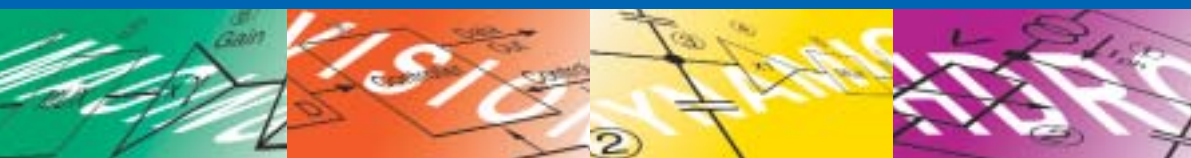


HDRC[®]

MORE THAN YOU CAN SEE



Imager and Camera Features

OMRON
Automotive Electronics
Technology GmbH

HDRC® – More than You Can See



Blinding high beams from the oncoming vehicle and faint return signals from the distant pedestrian, who is only illuminated by an infrared headlight, are captured faithfully and simultaneously by the high-dynamic-range CMOS (**HDRC®**) camera without the need for aperture or shutter control (integration-time).

In the absence of saturation, the license plate is readily legible while at the same time, because of good contrast resolution and spectral sensitivity extending out to infrared at very low intensity levels, the pedestrian is detected clearly by the **HDRC®** sensor while he is invisible to our eyes.

The same scene recorded with a CCD camera which is sensitive to the infrared but cannot handle the dynamic range.



HDRC® Imager and Camera Features

Technical data are preliminary and subject to change.

HDRC® imagers are protected by several international patents. **HDRC®** is a registered trademark. All images have been taken by IMS CHIPS, Stuttgart.

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Eye-Like Electronic Vision: HDRC® Fundamentals and Images

The perception and recording of images has intrigued mankind for ages. With our eyes, we can perceive scenes with rich details in brightness and color over a high range of local intensities within each scene. In paintings and films, sophisticated interpretations and recordings of our visual perception of dynamic range and color have been produced. While electronic imaging with CCDs and digital signal processing has given rise to a significant electronic vision industry, CCD sensors still have a rather limited dynamic range due to their linear response and, consequently, cannot match our eyes.

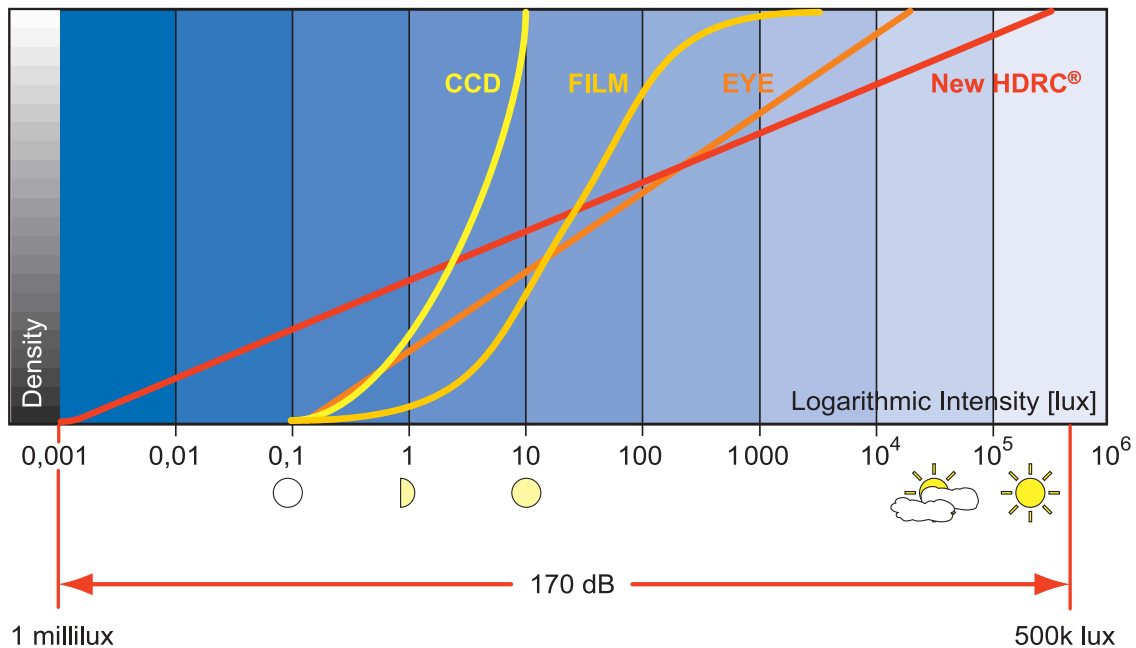
This brochure explains the fundamentals and presents the newest recorded images of a revolutionary electronic imaging technology proceeding with mainstream CMOS technology and yet fundamentally superior to other active pixel developments based on CMOS.

Our High-Dynamic-Range CMOS (**HDRC®**) digital imaging technology was patented and demonstrated first in 1992. It has matured to its seventh generation.

HDRC® Movies are available on CD and on the Internet. <http://www.HDRC.com>.

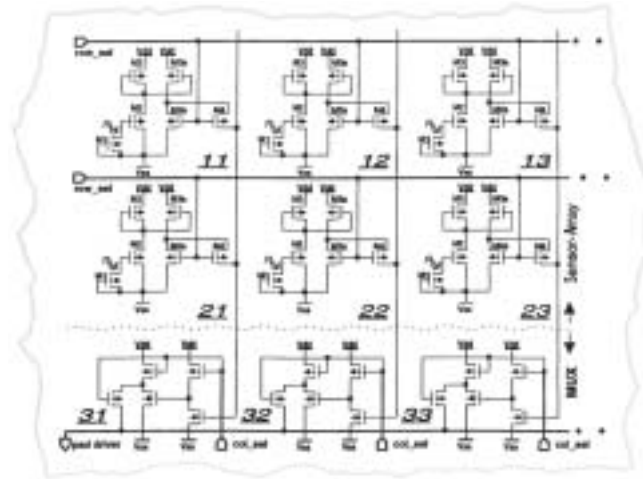
Imaging	Response	Scene Dynamic Range	Color Constancy
Our eyes	Logarithmic	Very high	Yes
Painting	Eye-like, logarithmic	High	Depending on the artist
Film	Pseudo eye-like, pseudo logarithmic	High	Yes
Vidicon	Linear	Small	No
CCD	Linear	Small	No
Other CMOS	Linear	Small	No
HDRC CMOS	Eye-like, logarithmic	Very high	Yes

Response Curve of the new HDRC®

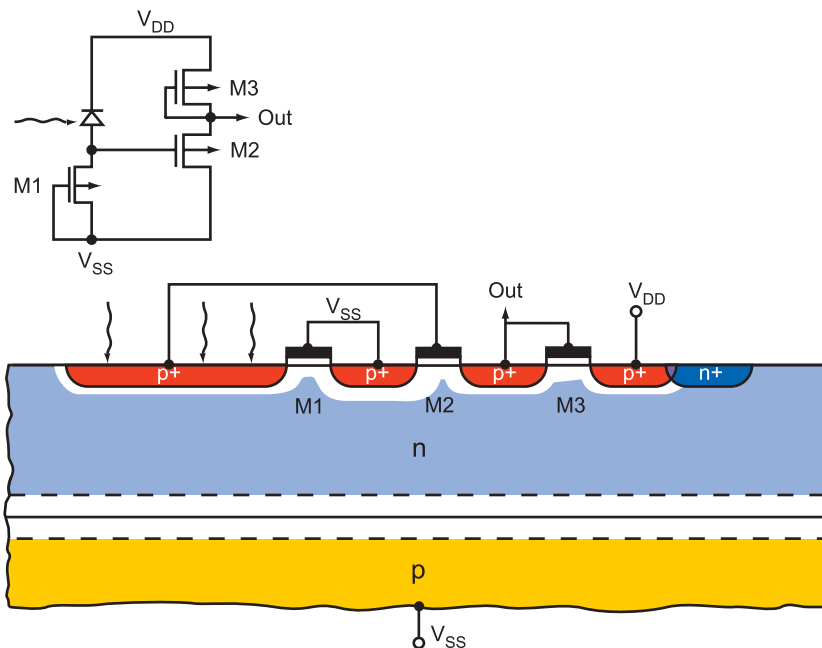


The Basic HDRC® Patent

This image recorder patent was filed on 3/24/1992 and an article appeared first in IEEE Micro, Volume 13, February 1993, page 50-56.

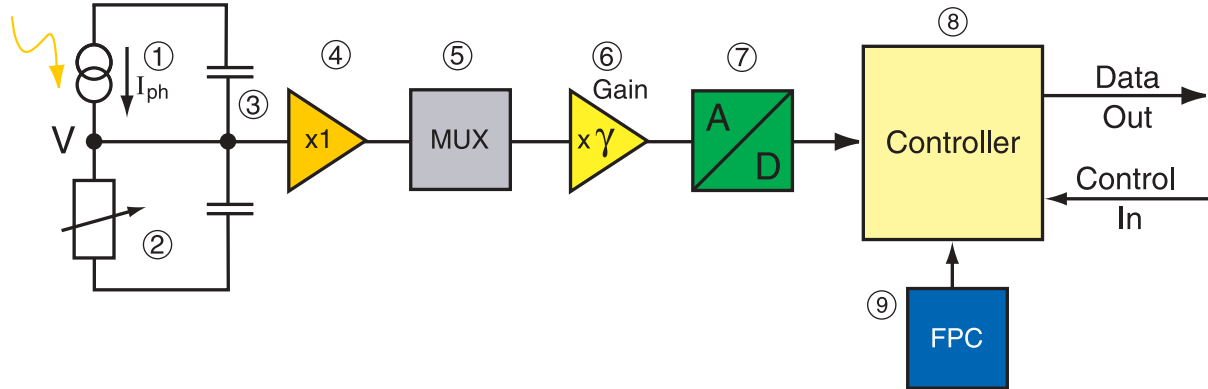


Log Compressing Pixel



This schematic cross section shows the HDRC® pixel in its PMOS implementation.

HDRC® VGA Camera Front-End OCP



- | | |
|--|------------------------------------|
| 1. Photodiode | 6. Amplifier |
| 2. Log Transistor $V \sim \log I_{ph}$ | 7. Video A/D converter |
| 3. Pixel capacitances | 8. Controller |
| 4. Pixel buffer | 9. Fixed-pattern correction memory |
| 5. Multiplexer | |

HDRC® VGA Camera Characteristics

The MAGIC of **HDRC®** imaging means that the pixel array on the **HDRC®** imager always acquires the **MAximum imaGe Information Contents** independent of

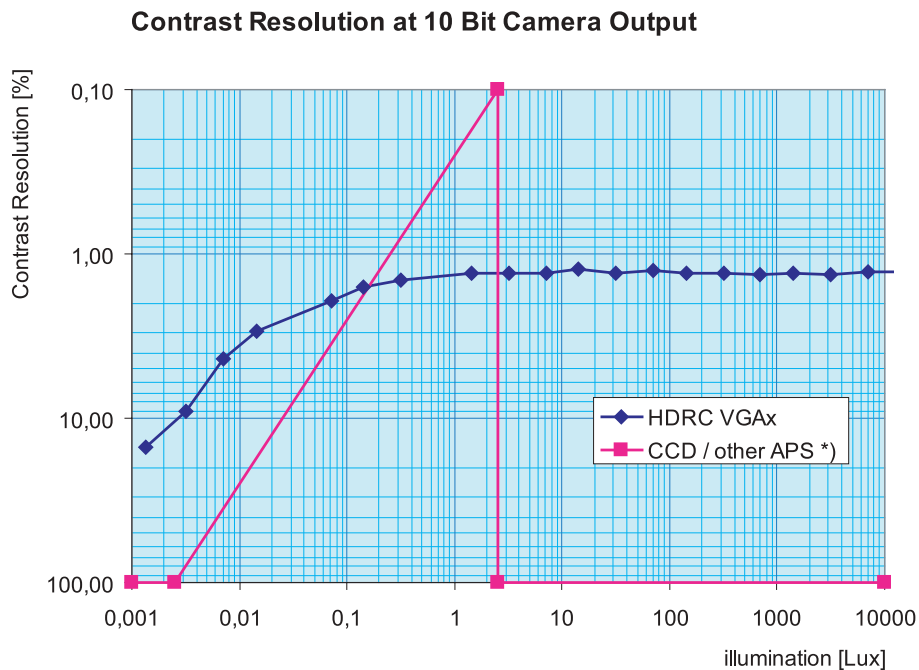
GAIN=RANGE=CONTRAST
OFFSET=BRIGHTNESS
COLOR SATURATION

operations.



Control of these operations for recording or/and display purposes can be performed on-line with camera-module image settings.

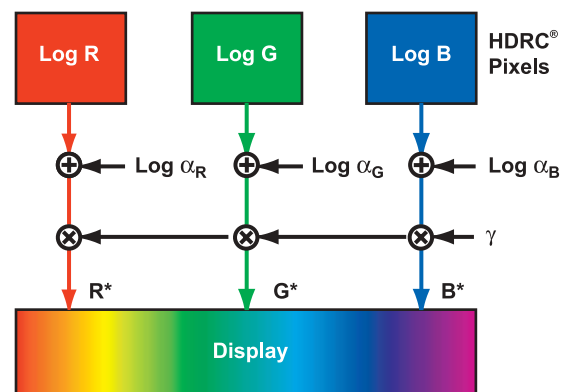
Contrast Resolution at 10 Bit Camera Output



*) High Performance Integrating Sensors:
4 V/(Lux sec) and 10 mV/s Dark Current

HDRC® Color Imaging

HDRC® color imaging benefits again from following nature's fundamentals: The R, G, B color receptors in our eyes with their individual logarithmic responses deliver signals which are composed to provide our perception of colors. Strictly analogous, we superimpose the Log R, Log G, Log B signals directly pixel by pixel to generate color images.



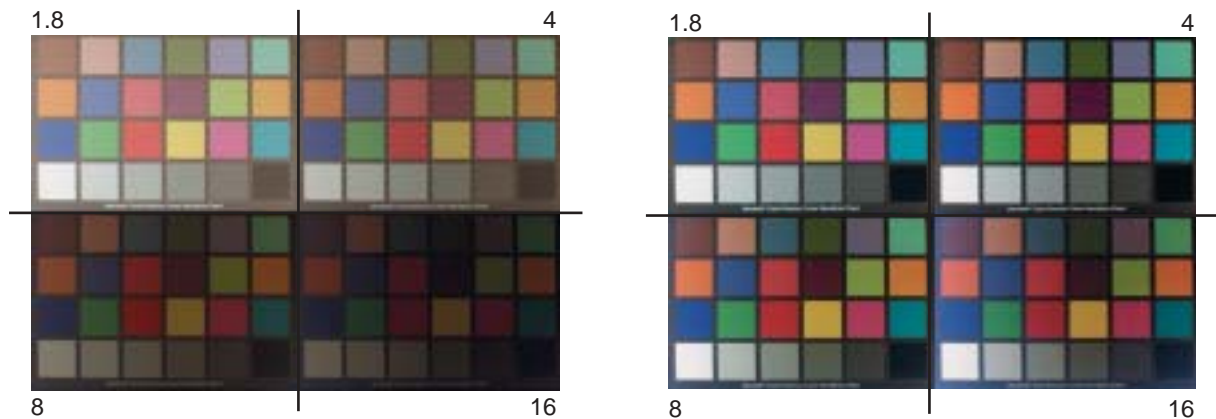
The outputs of the log-compressing pixels are recorded directly as voltages $\log R(x, y)$, $\log G(x, y)$ and $\log B(x, y)$. If, in a simple model, we describe the local recorded intensity $I(\lambda, x, y)$ as the product of the irradiance $L(\lambda)$ and the object reflectances $\text{Refl}(\lambda, x, y)$:

$$I(\lambda, x, y) = L(\lambda) \cdot \text{Refl}(\lambda, x, y)$$

the log intensity recorded by the HDRC® imager becomes

$$\text{Log } I(\lambda, x, y) = \text{log } L(\lambda) + \text{log } \text{Refl}(\lambda, x, y).$$

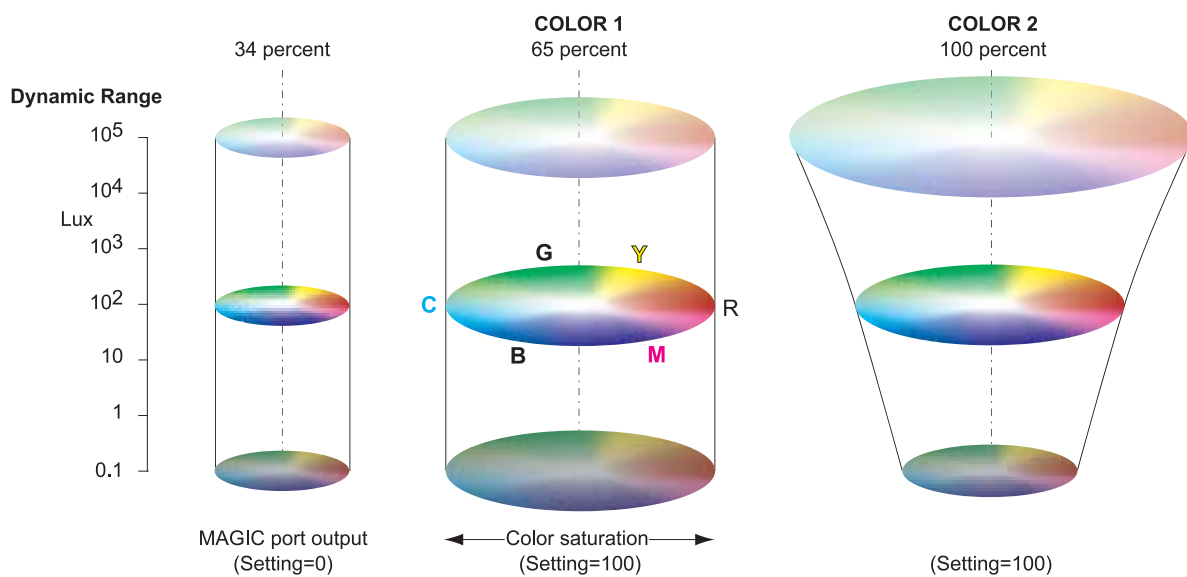
HDRC® Color Constancy



We perceive the color of a rose as orange in bright sunlight as well as in a dimly lit room. This phenomenon of color constancy is demonstrated by the following frames of the Macbeth® color checker taken with a color **HDRC®** camera at 30 frames/s with 4 apertures that are 7 f-stops apart. In spite of this range of

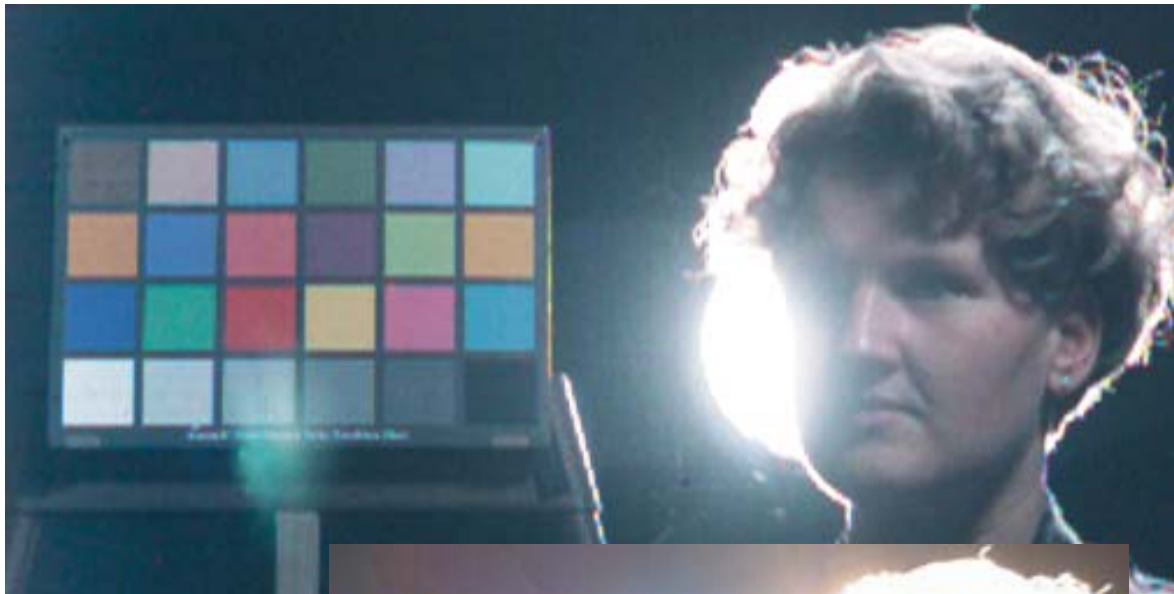
severe under- to severe over-exposure, the image information contents are recorded perfectly by the **HDRC®** sensor, although the primary images on the left do not show this. However, after just adding the appropriate log-luminance offset, all frames show the chart as we like to see it.

HDRC® High Color Saturation



HDRC® Images: Color Constancy

HDRC® 4PC, 512x256 pixels, 30 frames/s

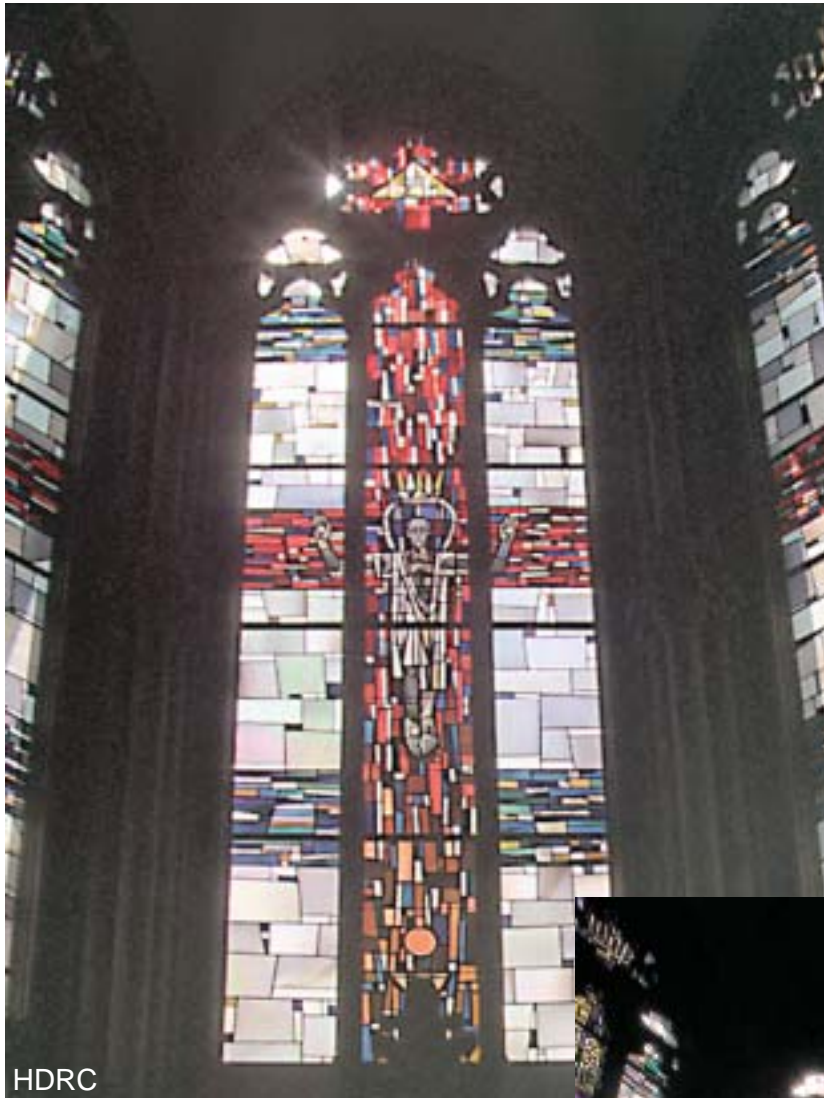


Digital CCD camera, 1280x960 pixels, automode

Dynamic range, color constancy and backlighting performance of the **HDRC®** camera are shown in this more challenging scene (as far as it is printable). This is the direct image with just the operations explained above.

For comparison, the digital CCD camera has reached its limits in spite of its advantage in resolution and of all its post-processing power (A film cannot handle this scene either).

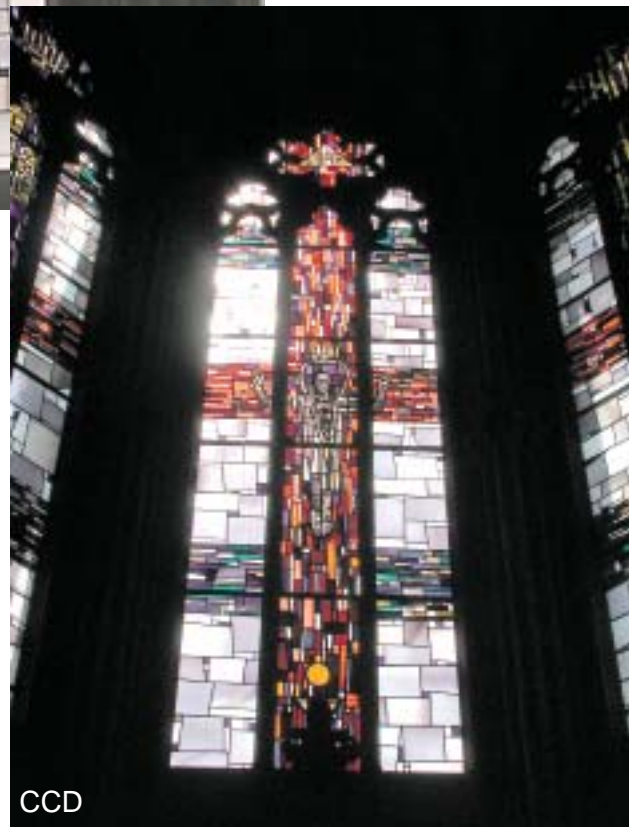
HDRC® VGA Display of RGB-Color



HDRC

HDRC® VGA digital video camera, recorded with 120 dB dynamic range, 30 frames/s.

HDRC® MAGIC at work appears in these stained-glass windows enlightened by the sun. Three frames from the sun's progression through the choir of St. Johns in Stuttgart have been mounted here to capture the MAGIC of this demanding scene. Challenging for our eyes and out of reach for any other image recorder, the six decades of luminous intensity are captured faithfully by the HDRC® camera.

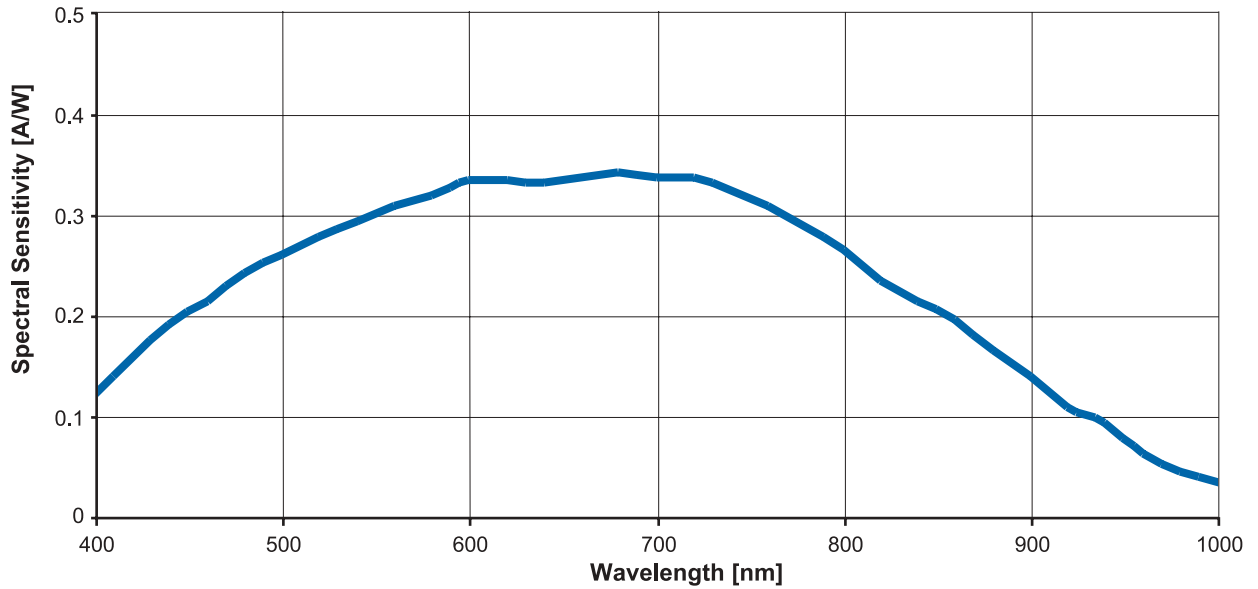


CCD

Digital CCD Still camera (1536 x 2048 pixels), automatic gain and exposure.

CCD:
white-saturated glass panels
and black-saturated walls

HDRC® Spectral Sensitivity of Photodiodes




Spectral sensitivity photodiodes in a 0.25 μm CMOS technology exhibits good spectral sensitivity from 400 nm to beyond 900 nm.

HDRC® Safe in any Scene I

Car with high beams at 80 m and pedestrian at 100 m



Scene illuminated with low beam and permanent infrared (NIR) high beam

In cooperation with 

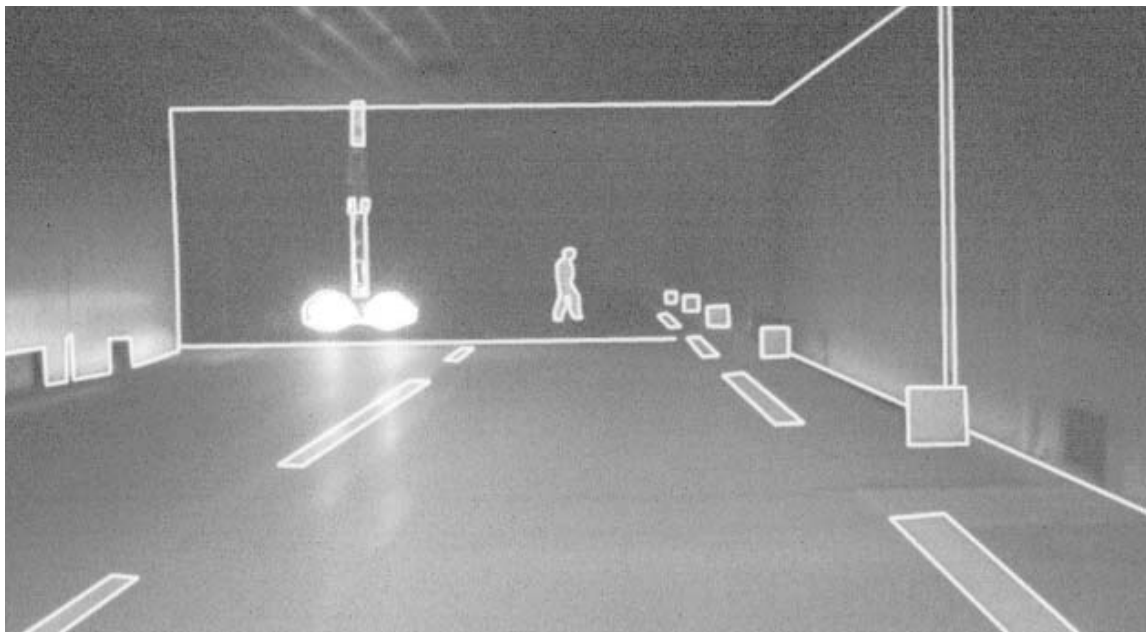
HDRC®: Safe in any Scene II

Two pedestrians at 120 m in the 140 m HELLA light tunnel at absolute darkness




Scenario with permanent infrared high beam

Example for display mode: edge-enhanced features

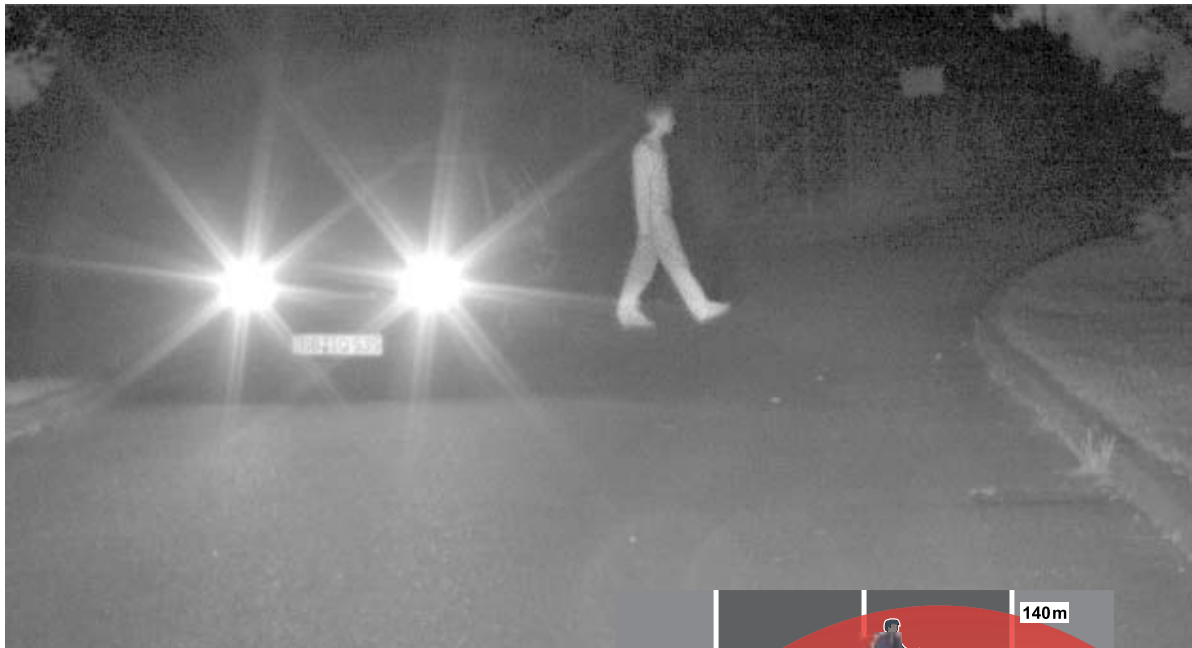


Scenario with permanent infrared high beam

In cooperation with 

HDRC® Night Vision: The Challenge

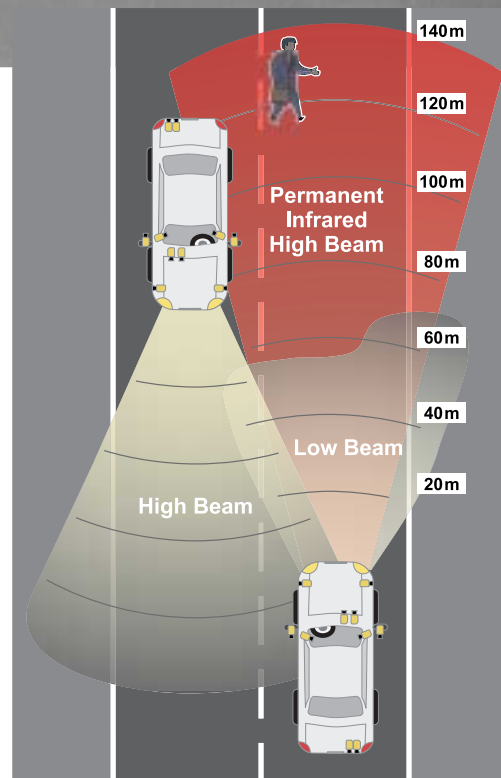
In the future, for the safe usage of a vehicle driver assistance systems will become more important. The rising requirement on safety and higher comfort will lead to an intensified demand for high performance camera applications. HDRC technology with its enormous dynamic range ensures a safe image in any scene. Especially the high sensitivity in NIR enables the display of a most naturally appearing image, which simplifies the recognition of the important information.



HDRC® VGA digital video camera, recorded with 120 dB dynamic range, 35 frames/s.



Digital CCD camcorder (768 x 576 pixel) 25 frames/s, night shot mode automatic gain and exposure



Scenario with permanent infrared high beam

Conventional Imaging

A comparison of conventional CCD imaging and the **HDRC**[®] imaging technology illustrates the superiority of **HDRC**[®] as a result of its revolutionary concept based on human visual perception.

The power of human visual perception lies in its very high dynamic range, its robust object detection due to high and constant contrast resolution in both bright and dark regions of a scene: On a gray scale we perceive equal relative steps as equally spaced levels. A one-percent step in a bright part of the image means a larger absolute step while it means very fine absolute steps in darker regions of an image. This is exactly the performance of each pixel in **HDRC**[®] silicon imagers.

The images on this page were taken with matured CCD cameras with the state-of-the-art analog and digital signal processing built in. Although the recent active CMOS pixel sensors are robust against the CCD-specific blooming, their dynamic range tends to be smaller than that of refined CCD sensors so that images turn out poorer than those of CCD cameras.

In comparison with the **HDRC**[®] images on the opposite page, it should be taken into account that they are direct images following just those operations outlined in this brochure and that the sensor output data contain at least two more decades of intensity information beyond what appears in print.



Process control

B/W CCD Camera



Traffic control

B/W CCD Camera



Color imaging

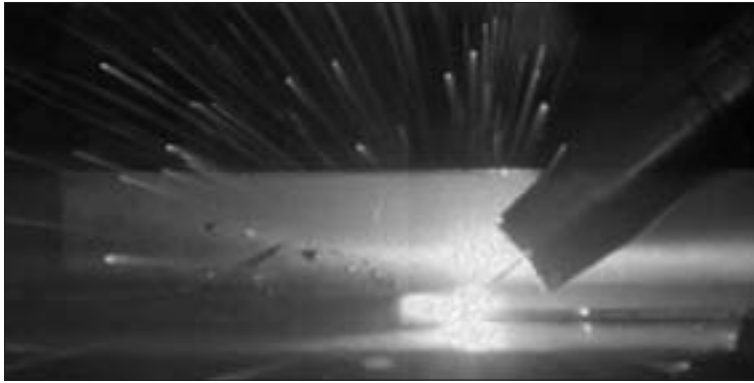
CCD Digital Camcorder 768x552 pixels



High contrast imaging

CCD Camera

HDRC® The New Electronic Vision



HDRC® 2 256 x 128 pixels

1994 0.8 μm CMOS

This welding scene was taken in 1994 with the digital HDRC® 2 EC camera without exposure control and with 120 frames/s. The access time per pixel is constant at 140 ns independent of luminance resulting in the unique high-speed features of HDRC®.



HDRC® 2 256 x 128 pixels

1994 0.8 μm CMOS

This tunnel scene with its dynamic range of 100000:1 was taken in 1994 with the HDRC® 2. Random and non-destructive readout of each pixel at a constant speed of 140 ns per pixel allows direct trading of the subframe rate versus subframe speed. 7000 subframes at a size of 32 x 32 pixels can be recorded per second and output channel. Right and left channels increase readout speed and can produce stereo data.



HDRC® 4 512 x 256 pixels

1997 0.5 μm CMOS

HDRC® 4 PC acquisition and printing of this colorful scene under tough spotlight conditions demonstrate the quality of the straight raw digital image taken at 30 frames/s and without any local signal processing and color correction.



HDRC® VGAx 640 x 480 pixels

2003, 0.25 μm CMOS

The video recording of the replica of Michelangelo's "Maria" demonstrates the natural, eye-like response of the HDRC® VGAx camera as compared with a high-performance CCD camcorder.

Comparison of HDRC® and CCD



8:56pm / 0.1 lux

HDRC® VGA1, digital video camera, recorded with 120 dB dynamic range, 25 frames/s.



CCD, digital camcorder (768 x 552 pixels), automatic gain and exposure.

Waving Scene at 40 millilux



HDRC VGAX

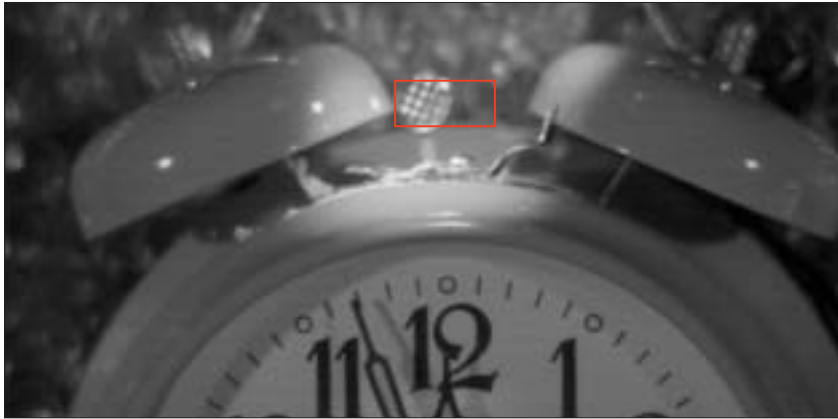
HDRC® VGAX, digital video camera, recorded with 170 dB dynamic range, 45 frames/s.



CCD

CCD, digital camcorder, 25 frames/s, night shot mode automatic gain and exposure.

HDRC® High-Speed Image Acquisition



120 full frames/s, 512 x 256 pixels



High-speed mode
3787 subframes/s,
64 x 32 pixels

In **HDRC**® cameras, the "shutter" time is constant at less than 80 ns irrespective of the brightness of the scene. Pixel data arrive at a constant rate synchronous with the imager clock. This allows a very straight-forward camera architecture. The random access to each pixel facilitates high-speed, intelligent

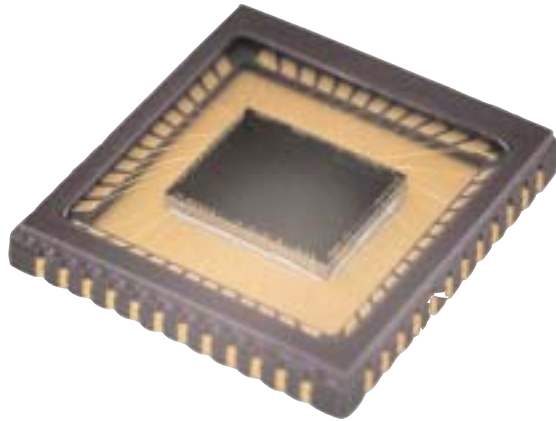
access to any subframe (block) size or subsampling ratio and a trade of frame speed versus frame size. The alarm-clock scene was taken at 120 full frames/s with 128k pixels per frame and the close-up runs at almost 4000 frames/s with 2k pixels per frame.

HDRC® Imaging Modules

Key Features of our new generation imager VGA3 in comparison to our well known prototype VGAX

	VGAX	VGA3
Introduction	2004	1 st qu. 2006
Chip Size (mm²)	8.7 x 6.4	7.0 x 5.3
Pixel	768 x 496	768 x 496
Pixel area (µm²)	10 x 10	7.4 x 7.4
Image diagonal (inch)	1/2	1/3
Dynamic Range (dB)	170	> 160
Sensitivity (lux)	0.001	< 0.005
Frame rate (1/s)*	30	30
Shutter	Rolling	Rolling
A/D Converter	10 bits	10 bits, on-chip
Controller on-chip	No	Yes
B/W, Color	B/W, Color	B/W, Color

* VGA size (640 x 480)



VGA3 Chip

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