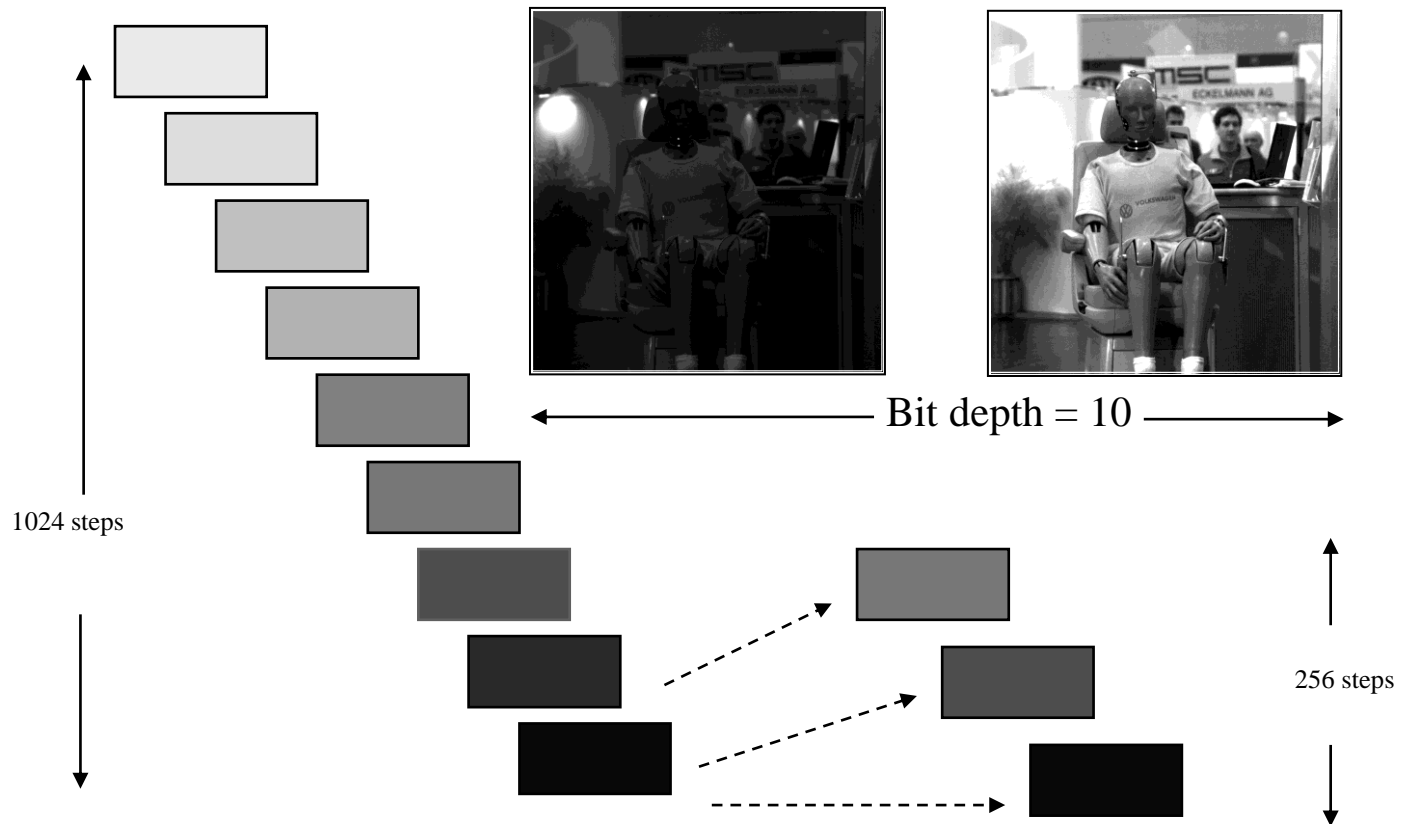


Bit Depth for Machine Vision Cameras

*16, 14, 12, 10 & 8-bits cameras,
What does it really mean?*



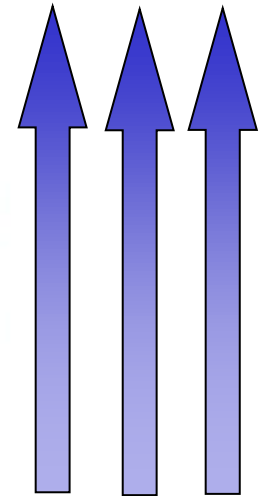
Analog vs. Digital

Sensor vs. Camera

Analog vs. Digital

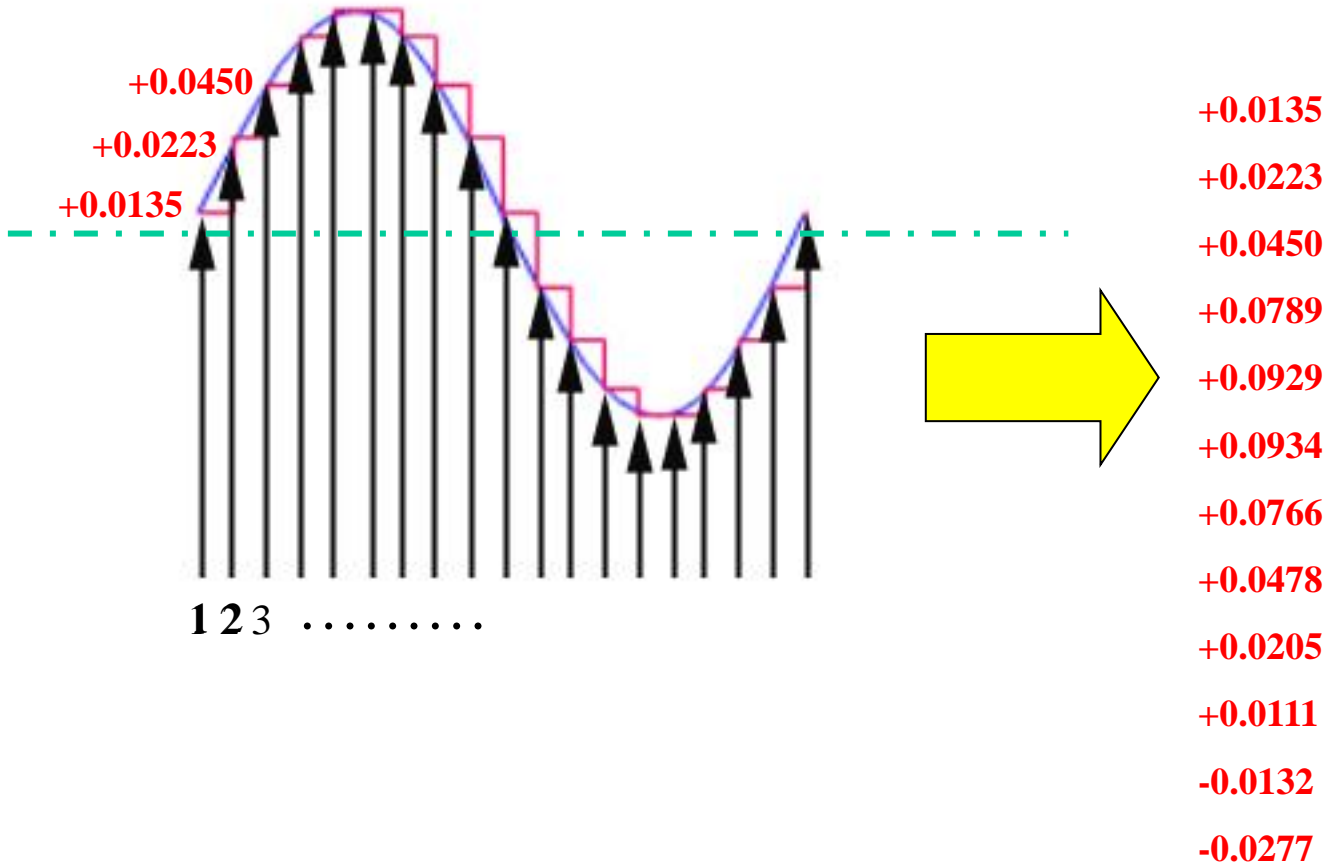


continuous
(analog)

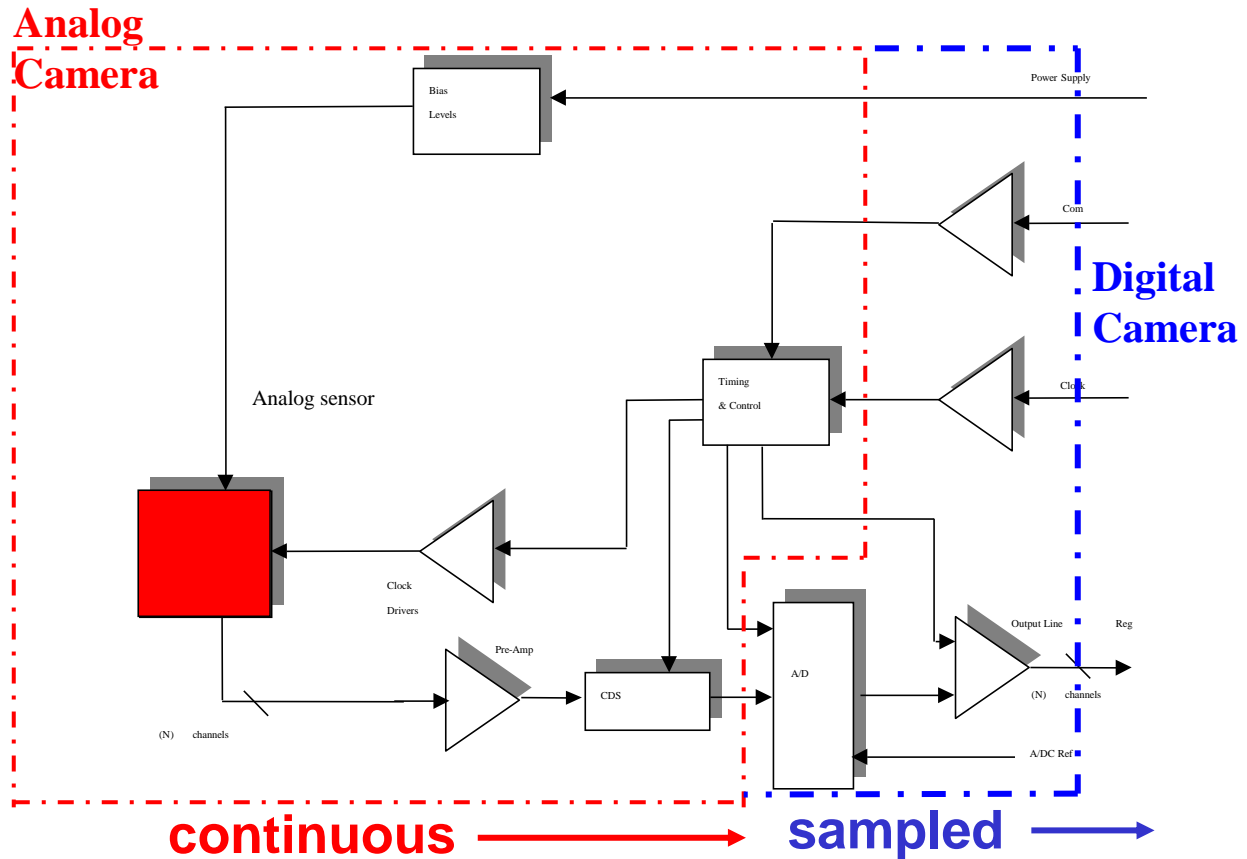


sampled
(digital)

Analog vs. Digital



Analog vs. Digital Sensor vs. Camera



Definitions

SNR, Dynamic Range & Bit Depth

Definitions

Signal-to-Noise Ratio (SNR)

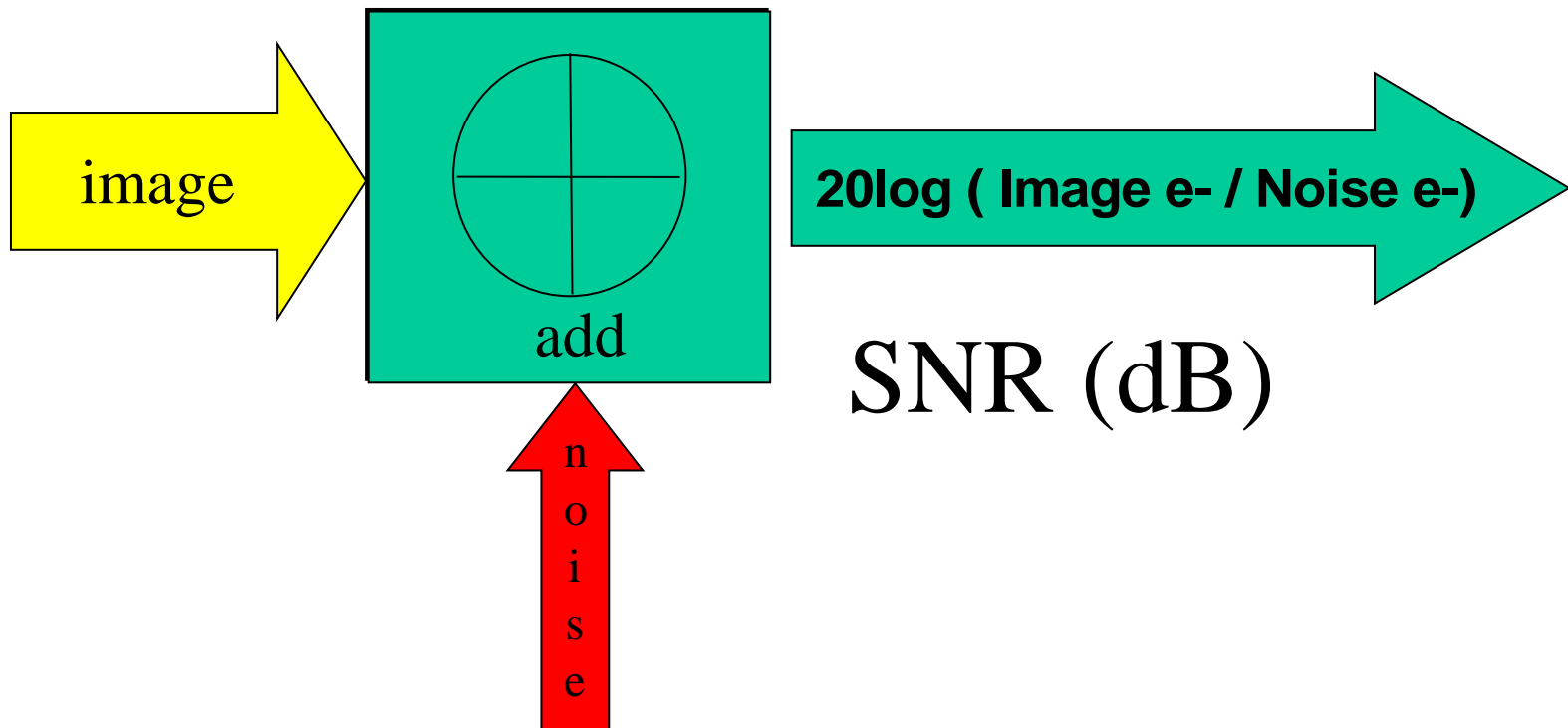
SNR is the ratio of the overall rms signal level to the rms noise level, expressed in dB.

SNR is the relationship between the usable intended signal and extraneously noise present, usually measured at the source. It is expressed in dB.

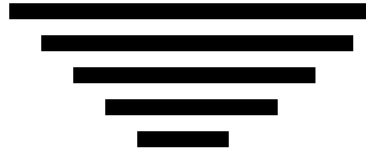
SNR is the amplitude of the signal compared to the noise. The higher the SNR the lower the number of errors.

Definitions

Signal-to-Noise Ratio (SNR)



Best Case - *SNR for Sensor Only*



Definitions

Signal-to-Noise Ratio (SNR)

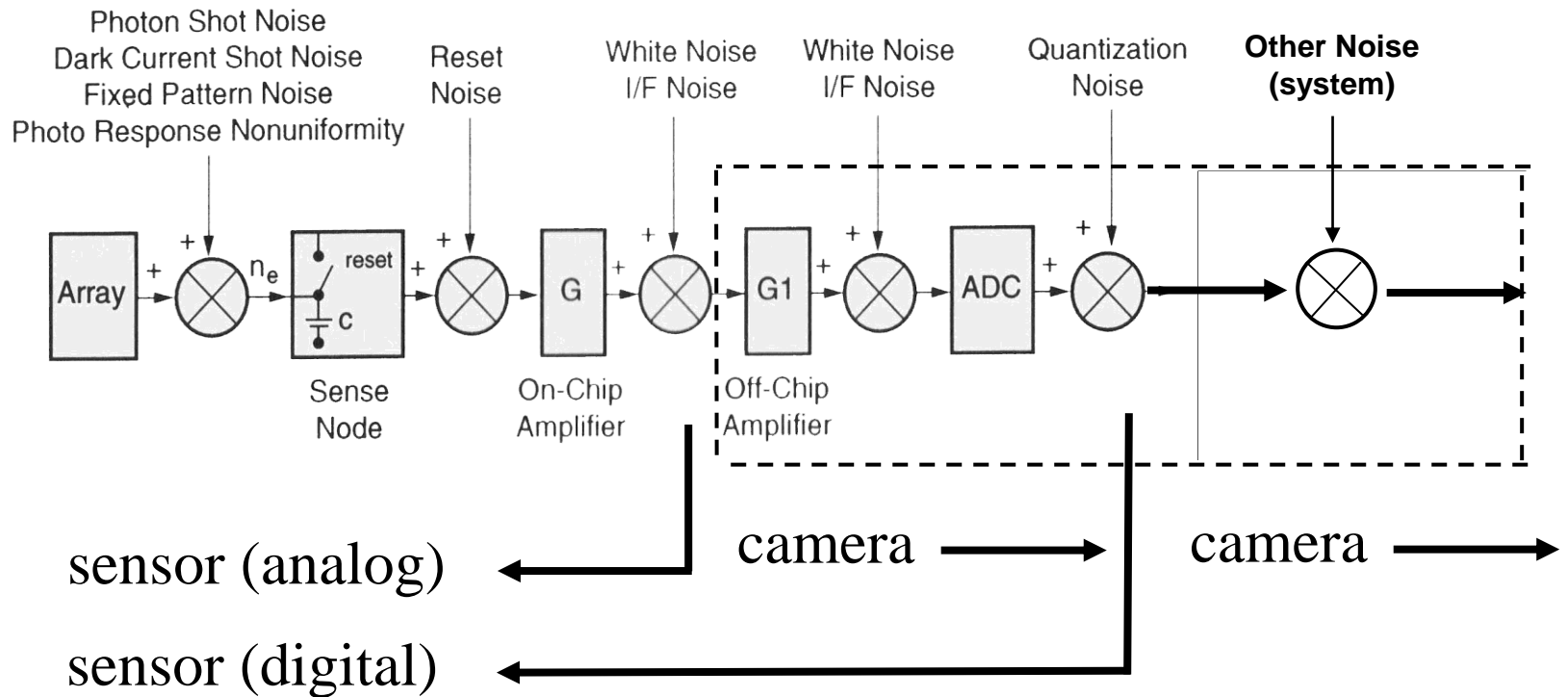
$$\text{SNR (dB)} = 20\log (\text{Image e-} / \text{Noise e-})$$

$$= 20\log (50,000 / 200) = 20\log (250) = 47.96 \text{ dB}$$

Ratio	SNR (dB)	Bits	Pixel e-/200 e-	Pixel e-/50 e-
256	48	8	50,000	13,000
512	54	9	100,000	25,000
1024	60	10	200,000	50,000
2048	66	11	400,000	100,000
4096	72	12	800,000	200,000
16384	84	14	3,000,000	800,000
65536	96	16	13,000,000	3,000,000

Definitions

System Signal-to-Noise Ratio (SNR)



Definitions

Other Noise (system)

- spatial under sampling (beyond the limiting resolution)
- color reconstruction
- compression noise, if compression is used
- power line noise
- conducted noise from other equipment
- display noise (i.e. truncation, aliasing, wrong gamma)
- lens related distortion
- wrong image format (truncated bit depth)

Definitions

Dynamic Range

Dynamic range is the number of colors or shades of gray that can be represented by a pixel.

Dynamic range is a measurement of the number of bits used to represent each pixel in a digital image. The smallest unit of data stored in a computer is called a bit.

Dynamic range is the ratio of contrast, tonal range or density in an image between black and white. The number 0.0 represent white and black is 4.0.

Dynamic range is the measurement of the accuracy of an image in color or gray level. More bits of dynamic range results in much finer gradations being preserved.

Dynamic range is a term used frequently in numerous fields to describe the ratio between the smallest and largest possible values of a changeable quantity.

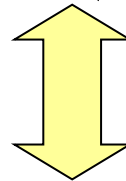
Definitions

Dynamic Range

Dynamic Range (DR) is the ratio of the maximum output signal, or saturation level, of an image sensor to the dark noise level of the imager.

The dark noise level, or noise floor of an imager is expressed as the root mean square (rms) variation in dark signal voltage.

$$\text{DR [dB]} = 20\text{LOG} (V_{\text{sat}} / V_{\text{Dark,rms}})$$

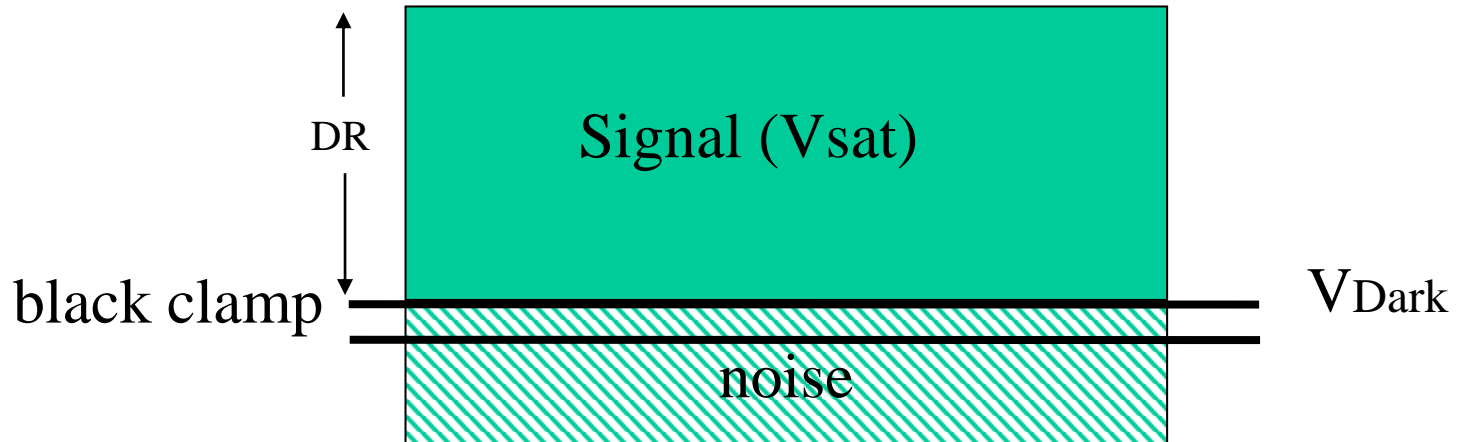


$$\text{SNR (dB)} = 20\text{log} (\text{Image e-} / \text{Noise e-})$$

Definitions

Dynamic Range

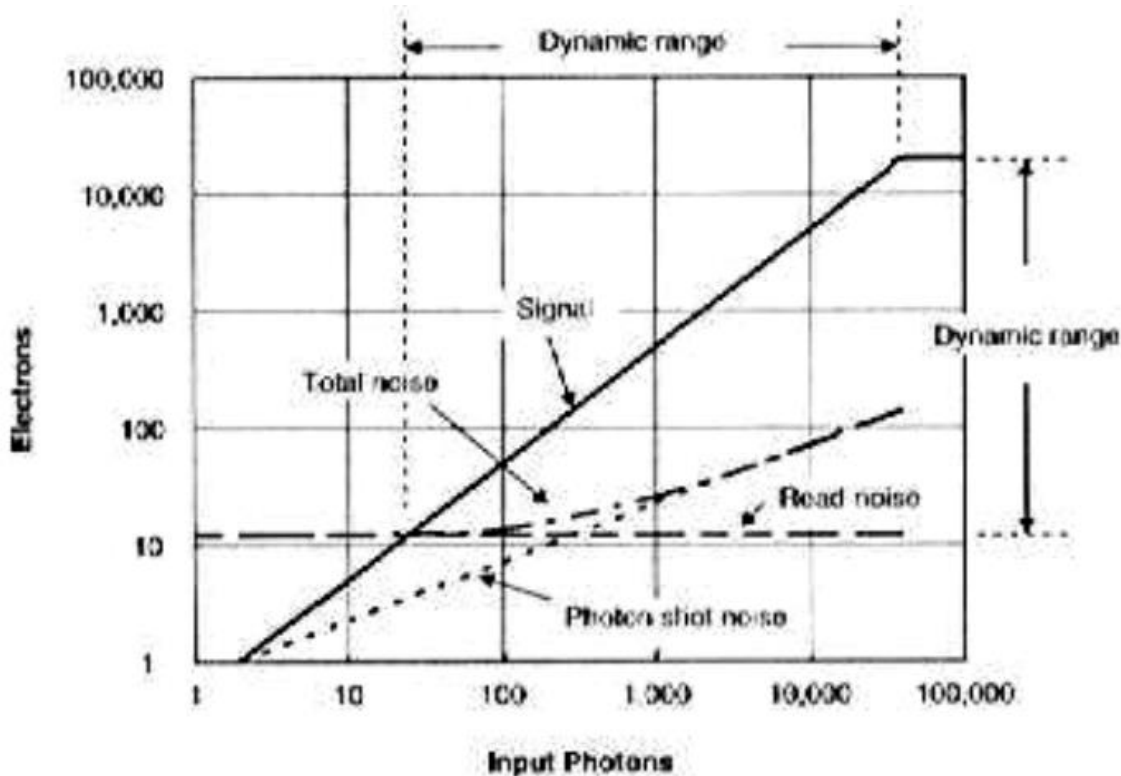
$$\text{DR [dB]} = 20\text{LOG} (V_{\text{sat}} / V_{\text{Dark,rms}})$$



$$\text{SNR (dB)} = 20\text{log} (\text{Image e-} / \text{Noise e-})$$

Definitions

Dynamic Range



(1) Reference - "Image Sensors & Signal Processing for Digital Still Cameras" CRC Taylor & Francis, pg 67.

sales@visionsystech.com

Definitions

Bit Depth

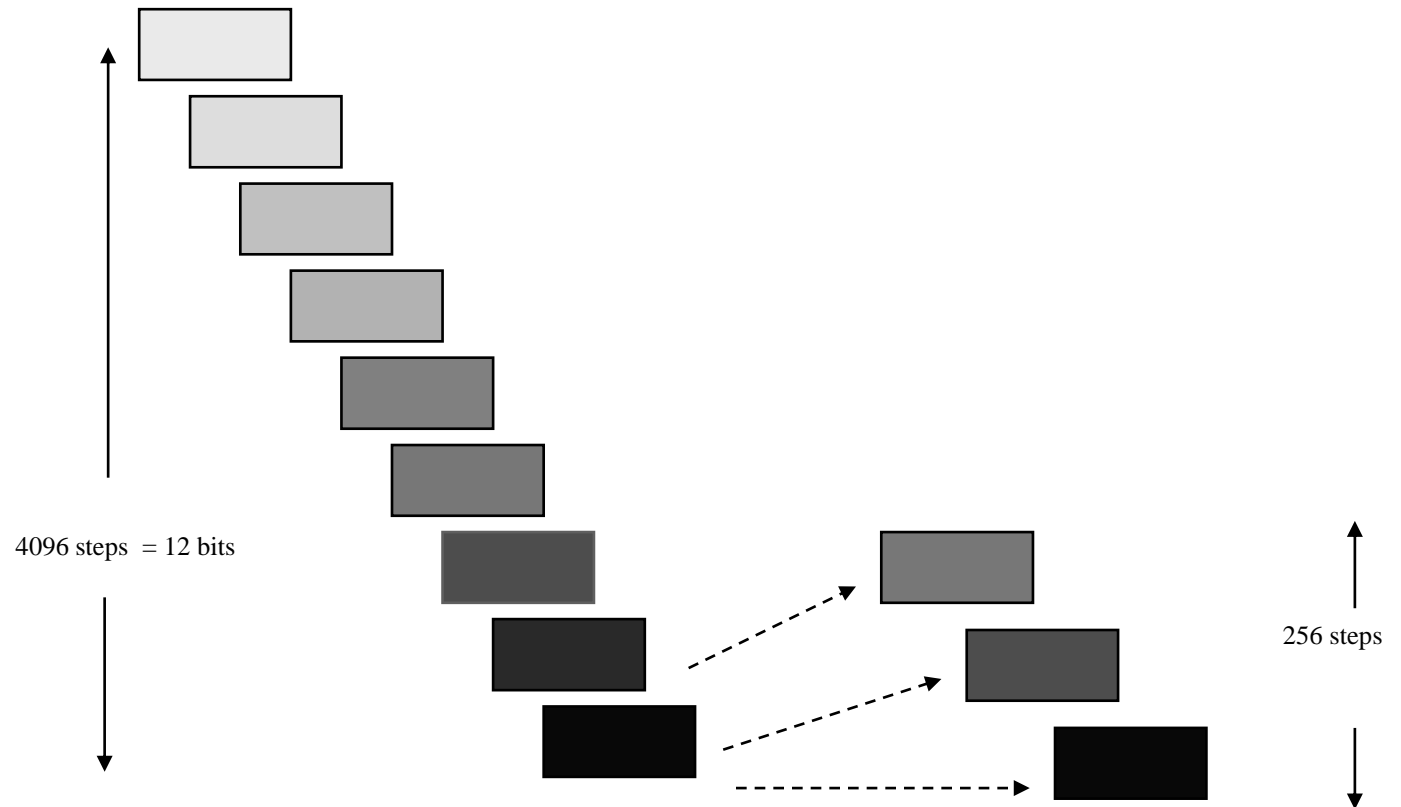
Bit depth is the number of bits used to define each image pixel, 24-bit color, 8-bit color, 8-bit grayscale, 1-bit bitonal. The greater the bit depth, the greater the number of tones (grayscale or color) that can be represented.

Also called pixel depth or color depth. Bit depth measures how much color information is available to display or print each pixel in an image. Greater bit depth (more bits of information per pixel) means more available colors and more accurate color representation in the digital image.

The number of bits per pixel determine the number of shades of gray or variations of colors that can be displayed.

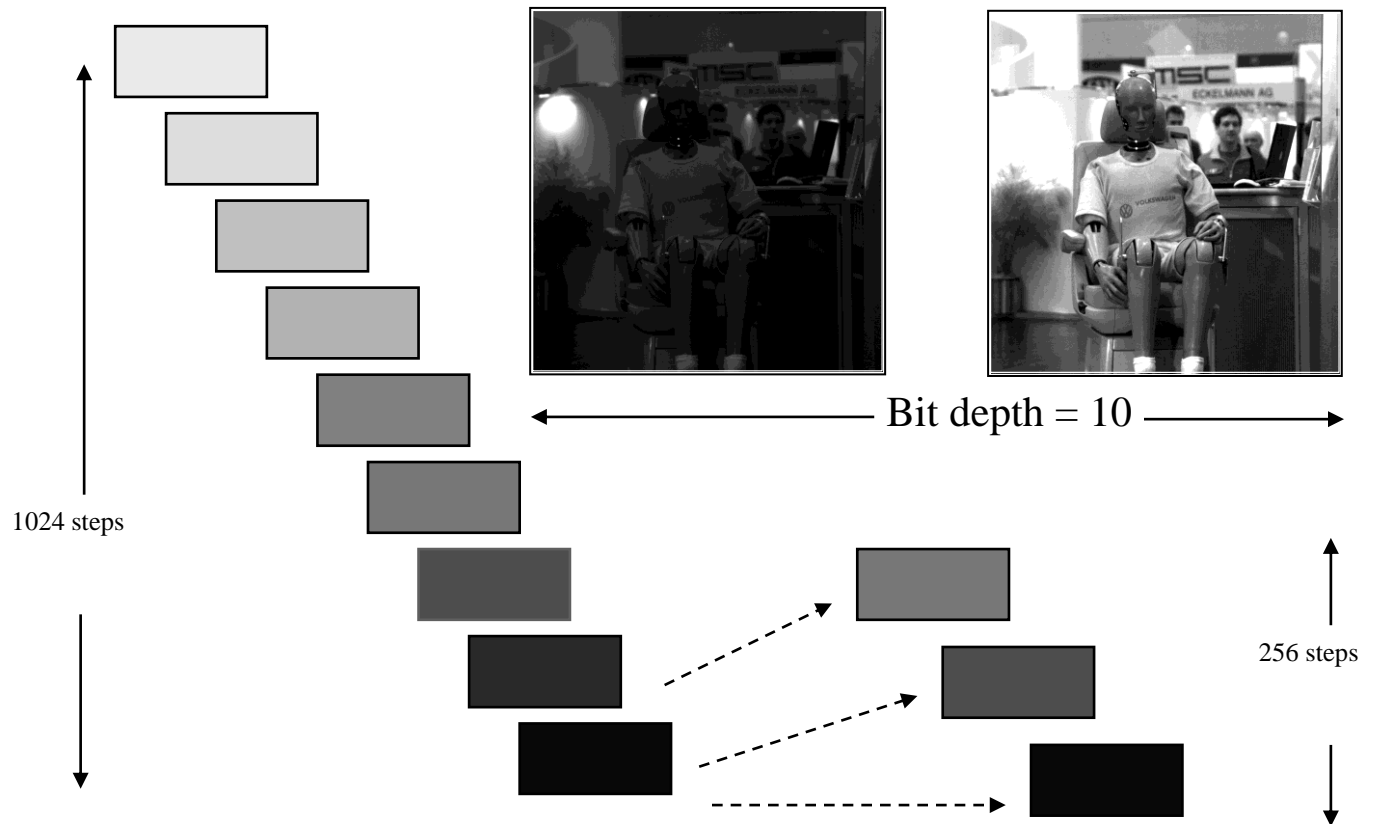
Viewing the Image Bit Depth on a PC

What can be actually be seen?



Viewing the Image Bit Depth on a PC

What can be actually be seen?

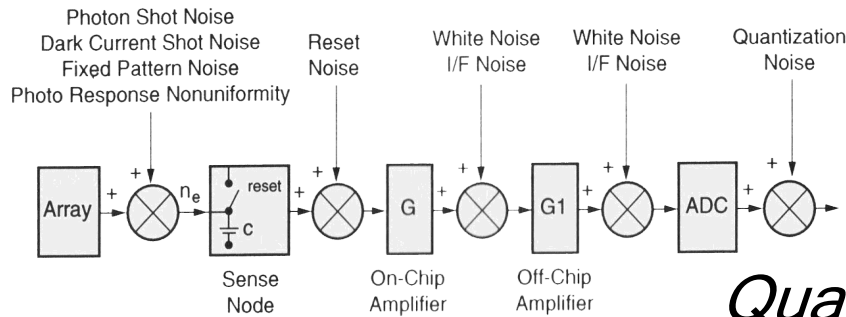


Display FAQs

- LCDs have a better contrast than Plasma.
- RGB settings are typically 0.55 or the inverse of 1.8
- Contrast ratios are very important for good looking color images on LCD displays. As an example, a LCD monitor with 200:1 contrast can not display an 8-bit image. Use LCD monitors with 400 to 512:1 or greater contrast ratio.
- LCD displays should have a brightness setting of at least 400 NITS for outdoor use (800 NITS is better). LCD's are brighter than Plasma displays
- Video (analog) displays have a different gamma setting than RGB computer monitors (typically 0.45 or the inverse is 2.2)

Making the Bits

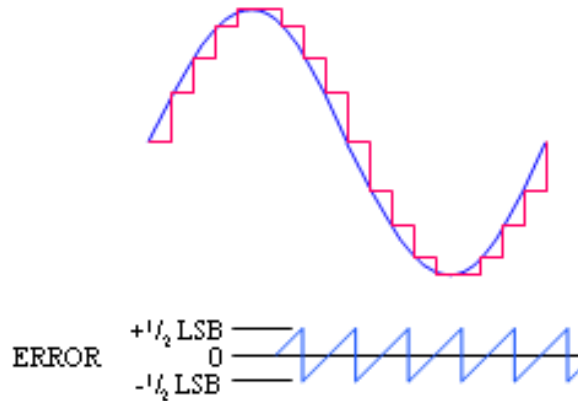
Quantization Errors from ADC's



Making the Bits

Quantization Errors from ADC's

$$\frac{1}{\sqrt{12}} \text{LSB} \approx 0.289 \text{ LSB}$$



A/D Converter Resolution (Binary Code)		(*) Value of 1LSB		(*)Value of 1/2LSB	
Number of Bits (n)	Number Of Increments (2^n)	0 to +10V Range (mV)	+10V Range (mV)	0 to +10V Range (mV)	+10V Range (mV)
16	65536	0.152	0.305	0.076	0.152
12	4096	2.44	4.88	1.22	2.44
11	2048	4.88	9.77	2.44	4.88
10	1024	9.77	19.5	4.88	9.77
9	512	19.5	39.1	9.77	19.5
8	256	39.1	78.2	19.5	39.1

(*) Note: scale 0 to 10 volt range to 0 to 1 volt for video

And the percentage of quantization error for various ADCs can be seen in the following table.

ADC Res	8	9	10	12	14	16
Q error (%)	0.113	0.056	0.028	0.007	0.0017	0.0015

Knowledge

Be more informed about technical specs

Knowledge

Be more informed about technical specs

Number Bits	8	10	12	14	16
Ratio	256:1	1024:1	4096:1	16384:1	65536:1
Infor Increase	-----	4x	16x	64x	256x
Max. SNR Range (dB)	48	60	72	84	96

Some camera manufactures say their cameras produce 14 bits, however, when you look at their own application notes, the performance is shown to have a dynamic range of 1320:1. That is amazing since a 11-bit dynamic range should be 2048:1 and a 10-bit dynamic range would be 1024:1. Therefore, claiming a 14-bit camera with a dynamic range of 1320:1, you can get the same performance out of a camera with an 11-bit dynamic range.

Conclusion

Be more informed about technical specs

- When in doubt, error on the conservative side
- Don't promise more bits than we can produce
- Know some key numbers for SNR, Dynamic Range and Bit Depth