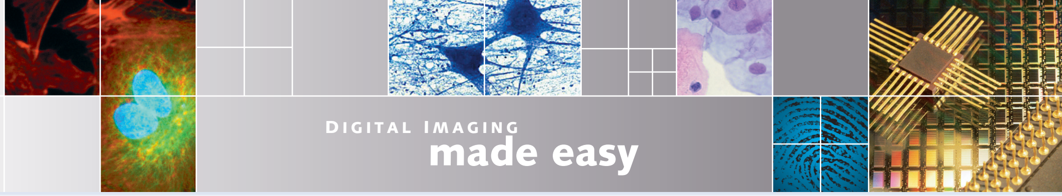


TECHNICAL NOTE

# Rolera EM-C² Binning Functionality Description

Due to technical design reasons the Rolera EM-C² camera has a combination of vertical analog binning and horizontal digital binning. The vertical clocks are clocked such way that the charge it's combined in the vertical direction prior to readout (like in the typical binning) while the digital binning in the horizontal direction it's performed after the digitization of the readout analog signal, in the digital domain.

## Advantages of the Binning mode

### Frame Rate

Frame rate is increased with the binning scheme employed - no changes in performance.

### Noise

There is also a noise advantage – it's reduced by a factor of sqrt (binning).

For example, a 4x4 EM-C² binning reduces the noise by a factor of sqrt(4) = 2 because the camera performs a digital average of the horizontal pixels "combined" in the binning. A special module in the FPGA takes care of the digital binning, based on frequency and binning factor.

The signal to noise ratio (SNR) is increased by binning in the EM-C² camera but not at the same rate would be increased in a traditional analog binning.

The math behind SNR calculations it's the following:

**SNR** $(S_{Total}/\sigma_{Total}) = (S*QE) \,/\, \mathrm{sqrt}[(S*QE*F^2) + (D*F^2) + (\sigma_R/G)^2 + (\sigma_E/G)^2]$

Where:

- QE = quantum efficiency
- S = signal in number of incident photons acquired during exposure time
- F = excess noise factor (typ. F=1.2) when using electron multiplication
- $\sigma_{Total}$ = total noise (readout+dark+offchip electronics)
- $\sigma_R$ = readout noise (in number of electrons)
- $\sigma_E$ = electronics noise (in number of electrons) due to off-chip circuitry at 40 MHz operation
- D = total dark-related signal

For high illumination levels the SNR is improved by 4x/16x/64x times when binned 2x/4x/8x *regardless* the type of binning employed because

**SNR** $(S_{Total}/\sigma_{Total}) = \mathrm{sqrt}[(S*QE)$

At low illumination levels, the SNR is reduced to the following:

**SNR** $(S_{Total}/\sigma_{Total}) = (S*QE) \,/\, \mathrm{sqrt}[(D*F^2) + (\sigma_R/G)^2 + (\sigma_E/G)^2]$

Example: For a typical vertical analog binning and horizontal analog binning, a 2x2 binning would provide an increase in SNR:

**SNR** $(S_{Total}/\sigma_{Total}) = (4*S*QE) \,/\, \mathrm{sqrt}[4*(D*F^2) + (\sigma_R/G)^2 + (\sigma_E/G)^2]$
a roughly 4x SNR improvement, supposing negligible dark current.

While for EM-C2 (with analog vertical binning and digital horizontal binning) a 2x2 binning would provide an increase in SNR of :

**SNR** $(S_{Total}/\sigma_{Total}) = (4*S*QE) \,/\, \mathrm{sqrt}[4*(D*F^2) + 2*(\sigma_R/G)^2 + 2*(\sigma_E/G)^2]$
a roughly 4/sqrt(2)=2.83x SNR improvement.

For the other binning schemes, the camera specs are improved at the expense of the spatial resolution, as following:

| Binning | Frame rate (Hz)* | Noise reduction (x) | SNR improvement (x) |
|---|---|---|---|
| 1x1 | 34 | 1.000 | 1.000 |
| 2x2 | 63 | 0.707 | 2.828 |
| 4x4 | 107 | 0.500 | 8.000 |
| 8x8 | 166 | 0.354 | 22.627 |

*at 40 MHz pixel rate

### Summary

The EM-C² camera employs a combination of analog and digital binning. This allows frame-rate improvements as well as SNR improvements but due to the digital binning aspect the SNR improvement is not as efficient as it would be in a pure analog binning regime.

Q IMAGING

Tel 604.530.5800 ▪ Fax 604.539.1825 ▪ info@qimaging.com
**www.qimaging.com**