Optronis
Make time visible

CamPerform CP series

White Paper

Version 2016\WP CamPerform_01_en

CP70 series

CP80 series

CP90 series

CoaXPress®

GEN<i>CAM

1288 EMVA Standard Compliant

CamPerform CMOS cameras

CamPerform cameras from Optronis are high performant and are typically used in quality control, process optimization, R&D, material test, in 2D/3D Machine Vision, in inspection systems and longtime recording systems.

As well as the reliability which comes from compliance with EMVA1288, the GenICam software interface standard and CoaxPress cerification, Optronis has once again proved the suitability of its camera technology for machine vision in electrodynamic stress tests.

The key technology for the front end of Optronis image processing systems is CMOS (Complementary metal oxide semiconductors). CMOS is, due to the direct and almost zero-delay access to the respective pixel not only flexible, but so fast, that extreme image repetition rates can be reached for small as well as large format image sensors. High-speed machine vision standard image sensors approach transfer rates of up to ~ 2 billion pixels per second (CP80-4, CP80-25, CP70-12).
This equals about 100 times higher frame rate compared to fast CCD sensors and gives access to new applications in the machine vision: e.g. 100 % control (Area Optical Inspection AOI) as well as 3D measurements are areas where fast CMOS sensors are used.

The back end of the cameras consist of a CoaXPress interface that allows to supply the camera, to select camera parameter and to transfer images. CoaXPress is one of the fastest standardized image data interfaces, that is developed specially for the high end machine vision (see Paragraph CoaXPress).

Especially for customers, who would like to use the high performance cameras for their application, Optronis will be a reliable and competent partner.

CoaxPress

Optronis CamPerform cameras are equipped with a CoaXPress interface. CoaXPress is a modern, high perfomant camera interface that transfers image data from cameras (Device) to a frame grabber (Host). It combines ruggedized 75 Ohm coaxial cables with state of the art high speed serial and digital data technology, allowing up to 6,25 Gigabits per second data rate per Coaxcable.

Following Data Transfer Bitrates via one Coaxcable are supported:

- 1,250 Gigabits per second
- 2,500 Gigabits per second
- 3,125 Gigabits per second
- 5,000 Gigabits per second
- 6,250 Gigabits per second

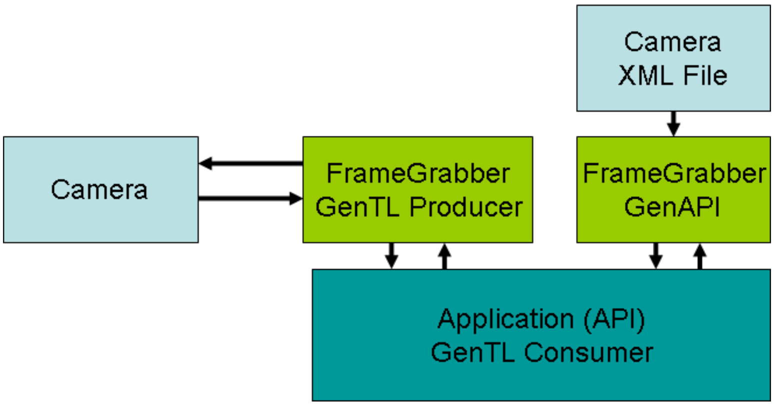
With the extension of more than one Coaxcable (Link Aggregation) the transfer rate can increased linearly. Optronis cameras offer up to four Coax channels that allow an overall data rate of up to 4 x 6,25 Gigabits per second = 25 Gigabits per second.

The available Power, that can be supported by one or more Coaxcables (max. 13 Watts per Coaxcable) can be used to supply the camera. This allows to operate the camera independently from any other external power supply.

CoaXPress is characterized im comparison to other high speed interfaces by a particular large transmission length, without the use of repeaters. As an example please refer to CoaxPress certification program “Cable (Cable Assembly)” to find certified CoaxPress cables:
http://jiia.org/en/cxp/
The reported maximum cable length (status July 15) is about 40 meters at 6,250 Gigabits per second and up to 100 meters at 3,12 Gigabits per second. Extreme cable lengths of up to 200 meters at lowest transfer rates (1,250 Gigabits per second) are – along CoaXPress specification - feasible.

GenICam

Optronis CamPerform cameras use the GenICam Standard. GenICam (generic interface for cameras) is a programming interface for cameras that are used in machine vision applications. Goal of the standard is the separation of the interface technology of industrial cameras from the programming interface of the application (API).



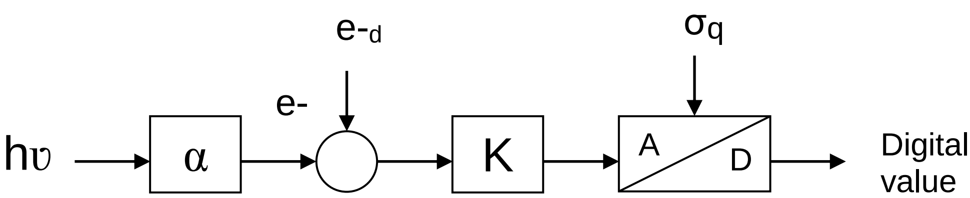
GenICam consist of two modules that help to solve the most important tasks in machine vision:

- The GenAPI module is used to configure the camera, to control access to the camera and the camera control. It uses a camera description file that exists in XML format (as an independent XML file or as a file located in the camera itself).
- The GenTL module consist of a GenTL Producer (located on the frame grabber side) and the GenTL consumer (application) and composes the transportation layer between camera data and the user application (API).

GenICam uses for better compatibility the denotation and typification of the SFNC (Standard Feature Naming Convention) to identify common camera characteristics.

EMVA1288

Optronis CamPerform cameras are specified and tested along the EMVA1288 3.0 Standard. The EMVA1288 Standard serves to characterise monochrome as well as color cameras in a comprehensive way. Data that are identified are amongst others sensitivity, linearity, Noise, dark currents, sensor non-uniformities, defect pixels…
EMVA1288 provides a mathematical model, that can be used to calculate camera characteristics based on the theory of the quantum physics:

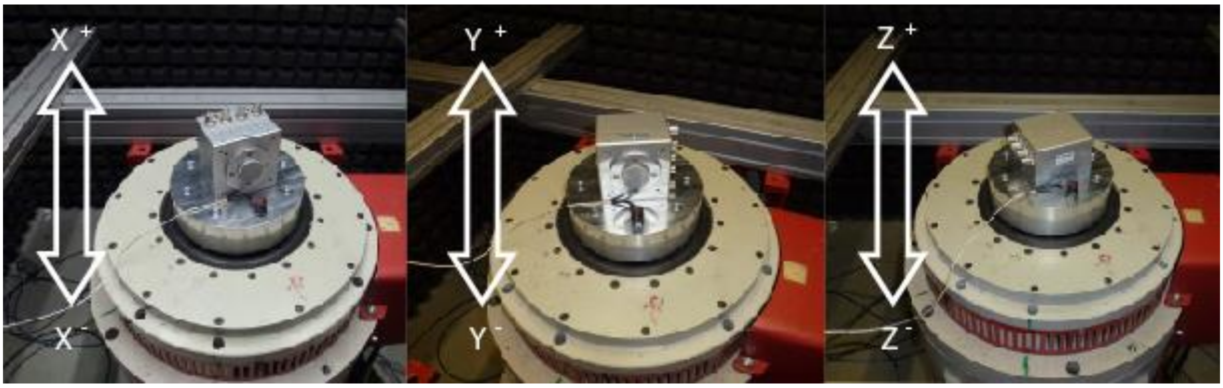


Whereas $h\upsilon$ designates the number of photons that hits an image pixel (picture element). α is the quantum efficiency, that converts the number of photons in a number of photoelectrons (e-). Together with the number of dark current induced electrons ($e\text{-}_d$) the total number of electrons are multiplied by a system specific Gain K. The analog/digital conversion that is influenced by A/D noise (σ_q) results in a digital value of the image pixel. With this calculation the electrooptical or physical behaviour of the pixel and even the whole image sensor of the camera is characterized. The EMVA1288 values are evidenced in extensive test logs.

Optronis will be a reliable and competent partner for customers that need specific camera performance values for their application, knowing that due to the application a specific factory calibration procedure will be needed. Optronis has long term experience and can help to ship reliable characteristics of their camera technology.

Elekrodynamic stress tests

Optronis proves the test and application ranges for its cameras using electrodynamic stress tests. As a result, it is now official: Optronis cameras can cope with the demands of harsh environments. Robust components such as the Optronis CamPerform series are required above all for use in industrial production environments. Hence, the cameras were subjected to a range of stress tests, including vibration, noise and various shock and impact tests.
To perform the tests, the Optronis camera was secured to a shaker. The parameters required for controlling the various tests were entered via a PC and transmitted to the shaker controller. The control signal needed for the test process was generated by this controller and transmitted to the shaker via the power electronics. Vibration and noise tests were conducted at a frequency range of 2 to 2000 Hz, while the cameras were tested at 30g in the repeated shock test and at up to 100g in the impact acceleration tests. The testing was performed along three rectangular coordinate axes. The resulting base point acceleration was measured using an acceleration sensor. The direct or adaptive control concepts implemented on the controller ensure that the measured accelerations lie within the range of tolerance specified by the standard.
The values are evidenced in extensive test logs which - as well as target and actual acceleration and permitted deviation - also contain information on the sensors, shaker parameters and test process used.



CMOS camera basics

Sensitivity

There are several ways to describe the sensitivity of image acquisition system. In former analogue systems, the use of e.g. photographic films, the sensitivity was long time characterized by ISO value as generally accepted parameter. With the introduction of CCD and CMOS image sensors, the ISO value gave only insufficient information due to noise characteristics that weren´t well described for different ISO values. A comparison of different camera systems became consequently difficult. Today Optronis specify cameras along the ISO12332 standard – with the indication of ISO values for saturation based and different signal to noise ration (SNR40 and SNR10) according to high image quality and low image quality – and with the help of physical parameters.

An important parameter is the sensitivity of the image sensor, given typically at a Wavelength of λ = 550nm:

$$Sensitivity\left[\frac{V}{lux \cdot \sec}\right]$$

At this wavelength following relation can be applied:

$$1\ lux = 0{,}001464\ \left[\frac{W}{m^2}\right] \quad @\ 550\ \text{nm}$$

This results in following sensitivity:

$$Sensitivity\left[\frac{V}{lux \cdot \sec}\right] or \left[683\,\frac{V \cdot m^2}{W \cdot \sec}\right] \quad @\ 550\ \text{nm}$$

With full A/D converter value at full quantum well with typical 1 Volt and 10 bits grey scale – equivalent to 1024 digital numbers (DN), bits or grey levels – this leads to:

$$Sensitivity\quad 1024\left[\frac{DN}{lux \cdot \sec}\right] or\ \ 70000\left[\frac{DN \cdot m^2}{W \cdot \sec}\right] \quad @\ 550\ \text{nm}$$

A given sensitivity in (V/s)/(W/m²) can be as follow calculated in a sensitivity with unit (A/W):

$$Sensitivity\left[\frac{A}{W}\right] = Sensitivity\left[\frac{V \cdot m^2}{W \cdot \sec}\right] \cdot \frac{Full\_Well\_Capacity\left[\frac{e-}{V}\right] \cdot q\left[\frac{A\sec}{e-}\right]}{PixelSize\ \left[m^2\right]}$$

The well capacity is given in electrons at full dynamics of the A/D converter in Volts. Full dynamics of A/D is often given at 1 Volt. The unit charge is given at q = 1,602*Exp-19.
The quantum efficiency can be calculated to be:

$$\alpha\ [\%] = 100 \cdot \frac{Sensitivity\left[\frac{A}{W}\right] \cdot h\left[J\sec\right] \cdot c\left[\frac{m}{\sec}\right]}{q\left[A\sec\right] \cdot \lambda\left[m\right]}$$

q is the unit charge 1,602*10Exp-19 Asec, h the Planck constant 6,626*10Exp-34 Jsec, c the velocity of light 300000 m/sec and λ the wavelength of the incoming light.

According to EMVA1288 the quantum effieciency α is calculated by the ratio of Responsivity R of an image pixel and system gain K:

$$\alpha\ [\%] = 100 \cdot \frac{R}{K}$$

R and K are values identified out of the sensivity curve and the photon transfer plot.

Global / Rolling Shutter

Global and rolling shutter describe the electro-optical shutter of a CMOS camera:

With global shutter the shutter operates time synchronous for every image pixel: at the beginning of an exposure time, all charges of the image pixel are reset on “reset-level”. The exposure starts then time synchronous for all image pixel. At the end of the exposure time, the charges of the image pixel are shifted time synchronous into an analogue memory that is located in parallel to the image pixel. Advantage of this process is the achievable minimum exposure time that can be reach as low as 1 microsecond. This allows to freeze even fastest object movements. The motion blur becomes minimal.
The rolling shutter operates row wise. The exposure time of different rows is shifted in time. Advantage of this process compared to global shutter is the lower noise (Correlated Double Sampling CDS), a higher dynamics and a higher image quality. Disadvantage of the rolling shutter is a hashed image at fast object movements.

Optronis cameras are optimised for fast object movements and operate consequently and preferably in global shutter mode.

Region of Interest (ROI)

CMOS cameras allow the readout of fractions of images (ROIs). Compared to CCD cameras, the sensor has not readout completely but only the part that is of certain interest. Advantage of the readout of image regions is the increase of frame rate, the image rate of the image sensor. For calculation of the maximum image rate Optronis offers calculation sheets for its cameras.

Due to the different architecture of the image sensors, they are classified in row-wise operating sensors and row- and column wise operating sensors: for row-wise operating sensors, the increase of speed will only be reached by reducing the number of image rows. For row- and column wise operating sensors the speed increase will be performed by reducing number of rows or/and columns.

CMOS cameras allow also the readout of several image fragments out of one image. For row-wise operating sensors, several independent blocks of successive rows can be readout (mostly without overlap of the blocks). For row- and column wise operating sensors the readout of several independent image fractions (with or without overlap) can be readout. Though each image fraction can be different in frameformat, the frame grabber can limit image fractions to be readout at the same frame format.

Dynamic Range (DR) / Signal to Noise Ratio (SNR)

The cameras offer a typical digital dynamic range of 8 bits (equivalent 256 grey levels). Some models offer 10 bits (equivalent 1024 grey levels) up to 12 bits (equivalent 4096 grey levels). The cameras are available as monochrome or color cameras. Color cameras are equipped by a bayer Pattern and transfer raw image data. A separation of the raw data in RGB is due to the factor of 3 higher transfer bandwith done by the frame grabber of inside the GPU/CPU of the Personal Computer.

Calculting the dynamic range (DR) along EMVA1288, the value is calculated by the ratio of saturation (at SNR=max) to sensitivity threshold (SNR=1). The calculated dynamic range can exceed or fall below the typical digital dynamic range.
The maximum signal to noise ratio along EMVA1288 is calculated by the square root of the number of electrons in saturation condition.