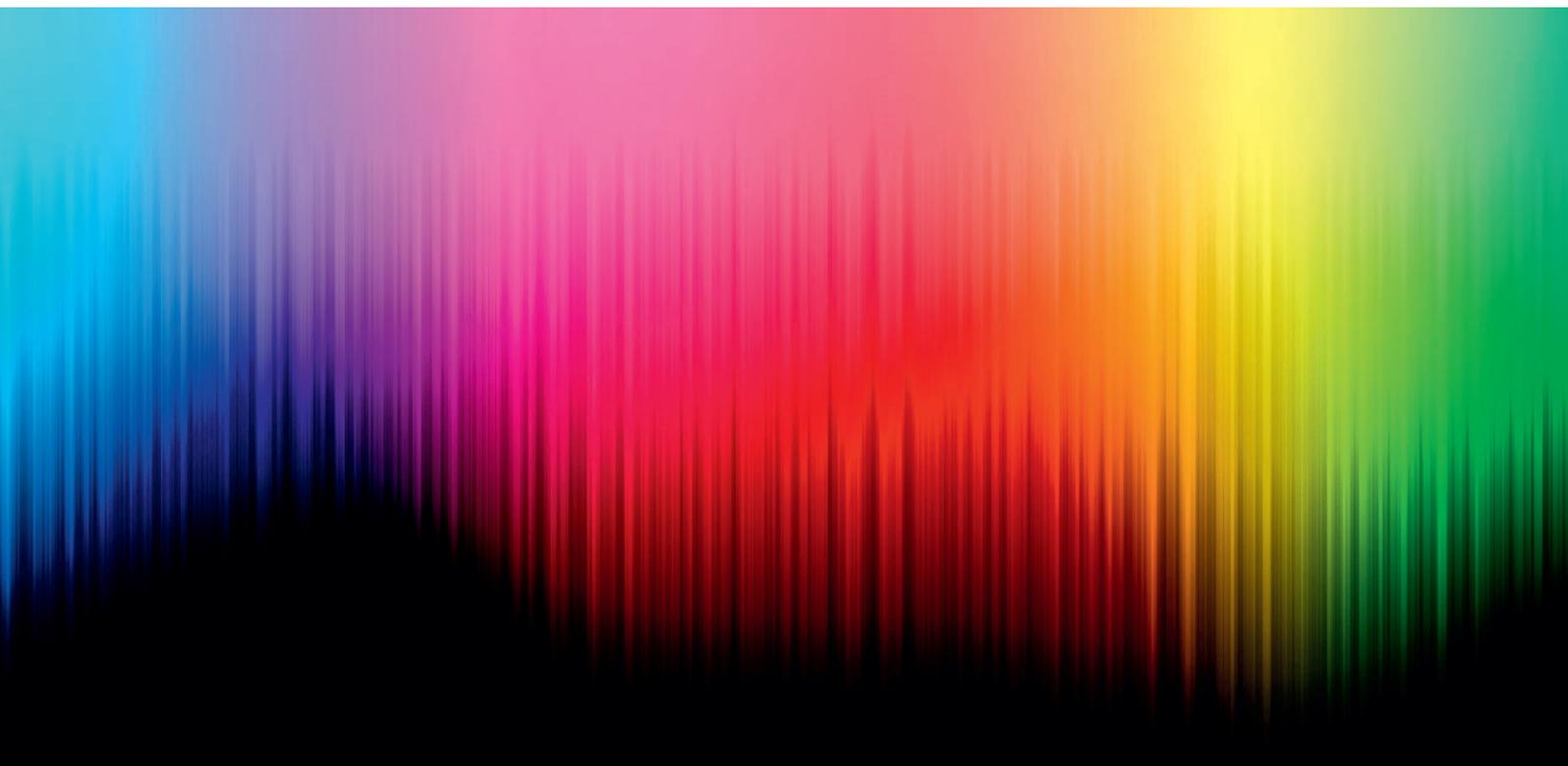


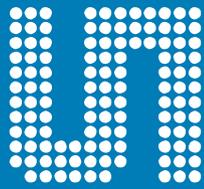
# Product Document

# Image Sensor Solutions

CMOSIS

am 



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Sensing is life.

# We provide advanced sensor solutions for the most challenging applications.

## **Our portfolio**

ams is a global leader in the design and manufacture of advanced sensor solutions. Leading manufacturers around the globe rely on ams' sensor know-how for advanced systems design technology which is smarter, safer, and easier-to-use and more environment-friendly. ams' sensor solutions are at the heart of ams products and technologies that define our world today – from smartphones and mobile devices to smart homes and buildings, industrial automation, medical technology and connected vehicles. Our products drive applications requiring small form factor, low power, highest sensitivity and multi-sensor integration. We offer a full solution: sensors (including optical sensors), interfaces and related software.

## **Our expertise**

We offer our customers a deep system understanding and application know-how and give them the differentiation that is needed to be successful in many markets.

## **Focus on research and development**

With over 30 years' ASIC experience, we have a thorough understanding of analog and TDC design. A strong focus on research and development and the continuous expansion of our existing product portfolio allows us to always offer our customers cutting-edge technology.

# Dragster High Resolution Line Scan Sensor

## General Description

Dragster is a series of digital line-scan sensors using two types of basic elements: a single line element with  $7\mu\text{m} \times 7\mu\text{m}$  and  $3.5\mu\text{m} \times 3.5\mu\text{m}$  pixel size, and a dual line element with mono and color option, and  $7\mu\text{m} \times 7\mu\text{m}$  pixel size.

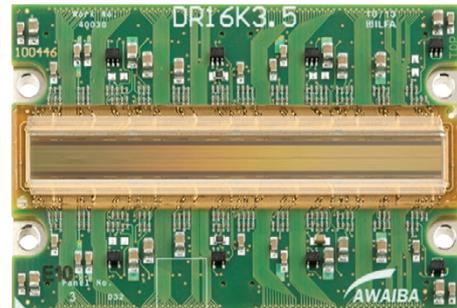
All sensors share the same electrical interface and are pin compatible with each other. The Dragster sensors are highly scalable which make them ideal for various applications. In addition, they can easily be integrated in standard cameras or image processing boards due to their simple, all digital interface.

## Applications

- Motion capture
- High-end barcode scanning
- Automated Optical Inspection in SMD
- Flat Panel Inspection
- Food Sorting

## Main Features

Resolution	2 K to 24 K
Pixel depth	13 bit
Pixel size	$7 \times 7 \mu\text{m}$ or $3.5 \times 3.5 \mu\text{m}$
Fill factor	100 %
Max frame rate	80 kScan/s
Data output	Tap Parallel / LVCMOS TTL
Chroma	Mono and RGB (for dual line)
Power	400 mW / 2k pixels
Responsivity nominal gain	$77 \text{ DN/nJ/cm}^2 @12\text{bit}$
Full well capacity	46000 e-
Dynamic range	68 dB
DSNU / PRNU rms	4 DN / 0.7 %
Temporal noise dark rms	1.5 DN
Packages	Invar, Ceramic LCC
RoHS compliance	Yes
Product Status	Production



# Dragster Evaluation Board

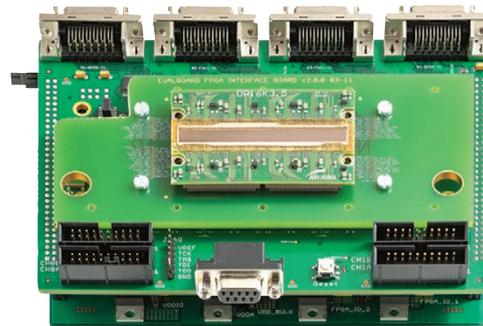
## General Description

The evaluation system features a highly configurable hardware which enables an easy setup of the Dragster line scan family for a quick sensor evaluation. Image data is transferred to a frame grabber over high speed camera link. Any grabber that supports at least a camera link base configuration can directly acquire data from any Dragster version.

The system controls sensor operation using an FPGA to define the state machine timings. It acquires data synchronously and multiplexes that data up to 2 camera link full interfaces. Over an RS232 serial interface, the user can have access to the state machine configuration and all sensor registers. The evaluation board supports all sensors from 2k to 16k.

## Main Features

PC Interface protocol	4X Camera Link
Programmable unit	FPGA - XILINX / Spartan 3
Power supply	External 12V DC
Dimensions (mm)	165 x 120 x 40
Sensors	1x Dragster





# NanEye

## General Description

The NanEye 2D and NanEye Stereo sensors provide a true system on chip camera head with fully self timed readout sequencing, AD conversion to 10 bit and bit serial data transmission over LVDS. AWAIBA's proprietary data interface technology permits cable lengths up to 3m without any additional components at the distal end. Due to the low energy dissipation on the interface, no complicated shielding is required to meet EMC norms. With its 250 x 250 pixels at 3um pitch, the sensors provide clear and sharp images with outstanding MTF in a very compact size. A frame rate of 43-62fps permit synchronization to any type of display.

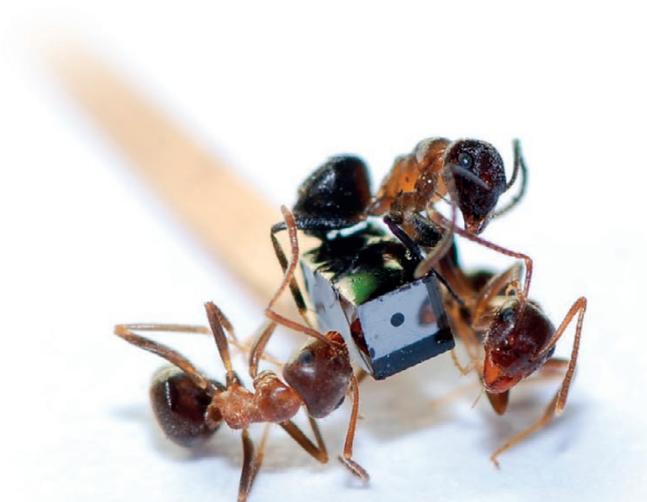
The NanEye sensor provides delay free, smooth video operation resulting in a safe operation and a clear diagnosis. The sensors are connected to minimal diameter cabling solutions. As an option, a small lens can be assembled to the chip. This option does not increase the total diameter of the sensor, making it the world's most compact digital camera.

## Applications

- Medical endoscopy
- Dental imaging
- Surgical robotics
- Eye tracking

## Main Features

Resolution	62.5 KPix - 250(H) x 250(V)
Pixel depth	10 bit
Pixel size	3 x 3 μm
Frame rate	43-62 fps
Data output	10 bit digital LVDS
Chroma	Mono, RGB
Power	4.6 mW at nominal supply 1.8V
Operating temperature	-20°C to 60°C
Sensitivity	11.5 DN/nJ/cm <sup>2</sup> at maximum gain
Full well capacity	15800 e-
Dynamic range	58 dB
FPN / PRNU	< 0.5 % / < 1 % (software corrected)
Temporal noise dark rms	1.1 DN
Footprint including lens	1.0 x 1.0 x 1.7 mm <sup>3</sup>
Lens options	90FOV/f2.7 , 90FOV/f4.0, 90FOV/f6.0, 120FOV/f2.8, 120FOV/f4.0, 160FOV/f2.4
Rohs compliance	Yes
Product Status	Production



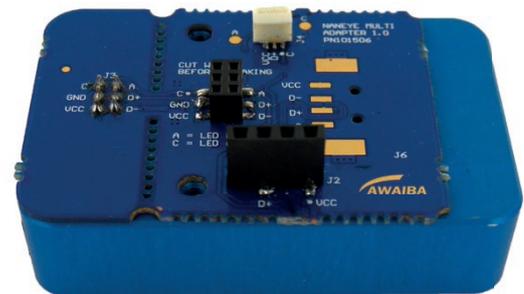
# NanoUSB2 Evaluation Board

## General Description

The nanoUSB2 board is the hardware between the camera and the PC and does the deserialisation of the bit serial LVDS data stream coming from the NanEye sensors and translates it to a USB2 protocol that will interface over a standard USB2 connection to a PC. The supplied viewer software controls the NanEye camera, and displays the video images. The software gives full control over all sensor settings and allows to test different image correction and enhancement algorithms, such as corrections for offset and gain error, color reconstruction, etc. The nanoUSB2 board can also drive the optional LED illumination.

## Main Features

PC interface protocol	USB2
Programmable unit	FPGA - XILINX Spartan 3E
Power supply	USB2 5V
Dimensions (mm)	40 x 8 x 5
Sensors	1x NanEye 2D
Product Status	Production



# NanEye Fiber Optic Box 2.0

## General Description

NanEye Fiber Optic Box Demo Kit 2.0 is a fully embedded all in one image processing unit that interfaces the NanEye® micro camera head signals and provides an output of 1080p/60 format HDMI video signal which can be directly plugged to a HDMI compatible monitor. No additional PC or image processing is required.

The Demo Kit embeds advanced image processing algorithms to automatic control exposure settings, construct the color data from the raw binary stream and displays an output image of 750 x 750 pixels over an HDMI interface. The USB3 interface allows the connection to the NanEye viewer running on a PC to get access to the sensors' raw images and control settings.

The Demo Kit includes a fiber light source, which provides light to the tip of the NanEye® Sensor probe via a 0.5mm plastic optic fiber. The fiber and NanEye® camera are housed in a 2.3mm diameter lumen of 1m length that can be plugged and unplugged easily from the processing and illumination unit. The illumination intensity is adjustable by a manual dial. The unit is supplied by a 12V wall charger and provides galvanic isolation to the camera head. It can interface to any standard monitor with HDMI input. The main body of the Demo Kit measures only 17cm x 17cm x 5.6cm and provides all necessary video processing and display driving plus the adjustable illumination.

## Main Features

PC interface	HDMI Direct Interface
Power supply	external
Dimensions (cm)	17 x 17 x 5.6
Sensors	2 x NanEye 2D
Product Status	Production



# CMV300

## General Description

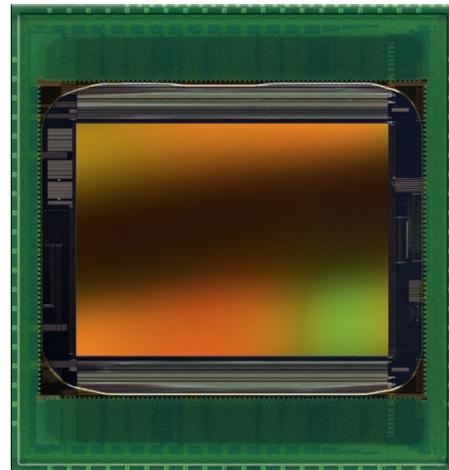
The CMV300 is a high speed CMOS image sensor developed for machine vision applications. The image array consists of  $7.4 \times 7.4 \mu\text{m}$  „pipelined“ global shutter pixels allowing exposure during read out and CDS operation. The user can choose between four digital LVDS serial outputs of 12 bits each, or one 10-bit parallel CMOS output. The image sensor integrates a programmable gain amplifier and offset regulation. Higher frame rates can be achieved in row-windowing or row-subsampling mode. All modes are programmable using the SPI interface. All internal exposure triggers, read-out timings and high speed clocks are generated by a programmable on-board sequencer and PLL. External triggering and exposure programming is also possible. Extended optical dynamic range can be achieved by multiple integrated high dynamic range modes.

## Applications

- 3D imaging
- Machine vision
- Motion capture
- Bar and 2D code

## Main Features

Resolution	0.3 MP - 640 (H) x 480(V)
Pixel size	$7.4 \times 7.4 \mu\text{m}$
Optical format	1/3"
Shutter type	Global shutter
Frame rate	480 fps (LVDS 12 bit), 120 fps (CMOS 10 bit)
Output interface	4 LVDS outputs @ 480 Mbps - 10-bit CMOS output @ 40 Mhz (120 fps)
Sensitivity	6 V/lux.s
Conversion gain	0.2 LSB/e- (12 bit)
Full well charge	20000 e-
Dark noise	20 e- (RMS)
Dynamic range	60 dB
SNR max	43 dB
Parasitic light sensitivity	1/50000
Extended dynamic range	Yes, up to 90 dB
Dark current	125 e-/s (25°C)
Fixed pattern noise	< 4 LSB (<0.1% of full swing)
Chroma	Mono and RGB
Supply voltage	1.8V / 3.3V
Power	700 mW
Operating temperature	-30°C to +70°C
RoHS compliance	Yes
Package	58 pins BGA
Product Status	Production



# CMV2000

## General Description

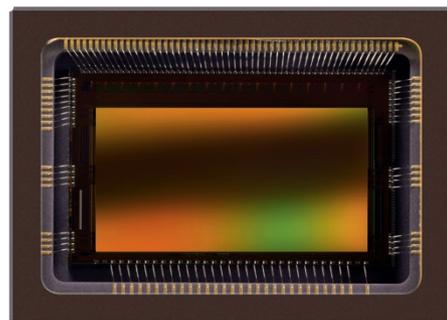
The CMV2000 is a high sensitivity, pipelined global shutter CMOS image sensor with 2048 x 1088 pixel resolution capable of HD format. Pipelining allows exposure during read out. The state-of-the-art pixel architecture offers true correlated double sampling (CDS) reducing the fixed pattern noise and dark noise significantly. The imager integrates 16 LVDS channels each running at 480 Mbps resulting in a 340 fps frame rate at full resolution at 10 bit per pixel. Read-out is programmed over a serial peripheral interface. An internal timing generator produces the signals needed for read-out and exposure control of the image sensor. External exposure triggering remains possible. A 12 bit per pixel mode is available at reduced frame rate.

## Applications

- 3D imaging
- ITS
- Machine vision
- Motion capture
- Video/broadcast
- Bar and 2D code
- Biometrics

## Main Features

Resolution	2MP - 2048 (H) x 1088 (V)
Pixel size	5.5 x 5.5 $\mu\text{m}$
Optical format	2/3"
Shutter type	Global shutter
Frame rate	340 fps (10 bit), 70 fps (12 bit)
Output interface	16 LVDS outputs @ 480 Mbps
Sensitivity	5.56 V/lux.s
Conversion gain	0.075 LSB/e-
Full well charge	13500 e-
Dark noise	13 e- (RMS)
Dynamic range	60 dB
SNR max	41.3 dB
Parasitic light sensitivity	1/50000
Extended dynamic range	Yes, up to 90 dB
Dark current	125 e-/s (25°C)
Fixed pattern noise	< 1 LSB (<0.1% of full swing)
Chroma	Mono, NIR enhanced and RGB
Supply voltage	1.8V / 3.3V
Power	600 mW
Operating temperature	-30°C to +70°C
RoHS compliance	Yes
Package	95 pins $\mu\text{PGA}$ /LGA or 92 pins LCC
Product Status	Production



# CMV4000

## General Description

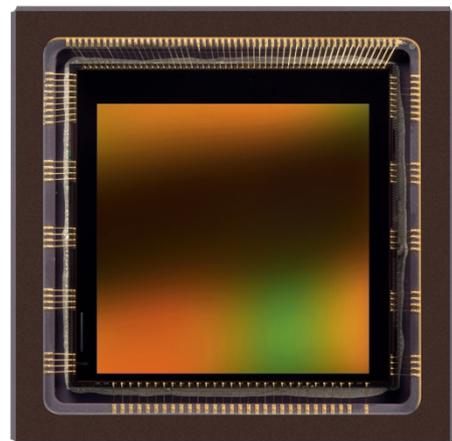
The CMV4000 is a high sensitivity, pipelined global shutter CMOS image sensor with 2048 x 2048 pixel resolution capable of HD format. Pipelining allows exposure during read out. The state-of-the-art pixel architecture offers true correlated double sampling (CDS) reducing the fixed pattern noise and dark noise significantly. The imager integrates 16 LVDS channels each running at 480 Mbps resulting in a 180 fps frame rate at full resolution at 10 bit per pixel. Read-out is programmed over a serial peripheral interface. An internal timing generator produces the signals needed for read-out and exposure control of the image sensor. External exposure triggering remains possible. A 12 bit per pixel mode is available at reduced frame rate.

## Applications

- Machine vision
- Motion control
- Traffic monitoring
- High speed inspection
- Security
- 3D cameras

## Main Features

Resolution	4MP - 2048(H) x 2048 (V)
Pixel size	5.5 x 5.5 $\mu\text{m}$
Optical format	1"
Shutter type	Pipelined global shutter with true CDS
Frame rate	180 fps (10 bit), 37 fps (12 bit)
Output interface	16 LVDS outputs @ 480 Mbps
Sensitivity	5.56 V/lux.s
Conversion gain	0.075 LSB/e-
Full well charge	13500 e-
Dark noise	13 e- (RMS)
Dynamic range	60 dB
SNR max	41.3 dB
Parasitic light sensitivity	1/50000
Extended dynamic range	Yes, up to 90 dB
Dark current	125 e-/s (25°C)
Fixed pattern noise	< 1 LSB (<0.1 % of full swing)
Chroma	Mono, Mono (NIR enhanced) and RGB
Supply voltage	1.8 V / 3.3 V
Power	600 mW
Operating temperature	-30°C to +70°C
RoHS compliance	Yes
Package	95 pins $\mu\text{PGA}$ /LGA or 92 pins LCC
Product Status	Production



# CMV8000

## General Description

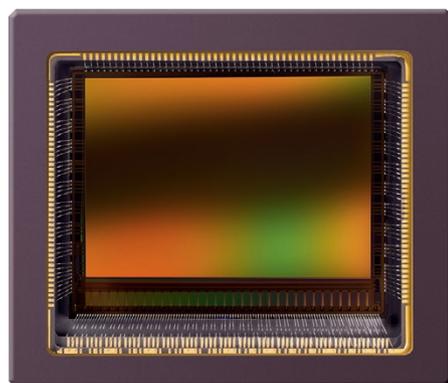
The CMV8000 is a global shutter CMOS image sensor in a 4/3" optical format. The image array consists of 5.5 x 5.5 μm pipelined global shutter pixels which allow exposure during read out while performing CDS operation reducing fixed pattern and dark noise significantly. The image sensor also integrates a programmable gain amplifier and offset regulation. All operation modes are programmable using a SPI interface. A programmable onboard sequencer generates all internal exposure and read out timings. External triggering and exposure programming are also possible. Extended optical dynamic range can be achieved by multiple integrated high dynamic range modes. A 12-bit per pixel mode is available at reduced frame rates.

## Applications

- Machine vision
- Motion control
- Traffic monitoring
- High speed inspection
- Security

## Main Features

Resolution	8MP - 3360 (H) x 2496 (V)
Pixel size	5.5 x 5.5 μm
Optical format	4/3"
Shutter type	Pipelined global shutter with true CDS
Frame rate	104 fps (10 bit), 40 fps (12 bit)
Output interface	16 LVDS outputs @ 600 Mbps
Sensitivity	5.56 V/lux.s
Conversion gain	0.077 LSB/e-
Full well charge	11700 e-
Dark noise	8.6 e- (RMS)
Dynamic range	61 dB
SNR max	41.3 dB
Parasitic light sensitivity	1/20000
Extended dynamic range	Yes, up to 90 dB
Dark current	41.2 e-/s (25°C)
Fixed pattern noise	< 1 LSB (<0.1 % of full swing)
Chroma	Mono and RGB
Supply voltage	1.8 V / 3.3 V
Power	900 mW
Operating temperature	-30°C to +70°C (TBC)
RoHS compliance	Yes (TBC)
Package	107 pins μPGA
<b>Product Status</b>	<b>Pre-Production</b>



# CMV12000

## General Description

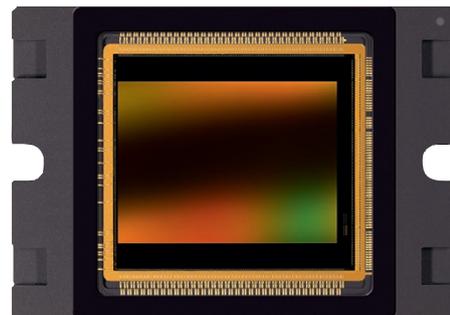
The CMV12000 is a global shutter CMOS image sensor in a APS-C optical format supporting Ultra HD imaging (4k). The image array consists of 5.5 x 5.5  $\mu\text{m}$  pipelined global shutter pixels which allow exposure during read out while performing CDS operation reducing fixed pattern and dark noise significantly. The image sensor also integrates a programmable gain amplifier and offset regulation. All operation modes are programmable using a SPI interface. A programmable on-board sequencer generates all internal exposure and read out timings. External triggering and exposure programming is also possible. Extended optical dynamic range can be achieved by multiple integrated high dynamic range modes. A 12-bit per pixel mode is available at reduced frame rates.

## Applications

- Machine vision
- Motion control
- Traffic monitoring
- High speed inspection
- Broadcast

## Main Features

Resolution	12MP - 4096 (H) x 3072 (V)
Pixel size	5.5 x 5.5 $\mu\text{m}$
Optical format	APS-like
Shutter type	Pipelined global shutter with true CDS
Frame rate	300 fps (10 bit), 132 fps (12 bit)
Output interface	64 LVDS @ 600 Mbps
Sensitivity	4.64 V/lux.s
Conversion gain	0.075 LSB/e
Full well charge	13500 e-
Dark noise	13 e- (RMS)
Dynamic range	60 dB
SNR max	41.3 dB
Parasitic light sensitivity	1/50000
Extended dynamic range	Yes, up to 90 dB
Dark current	125 e-/s (25°C)
Fixed pattern noise	< 1 LSB (<0.1 % of full swing)
Chroma	Mono and RGB
Supply voltage	1.8 V / 3.3 V
Power	4200 mW
Operating temperature	-30°C to +70°C
RoHS compliance	Yes
Package	237 pins $\mu\text{PGA}$
Product Status	Production



# CMV20000

## General Description

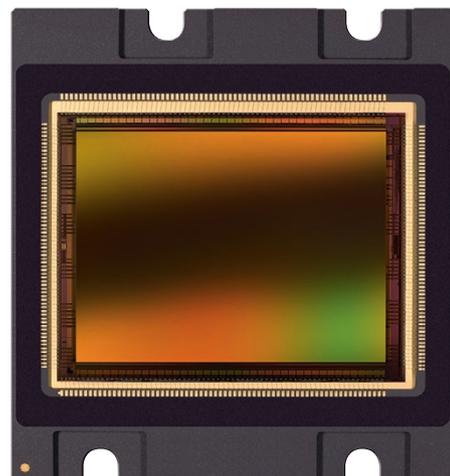
The CMV20000 is a global shutter CMOS image sensor in a 35 mm optical format. The image array consists of 6.4 x 6.4  $\mu\text{m}$  pipelined global shutter pixels which allow exposure during read out while performing CDS operation reducing fixed pattern and dark noise significantly. The image sensor also integrates a programmable gain amplifier and offset regulation. All operation modes are programmable using a SPI interface. A programmable on-board sequencer generates all internal exposure and read out timings. External triggering and exposure programming is also possible. Extended optical dynamic range can be achieved by multiple integrated high dynamic range modes.

## Applications

- Machine vision
- Motion control
- High speed inspection
- Scientific
- Medical

## Main Features

Resolution	20MP - 5120 (H) x 3840 (V)
Pixel size	6.4 x 6.4 $\mu\text{m}$
Optical format	35 mm
Shutter type	Pipelined global shutter with true CDS
Frame rate	30 fps (12 bit)
Output interface	16 LVDS channels @ 480 Mbps
Sensitivity	8.3 V/lux.s
Conversion gain	0.25 LSB/e <sup>-</sup>
Full well charge	15000 e <sup>-</sup>
Dark noise	8 e <sup>-</sup> (RMS)
Dynamic range	66 dB
SNR max	41.7 dB
Parasitic light sensitivity	1/50000
Extended dynamic range	Yes, up to 90 dB
Dark current	125 e <sup>-</sup> /s (25°C)
Fixed pattern noise	< 8 LSB (<0.2 % of full swing)
Chroma	Mono and RGB
Supply voltage	1.8 V / 3.3 V
Power	1100 mW
Operating temperature	-30°C to +70°C
RoHS compliance	Yes
Package	143 pins PGA
<b>Product Status</b>	<b>Production</b>



# CMV50000

## General Description

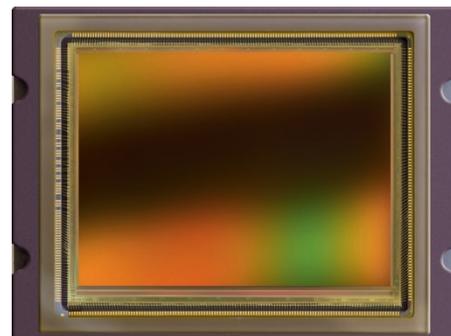
The CMV50000 is a global shutter CMOS image sensor with 7920 x 6004 pixels, supporting Ultra HD (8K) imaging. The image array consists of 4.6 x 4.6  $\mu\text{m}$  pipelined global shutter pixels which allow exposure during read out while performing CDS operation reducing fixed pattern and dark noise significantly. The CMV50000 has 22 digital sub-LVDS outputs (serial) each running at 830 Mbps. This results in 30 fps frame rate at full resolution in 12 bit mode. Higher frame rates can be achieved in row-windowing mode or row-subsampling mode. The implementation of black reference pixels allows for on-chip black clamping and row noise reduction. The on-chip PLL and channel multiplexing facilitate easy integration of the chip in a camera system. Multiple internal and external triggering modes make the sensor very flexible for a variety of applications. Extended optical dynamic range can be achieved by different exposure time for odd/even columns.

## Applications

- High end inspection
- Document scanning
- Aerial mapping/security
- Flat panel inspection
- 8 K video production

## Main Features

Resolution	47.5 MP - 7920(H) x 6004(V)
Pixel size	4.6 x 4.6 $\mu\text{m}$
Optical format	45.7 mm diagonal
Shutter type	Pipelined global shutter with true CDS
Frame rate	30 fps (12 bit)
Output interface	22 sub-LVDS channels @ 830 Mbps
Full well charge	14000 e
Dark noise	8.8 e (RMS)
Dynamic range	64 dB
SNR max	41.6 dB
Parasitic light sensitivity	1/18000
Dark current	66.e/s (60°C)
Fixed pattern noise	<7 LSB (< 0.2% of full swing)
Power	3.0 W
Operating temperature	-30°C to 70°C
Sensitivity	4 V/lux.s
Conversion gain	0.27 DN/e
Extended dynamic range	Yes, interleaved
Chroma	Mono and RGB
Supply voltage	3.3/2.7/1.8/1.2V
RoHS compliance	Yes (TBC)
Package	141 pins ceramic PGA
<b>Product Status</b>	<b>Production</b>



# CHR70M

## General Description

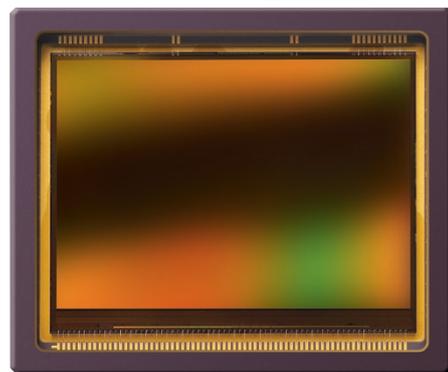
The CHR70M is a high resolution CMOS image sensor with 10000 x 7096 pixels. The image array consists of 3.1 x 3.1  $\mu\text{m}$  pinned diode pixels, which share a number of transistors (2 pixels sharing). The image sensor has 8 analog outputs, each running at 30MHz resulting in a frame rate of 3fps at full resolution. Higher frame rates can be achieved in windowing mode or sub-sampling mode. The image sensor also integrates a programmable gain amplifier and offset regulation. These and other settings are all programmable using the SPI interface. A programmable on-board sequencer generates all internal exposure and read out timings. External triggering and exposure programming is also possible.

## Applications

- Ultra high resolution imaging
- Document scanning
- Flat panel, PCB inspection
- Areal photography

## Main Features

Resolution	70MP - 10000 (H) x 7096 (V)
Pixel size	3.1 x 3.1 $\mu\text{m}$
Optical format	35 mm
Shutter type	Electronic rolling shutter with true CDS correction
Frame rate	3 fps
Output interface	8 analog channels
Sensitivity	1.24 V/lux.s / 0.88 V/lux.s without microlens
Conversion gain	63 $\mu\text{V}/\text{e}^-$
Full well charge	13000 $\text{e}^-$
Dark noise	10 $\text{e}^-$ (RMS)
Dynamic range	63 dB
SNR max	41.1 dB
Parasitic light sensitivity	-
Extended dynamic range	No
Dark current	3.2 $\text{e}^-/\text{s}$ (25°C)
Fixed pattern noise	< 0.09% of full swing)
Chroma	Mono and RGB
Supply voltage	3.3V
Power	435 mW
Operating temperature	0°C to +60°C
RoHS compliance	Yes
Package	65 pins PGA
Product Status	Production



# CMV + CHR Evaluation Systems

The evaluation kits can be used for testing and verifying the operation and image quality of the respective image sensor.

## **Evaluation Kits include:**

- Camera
- Power cable
- Power adapter / lab supply
- Lens Holder
- USB 2.0 or camera link interface
- USB or camera link cable
- Documentation (including schematics and VHDL code)
- Software

The systems allow the user to evaluate all aspects of the Sensors with full access to the sensor registers and RAW sensor data. Single or multiple image grabbing and saving is possible in multiple formats. Color processing is not supported by evaluation systems. Evaluations systems are offered as a rental system or can be purchased. In case a system is purchased a sensor must be purchased separately.

# Custom Products

ams provides innovative turn-key image sensor solutions based on in-house design, characterization and qualification facilities for image sensor research, development and volume production. With our strong technology portfolio we optimize your image sensor solution to fit your exact needs and offer state-of-the-art performance.

## Why choose a custom solution?

- Create a unique product:
- Differentiating compared to existing solution and competition
- Outperforming off-the-shelf solutions
- Perfect match with your overall system needs
- Long term availability
- Control of supply chain

## Our key technology offerings:

- Global shutter pixels
- High-speed read-out and data conversion (array and line scan)
- High resolution
- Large area sensors (up to wafer-scale)
- Low-noise, HDR pixels for low light imaging and professional imaging applications
- Backside illumination (BSI) for (E)UV and visible range
- TDI imaging
- Miniature camera modules for endoscopic applications
- Ceramic and COB packaging options (PGA, BGA, CSP, ...)
- Custom glass lid coatings, filters
- Extended environmental testing including industrial, space and automotive qualifications

Sensor development takes place in several phases, with milestones and review meetings in between.

## A typical development flow consists of:

- Specification review and architectural study
- IC layout and verification
- Design of custom packages and cover glass
- Device prototyping
- Device characterization and qualification
- Camera design-in support
- Volume production

The development time and costs depend on the image sensor complexity. During development, the customer is in direct contact with the development team. If you would like to discuss a custom CMOS image sensor project with us please contact us.





# ams worldwide



- **hq** | headquarters
- **pf** | production facility
- **dc** | design center
- **tc** | test center
- **ac** | application center
- **so** | sales office

**USA**  
Hermosa Beach, CA **dc**  
Mercerville, NJ **dc**  
Plano, TX **dc, so**  
Cupertino, CA **so**  
Santa Clara, CA **so**



**Europe**

Premstaetten, AT **hq, pf, dc**  
 Antwerp, BE **dc**  
 Cambridge, UK **dc**  
 Corsico, IT **so**  
 Eindhoven, NL **dc**  
 Funchal, PT **dc**  
 Jena, DE **dc, so**  
 Martigny, CH **dc**

Navacchio, IT **dc**  
 Nuernberg, DE **dc**  
 Orléans Cedex , FR **so**  
 Oulu, FI **dc**  
 Pavia, IT **dc**  
 Plymouth, GB **tc**  
 Rapperswil, CH **dc, so**  
 Reutlingen, DE **dc, so**

Rueschlikon, CH **dc**  
 Stokenchurch, UK **dc**  
 Stutensee, DE **dc**  
 Valencia, ES **dc**  
 Corsico, IT **so**  
 Helsinki, FI **so**  
 Orléans Cedex, FR **so**  
 Wildau, DE **ac**

**Asia**

Calamba, PH **tc**  
 Singapore **pf, so, ac**  
 Tokyo, JP **dc, so**  
 Hyderabad, IN **dc**  
 Seoul, KR **so**

Beijing, CN **dc**  
 Shanghai, CN **so**  
 Shenzhen, CN **so**  
 Suzhou, CN **so**  
 Taipei, TW **so**



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