HDRC®
CMOS-Bildsensorik mit höchster Dynamik

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<table>
<thead>
<tr>
<th>IMAGING</th>
<th>RESPONSE</th>
<th>SCENE DYNAMIC RANGE</th>
<th>COLOR CONSTANCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our eyes</td>
<td>Logarithmic</td>
<td>Very high</td>
<td>Yes</td>
</tr>
<tr>
<td>Painting</td>
<td>Eye-like, logarithmic</td>
<td>High</td>
<td>Depending on the artist</td>
</tr>
<tr>
<td>Film</td>
<td>Pseudo eye-like, pseudo logarithmic</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>Vidicon</td>
<td>Linear</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>CCD</td>
<td>Linear</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>Other CMOS</td>
<td>Linear</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>HDRC</td>
<td>Eye-Like, logarithmic</td>
<td>Very high</td>
<td>Yes</td>
</tr>
</tbody>
</table>
The Revolution in Electronic Imaging

Response curve of the HDRC VGAX and other sensors

- CCD
- FILM
- EYE
- HDRC VGAX

Density:
- 0.001
- 0.01
- 0.1
- 1
- 10
- 100
- 1000
- 10^4
- 10^5
- 10^6

Logarithmic Intensity [lux]:
- 170 dB
- 300k lux

1 millilux
Dynamic Range

Relative Intensity

- 10^{-6} to 10^{-5} to 10^{-4} to 10^{-3} to 10^{-2} to 10^{-1} to 1

- 6 Decades
- 20 Octaves

- 2s, 1/2, 1/8, 1/30, 2, 2.8, 4, 5.6, 6, 11, 16, 22, 1/30, 1/125, 1/500, 1/2000
Time-Continuous Log-Compressing Pixel

Filed 03/24/1992       International Patents
HDRC® High-Dynamic Range Camera 1996
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.
### Sobel Operator HDRC vs. CCD

<table>
<thead>
<tr>
<th></th>
<th>CCD</th>
<th>HDRC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Original Image</strong></td>
<td><img src="image1" alt="Original Image CCD" /></td>
<td><img src="image2" alt="Original Image HDRC" /></td>
</tr>
<tr>
<td><strong>Sobel Operator</strong></td>
<td><img src="image3" alt="Sobel Operator CCD" /></td>
<td><img src="image4" alt="Sobel Operator HDRC" /></td>
</tr>
</tbody>
</table>

*Courtesy: OMRON*
CMOS Imager Signal-to-Noise and Dynamic Range

Flat-Field Signal-to-Noise

Green Lux (555 nm)

HDRC VGAx
20°C
Independent of int. time

4T CMOS PPD
APS 20°C 10ms 1)

XDR CMOS
APS 64°C 10ms 1)

1) Janesick 2003
Person at 10 m, 40 mLux

CCD                      HDRC VGAx
Night Vision: The Challenge

Scenario with permanent infrared high beam

Permanent Infrared High Beam

High Beam

Low Beam

20m

40m

60m

80m

100m

120m

140m
Spectral Sensitivity of Photodiodes
Car with high beams at 80 m and pedestrian at 100 m

Scenario illuminated with low beam and permanent infrared (NIR) high beam 2001

In cooperation with
Pedestrians in Absolute Darkness

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

Scene illuminated with permanent infrared (NIR) high beam

2001

In cooperation with
Scene illuminated with (NIR) high beam. License plate between headlights and the distant pedestrian are detected clearly.
Fast motion at low light levels presents fundamental problems for all imagers, which need exposure (or integration) time to generate an image. HDRC pixels track the photon flux continuously. They produce sharp contours and texture under any lighting and speed conditions.
HDRC® Night Vision – Safe In Any Scene

CCD

HDRC
Electronic Eyes on Wheels

- Traffic Signs
- Night Vision
- Road Hazard
- Lane Following
- Intelligent Cruise
- Collision Avoidance
- Intelligent Headlights
- Parking Aid
- Dead Angle View
- Front-Seat Occupation
- Distraction and Fatigue Warning
- Driver Identification
- Cross Traffic and Side Impact Warning
- Rear View Lane Change

2010 ca. 40 Billion Euro
Over- or Under-exposure? No Problem for HDRC®

Recorded HDRC® images displayed after offset adjustment.
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 HDRC® image without post-processing. 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).
CCD: White-saturated glass panels and black-saturated walls.

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.
Turn-On of Headlight

CCD

HDRC
Turn-On of Headlight 3 Frames

**CCD**

- 0.0 sec
- 0.5 sec
- 1.0 sec

**HDRC**

- 0.0 sec
- 0.5 sec
- 1.0 sec
Airport Sun, Fog, Night

HDRC®
Camera-Guided
Aircraft Docking

High Dynamic Range
High Sensitivity
High Contrast Resolution
One Camera Setting for All

Courtesy: Honeywell Airport Systems and Gevitec