Noise in Digital Photography

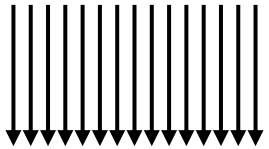
- What is noise? Noise is anything that keeps a perfectly smooth surface from looking perfectly smooth in your picture.
- There are several *sources* of noise.
- There are things you can do at capture time to reduce noise.
- There are things you can do in editing that amplify noise.
- There are some amazing tools to reduce noise when editing.

Sharpness and noise are related:

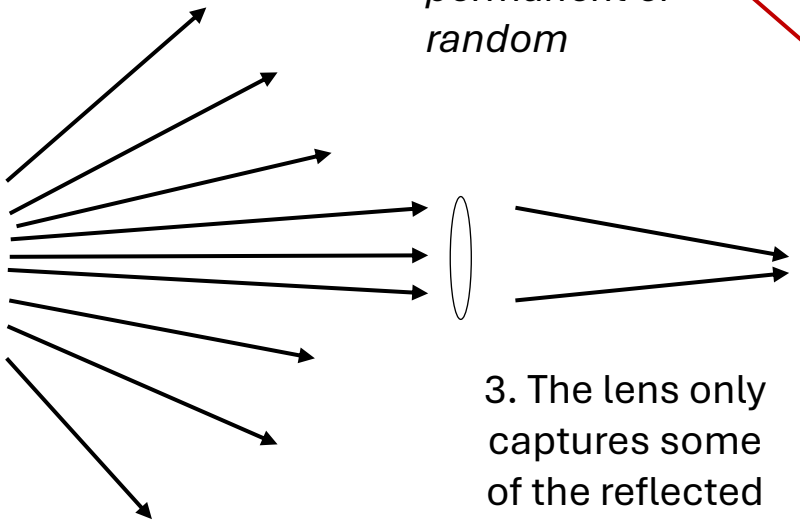
- The noisier your picture, the less sharp it will appear.
- The trick is to reduce noise without also reducing sharpness.
- Early sharpening algorithms looked at neighboring pixels (for example, 3x3, 5x5, or 7,7) to detect features that could be preserved. AI algorithms look at an enormous region around each pixel (hundreds to thousands of pixels) to look for features, while also using knowledge of what kinds of features are likely based on training.

The Main Sources of Noise

1. There are only so many photons from the light source



2. Only some of them get reflected



Some pixels can get stuck on or off.

This can be permanent or random

Pixels aren't equally sensitive to light.

3. The lens only captures some of the reflected photons

4. The sensor only converts some of the photons to electrons

(less than a 1/3)

Stray electrons constantly get added to each pixel.

The hotter the sensor and longer the exposure, the more stray electrons.

5. The A/D converter rounds the electron count to the nearest 12-bit (4096 possible values) or 14-bit number (16192 possible values).

6. Numbers in your file describing the brightness of each pixel!

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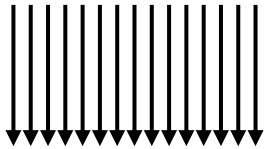

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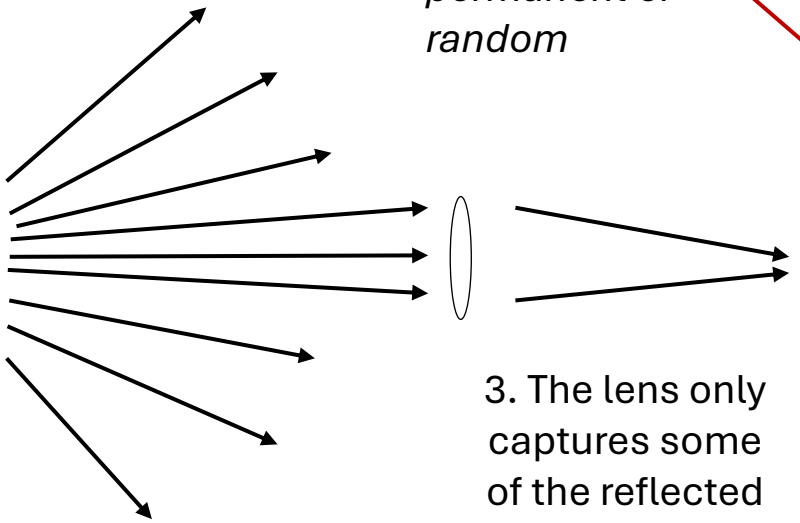

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Shot Noise

Hot Pixels

Blinkers

Some pixels can get stuck on or off.

This can be permanent or random

PRNU

Fixed Pattern Noise

Pixels aren't equally sensitive to light.

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(less than a 1/3)

Quantum Efficiency

Dark Current

Stray electrons constantly get added to each pixel.

The hotter the sensor and longer the exposure, the more stray electrons.

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Quantization Noise

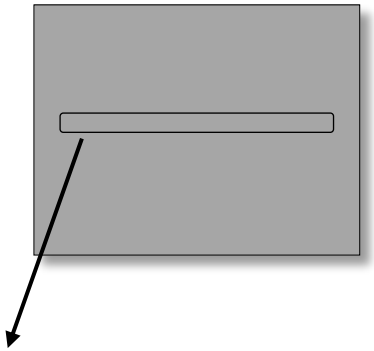
6. Numbers in your file describing the brightness of each pixel!

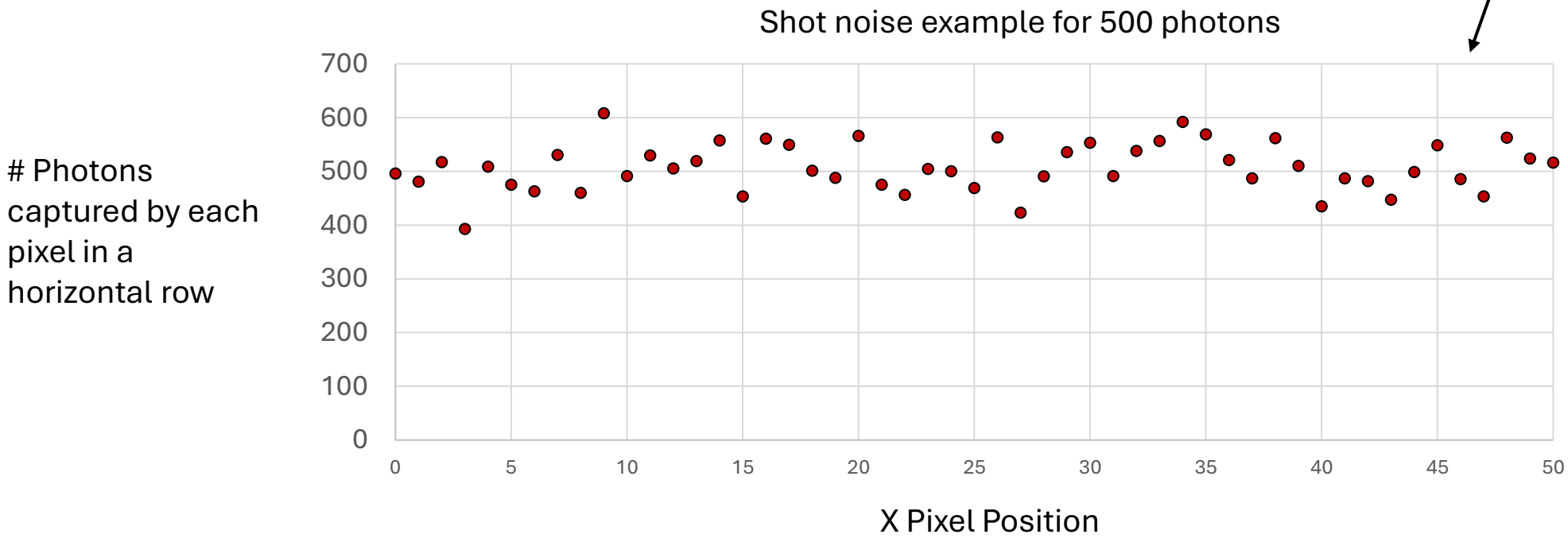
A quick lesson in physics:

There are only so many photons, and they arrive randomly

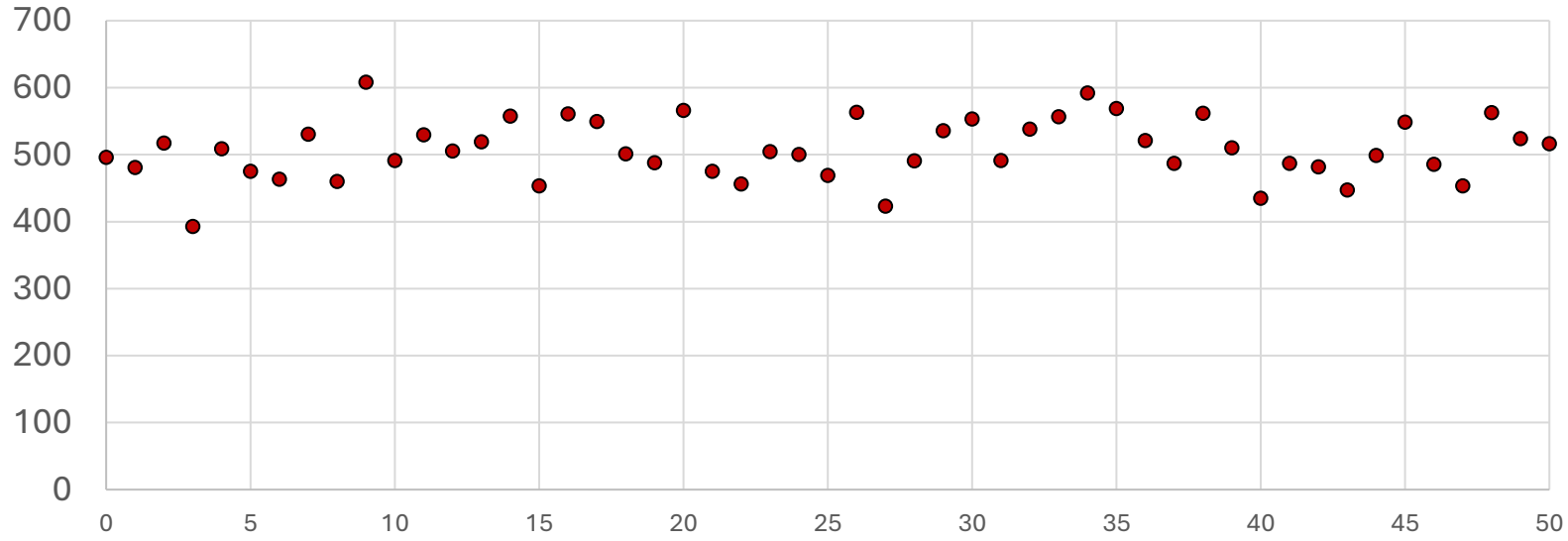
What does this mean?

If you take a picture of a grey card, and the grey card is exposed so the sensor averages 500 photons at each pixel. You'll get 500 photons at some pixels, or 490, or 525, or 476, etc. The variation is huge – it is proportional to the square root of the number of photons!

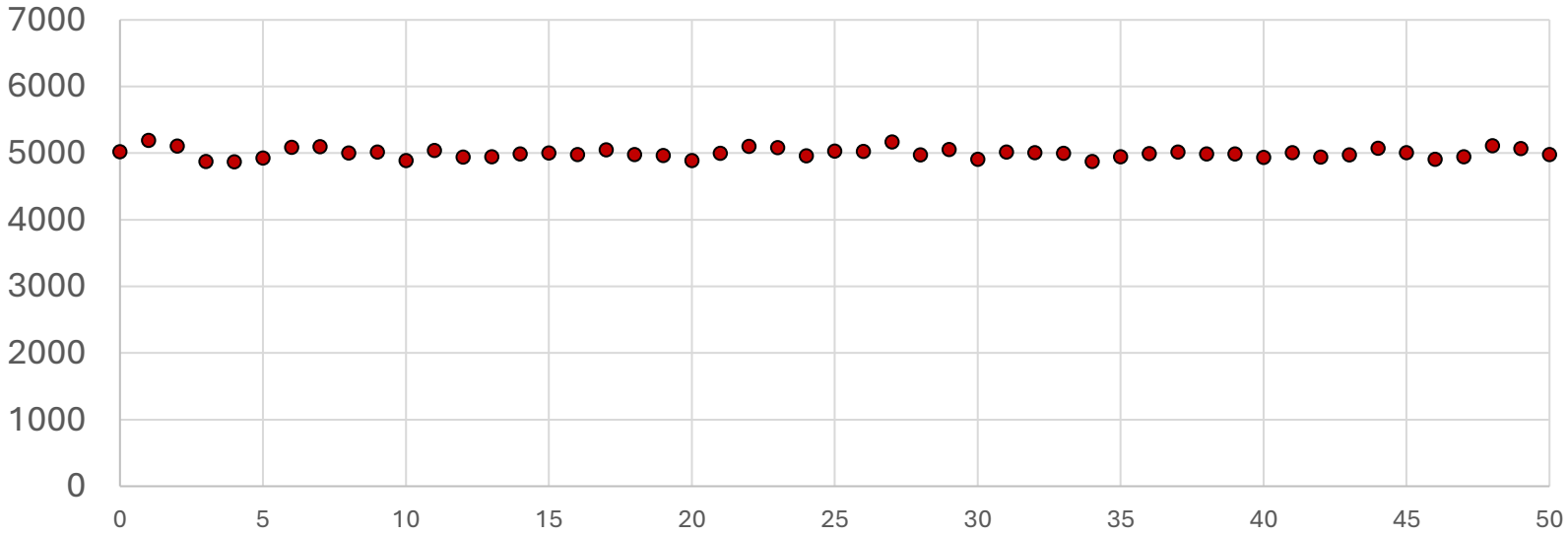




Photons captured by each pixel in a horizontal row



What if I have 10 times more light ?



X Pixel Position

Sensor noise

- All sensors have defects, except for expensive hand-selected sensors made for astronomy and military applications.
- Single pixel defects.
    - Can be hundreds on a sensor.
    - The number of bad pixels can increase over the life of a sensor, usually due to alpha hits. Alpha particles are high-speed particles, usually from outer space that make it through our atmosphere.
    - Usually corrected in-camera before the RAW file is produced. These are corrected using a dynamic algorithm so that new defects can also be caught. There is no map in the camera of where all the bad single-pixel defects are.
    - Not all single-pixels defects are caught, which is when you get a hot pixel on your sensor.
- Cluster defects
    - When there are two or more adjacent bad pixels. There are very few of these on a sensor.
    - A map, or list of cluster defects is created at manufacturing time. After each picture is taken, these defective clusters are interpolated over before the raw file is created. There are typically none allowed in the center of the sensor, and only a few in the outer regions of the sensor.

Dark Current Sensor noise, aka Dark Noise

- All sensors accumulate stray electrons during exposure.
- For exposures less than a second dark noise isn't noticeable.
- Each pixel accumulates noise at a different rate.
- The hotter the sensor, or longer the exposure, the more dark noise accumulates. This presents a problem for mirrorless cameras because the sensor is always on, thus runs hotter than the sensor in a DSLR.
- There is a setting in the camera to reduce this noise. It works like this:
    1. The camera takes the picture
    2. The camera closes the shutter and takes a completely dark picture at the same exposure time and ISO setting as the picture in (1.)
    3. The camera subtracts the picture taking in (2.) from the picture taken in (1.), and that's your final picture.

Canon: Long exposure Noise Reduction

Nikon: Lone Exposure NR

Sony: Long Exposure NR or Noise Reduction for Long Exposure

Fujifilm: Long Exposure Noise Reduction

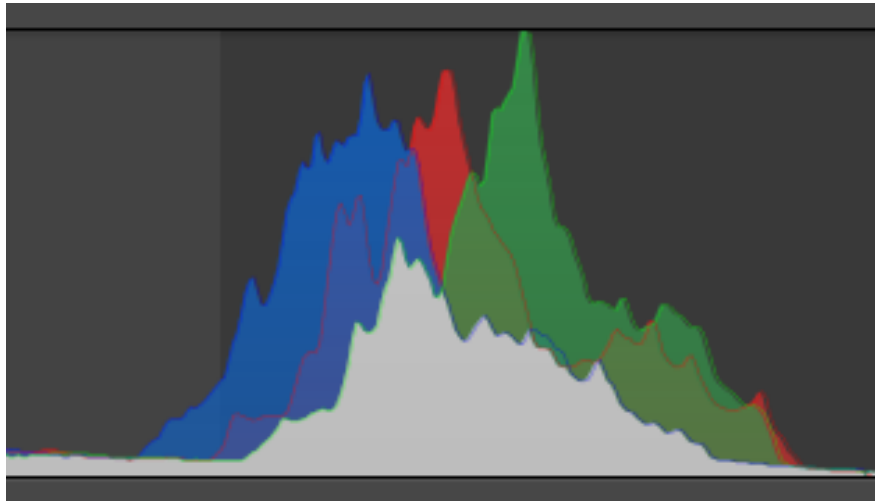
Panasonic: Long Shutter Noise Reduction

Olympus: Noise Reduction

Pentax: Slow Shutter Speed NR

How do we get more photons ?

1. Put lots of light on the subject (flash, studio lights, reflectors, open your curtains, go outside)
2. Use ISO 100, or the lowest ISO you can get away with.
3. Use a large aperture.
4. Use a long enough exposure and white enough aperture so the whitest thing in the scene almost over-exposes
5. Check your histogram – increase the exposure until the right side is almost clipping
6. Use a camera with a full-frame sensor. You will collect more total photons.



Things that add or amplify noise

1. Conversion from Bayer space to R,G,B per pixel, aka de-mosaicking. This is the first thing Adobe RAW/Lightroom do when opening a RAW file. This adds both luminance and chroma noise. It has to be done. The best conversion available is the Adobe Denoise feature, which is an AI-based demosaic algorithm.

   NOTE: Foveon sensors are a special case. While they have R,G,B values for each pixel and don't need the demosaic conversion, the spectral overlap of the R,G,B values requires heavy math to correct, which adds an equivalent amount of noise.

2. JPG conversion, including shooting in JPG. **Shoot in RAW for lowest noise**. One exception: If you know you will use the JPG out of the camera as-is, without any editing, you can shoot in JPG without loss.
3. Focus stacking
4. Bringing up the shadow slider
5. Turning up the saturation
6. Turning up sharpening
7. Storing and retrieving results in 8-bit rather than 16-bit format. If you're moving images over to Zerene or Helicon to stack, use a 16-bit file format.

- For night shots, always turn on long-exposure noise reduction.
- When processing astronomy pictures, dial-down the amount of Denoise you apply in Adobe Denoise (Lightroom or Photoshop). Denoise can do weird things, like linking stars together, or deleting stars.
- In edit, selectively sharpen the subject, not the whole picture. Some perception of noise and sharpness is relative.
- Use minimum compression (aka highest quality setting) when exporting to jpg.
- The goal isn’t zero noise. Zero-noise silky-smooth surfaces in a picture can look fake or plasticky.