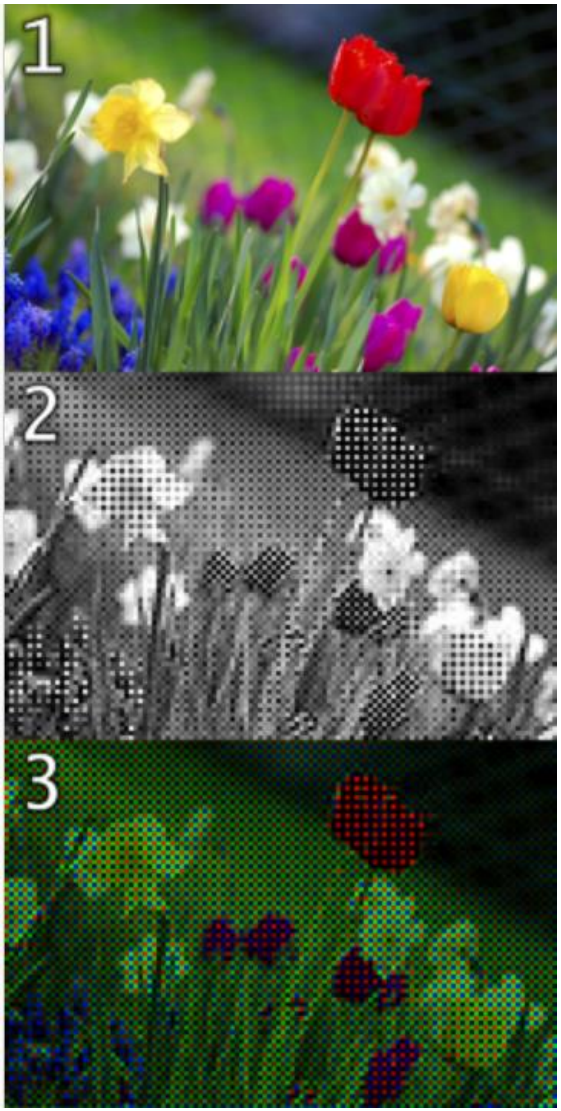






MACHINE VISION

COLOR CAMERAS VS MONOCHROME (GREY SCALE) CAMERAS



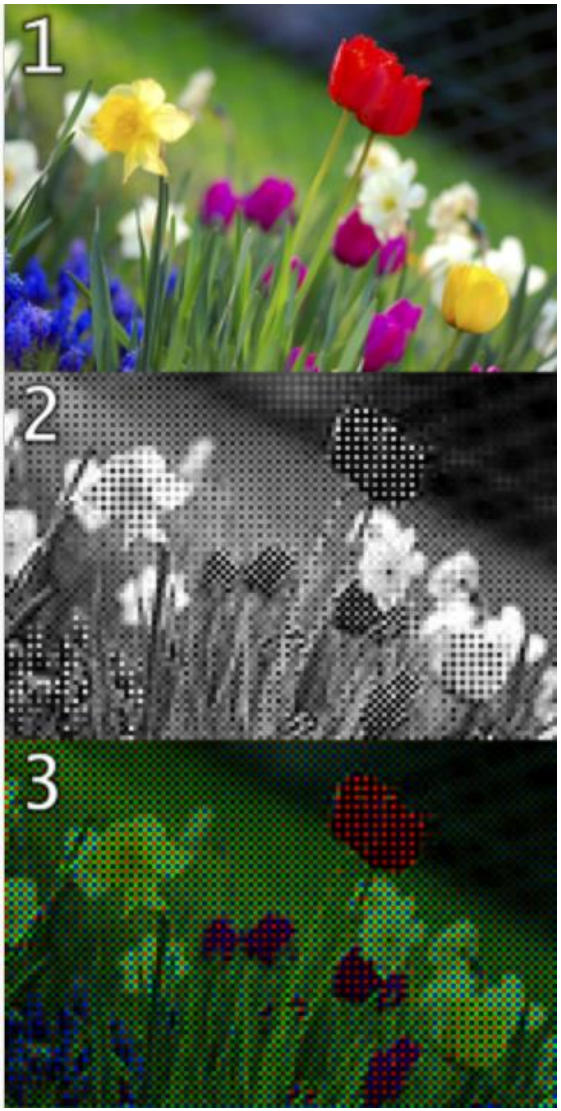
Original Full Color Picture

Bayer Pixeled Gray Scale
Resolution Representation

As Seen by the Camera
Bayer Filter Color Image

MACHINE VISION

COLOR CAMERAS VS MONOCHROME (GREY SCALE) CAMERAS



Original Full Color Picture

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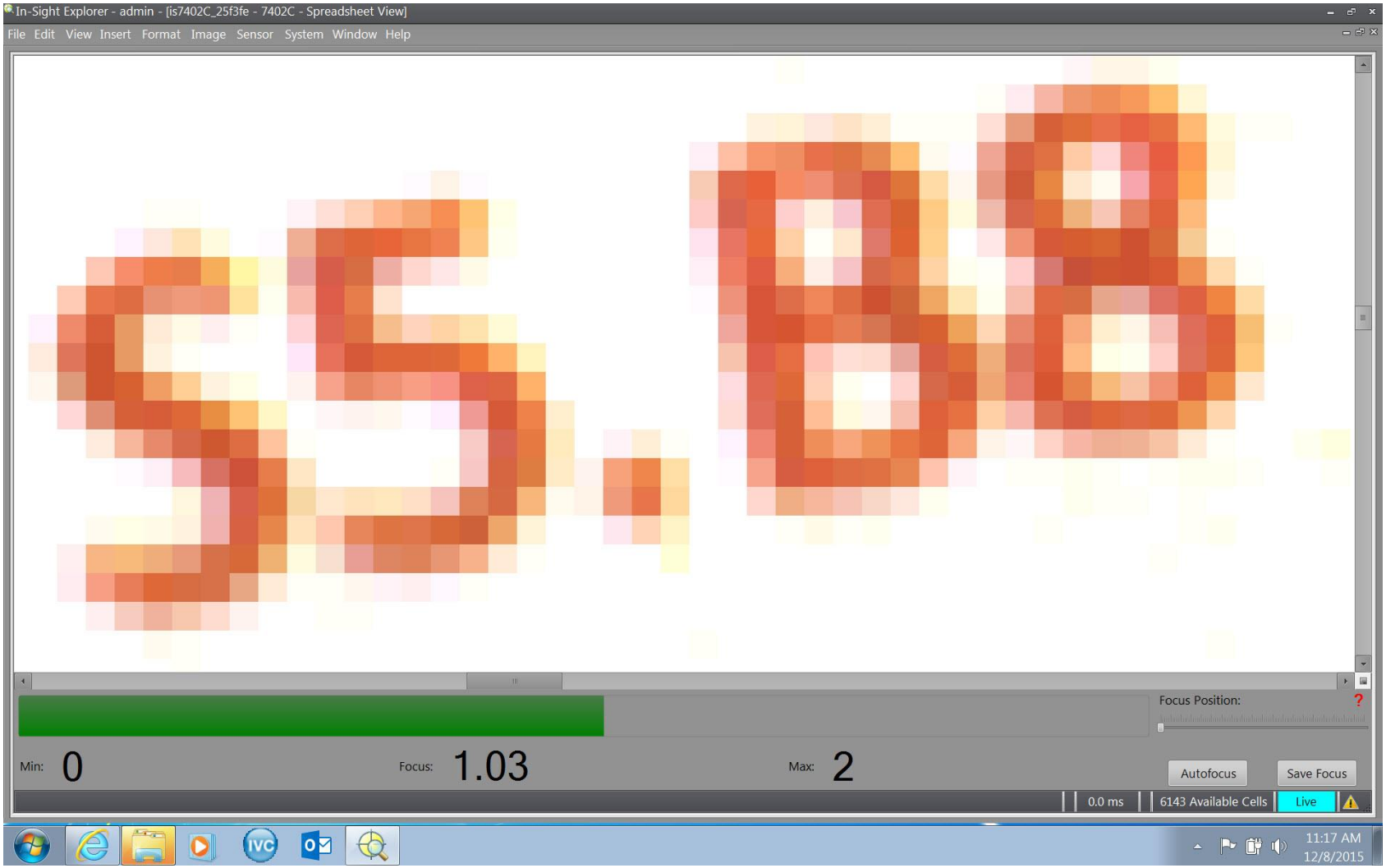
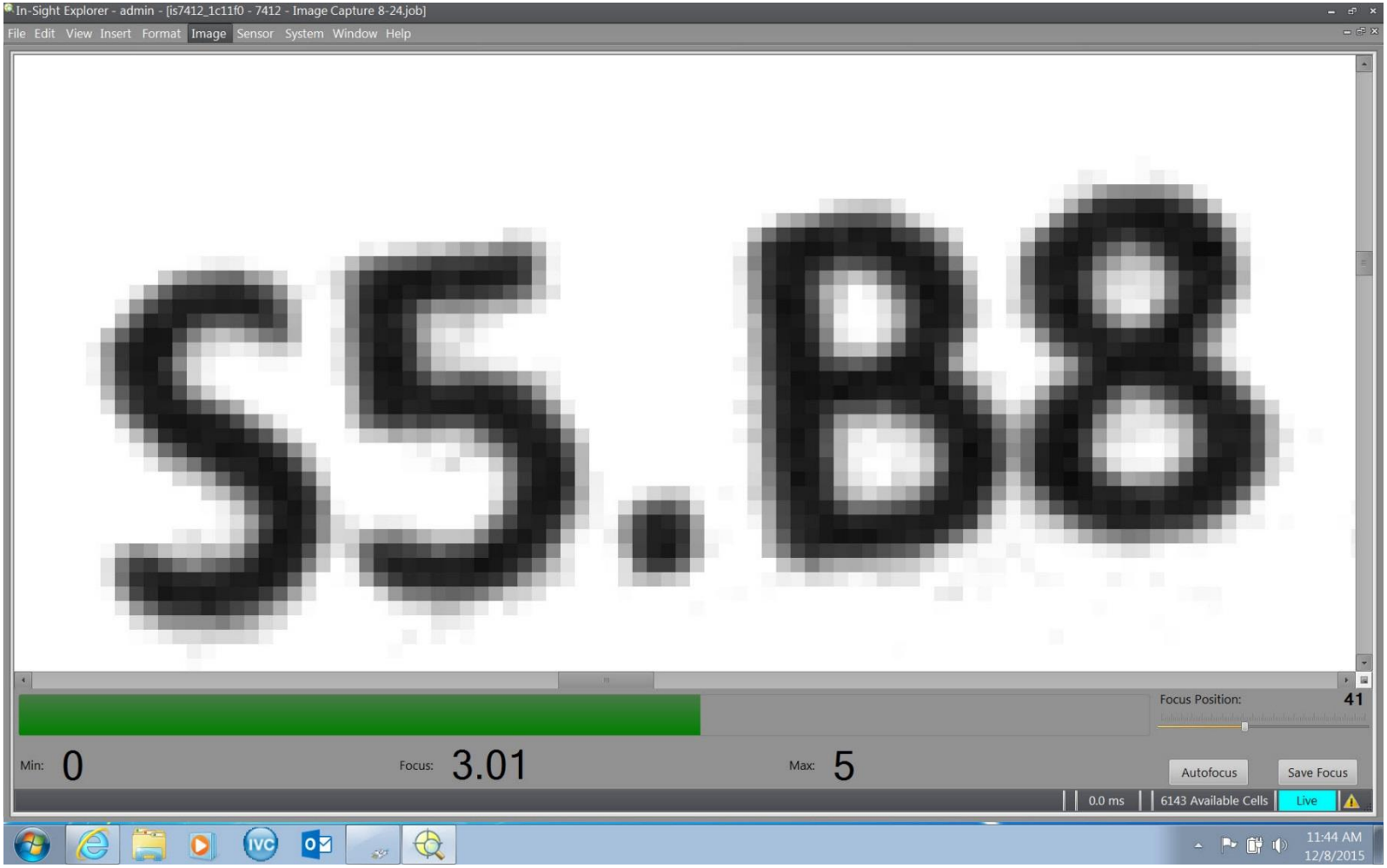
Bayer Filter Color Image

MACHINE VISION



MACHINE VISION



DESIGN VS. PRACTICE

- **Bottles designed with 2+ layers colored labels**
- **Laser to etch top layer and reveal color below**
  - This is Design for Inspection compliant
- **Very difficult to etch only one layer**
  - More difficult as laser ages
  - Laser etches too much or not enough
  - Results in ***too little contrast***

WHITE BOTTLE

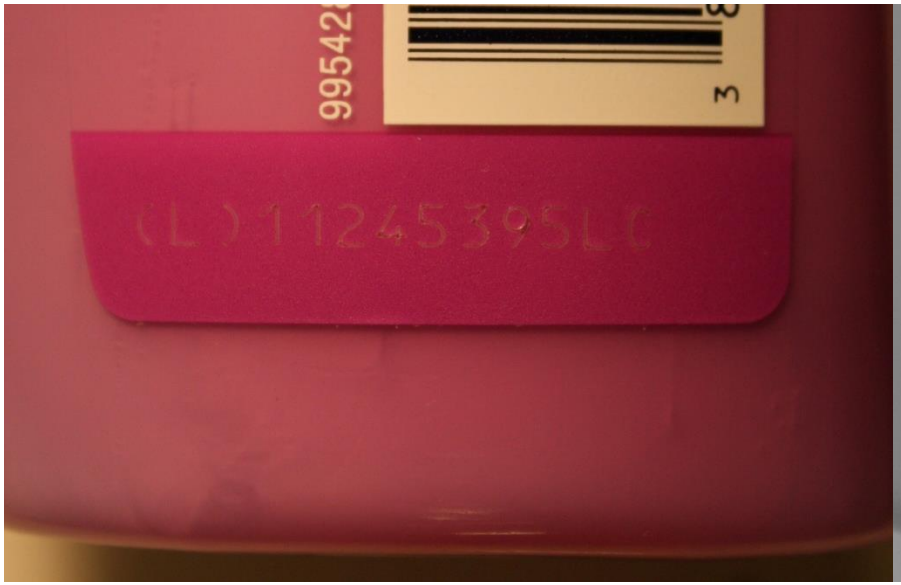
- **White bottles**
  - Blue labels etch to reveal white label, white bottle

Human Vision

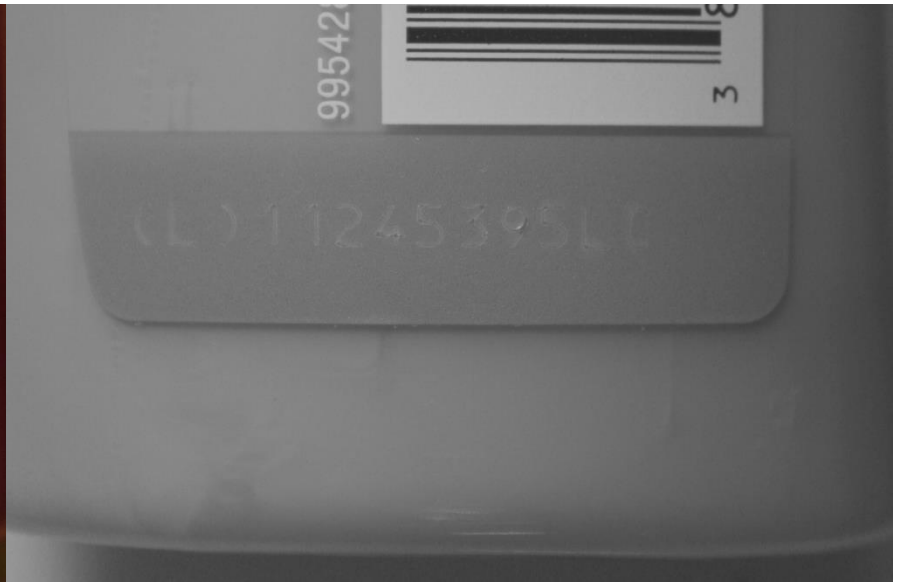
Machine Vision

BLUE BOTTLE

- **Pink bottles**
  - Pink labels etch to reveal white label underlayment but then also reveal pink bottle resulting in low contrast for the camera



Human Vision



Machine Vision

SOLUTIONS

- **Fix the laser**
  - Balance too precarious to be maintained
- **Design for Inspection System**
  - Small changes to current system

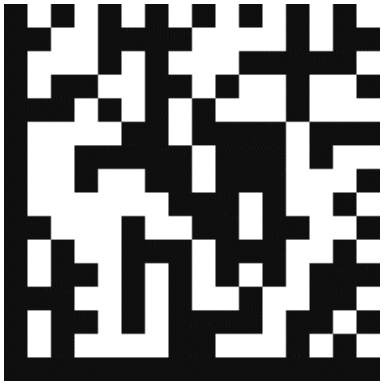
DESIGN FOR INSPECTION

- **Label color to be a contrasting color to the bottle color (eg. blue label on white bottle or white label on blue bottle)**
- **Underlayment label layer no longer necessary**
  - Fewer laser adjustments
- **Proper lighting for contrast**
  - Complimentary color filters

BARCODES

- **Barcodes also benefit from Design for Inspection**
  - Colors
  - Placement
  - Size
  - Packaging Materials
  - Marking Technology

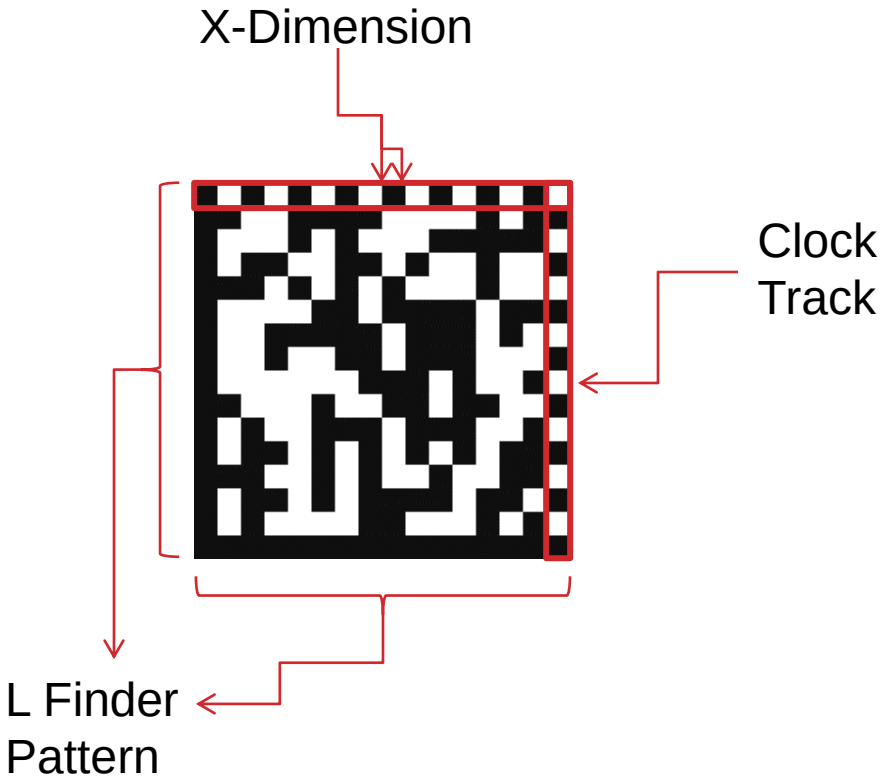
1D Barcode



2D Barcode

BARCODE BASICS

- **X-Dimension: width of a single module of the barcode**
  - Must be constant

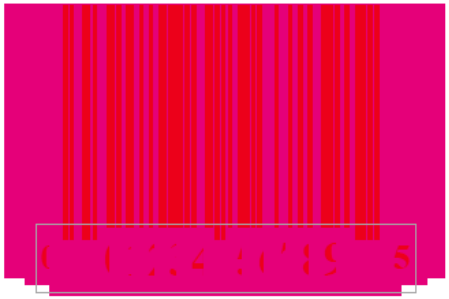


BARCODE BASICS

Contrast high enough?

Print Contrast Signal PCS = Refl.light – Refl.dark / Refl.light (minimum 75%)

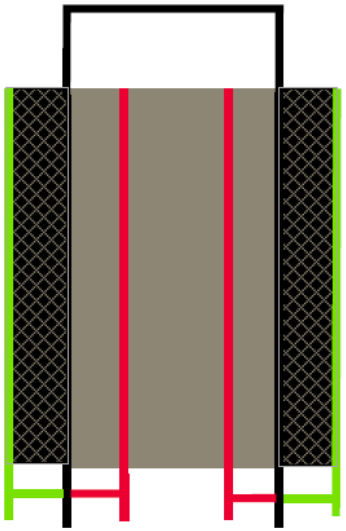
Red on white looks OK to us, but not to the scanner



BARCODE BASICS

Average Bar Deviation

Represents aim bar width



Represents amount of **gain** or **loss** allowable

BARCODE BASICS

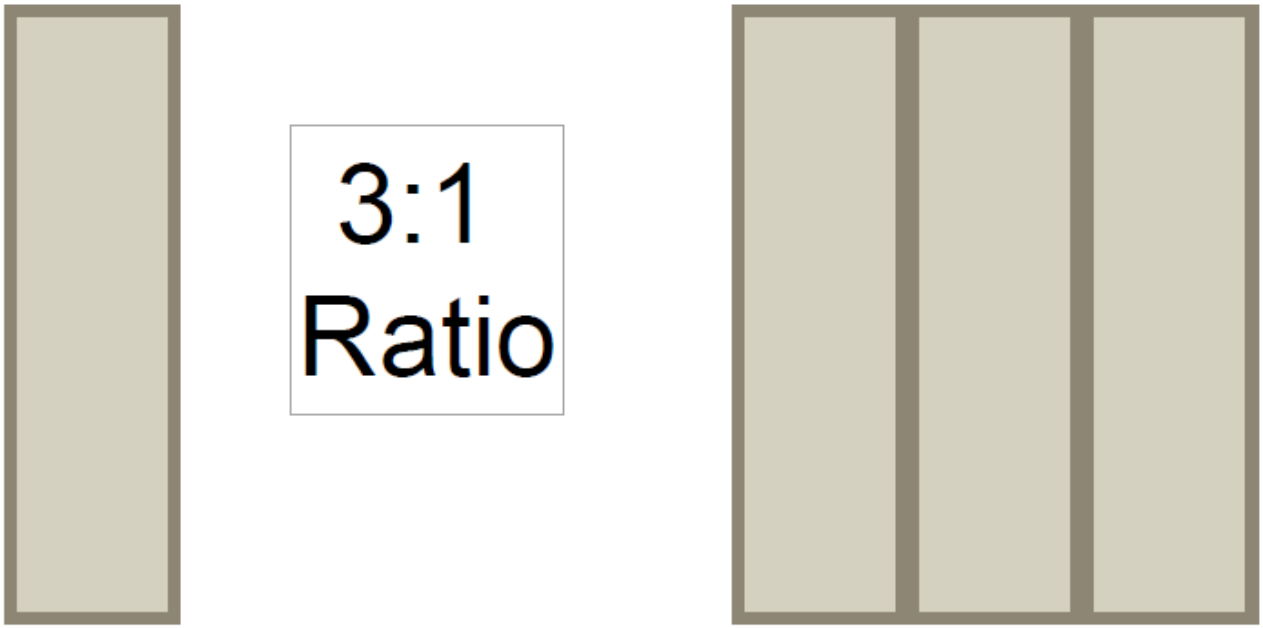
Quiet Zones / Light Margins

Allow for the appropriate quiet zones

Clear areas around the bar code necessary for the scanner to properly recognize and read the bar code. They are free of wording, graphics, closures, perforations or scores.

BARCODE BASICS

Wide to Narrow Ratio

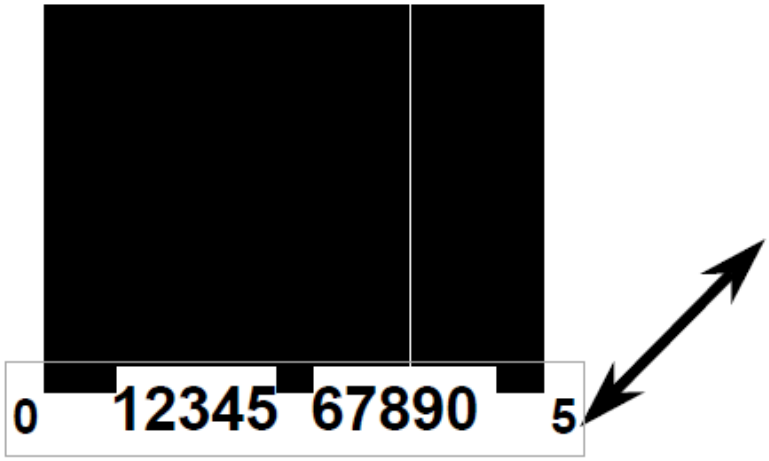


3:1
Ratio

Width of the wide elements when compared to the width of the narrow elements.

BARCODE BASICS

Check Character for UPC/EAN



1. 0+2+4+6+8+0=20

(20 X 3 = 60)

2. 1+3+5+7+9=25

3. 60+25=85

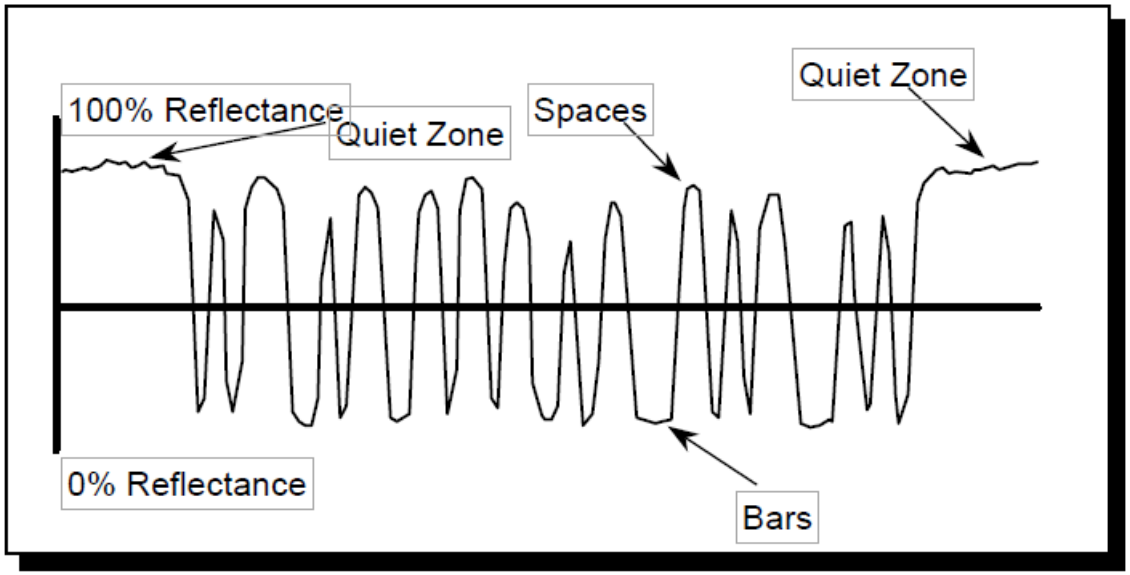
Check Character = the number added to the sum of 85 is a multiple of 10. The check number = 5

Example is a UPC Modulo 10 Check Character Calculation

BARCODE BASICS -QUALITY

What are ANSI/CEN/ISO Quality Parameters?

ANSI / CEN / ISO - Evaluation based on how the scanning or reading equipment 'sees' the bar code. Quality parameters are calculated using reflectance values from the bar code's *Scan Reflectance Profile (SRP).*



BARCODE BASICS

ANSI/CEN/ISO *Scan (SRP)* Grades

Lowest parameter grade for each scan path = Scan or *SRP* Grade

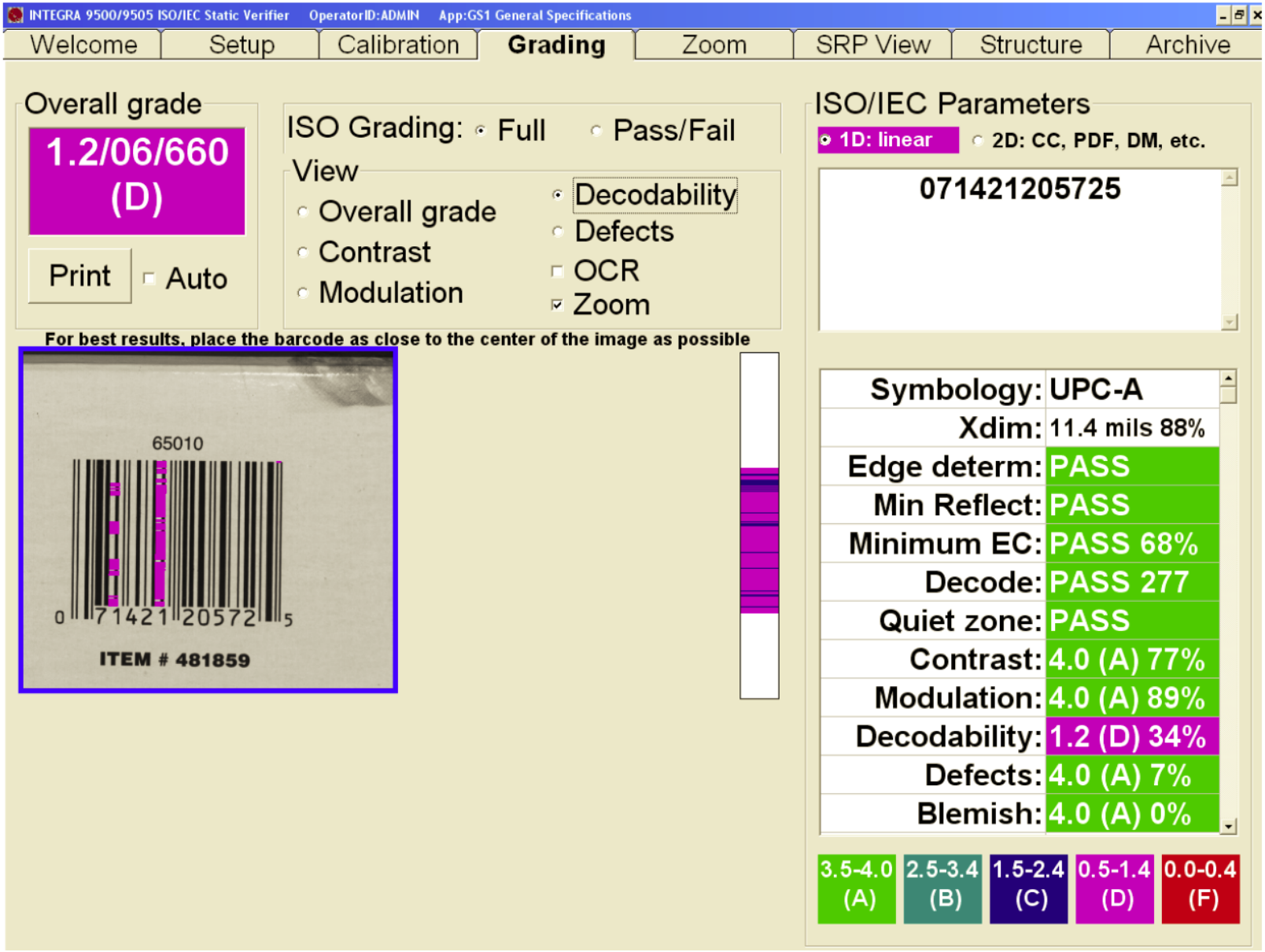
Edge Determination	Pass = A
Minimum Reflectance	3% = A
Symbol Contrast	70% = A
Edge Contrast	47 %= A
Modulation	55% = C
Defects	17% = B
Decode	Pass = A
Decodability	60% = B
Quiet Zones	Pass = A

BARCODE BASICS

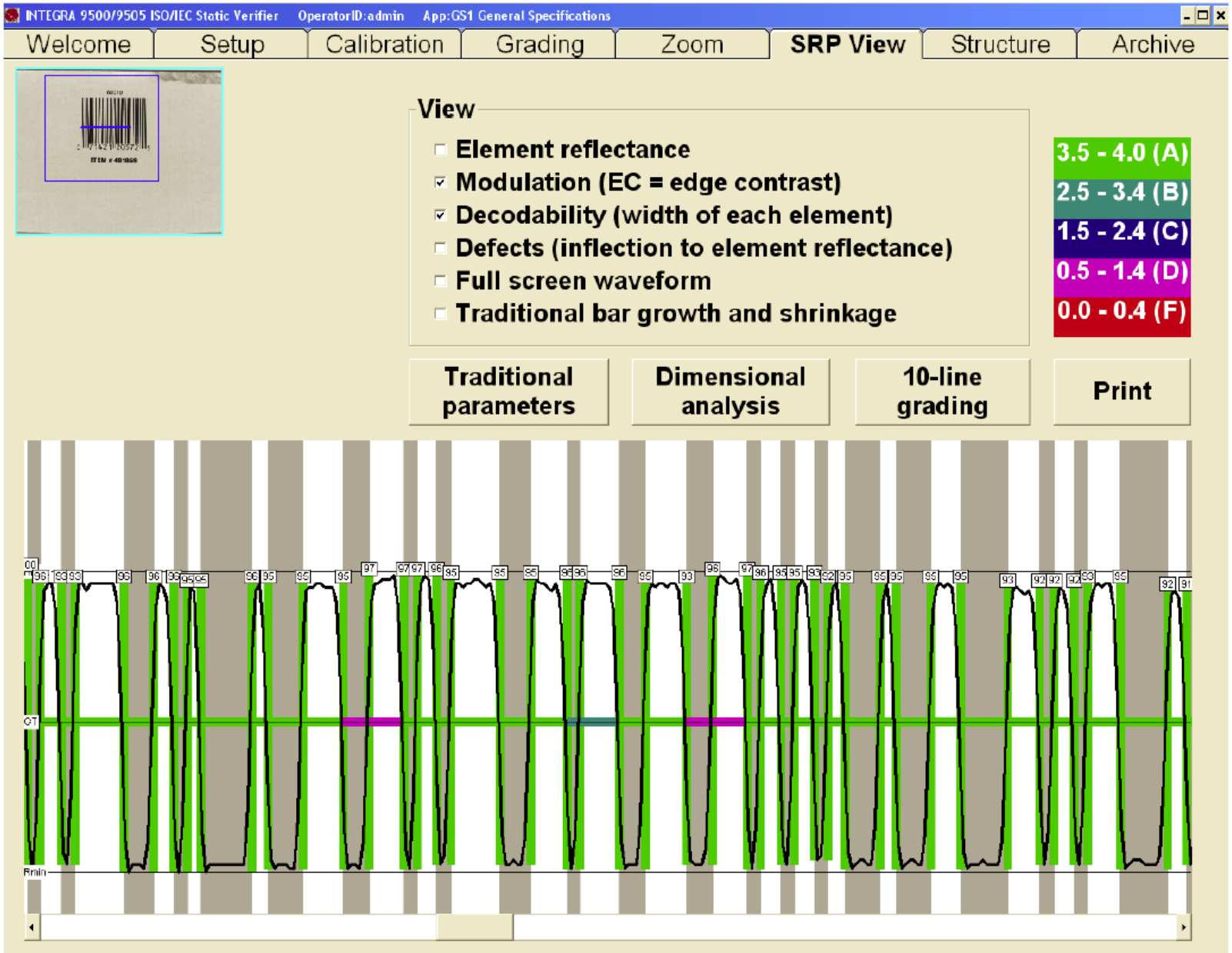
Print Quality Check List

Quality Factors	ANSI, or Trad'l	Visual	Verifier
Edge Determination (Global Threshold)	A		X
Reflectance Minimum	A		X
Edge Contrast Minimum	A		X
Symbol Contrast	A		X
Modulation	A		X
Defects	A		X
Decodability	A		X
Decode	A		X
Quiet Zones (Clear Margins)	A	X	X
Print Contrast Signal (PCS)	T		X
Wide/Narrow Ratio	T		X
Average Bar Deviation	T		X
Check Character Calculation	T		X
Symbol/Human Readable Match	T		X
Symbol Location relative to Label	T	X	
Label Size	T	X	
Symbol(s) Placement on Product	T	X	

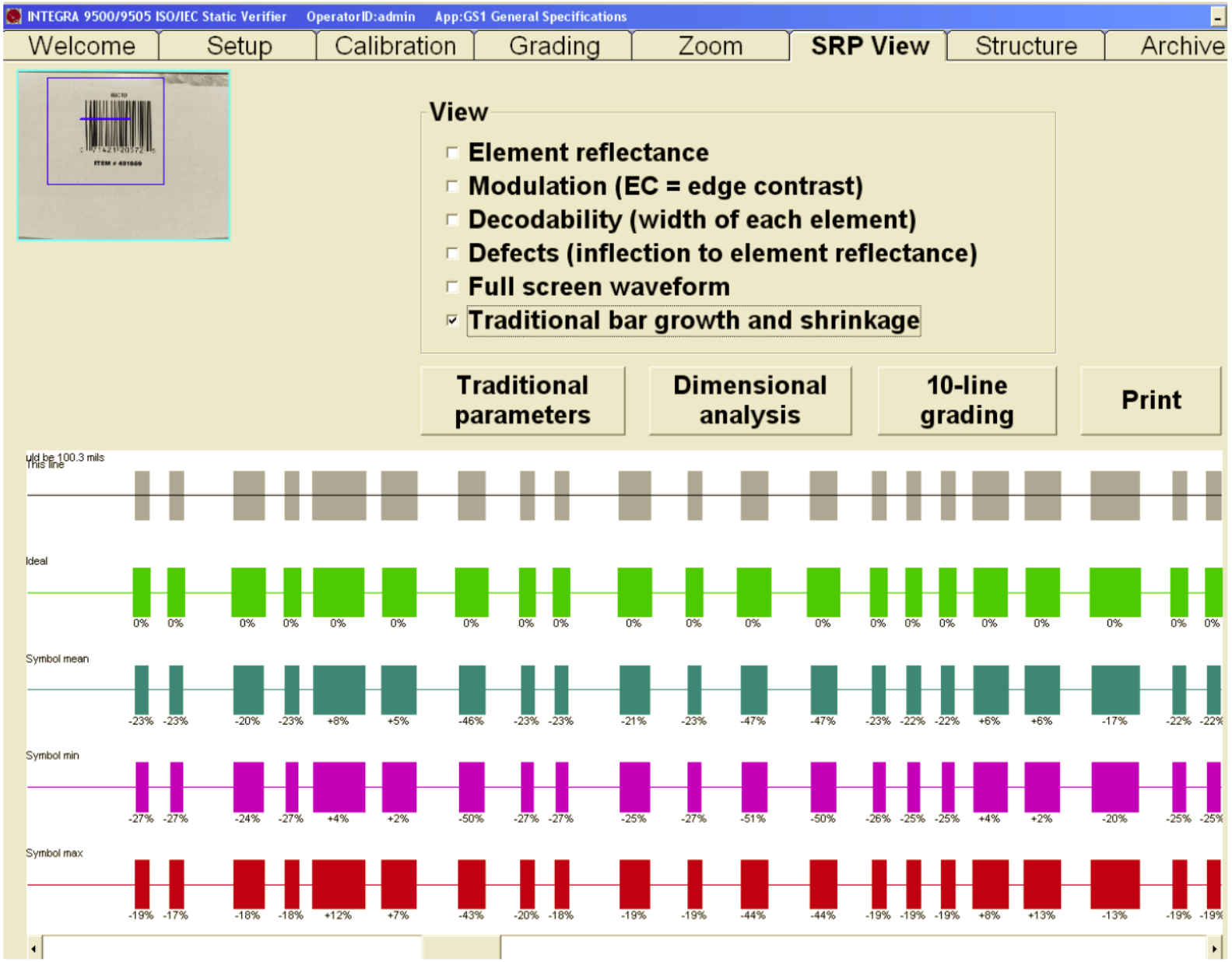
BARCODE VERIFICATION



BARCODE VERIFICATION

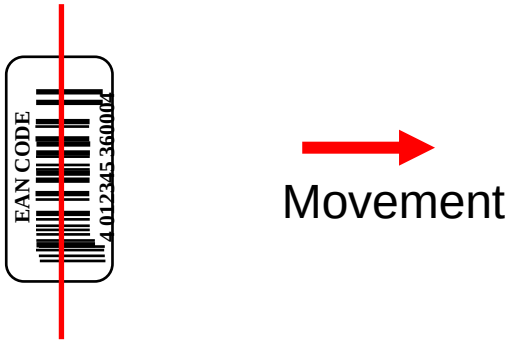


BARCODE VERIFICATION

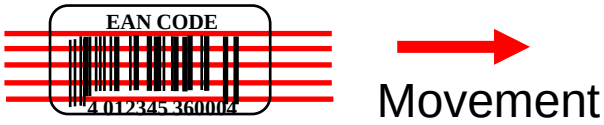


SCANNING OPTIONS

Line
("Ladder")

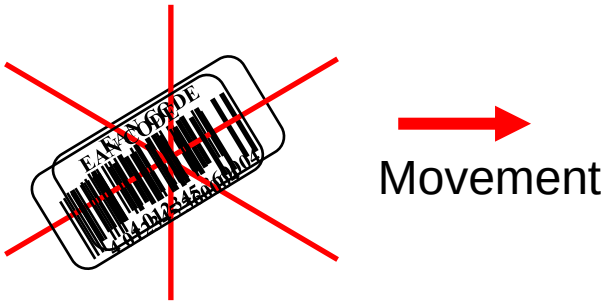


Raster
("Picket Fence" or Stationary)



Oscillating Mirror

Omni Directional



GENERAL PLACEMENT

- **Distance between barcode and edge of packaging should be great enough to reasonably avoid damage during shipping**
- **Barcodes should not be obstructed by outer packaging**
- **Quiet Zone: the area around the symbol that shall be free from any print matter**

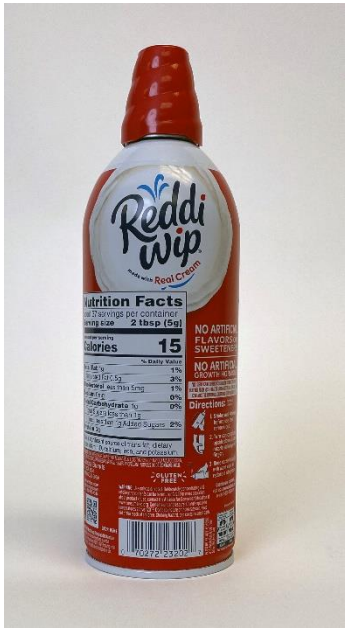
ROUND CONTAINER PLACEMENT

- Distance between barcode and edge of packaging should be great enough to reasonably avoid damage during shipping
- Barcodes should not be obstructed by outer packaging
- Quiet Zone: the area around the symbol that shall be free from any print matter
- Barcode shall be in Ladder Orientation to allow for maximum product rotation while still presenting a non distorted code image to the reader

ROUND CONTAINER CODE PLACEMENT – SHOULD BE LADDER ORIENTATION

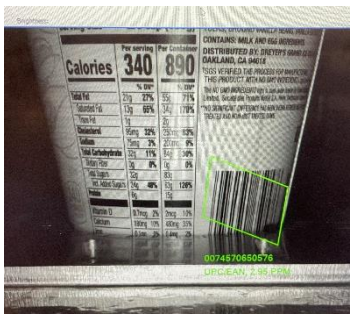
+/- 65 deg rotation max

+/- 40 deg rotation max

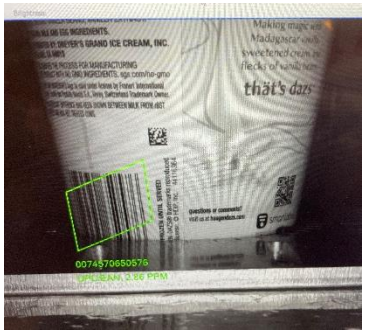


ROUND CONTAINER CODE PLACEMENT – SHOULD BE LADDER ORIENTATION

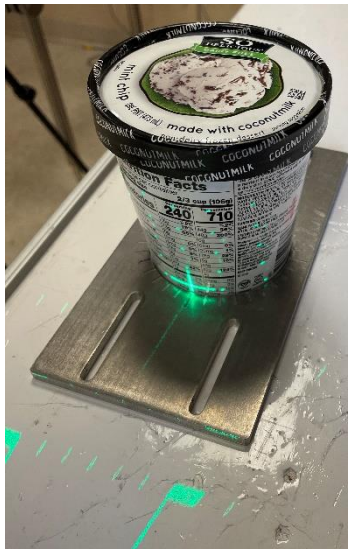
+ 40 deg rotation max

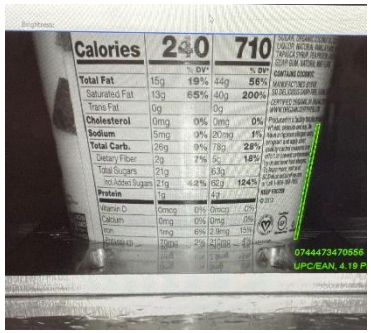


- 40 deg rotation max



+ 65 deg rotation max





-65 deg rotation max

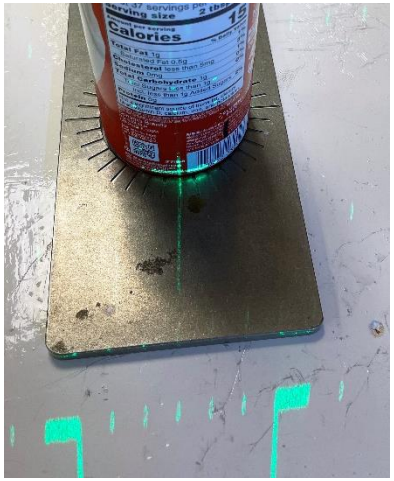
ROUND CONTAINER CODE PLACEMENT – SHOULD BE LADDER ORIENTATION

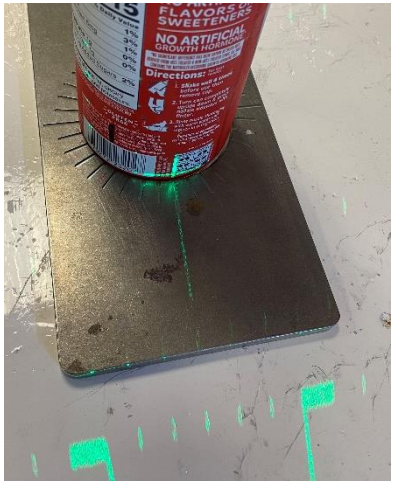
+ 40 deg rotation max

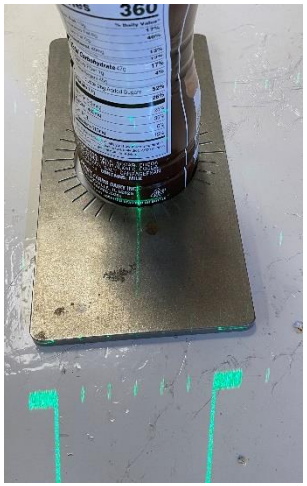
- 40 deg rotation max

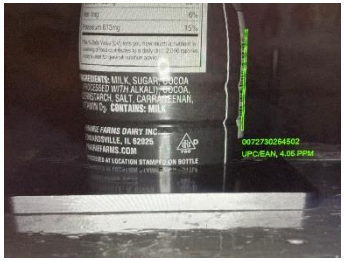
+ 65 deg rotation max

-65 deg rotation max









BARCODE COLORS AND CONTRAST

- **Black and white is the best combination**
- **Dark areas should use solid dark colors (black, dark blue, dark brown)**
- **Light areas should use bright and reflective colors (white, yellow)**
- **Intermediate colors should not be used**
- **Barcodes with lower levels of contrast can typically be read but only at slower speeds and varying depths of field**
- **Barcodes must be large enough to have clearly defined lines and spaces**

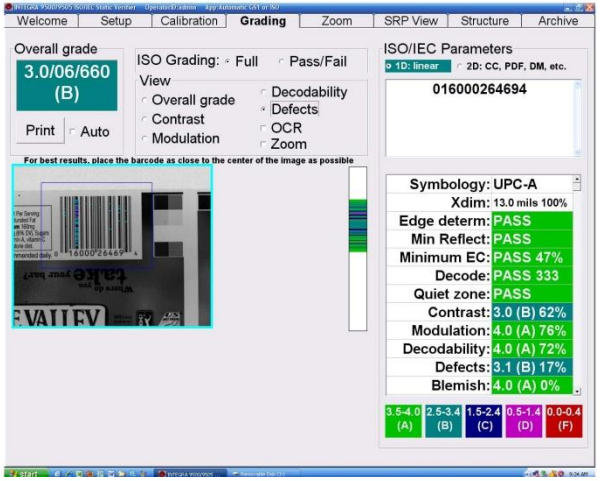
EXAMPLES OF POOR CONTRAST CODES

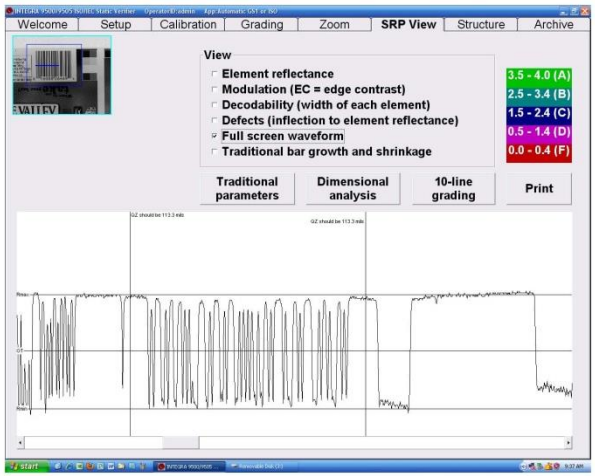
1D BARCODES

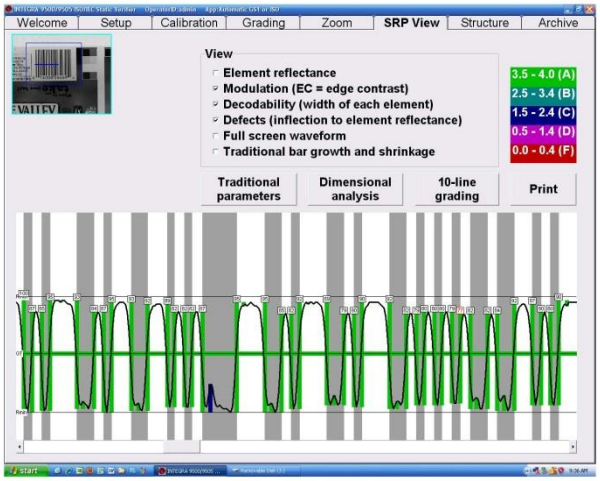
- **ANSI Standards and GS1 dictate black and white**
  - Variations **may** be acceptable
  - Barcodes with contrast can typically be read but at slower speeds and varying depths of field
- **‘Quiet Zone’ around the barcode**
  - Quiet Zone: the area to the left and right of the symbol that shall be free from any print matter with a width that must be greater than or equal to 10 times the X-dimension

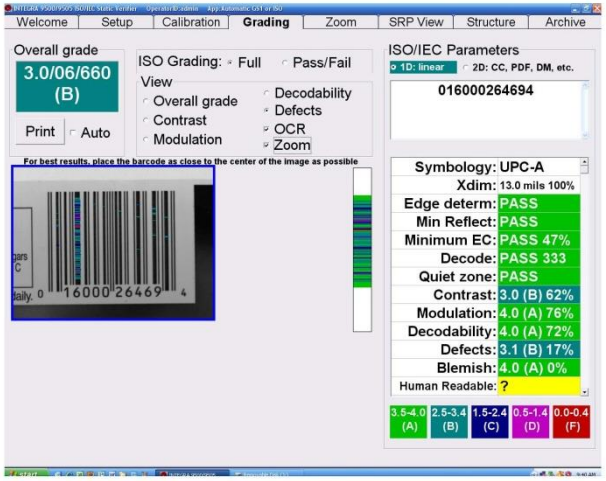
BARCODE REQUIREMENTS

MANY FACTORS AFFECT READABILITY





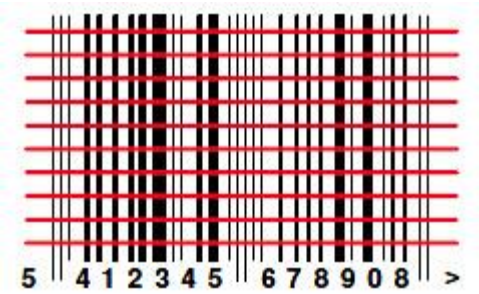




CODES IN MOTION: SCANNING REDUNDANCY

- **1D barcodes should allow for 10 scans per symbol for vertical redundancy and statistical stability**
  - Creates average of scans for overall symbol grade
- **Minimizes damage from defects or variation in the symbol**

Product Motion



BARCODE PRINTING ON PACKAGING MATERIALS

- **Packaging and ink should have low reflectance to avoid glare and ‘blinding’ the scanner**
- **Packaging and ink should have similar reflectance values**
- **Transparent backgrounds often confuse the scanner**
- **Marking technology and packaging materials should be consistent**

SYMBOL MARKING TECHNOLOGY

Substrate / Technology	Paper	Corrugated	Glass	Plastic	Metal
Inkjet	Yes	Yes	Yes	Yes	Yes
Laser Etch	For specific colours *or* specific finishing	For specific colours *or* specific finishing	under certain conditions	If contrast can be achieved *or* specific finishing	Painted *or* oxidised
Thermal transfer (on-demand)	Useful for adhesive labels	No	No	Plastic films	No
YAG Laser	Coloured background *or* specific finishing	Coloured background *or* specific finishing	No	Yes	Yes
Ink jet (on-demand)	Yes	Yes	No	No	No
Direct Part Marking	Film transfer	Film transfer	No	Yes	Yes

TEXT - OPTICAL CHARACTER RECOGNITION (OCR)

- **Conversion of scanned images of text into machine-encoded text**
- **The need for fonts recognizable by computers and humans prompted the development of OCR A and OCR B**
  - Machines don’t have ‘context clues’

OCR A

OCR B

A	B	C	D	E	F	G	H	I	J	K	L	M	N
O	P	Q	R	S	T	U	V	W	X	Y	Z	a	b
c	d	e	f	g	h	i	j	k	l	m	n	o	p
q	r	s	t	u	v	w	x	y	z	0	1	2	3
4	5	6	7	8	9	!	@	#	$	%	^	&	*

CONFUSION PAIR EXAMPLES

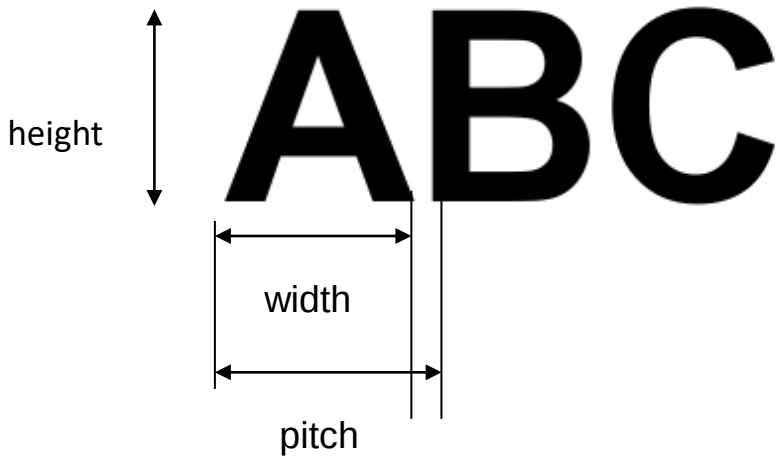
OCR A	OCR B	Times New Roman
S5	S5	S5
HN	HN	HN
B38	B38	B38
O0	O0	O0

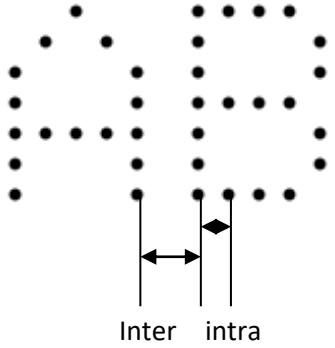
OCR A	OCR B	Times New Roman
C	C	C
D	D	D
Q	Q	Q
O	O	O
0	0	0
3	3	3
8	8	8

SEGMENTATION PARAMETERS

Character Parameters:

- Minimum/Maximum width
- Minimum/Maximum Height
- Minimum Aspect Ratio
- Pitch
- Angle/Skew range
- Inter-character gap
- Intra-character gap
- Fragment overlap
  - Specifies how much 2 characters must overlap in the horizontal direction to be part of same character

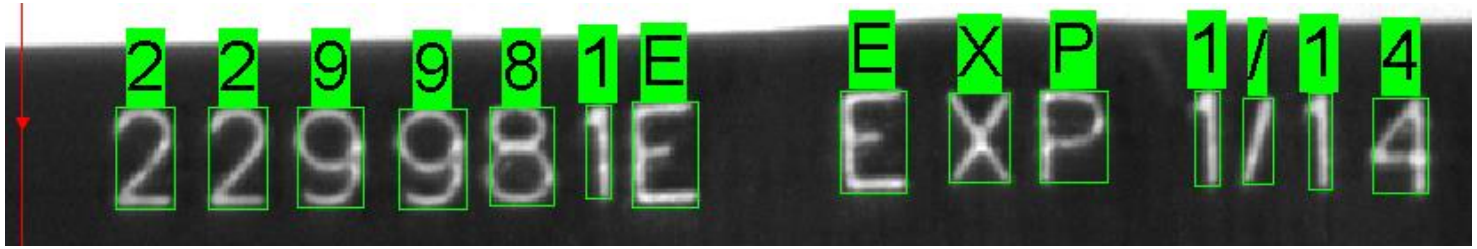




SEGMENTATION EXAMPLE

Segmentation Error

Good Segmentation



IS5600– 4.5msec/character

OCR GUIDELINES

- **Minimum Stroke Width – 3 to 4 pixels**
- **Ideal Character Height – 20-40 pixels**
- **Minimum Character size – 8x8 for regular, 2x2 for special small characters like periods**
- **A minimum surrounding border of about half a character size between the characters and ROI is recommended**
- **Fixed character and stroke width preferable to variable width**

QUALITY CONTROL

- **Cylindrical products work best with a ladder-style barcode orientation**

- **Picket Fence orientation**

- **Ladder orientation**

QUALITY CONTROL

- **Quality should not be a simple check at the end of the process but should be built into the development process with checks at each stage.**
- **Decode: symbol relays the correct information**
- **Modulation: the consistency of reflectance of dark to light areas**
- **Axial Uniformity: evenly scaled across the X and Y axes**
- **Grid uniformity: distortion of the grid on an angle**

QUALITY CONTROL

- **Error correction: method of reconstructing data that is lost via damages or erasure of the symbol**
- **Fixed pattern damage: damage to finder pattern, quiet zone, clock track in the symbol**
- **Print Growth: how symbols may have grown or shrunk from target size (likely due to printer or ink errors)**

ADDITIONAL INFLUENCES

- Available space for printing
- Printing speed
- Sector norms and conventions
- Customer Requirements
- Regulatory Requirements

REASONS TO DESIGN PACKAGING FOR INSPECTION

- More consistent manufacture and inspection
- Small changes with big impact
- Higher quality for end user
- Less machine downtime
- Fewer false positive rejects
- Fewer changeover adjustments