

## Improved 4 Tap Channel Balancing on Cameras with Kodak Sensors

With regard to good image quality, CCD sensors are still virtually unrivalled. They offer low noise, high quantum efficiency, and very linear behavior. However, each output tap that delivers the image data from a CCD sensor only has limited bandwidth. The performance requirements for industrial cameras have increased drastically over the last few years, and the limited bandwidth available from a single output tap often does not meet these needs. Standard CCD sensors, for example the Sony ICX285 with a resolution of 1.45 megapixels and one data output tap, typically offer a maximum image capture rate of about 30 frames per second (fps). These days, however, many industrial applications require at least 50 fps. And depending on the velocity of the production process, up to 100 fps are sometimes required.



A few years ago, CCD camera manufacturers began reacting to the increased demands by introducing a “dual tap” concept. The data output from the sensor is distributed between two “taps”, thus doubling the available output bandwidth and allowing twice the frame rate of a single output sensor. This concept has proven successful throughout the years, and cameras employing two tap sensors have become well established in the marketplace. The following Basler pilot cameras, for instance, use two tap sensors:

Model	Sensor	Resolution	Speed	Interface
piA640-210 gm/gc	Kodak KAI-0340	648 x 488 (VGA)	210 fps	GigE
piA1000-60 gm/gc	Kodak KAI-1020	1004 x 1004 (1 MP)	60 fps	GigE
piA1600-35 gm/gc	Kodak KAI-2020	1608 x 1208 (2 MP)	35 fps	GigE
piA1900-32 gm/gc	Kodak KAI-2093	1928 x 1084 (2 MP)	32 fps	GigE

However, the requirements for industrial applications and the sensor concepts developed to meet them have evolved. Some new sensors are now based on a “multi tap” concept. The latest state-of-the-art technology is a sensor with four taps that can, for example, be found in several high end Kodak sensors. This “multi-tap” sensor technology is used in the Basler aviator camera series. With the aviator, the following frame rates are possible:

Model	Sensor	Resolution	Speed	Interface
avA1000-120 km/kc	Kodak KAI-1050	1024 x 1024 (1 MP)	120 fps	Camera Link
avA1000-100 gm/gc	Kodak KAI-1050	1024 x 1024 (1 MP)	101 fps	GigE
avA1600-65 km/kc	Kodak KAI-2050	1600 x 1200 (2 MP)	67 fps	Camera Link
avA1600-50 gm/gc	Kodak KAI-2050	1600 x 1200 (2 MP)	55 fps	GigE
avA1900-60 km/kc	Kodak KAI-2150	1920 x 1080 (2 MP)	62 fps	Camera Link
avA1900-50 gm/gc	Kodak KAI-2150	1920 x 1080 (2 MP)	51 fps	GigE
avA2300-30 km/kc	Kodak KAI-4050	2330 x 1750 (4 MP)	31 fps	Camera Link
avA2300-25 gm/gc	Kodak KAI-4050	2330 x 1750 (4 MP)	26 fps	GigE

In the industrial environment and also in traffic control, many image analysis algorithms are based on the detection of object contours that are visible due to intensity changes in the acquired images. For these algorithms to work with nearly 100% reliability, it is essential to have a minimum number of intensity artifacts in the image data.

For camera manufacturers, it was a challenge to do tap balancing well on sensors with two taps and to achieve the required minimum level of intensity artifacts. When there are four taps, the complexity of properly adjusting the tap balance is even greater. But what does tap balancing mean and what are the problems associated with doing it correctly?

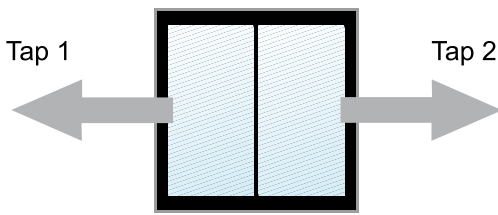


Figure 1: Two Tap Sensor

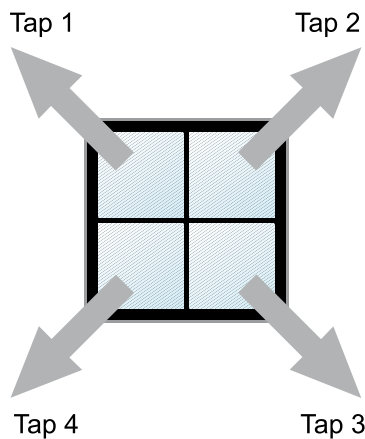


Figure 2: Four Tap Sensor

The difficulties associated with tap balancing are significant because there are a number of possible disturbing influences that must be compensated for. Each one of the taps on the sensor transports an analog signal via an amplifier stage to an analog-to-digital converter (ADC), and each tap has its own dedicated amplifier and ADC. Because component tolerances, reactions to temperature changes, and reactions to electromagnetic radiation may vary slightly for the component set associated with each tap, it means that the output from each quadrant may vary, even when the sensor is viewing a uniform object. This effect must be compensated for by using electronics and processing software within the camera. Continuously operating control circuits that measure the differences and calculate the required compensation factors from image to image have a disadvantage because they

cannot measure the behavior of the camera and maintain control with the degree of accuracy required to ensure the necessary uniformity. This required uniformity, however, is a critical prerequisite for most of the analysis algorithms.

The velocity advantage of multi-tap sensor technology is opposed by the challenges associated with the need to balance the separate sensor areas allocated to each tap and the need to deliver a homogenous image. Quad tap sensors that are not fully balanced exhibit horizontal and vertical “joints” that cross in the center of the image, and these joints can be apparent in the acquired images. When this is the case, reliable image analysis cannot be expected.

Only a comprehensive measurement of the characteristics of each tap’s performance over a wide range of conditions and the mapping of these characteristics into a well-defined parameter space can guarantee a balanced image. Camera manufacturers like Basler use a fully-automatic production system for balancing the taps. This system is not only responsible for making basic adjustments but also for fine tuning the tap balance over a wide variety of simulated situations based on various application-oriented and environmental constraints. This ensures comprehensive, careful balancing of the taps in each camera over the camera’s entire operating range.

The following sample images illustrate the relevance of a well-engineered balancing procedure. The images are acquired at different gain settings. You can easily see that a carelessly balanced camera will exhibit seemingly correct balancing in one given situation (e.g., a certain gain setting) while revealing a completely different picture in a different situation (e.g., with a higher gain). The “joints” between the tap areas will remain invisible over a variety of situations only if all of the influences on the tap balance are properly measured and the effects are given the correct weighting in the balancing procedure.

Figure 3 shows the difference between a Basler aviator camera and the standard type of CCD camera offered by many competitors. Comprehensive multi-tap balancing over the complete parameter space is implemented in all Basler aviator cameras. The standard cameras from the competition do not include comprehensive tap balancing, and the effect can clearly be seen in the images.

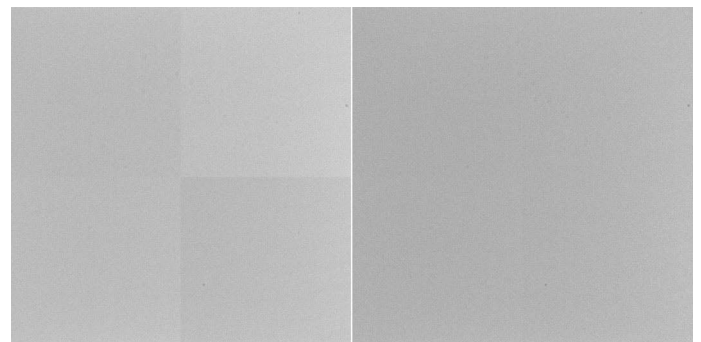


Figure 3: Unbalanced vs. Balanced Images

Figure 4 illustrates that tap balancing exhibits some dependency on the magnitude of the camera's gain setting and that there can be a large difference in gray values both in brightly illuminated areas of the image as well as in the darker areas. This proves that complete calibration of the camera over its entire operating range is absolutely essential to making the borders of each tap area invisible, even for demanding imaging applications.

These typical images for an unbalanced type of camera were provided by a device from one of Basler's competitors. The camera used to acquire these images is based on a Kodak KAI-1050 sensor running at 120 fps (mono + color). Visible differences can be detected in all of the images. The differences reach 15 to 20 gray values in 8 bit output modes and will influence or hinder the usability of the imaging results.

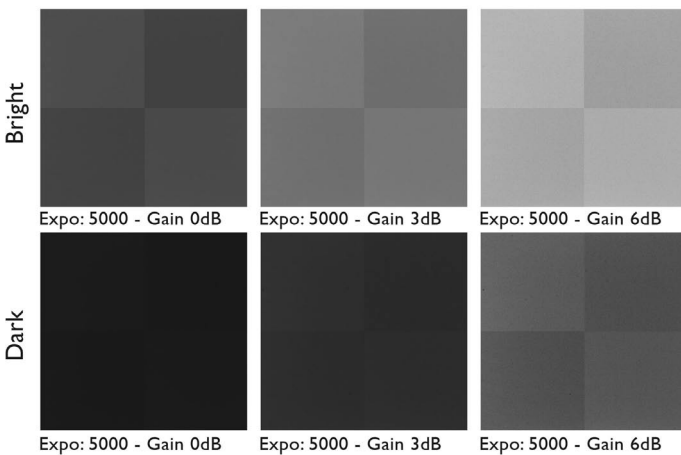


Figure 4: Unbalanced Images at Various Gain Settings

The images in Figure 5 are from a Basler aviator equipped with a KAI-1050 sensor running at 120 fps. Tap differences have been compensated for in all images. Notice the exceptional degree of image uniformity compared to the images from an unbalanced camera.

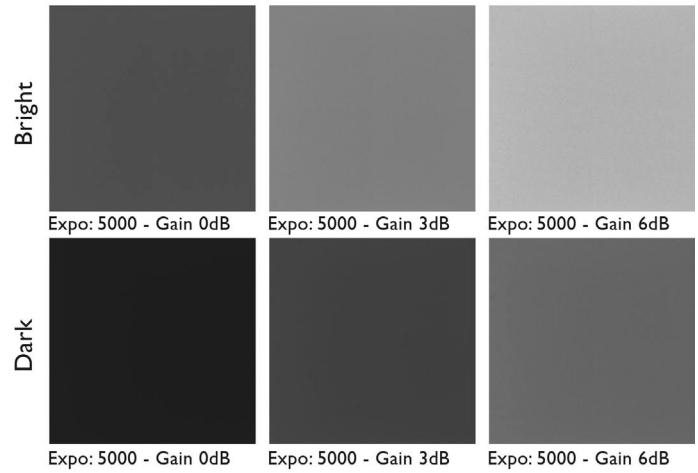


Figure 5: Balanced Images at Various Gain Settings

## Summary – Why Basler?

- Taps are factory calibrated over the entire operating range
- Calibration is automatically performed by the Basler CTT+ (Camera Test Tool Plus) to ensure reproducible camera quality
- Separate gain settings are available for each tap allowing manual adjustment if desired
- Separate black level settings are also available for each tap
- Basler cameras are fully GigE compatible