Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of “Quality Parts,Customers Priority,Honest Operation,and Considerate Service”,our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!

Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

KAI-04050

2336 (H) x 1752 (V) Interline CCD Image Sensor

Description

The KAI−04050 Image Sensor is a 4-megapixel CCD in a 1” optical format. Based on the TRUESENSE 5.5 micron Interline Transfer CCD Platform, the sensor features broad dynamic range, excellent imaging performance, and a flexible readout architecture that enables use of 1, 2, or 4 outputs. The sensor supports full resolution readout up to 32 frames per second, while a Region of Interest (ROI) mode enables partial readout of the sensor at even higher frame rates. A vertical overflow drain structure suppresses image blooming and enables electronic shuttering for precise exposure control.

Table 1. GENERAL SPECIFICATIONS

Parameter	Typical Value
Architecture	Interline CCD, Progressive Scan
Total Number of Pixels	2404 (H) × 1800 (V)
Number of Effective Pixels	2360 (H) × 1776 (V)
Number of Active Pixels	2336 (H) × 1752 (V)
Pixel Size	5.5 μm (H) × 5.5 μm (V)
Active Image Size	12.85 mm (H) × 9.64 mm (V), 16.06 mm (Diagonal), 1″ Optical Format
Aspect Ratio	4:3
Number of Outputs	1, 2, or 4
Charge Capacity	20,000 electrons
Output Sensitivity	34 μV/e^-
Quantum Efficiency	
Pan (−ABA, −QBA, −PBA)	44%
R, G, B (−FBA, −QBA)	31%, 37%, 38%
R, G, B (−CBA, −PBA)	29%, 37%, 39%
Read Noise (f = 40 MHz)	12 e^- rms
Dark Current	
Photodiode	7 e^-/s
VCCD	100 e^-/s
Dark Current Doubling Temp.	
Photodiode	7°C
VCCD	9°C
Dynamic Range	64 dB
Charge Transfer Efficiency	0.999999
Blooming Suppression	> 300 X
Smear	−100 dB
Image Lag	< 10 electrons
Maximum Pixel Clock Speed	40 MHz
Maximum Frame Rate	
Quad Output	32 fps
Dual Output	16 fps
Single Output	8 fps
Package	68 Pin PGA
Cover Glass	AR Coated, 2 Sides or Clear Glass

NOTE: All Parameters are specified at T = 40°C unless otherwise noted.

ON Semiconductor®

www.onsemi.com

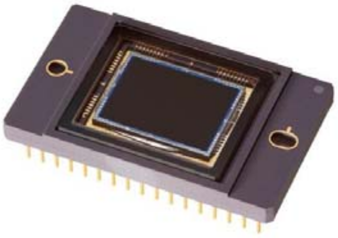


Figure 1. KAI−04050 Interline CCD Image Sensor

Features

- Bayer Color Pattern, TRUESENSE Sparse Color Filter Pattern, and Monochrome Configurations
- Progressive Scan Readout
- Flexible Readout Architecture
- High Frame Rate
- High Sensitivity
- Low Noise Architecture
- Excellent Smear Performance
- Package Pin Reserved for Device Identification

Application

- Industrial Imaging
- Medical Imaging
- Security

ORDERING INFORMATION

See detailed ordering and shipping information on page 2 of this data sheet.

February, 2017 − Rev. 6

The sensor is available with the TRUESENSE Sparse Color Filter Pattern, a technology which provides a 2x improvement in light sensitivity compared to a standard color Bayer part.

The sensor shares common pin-out and electrical configurations with other devices based on the TRUESENSE 5.5 micron Interline Transfer CCD Platform, allowing a single camera design to support multiple members of this sensor family.

ORDERING INFORMATION

Table 2. ORDERING INFORMATION − KAI−04050 IMAGE SENSOR

Part Number	Description	Marking Code
KAI−04050−AAA−JP−BA	Monochrome, No Microlens, PGA Package, Taped Clear Cover Glass, No Coatings, Standard Grade	KAI−04050−AAA Serial Number
KAI−04050−AAA−JP−AE	Monochrome, No Microlens, PGA Package, Taped Clear Cover Glass, No Coatings, Engineering Grade	
KAI−04050−ABA−JD−BA	Monochrome, Telecentric Microlens, PGA Package, Sealed Clear Cover Glass with AR Coating (Both Sides), Standard Grade	KAI−04050−ABA Serial Number
KAI−04050−ABA−JD−AE	Monochrome, Telecentric Microlens, PGA Package, Sealed Clear Cover Glass with AR Coating (Both Sides), Engineering Grade	
KAI−04050−ABA−JP−BA	Monochrome, Telecentric Microlens, PGA Package, Taped Clear Cover Glass, No Coatings, Standard Grade	
KAI−04050−ABA−JP−AE	Monochrome, Telecentric Microlens, PGA Package, Taped Clear Cover Glass, No Coatings, Engineering Grade	
KAI−04050−FBA−JD−BA	Gen2 Color (Bayer RGB), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass with AR Coating (Both Sides), Standard Grade	KAI−04050−FBA Serial Number
KAI−04050−FBA−JD−AE	Gen2 Color (Bayer RGB), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass with AR Coating (Both Sides), Engineering Grade	
KAI−04050−FBA−JB−B2	Gen2 Color (Bayer RGB), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass (No Coatings), Grade 2	
KAI−04050−FBA−JB−AE	Gen2 Color (Bayer RGB), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass (No Coatings), Engineering Grade	
KAI−04050−FBA−JB−B2−T	Gen2 Color (Bayer RGB), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass (No Coatings), Grade 2, Packed in Trays	
KAI−04050−QBA−JD−BA	Gen2 Color (TRUESENSE Sparse CFA), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass with AR Coating (Both Sides), Standard Grade	KAI−04050−QBA Serial Number
KAI−04050−QBA−JD−AE	Gen2 Color (TRUESENSE Sparse CFA), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass with AR Coating (Both Sides), Engineering Grade	
KAI−04050−CBA−JD−BA*	Gen1 Color (Bayer RGB), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass with AR Coating (Both Sides), Standard Grade	KAI−04050−CBA Serial Number
KAI−04050−CBA−JD−AE*	Gen1 Color (Bayer RGB), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass with AR Coating (Both Sides), Engineering Grade	
KAI−04050−CBA−JB−B2*	Gen1 Color (Bayer RGB), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass (No Coatings), Grade 2	
KAI−04050−CBA−JB−AE*	Gen1 Color (Bayer RGB), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass (No Coatings), Engineering Grade	
KAI−04050−CBA−JB−B2−T*	Gen1 Color (Bayer RGB), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass (No Coatings), Grade 2, Packed in Trays	
KAI−04050−PBA−JD−BA*	Gen1 Color (TRUESENSE Sparse CFA), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass with AR Coating (Both Sides), Standard Grade	KAI−04050−PBA Serial Number
KAI−04050−PBA−JD−AE*	Gen1 Color (TRUESENSE Sparse CFA), Telecentric Microlens, PGA Package, Sealed Clear Cover Glass with AR Coating (Both Sides), Engineering Grade	

*Not recommended for new designs.

See the ON Semiconductor *Device Nomenclature* document (TND310/D) for a full description of the naming convention used for image sensors. For reference documentation, including information on evaluation kits, please visit our web site at www.onsemi.com.

DEVICE DESCRIPTION

Architecture

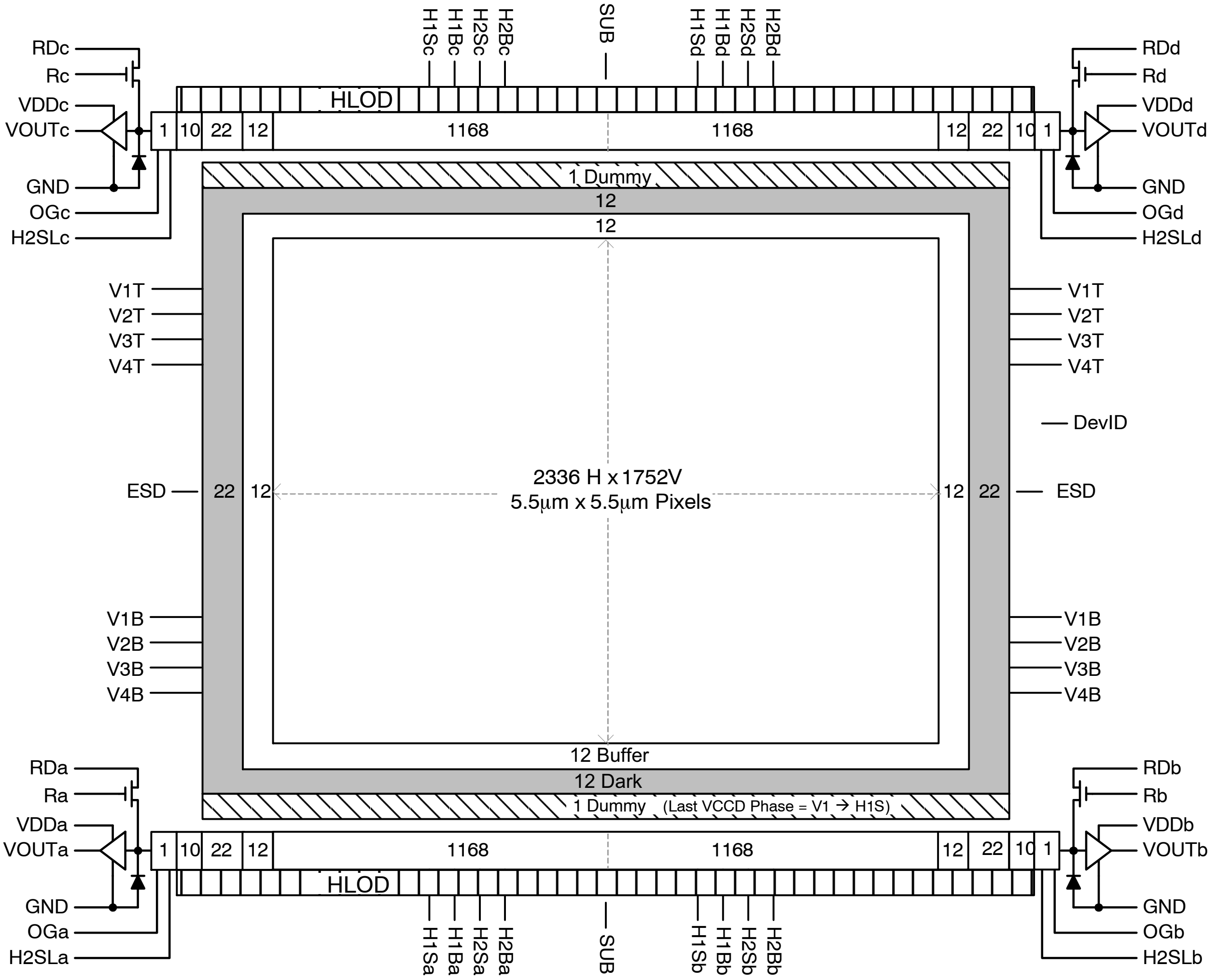


Figure 2. Block Diagram

Dark Reference Pixels

There are 12 dark reference rows at the top and 12 dark rows at the bottom of the image sensor. The dark rows are not entirely dark and so should not be used for a dark reference level. Use the 22 dark columns on the left or right side of the image sensor as a dark reference.

Under normal circumstances use only the center 20 columns of the 22 column dark reference due to potential light leakage.

Dummy Pixels

Within each horizontal shift register there are 11 leading additional shift phases. These pixels are designated as dummy pixels and should not be used to determine a dark reference level.

In addition, there is one dummy row of pixels at the top and bottom of the image.

Active Buffer Pixels

12 unshielded pixels adjacent to any leading or trailing dark reference regions are classified as active buffer pixels. These pixels are light sensitive but are not tested for defects and non-uniformities.

Image Acquisition

An electronic representation of an image is formed when incident photons falling on the sensor plane create electron−hole pairs within the individual silicon photodiodes. These photoelectrons are collected locally by the formation of potential wells at each photosite. Below photodiode saturation, the number of photoelectrons collected at each pixel is linearly dependent upon light level and exposure time and non−linearly dependent on wavelength. When the photodiodes charge capacity is reached, excess electrons are discharged into the substrate to prevent blooming.

ESD Protection

Adherence to the power-up and power-down sequence is critical. Failure to follow the proper power-up and power-down sequences may cause damage to the sensor. See Power-Up and Power-Down Sequence section.

Bayer Color Filter Pattern

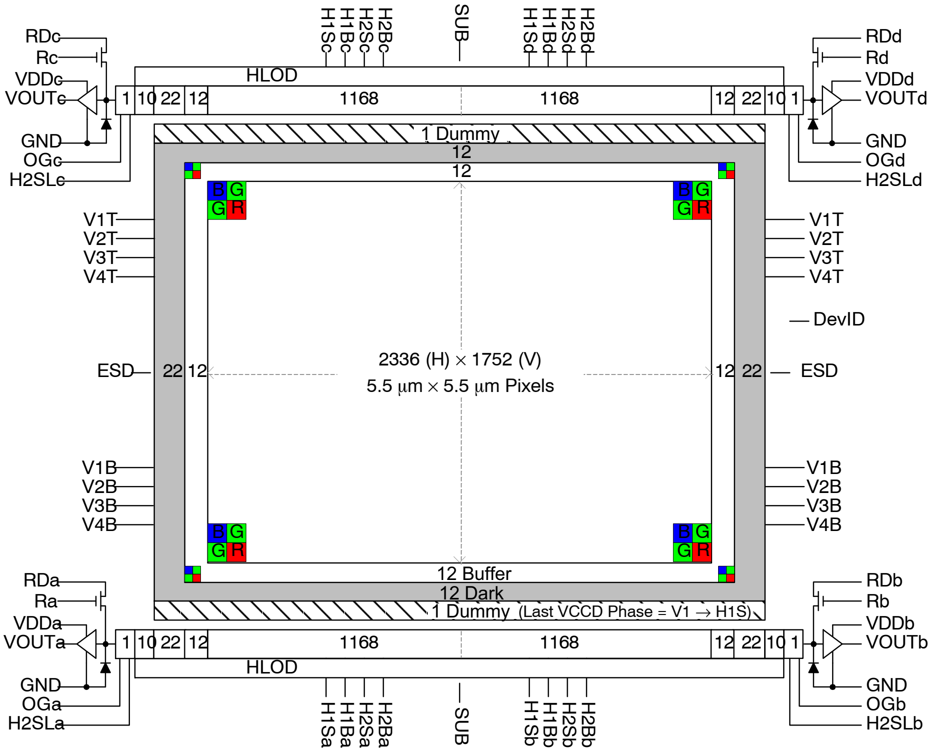


Figure 3. Bayer Color Filter Pattern

TRUESENSE Sparse Color Filter Pattern

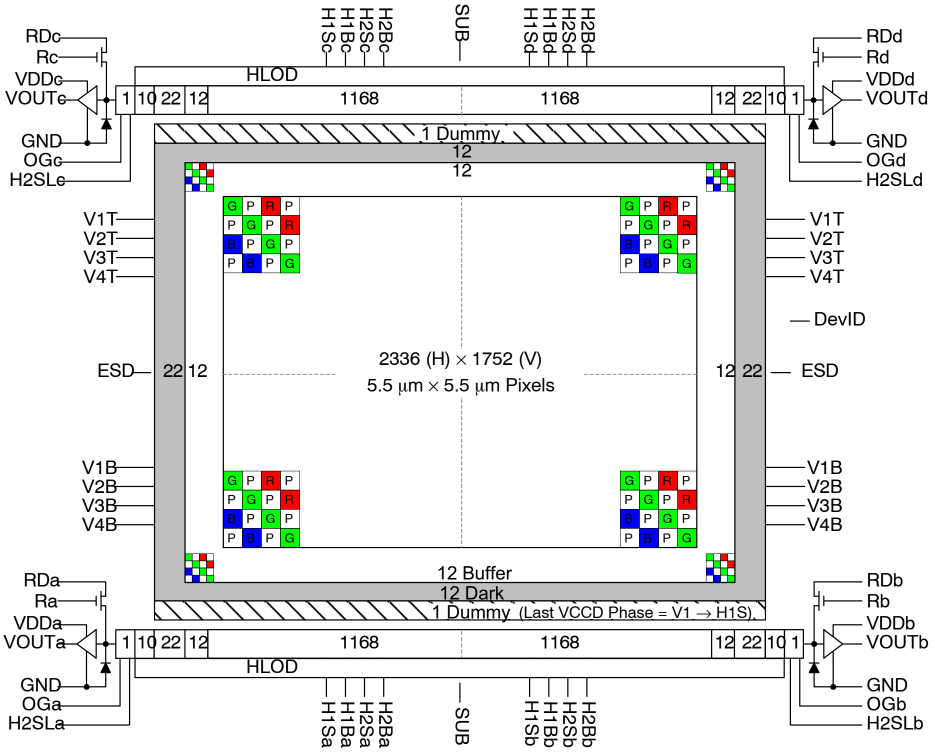


Figure 4. TRUESENSE Sparse Color Filter Pattern

Physical Description

Pin Description and Device Orientation

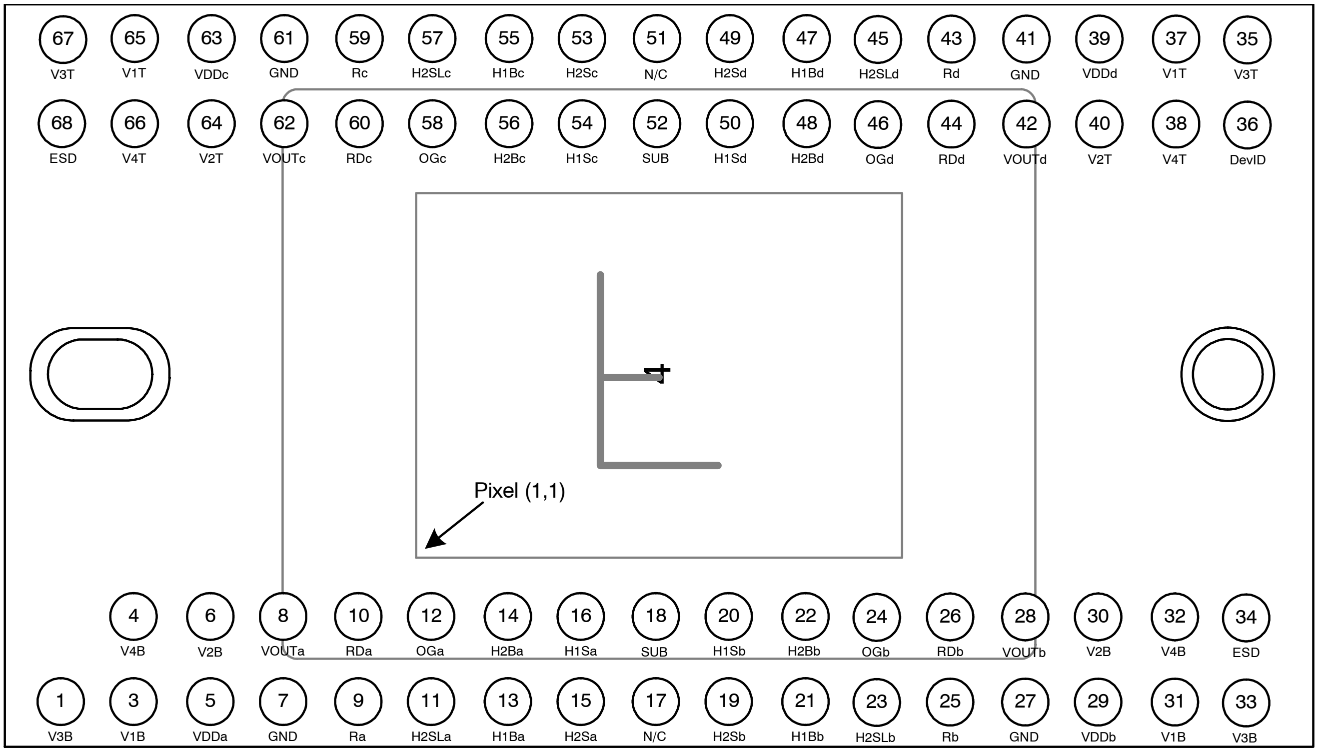


Figure 5. Package Pin Designations − Top View

Table 3. PACKAGE PIN DESCRIPTION

Pin	Name	Description
1	V3B	Vertical CCD Clock, Phase 3, Bottom
3	V1B	Vertical CCD Clock, Phase 1, Bottom
4	V4B	Vertical CCD Clock, Phase 4, Bottom
5	VDDa	Output Amplifier Supply, Quadrant a
6	V2B	Vertical CCD Clock, Phase 2, Bottom
7	GND	Ground
8	VOUTa	Video Output, Quadrant a
9	Ra	Reset Gate, Quadrant a
10	RDa	Reset Drain, Quadrant a
11	H2SLa	Horizontal CCD Clock, Phase 2, Storage, Last Phase, Quadrant a
12	OGa	Output Gate, Quadrant a
13	H1Ba	Horizontal CCD Clock, Phase 1, Barrier, Quadrant a
14	H2Ba	Horizontal CCD Clock, Phase 2, Barrier, Quadrant a
15	H2Sa	Horizontal CCD Clock, Phase 2, Storage, Quadrant a
16	H1Sa	Horizontal CCD Clock, Phase 1, Storage, Quadrant a
17	N/C	No Connect
18	SUB	Substrate
19	H2Sb	Horizontal CCD Clock, Phase 2, Storage, Quadrant b
20	H1Sb	Horizontal CCD Clock, Phase 1, Storage, Quadrant b
21	H1Bb	Horizontal CCD Clock, Phase 1, Barrier, Quadrant b
22	H2Bb	Horizontal CCD Clock, Phase 2, Barrier, Quadrant b

Table 3. PACKAGE PIN DESCRIPTION (continued)

Pin	Name	Description
23	H2SLb	Horizontal CCD Clock, Phase 2, Storage, Last Phase, Quadrant b
24	OGb	Output Gate, Quadrant b
25	Rb	Reset Gate, Quadrant b
26	RDb	Reset Drain, Quadrant b
27	GND	Ground
28	VOUTb	Video Output, Quadrant b
29	VDDb	Output Amplifier Supply, Quadrant b
30	V2B	Vertical CCD Clock, Phase 2, Bottom
31	V1B	Vertical CCD Clock, Phase 1, Bottom
32	V4B	Vertical CCD Clock, Phase 4, Bottom
33	V3B	Vertical CCD Clock, Phase 3, Bottom
34	ESD	ESD Protection Disable
35	V3T	Vertical CCD Clock, Phase 3, Top
36	DevID	Device Identification
37	V1T	Vertical CCD Clock, Phase 1, Top
38	V4T	Vertical CCD Clock, Phase 4, Top
39	VDDd	Output Amplifier Supply, Quadrant d
40	V2T	Vertical CCD Clock, Phase 2, Top
41	GND	Ground
42	VOUTd	Video Output, Quadrant d
43	Rd	Reset Gate, Quadrant d
44	RDd	Reset Drain, Quadrant d
45	H2SLd	Horizontal CCD Clock, Phase 2, Storage, Last Phase, Quadrant d
46	OGd	Output Gate, Quadrant d
47	H1Bd	Horizontal CCD Clock, Phase 1, Barrier, Quadrant d
48	H2Bd	Horizontal CCD Clock, Phase 2, Barrier, Quadrant d
49	H2Sd	Horizontal CCD Clock, Phase 2, Storage, Quadrant d
50	H1Sd	Horizontal CCD Clock, Phase 1, Storage, Quadrant d
51	N/C	No Connect
52	SUB	Substrate
53	H2Sc	Horizontal CCD Clock, Phase 2, Storage, Quadrant c
54	H1Sc	Horizontal CCD Clock, Phase 1, Storage, Quadrant c
55	H1Bc	Horizontal CCD Clock, Phase 1, Barrier, Quadrant c
56	H2Bc	Horizontal CCD Clock, Phase 2, Barrier, Quadrant c
57	H2SLc	Horizontal CCD Clock, Phase 2, Storage, Last Phase, Quadrant c
58	OGc	Output Gate, Quadrant c
59	Rc	Reset Gate, Quadrant c
60	RDc	Reset Drain, Quadrant c
61	GND	Ground
62	VOUTc	Video Output, Quadrant c
63	VDDc	Output Amplifier Supply, Quadrant c
64	V2T	Vertical CCD Clock, Phase 2, Top
65	V1T	Vertical CCD Clock, Phase 1, Top
66	V4T	Vertical CCD Clock, Phase 4, Top
67	V3T	Vertical CCD Clock, Phase 3, Top
68	ESD	EDS Protection Disable

1. Liked named pins are internally connected and should have a common drive signal.
2. N/C pins (17, 51) should be left floating.

IMAGING PERFORMANCE

Table 4. TYPICAL OPERATIONAL CONDITIONS

(Unless otherwise noted, the Imaging Performance Specifications are measured using the following conditions.)

Description	Condition	Notes
Light Source	Continuous Red, Green and Blue LED Illumination	1
Operation	Nominal Operating Voltages and Timing	

1. For monochrome sensor, only green LED used.

Specifications

Table 5. PERFORMANCE SPECIFICATIONS

Description	Symbol	Min.	Nom.	Max.	Unit	Sampling Plan	Temperature Tested at (°C)
ALL CONFIGURATIONS							
Dark Field Global Non-Uniformity	DSNU	–	–	2.0	mVpp	Die	27, 40
Bright Field Global Non-Uniformity (Note 1)		–	2.0	5.0	% rms	Die	27, 40
Bright Field Global Peak to Peak Non-Uniformity (Note 1)	PRNU	–	5.0	15.0	% pp	Die	27, 40
Bright Field Center Non-Uniformity (Note 1)		–	1.0	2.0	% rms	Die	27, 40
Maximum Photoresponse Nonlinearity	NL	–	2	–	%	Design	
Maximum Gain Difference between Outputs (Note 2)	ΔG	–	10	–	%	Design	
Maximum Signal Error due to Nonlinearity Differences (Note 2)	ΔNL	–	1	–	%	Design	
Horizontal CCD Charge Capacity	H_{Ne}	–	55	–	ke$^-$	Design	
Vertical CCD Charge Capacity	V_{Ne}	–	40	–	ke$^-$	Design	
Photodiode Charge Capacity (Note 3)	P_{Ne}	–	20	–	ke$^-$	Die	27, 40
Horizontal CCD Charge Transfer Efficiency	HCTE	0.999995	0.999999	–		Die	
Vertical CCD Charge Transfer Efficiency	VCTE	0.999995	0.999999	–		Die	
Photodiode Dark Current	I_{PD}	–	7	70	e/p/s	Die	40
Vertical CCD Dark Current	I_{VD}	–	100	300	e/p/s	Die	40
Image Lag	Lag	–	–	10	e$^-$	Design	
Anti-Blooming Factor	X_{AB}	300	–	–		Design	
Vertical Smear	Smr	–	−100	–	dB	Design	
Read Noise (Note 4)	n_{e-T}	–	12	–	e$^-$ rms	Design	
Dynamic Range (Notes 4, 5)	DR	–	64	–	dB	Design	
Output Amplifier DC Offset	V_{ODC}	–	9.4	–	V	Die	27, 40
Output Amplifier Bandwidth (Note 6)	f_{-3db}	–	250	–	MHz	Die	
Output Amplifier Impedance	R_{OUT}	–	127	–	Ω	Die	27, 40
Output Amplifier Sensitivity	$\Delta V/\Delta N$	–	34	–	µV/e$^-$	Design	
KAI−04050−ABA, KAI−04050−QBA, AND KAI−04050−PBA(7) CONFIGURATIONS							
Peak Quantum Efficiency	QE_{MAX}	–	46	–	%	Design	
Peak Quantum Efficiency Wavelength	λQE	–	500	–	nm	Design	

Table 5. PERFORMANCE SPECIFICATIONS (continued)

Description	Symbol	Min.	Nom.	Max.	Unit	Sampling Plan	Temperature Tested at (°C)
KAI−04050−FBA AND KAI−04050−QBA GEN2 COLOR CONFIGURATIONS WITH MAR GLASS							
Peak Quantum Efficiency	QE_{MAX}				%	Design	
Blue		–	38	–			
Green		–	37	–			
Red		–	31	–			
Peak Quantum Efficiency Wavelength	λQE				nm	Design	
Blue		–	460	–			
Green		–	530	–			
Red		–	605	–			
KAI−04050−FBA GEN2 COLOR CONFIGURATION WITH CLEAR GLASS							
Peak Quantum Efficiency	QE_{MAX}				%	Design	
Blue		–	35	–			
Green		–	34	–			
Red		–	29	–			
Peak Quantum Efficiency Wavelength	λQE				nm	Design	
Blue		–	460	–			
Green		–	530	–			
Red		–	605	–			
KAI−04050−CBA AND KAI−04050−PBA GEN1 COLOR CONFIGURATIONS WITH MAR GLASS (Note 7)							
Peak Quantum Efficiency	QE_{MAX}				%	Design	
Blue		–	39	–			
Green		–	37	–			
Red		–	29	–			
Peak Quantum Efficiency Wavelength	λQE				nm	Design	
Blue		–	470	–			
Green		–	540	–			
Red		–	620	–			
KAI−04050−CBA GEN1 COLOR CONFIGURATION WITH CLEAR GLASS (Note 7)							
Peak Quantum Efficiency	QE_{MAX}				%	Design	
Blue		–	36	–			
Green		–	34	–			
Red		–	27	–			
Peak Quantum Efficiency Wavelength	λQE				nm	Design	
Blue		–	470	–			
Green		–	540	–			
Red		–	620	–			

1. Per color.
2. Value is over the range of 10% to 90% of linear signal level saturation.
3. The operating value of the substrate voltage, V_{AB}, will be marked on the shipping container for each device. The value of V_{AB} is set such that the photodiode charge capacity is 680 mV.
4. At 40 MHz.
5. Uses 20LOG (P_{Ne} / n_{e-T}).
6. Assumes 5 pF load.
7. This color filter set configuration (Gen1) is not recommended for new designs.

TYPICAL PERFORMANCE CURVES

Quantum Efficiency

Monochrome, All Configurations

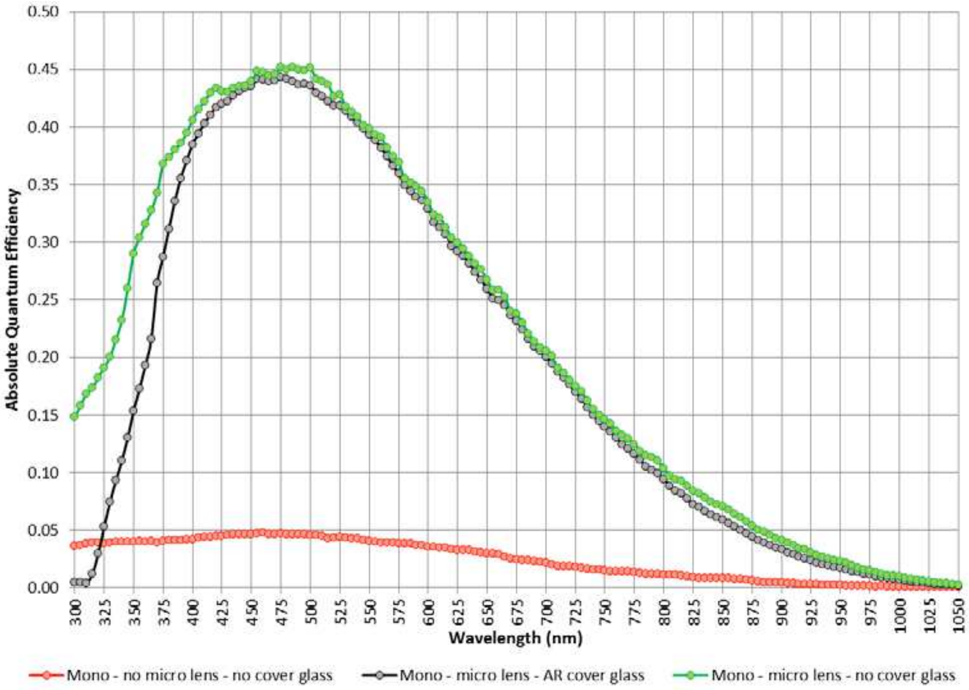


Figure 6. Monochrome Configurations − Quantum Efficiency

Color (Bayer RGB) with Microlens and MAR Cover Glass (Gen2 and Gen1 CFA)

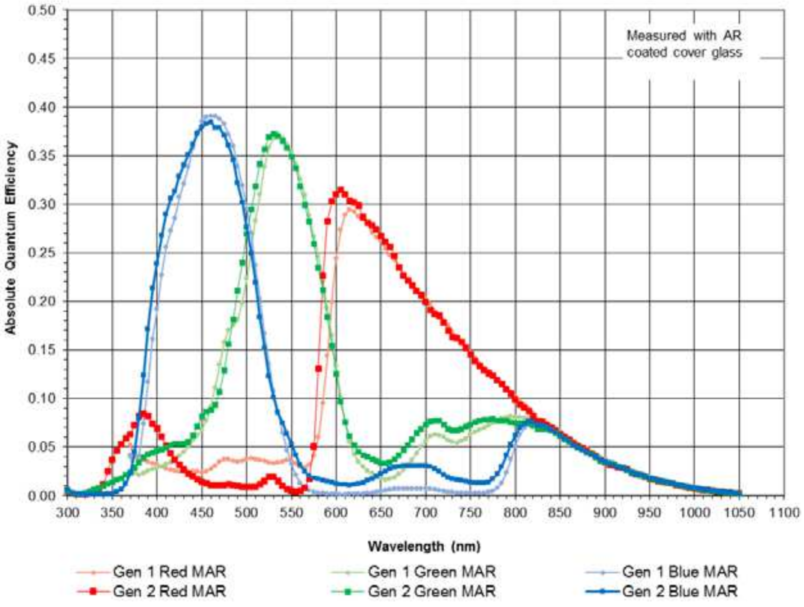


Figure 7. MAR Glass Color (Bayer) with Microlens Quantum Efficiency

Color (Bayer RGB) with Microlens and Clear Cover Glass (Gen2 and Gen1 CFA)

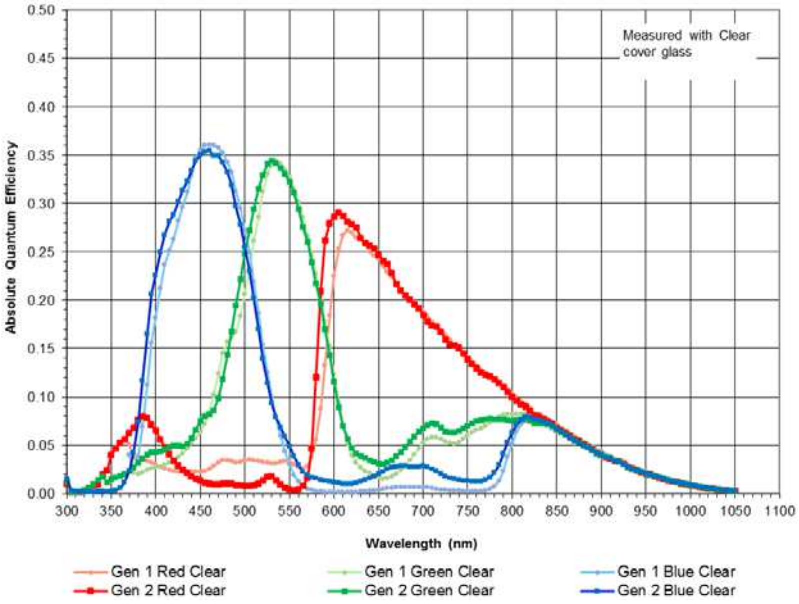


Figure 8. Clear Glass Color (Bayer) with Microlens Quantum Efficiency

Color (TRUESENSE Sparse CFA) with Microlens (Gen2 and Gen1 CFA)

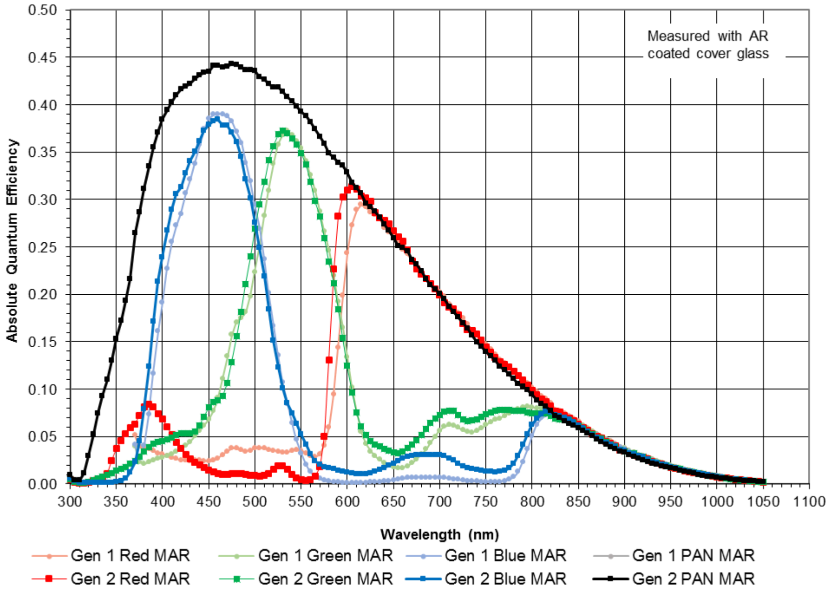


Figure 9. Color (TRUESENSE Sparse CFA) with Microlens Quantum Efficiency

Angular Quantum Efficiency

For the curves marked “Horizontal”, the incident light angle is varied in a plane parallel to the HCCD.
For the curves marked “Vertical”, the incident light angle is varied in a plane parallel to the VCCD.

Monochrome with Microlens

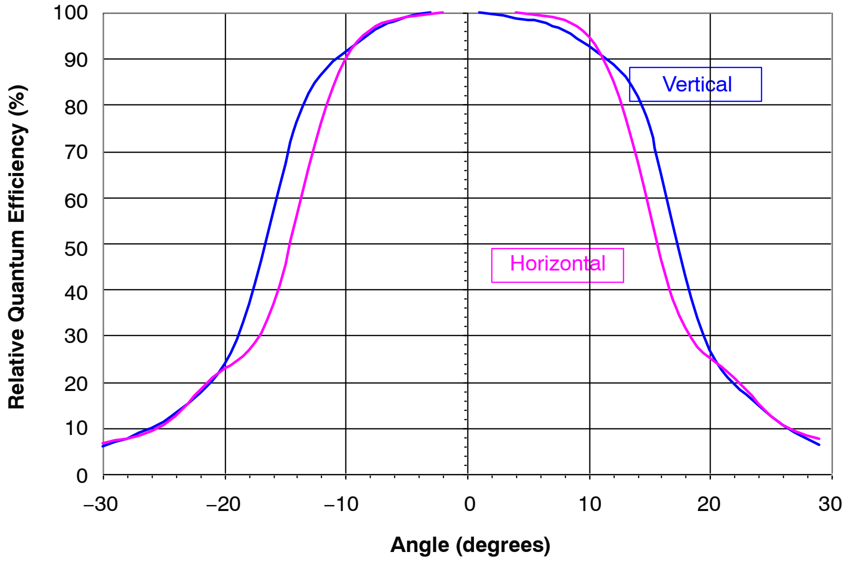


Figure 10. Monochrome with Microlens Angular Quantum Efficiency

Dark Current vs. Temperature

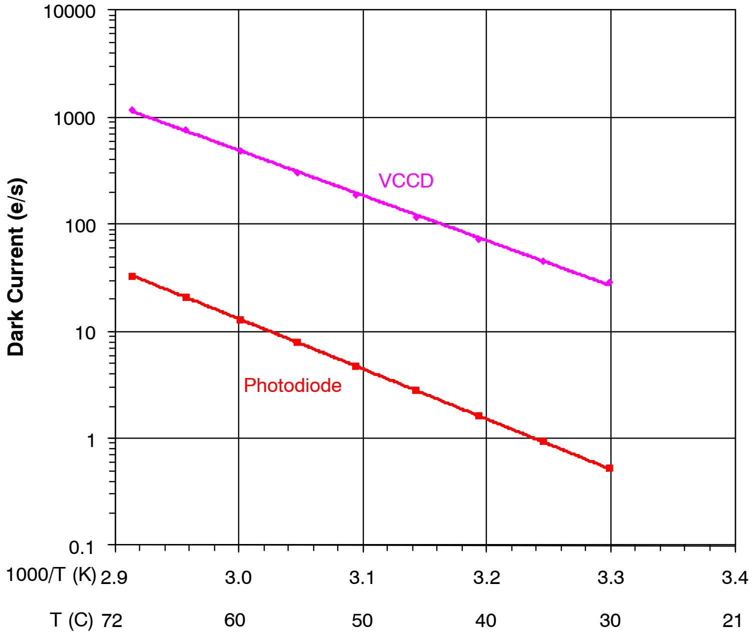


Figure 11. Dark Current vs. Temperature

Power-Estimated

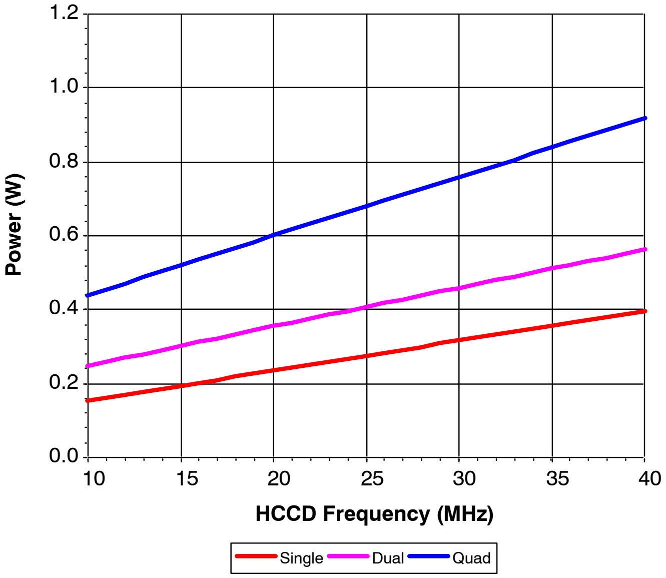


Figure 12. Power

Frame Rates

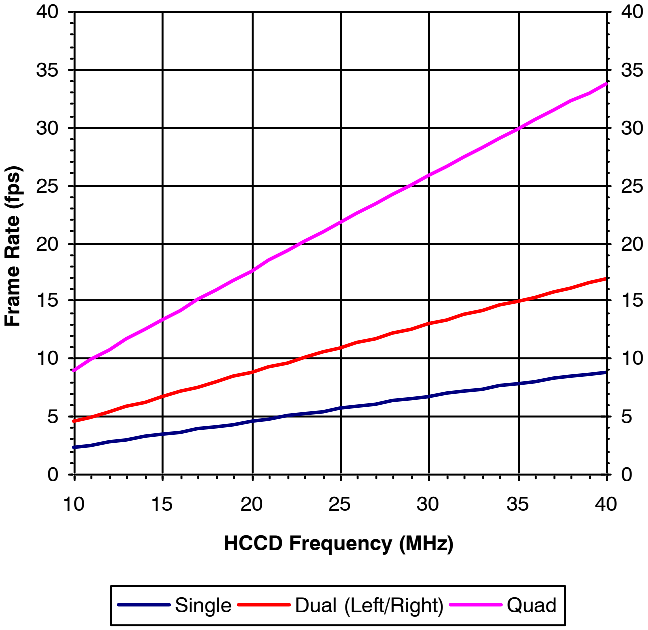


Figure 13. Frame Rates

DEFECT DEFINITIONS

Table 6. OPERATION CONDITIONS FOR DEFECT TESTING AT 40°C

Description	Condition	Notes
Operational Mode	Two Outputs, using VOUTa and VOUTc, Continuous Readout	
HCCD Clock Frequency	10 MHz	
Pixels per Line	2,560	1
Lines per Frame	992	2
Line Time	259.8 μs	
Frame Time	256.8 ms	
Photodiode Integration Time (PD_Tint)	Mode A: PD_Tint = Frame Time = 256.8 ms, No Electronic Shutter Used Mode B: PD_Tint = 33 ms, Electronic Shutter Used	
VCCD Integration Time	233.0 ms	3
Temperature	40°C	
Light Source	Continuous Red, Green and Blue LED Illumination	4
Operation	Nominal Operating Voltages and Timing	

1. Horizontal overclocking used
2. Vertical overclocking used
3. VCCD Integration Time = 900 lines x Line Time, which is the total time a pixel will spend in the VCCD registers.
4. For monochrome sensor, only the green LED is used.

Table 7. DEFECT DEFINITIONS FOR TESTING AT 40°C

Description	Definition	Standard Grade	Grade 2	Notes
Major Dark Field Defective Bright Pixel	PD_Tint = Mode A → Defect ≥ 88 mV or PD_Tint = Mode B → Defect ≥ 12 mV	40	40	1
Major Bright Field Defective Dark Pixel	Defect ≥ 12%	40	40	1
Minor Dark Field Defective Bright Pixel	PD_Tint = Mode A → Defect ≥ 44 mV or PD_Tint = Mode B → Defect ≥ 6 mV	400	400	
Cluster Defect	A group of 2 to 10 contiguous major defective pixels, but no more than 2 adjacent defects horizontally.	8	n/a	2
Cluster Defect (Grade 2)	A group of 2 to 10 contiguous major defective pixels	n/a	10	2
Column Defect	A group of more than 10 contiguous major defective pixels along a single column.	0	0	2

1. For the color device (KAI−04050−FBA ,KAI−04050−CBA, KAI−04050−QBA, or KAI−04050−PBA), a bright field defective pixel deviates by 12% with respect to pixels of the same color.
2. Column and cluster defects are separated by no less than two (2) good pixels in any direction (excluding single pixel defects).

Table 8. OPERATION CONDITIONS FOR DEFECT TESTING AT 27°C

Description	Condition	Notes
Operational Mode	Two Outputs, using VOUTa and VOUTc, Continuous Readout	
HCCD Clock Frequency	20 MHz	
Pixels per Line	2,560	1
Lines per Frame	992	2
Line Time	131.5 μs	
Frame Time	130.4 ms	
Photodiode Integration Time (PD_Tint)	Mode A: PD_Tint = Frame Time = 130.4 ms, No Electronic Shutter Used Mode B: PD_Tint = 33 ms, Electronic Shutter Used	
VCCD Integration Time	118.2 ms	3
Temperature	27°C	
Light Source	Continuous Red, Green and Blue LED Illumination	4
Operation	Nominal Operating Voltages and Timing	

1. Horizontal overclocking used
2. Vertical overclocking used
3. VCCD Integration Time = 900 lines x Line Time, which is the total time a pixel will spend in the VCCD registers.
4. For monochrome sensor, only the green LED is used.

Table 9. DEFECT DEFINITIONS FOR TESTING AT 27°C

Description	Definition	Standard Grade	Grade 2	Notes
Major Dark Field Defective Bright Pixel	PD_Tint = Mode A → Defect ≥ 14 mV or PD_Tint = Mode B → Defect ≥ 4 mV	40	40	1
Major Bright Field Defective Dark Pixel	Defect ≥ 12%	40	40	1
Cluster Defect	A group of 2 to 10 contiguous major defective pixels, but no more than 2 adjacent defects horizontally.	8	n/a	2
Cluster Defect (Grade 2)	A group of 2 to 10 contiguous major defective pixels	n/a	10	2
Column Defect	A group of more than 10 contiguous major defective pixels along a single column.	0	0	2

1. For the color device (KAI−04050−FBA ,KAI−04050−CBA, KAI−04050−QBA, or KAI−04050−PBA), a bright field defective pixel deviates by 12% with respect to pixels of the same color.
2. Column and cluster defects are separated by no less than two (2) good pixels in any direction (excluding single pixel defects).

Defect Map

The defect map supplied with each sensor is based upon testing at an ambient (27°C) temperature. Minor point defects are not included in the defect map. All defective pixels are reference to pixel 1, 1 in the defect maps. See Figure 14 for the location of pixel 1, 1.

TEST DEFINITIONS

Test Regions of Interest

Image Area ROI:	Pixel (1, 1) to Pixel (2360, 1776)
Active Area ROI:	Pixel (13, 13) to Pixel (2348, 1764)
Center ROI:	Pixel (1131, 839) to Pixel (1230, 938)

Only the Active Area ROI pixels are used for performance and defect tests.

Overclocking

The test system timing is configured such that the sensor is overclocked in both the vertical and horizontal directions. See Figure 14 for a pictorial representation of the regions of interest.

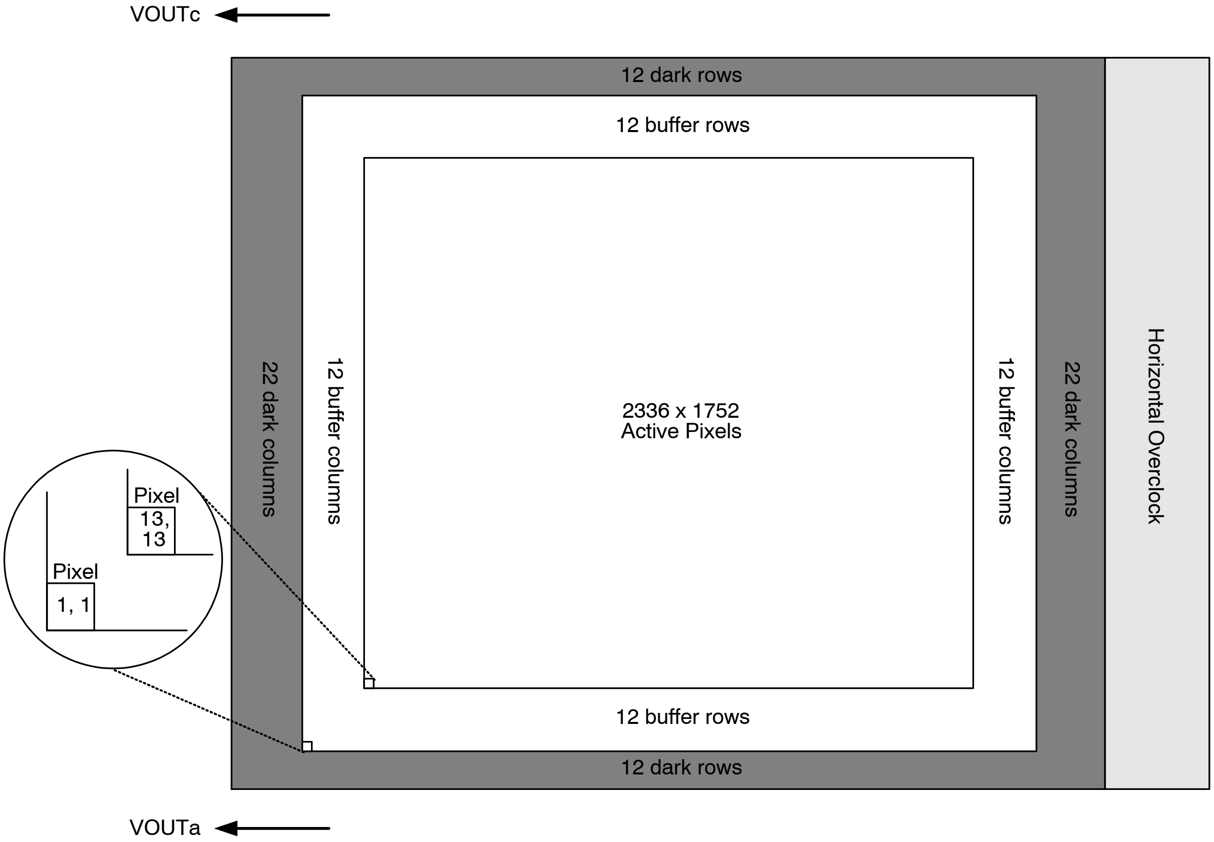


Figure 14. Regions of Interest

Tests

Dark Field Global Non-Uniformity

This test is performed under dark field conditions. The sensor is partitioned into 192 sub regions of interest, each of which is 146 by 146 pixels in size. (See Figure 15: Test Sub Regions of Interest.) The average signal level of each of the 192 sub regions of interest is calculated. The signal level of each of the sub regions of interest is calculated using the following formula:

$$\text{Signal of ROI[i]} = (\text{ROI Average in Counts} - \\ - \text{Horizontal Overclock Average in Counts}) \cdot \\ \cdot \text{ mV per Count}$$

Units : mVpp (millivolts Peak to Peak)

where i = 1 to 192. During this calculation on the 192 sub regions of interest, the maximum and minimum signal levels are found. The dark field global uniformity is then calculated as the maximum signal found minus the minimum signal level found.

Global Non-Uniformity

This test is performed with the imager illuminated to a level such that the output is at 70% of saturation (approximately 476 mV). Prior to this test being performed the substrate voltage has been set such that the charge capacity of the sensor is 680 mV. Global non-uniformity is defined as

$$\text{Global Non−Uniformity} = 100 \cdot \left(\frac{\text{Active Area Standard Deviation}}{\text{Active Area Signal}} \right)$$

Units : % rms

Active Area Signal = Active Area Average − Dark Column Average

Global Peak to Peak Non-Uniformity

This test is performed with the imager illuminated to a level such that the output is at 70% of saturation (approximately 476 mV). Prior to this test being performed the substrate voltage has been set such that the charge capacity of the sensor is 680 mV. The sensor is partitioned into 192 sub regions of interest, each of which is 146 by 146 pixels in size.(See Figure 15: Test Sub Regions of Interest.) The average signal level of each of the 192 sub regions of interest (ROI) is calculated. The signal level of each of the sub regions of interest is calculated using the following formula:

$$\text{Signal of ROI[i]} = (\text{ROI Average in Counts} - \text{Horizontal Overclock Average in Counts}) \cdot \text{mV per Count}$$

Where i = 1 to 192. During this calculation on the 192 sub regions of interest, the maximum and minimum signal levels are found. The global peak to peak uniformity is then calculated as:

$$\text{Global Uniformity} = 100 \cdot \left(\frac{\text{Max. Signal} - \text{Min. Signal}}{\text{Active Area Signal}}\right)$$

Units : % pp

Center Non-Uniformity

This test is performed with the imager illuminated to a level such that the output is at 70% of saturation (approximately 476 mV). Prior to this test being performed the substrate voltage has been set such that the charge capacity of the sensor is 680 mV. Defects are excluded for the calculation of this test. This test is performed on the center 100 by 100 pixels of the sensor. Center uniformity is defined as:

$$\text{Center ROI Uniformity} = 100 \cdot \left(\frac{\text{Center ROI Standard Deviation}}{\text{Center ROI Signal}}\right)$$

Units : % rms

Center ROI Signal = Center ROI Average − Dark Colum Average

Dark Field Defect Test

This test is performed under dark field conditions. The sensor is partitioned into 192 sub regions of interest, each of which is 146 by 146 pixels in size. In each region of interest, the median value of all pixels is found. For each region of interest, a pixel is marked defective if it is greater than or equal to the median value of that region of interest plus the defect threshold specified in the "Detect Definitions" section.

Bright Field Defect Test

This test is performed with the imager illuminated to a level such that the output is at approximately 476 mV. Prior to this test being performed the substrate voltage has been set such that the charge capacity of the sensor is 680 mV. The average signal level of all active pixels is found. The bright and dark thresholds are set as:

$$\text{Dark Defect Threshold} = \text{Active Area Signal} \cdot \text{Threshold}$$

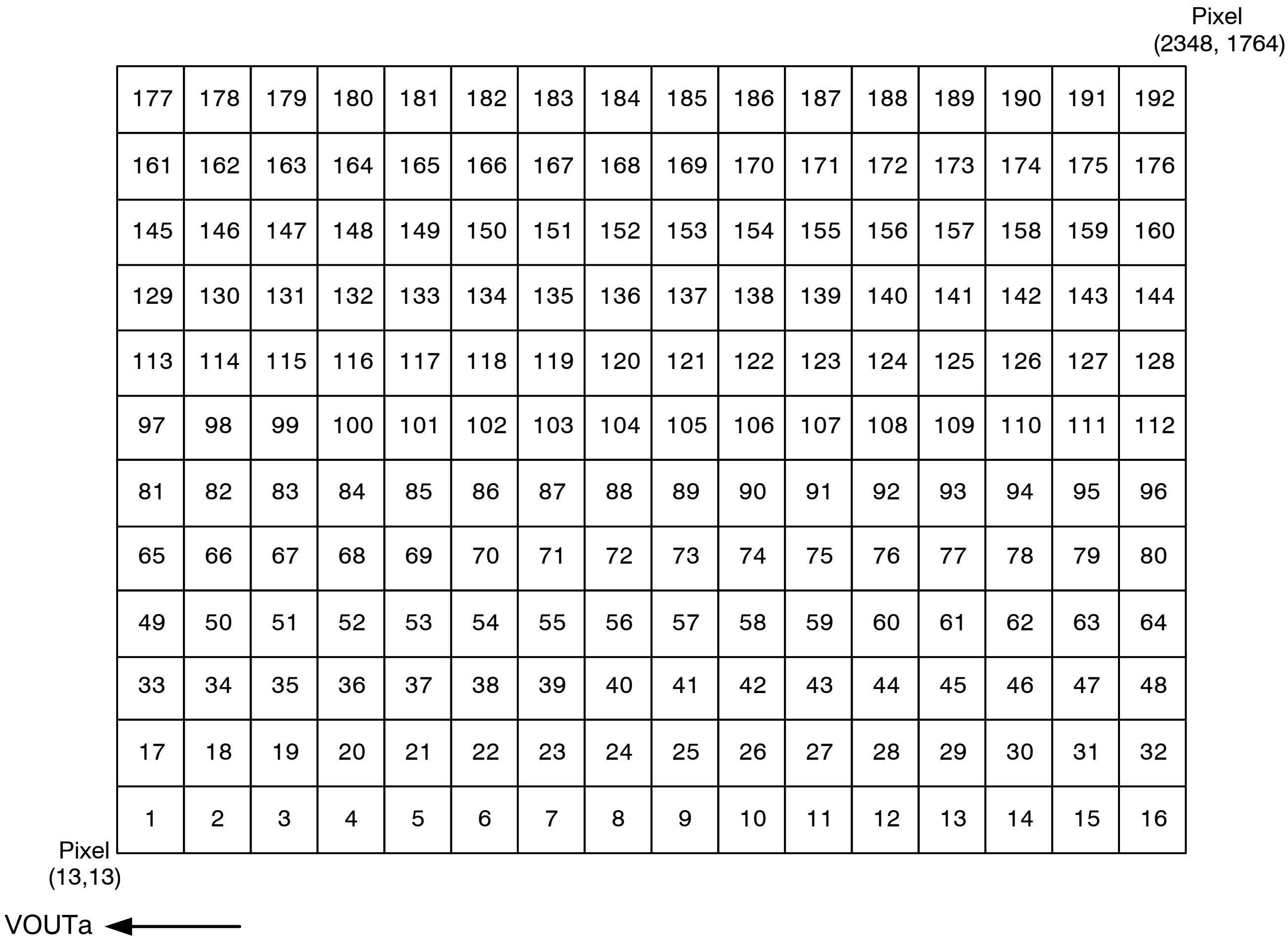
$$\text{Bright Defect Threshold} = \text{Active Area Signal} \cdot \text{Threshold}$$

The sensor is then partitioned into 192 sub regions of interest, each of which is 146 by 146 pixels in size. In each region of interest, the average value of all pixels is found. For each region of interest, a pixel is marked defective if it is greater than or equal to the median value of that region of interest plus the bright threshold specified or if it is less than or equal to the median value of that region of interest minus the dark threshold specified.

Example for major bright field defective pixels:

- Average value of all active pixels is found to be 476 mV
- Dark defect threshold: 476 mV · 12% = 57 mV
- Bright defect threshold: 476 mV · 12% = 57 mV
- Region of interest #1 selected. This region of interest is pixels 13, 13 to pixels 158, 158
  - Median of this region of interest is found to be 470 mV
  - Any pixel in this region of interest that is ≥ (470 + 57 mV) 527 mV in intensity will be marked defective
  - Any pixel in this region of interest that is ≤ (470 − 57 mV) 413 mV in intensity will be marked defective
- All remaining 192 sub regions of interest are analyzed for defective pixels in the same manner

Test Sub Regions of Interest



177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176
145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128
97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Figure 15. Test Sub Regions of Interest

OPERATION

Absolute Maximum Ratings

Absolute maximum rating is defined as a level or condition that should not be exceeded at any time per the description. If the level or the condition is exceeded, the device will be degraded and may be damaged. Operation at these values will reduce MTTF.

Table 10. ABSOLUTE MAXIMUM RATINGS

Description	Symbol	Minimum	Maximum	Unit	Notes
Operating Temperature	T_{OP}	−50	70	°C	1
Humidity	RH	5	90	%	2
Output Bias Current	I_{OUT}	–	60	mA	3
Off-Chip Load	C_L	–	10	pF	

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Noise performance will degrade at higher temperatures.
2. T = 25°C. Excessive humidity will degrade MTTF.
3. Total for all outputs. Maximum current is −15 mA for each output. Avoid shorting output pins to ground or any low impedance source during operation. Amplifier bandwidth increases at higher current and lower load capacitance at the expense of reduced gain (sensitivity).

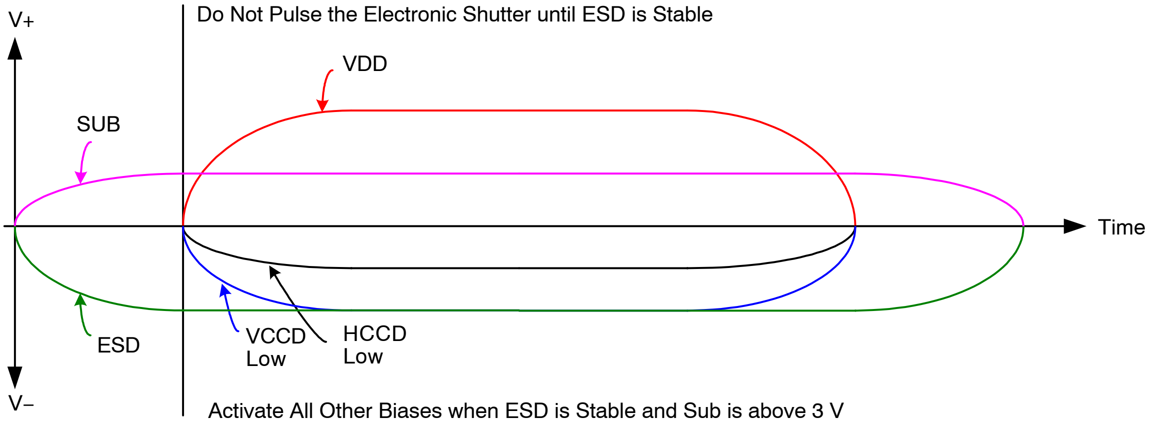
Table 11. ABSOLUTE MAXIMUM VOLTAGE RATINGS BETWEEN PINS AND GROUND

Description	Minimum	Maximum	Unit	Notes
VDDα, VOUTα	−0.4	17.5	V	1
RDα	−0.4	15.5	V	1
V1B, V1T	ESD − 0.4	ESD + 24.0	V	
V2B, V2T, V3B, V3T, V4B, V4T	ESD − 0.4	ESD + 14.0	V	
H1Sα, H1Bα, H2Sα, H2Bα, H2SLα, Rα, OGα	ESD − 0.4	ESD + 14.0	V	1
ESD	−10.0	0.0	V	
SUB	−0.4	40.0	V	2

1. α denotes a, b, c or d.
2. Refer to Application Note *Using Interline CCD Image Sensors in High Intensity Visible Lighting Conditions*

Power-Up and Power-Down Sequence

Adherence to the power-up and power-down sequence is critical. Failure to follow the proper power-up and power-down sequences may cause damage to the sensor.



Notes:

1. Activate all other biases when ESD is stable and SUB is above 3 V.
2. Do not pulse the electronic shutter until ESD is stable.
3. VDD cannot be +15 V when SUB is 0 V.
4. The image sensor can be protected from an accidental improper ESD voltage by current limiting the SUB current to less than 10 mA. SUB and VDD must always be greater than GND. ESD must always be less than GND. Placing diodes between SUB, VDD, ESD and ground will protect the sensor from accidental overshoots of SUB, VDD and ESD during power on and power off. See the figure below.

Figure 16. Power-Up and Power-Down Sequence

The VCCD clock waveform must not have a negative overshoot more than 0.4 V below the ESD voltage.

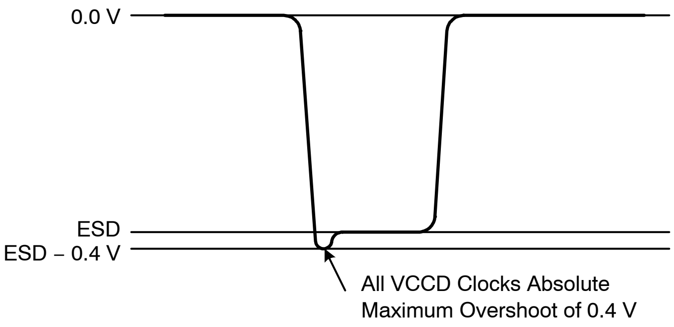


Figure 17. VCCD Clock Waveform

Example of external diode protection for SUB, VDD and ESD. α denotes a, b, c or d.

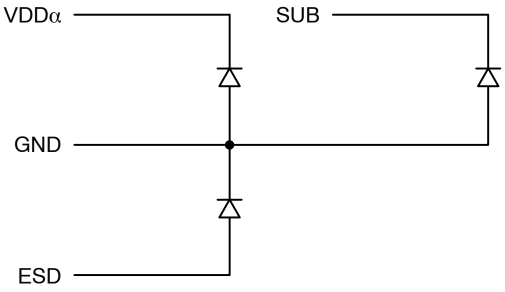


Figure 18. Example of External Diode Protection

DC Bias Operating Conditions

Table 12. DC BIAS OPERATING CONDITIONS

Description	Pins	Symbol	Min.	Nom.	Max.	Unit	Max. DC Current	Notes
Reset Drain	RDα	RD	11.8	12.0	12.2	V	10 μA	1
Output Gate	OGα	OG	−2.2	−2.0	−1.8	V	10 μA	1
Output Amplifier Supply	VDDα	V_{DD}	14.5	15.0	15.5	V	11.0 mA	1, 2
Ground	GND	GND	0.0	0.0	0.0	V	−1.0 mA	
Substrate	SUB	V_{SUB}	5.0	V_{AB}	V_{DD}	V	50 μA	3, 8
ESD Protection Disable	ESD	ESD	−9.5	−9.0	Vx_L	V	50 μA	6, 7, 9
Output Bias Current	VOUTα	I_{OUT}	−3.0	−7.0	−10.0	mA	–	1, 4, 5

1. α denotes a, b, c or d.
2. The maximum DC current is for one output. $I_{DD} = I_{OUT} + I_{SS}$. See Figure 19.
3. The operating value of the substrate voltage, V_{AB}, will be marked on the shipping container for each device. The value of V_{AB} is set such that the photodiode charge capacity is the nominal P_{Ne} (see Specifications).
4. An output load sink must be applied to each VOUT pin to activate each output amplifier.
5. Nominal value required for 40 MHz operation per output. May be reduced for slower data rates and lower noise.
6. Adherence to the power-up and power-down sequence is critical. See Power−Up and Power−Down Sequence section.
7. ESD maximum value must be less than or equal to V1_L + 0.4 V and V2_L + 0.4 V.
8. Refer to Application Note *Using Interline CCD Image Sensors in High Intensity Visible Lighting Conditions.*
9. Where Vx_L is the level set for V1_L, V2_L, V3_L, or V4_L in the application.

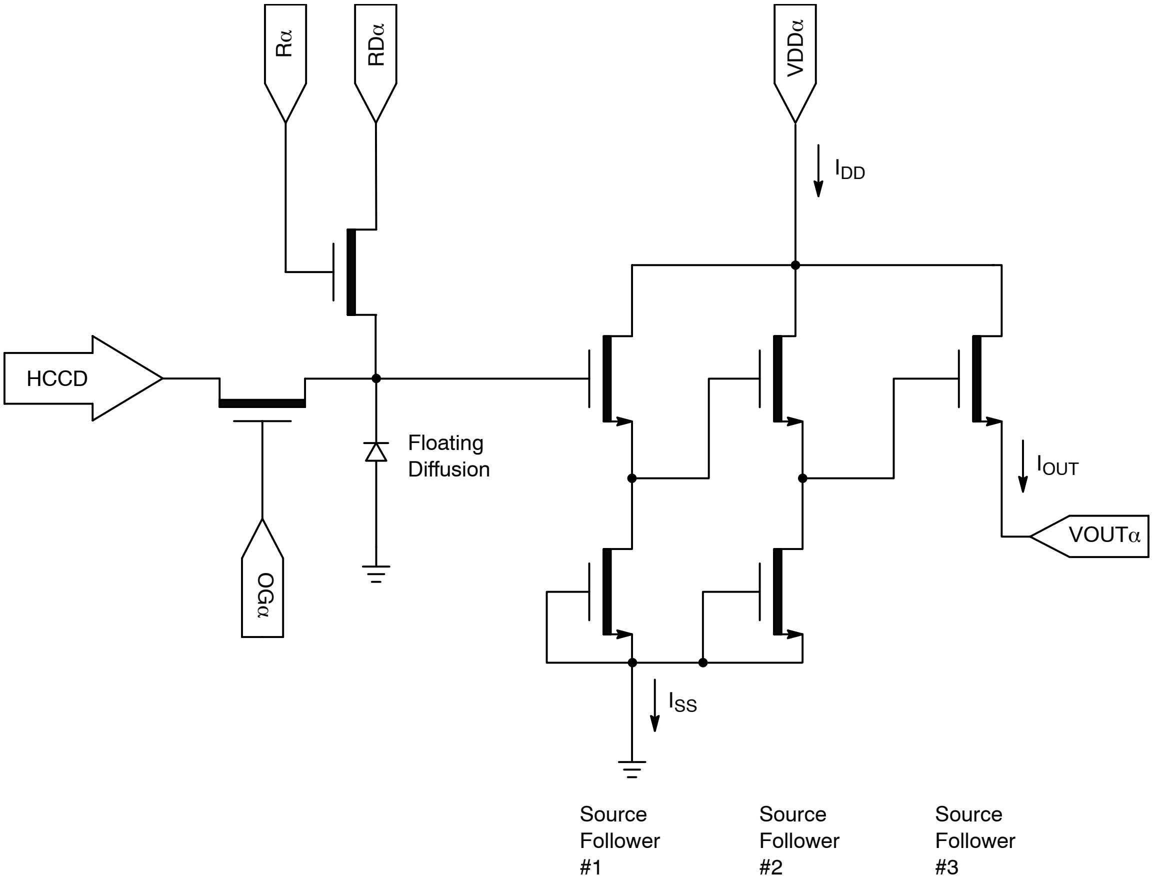


Figure 19. Output Amplifier

AC Operating Conditions

Table 13. CLOCK LEVELS

Description	Pins[1]	Symbol	Level	Min.	Nom.	Max.	Units	Capacitance[2]
Vertical CCD Clock, Phase 1	V1B, V1T	V1_L	Low	−8.2	−8.0	−7.8	V	21 nF (Note 6)
		V1_M	Mid	−0.2	0.0	0.2		
		V1_H	High	11.5	12.0	12.5		
Vertical CCD Clock, Phase 2	V2B, V2T	V2_L	Low	−8.2	−8.0	−7.8	V	21 nF (6)
		V2_H	High	−0.2	0.0	0.2		
Vertical CCD Clock, Phase 3	V3B, V3T	V3_L	Low	−8.2	−8.0	−7.8	V	21 nF (6)
		V3_H	High	−0.2	0.0	0.2		
Vertical CCD Clock, Phase 4	V4B, V4T	V4_L	Low	−8.2	−8.0	−7.8	V	21 nF (6)
		V4_H	High	−0.2	0.0	0.2		
Horizontal CCD Clock, Phase 1 Storage	H1Sα	H1S_L	Low	−5.2 (7)	−4.0	−3.8	V	200 pF (6)
		H1S_A	Amplitude	3.8	4.0	5.2 (7)		
Horizontal CCD Clock, Phase 1 Barrier	H1Bα	H1B_L	Low	−5.2 (7)	−4.0	−3.8	V	130 pF (6)
		H1B_A	Amplitude	3.8	4.0	5.2 (7)		
Horizontal CCD Clock, Phase 2 Storage	H2Sα	H2S_L	Low	−5.2 (7)	−4.0	−3.8	V	200 pF (6)
		H2S_A	Amplitude	3.8	4.0	5.2 (7)		
Horizontal CCD Clock, Phase 2 Barrier	H2Bα	H2B_L	Low	−5.2 (7)	−4.0	−3.8	V	130 pF (6)
		H2B_A	Amplitude	3.8	4.0	5.2 (7)		
Horizontal CCD Clock, Last Phase (Note 3)	H2SLα	H2SL_L	Low	−5.2	−5.0	−4.8	V	20 pF (6)
		H2SL_A	Amplitude	4.8	5.0	5.2		
Reset Gate	R1α	R_L (4)	Low	−3.5	−2.0	−1.5	V	16 pF (6)
		R_A	Amplitude	2.5	3.0	4.0		
Electronic Shutter (Note 5)	SUB	VES	High	29.0	30.0	40.0	V	1400 pF (6)

1. α denotes a, b, c or d.
2. Capacitance is total for all like named pins.
3. Use separate clock driver for improved speed performance.
4. Reset low should be set to −3 V for signal levels greater than 40,000 electrons.
5. Refer to Application Note *Using Interline CCD Image Sensors in High Intensity Visible Lighting Conditions.*
6. Capacitance values are estimated.
7. If the minimum horizontal clock low level is used (–5.2 V), then the maximum horizontal clock amplitude should be used (5.2 V amplitude) to create a –5.2 V to 0.0 V clock. If a 5 volt clock driver is used, the horizontal low level should be set to –5.0 V and the high level should be a set to 0.0 V.

The figure below shows the DC bias (VSUB) and AC clock (VES) applied to the SUB pin. Both the DC bias and AC clock are referenced to ground.

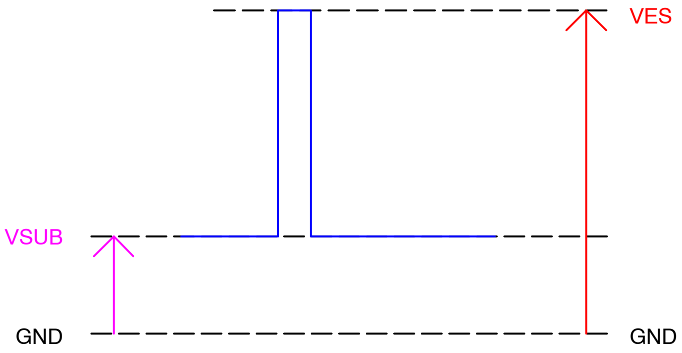


Figure 20. DC Bias and AC Clock Applied to the SUB Pin

Device Identification

The device identification pin (DevID) may be used to determine which Truesense Imaging 5.5 micron pixel interline CCD sensor is being used.

Table 14. DEVICE IDENTIFICATION

Description	Pins	Symbol	Min.	Nom.	Max.	Unit	Max. DC Current	Notes
Device Identification	DevID	DevID	20,000	25,000	30,000	Ω	50 μA	1, 2, 3

1. Nominal value subject to verification and/or change during release of preliminary specifications.
2. If the Device Identification is not used, it may be left disconnected.
3. Values specified are for 40°C.

Recommended Circuit

Note that V1 must be a different value than V2.

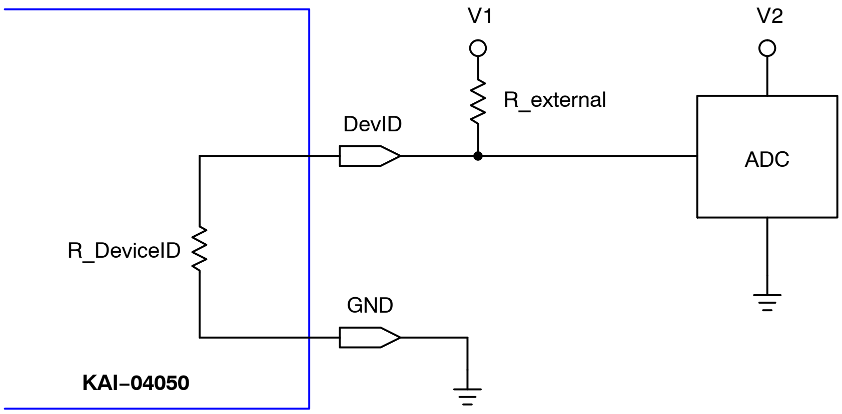


Figure 21. Device Identification Recommended Circuit

TIMING

Requirements and Characteristics

Table 15. REQUIREMENTS AND CHARACTERISTICS

Description	Symbol	Min.	Nom.	Max.	Unit	Notes
Photodiode Transfer	t_{PD}	1.0	–	–	μs	
VCCD Leading Pedestal	t_{3P}	4.0	–	–	μs	
VCCD Trailing Pedestal	t_{3D}	4.0	–	–	μs	
VCCD Transfer Delay	t_D	1.0	–	–	μs	
VCCD Transfer	t_V	1.6	–	–	μs	
VCCD Clock Cross-Over	V_{VCR}	75	–	100	%	
VCCD Rise, Fall Times	t_{VR}, t_{VF}	5	–	10	%	1, 2
HCCD Delay	t_{HS}	0.2	–	–	μs	
HCCD Transfer	t_e	25.0	–	–	ns	
Shutter Transfer	t_{SUB}	1.0	–	–	μs	
Shutter Delay	t_{HD}	1.0	–	–	μs	
Reset Pulse	t_R	2.5	–	–	ns	
Reset – Video Delay	t_{RV}	–	2.2	–	ns	
H2SL – Video Delay	t_{HV}	–	3.1	–	ns	
Line Time	t_{LINE}	32.9	–	–	μs	Dual HCCD Readout
		63.0	–	–		Single HCCD Readout
Frame Time	t_{FRAME}	29.7	–	–	ms	Quad HCCD Readout
		59.3	–	–		Dual HCCD Readout
		113.4	–	–		Single HCCD Readout

1. Refer to Figure 26: VCCD Clock Edge Alignment.
2. Relative to the pulse width.

Timing Diagrams

The timing sequence for the clocked device pins may be represented as one of seven patterns (P1−P7) as shown in the table below. The patterns are defined in Figure 22 and Figure 23. Contact ON Semiconductor Application Engineering for other readout modes.

Table 16. TIMING DIAGRAMS

Device Pin	Quad Readout	Dual Readout VOUTa, VOUTb	Dual Readout VOUTa, VOUTc	Single Readout VOUTa
V1T	P1T	P1B	P1T	P1B
V2T	P2T	P4B	P2T	P4B
V3T	P3T	P3B	P3T	P3B
V4T	P4T	P2B	P4T	P2B
V1B	P1B			
V2B	P2B			
V3B	P3B			
V4B	P4B			
H1Sa	P5			
H1Ba				
H2Sa (Note 2)	P6			
H2Ba				
Ra	P7			
H1Sb	P5		P5	
H1Bb			P6	
H2Sb (Note 2)	P6		P6	
H2Bb			P5	
Rb	P7		P7 (Note 1) or Off (Note 3)	P7 (Note 1) or Off (Note 3)
H1Sc	P5	P5 (Note 1) or Off (Note 3)	P5	P5 (Note 1) or Off (Note 3)
H1Bc				
H2Sc (Note 2)	P6	P6 (Note 1) or Off (Note 3)	P6	P6 (Note 1) or Off (Note 3)
H2Bc				
Rc	P7	P7 (Note 1) or Off (Note 3)	P7	P7 (Note 1) or Off (Note 3)
H1Sd	P5	P5 (Note 1) or Off (Note 3)	P5	P5 (Note 1) or Off (Note 3)
H1Bd			P6	
H2Sd (Note 2)	P6	P6 (Note 1) or Off (Note 3)	P6	P6 (Note 1) or Off (Note 3)
H2Bd			P5	
Rd	P7	P7 (Note 1) or Off (Note 3)	P7 (Note 1) or Off (Note 3)	P7 (Note 1) or Off (Note 3)

#Lines/Frame (Minimum)	900	1800	900	1800
#Pixels/Line (Minimum)	1213		2426	

1. For optimal performance of the sensor. May be clocked at a lower frequency. If clocked at a lower frequency, the frequency selected should be a multiple of the frequency used on the a and b register.
2. H2SLx follows the same pattern as H2Sx. For optimal speed performance, use a separate clock driver.
3. Off = +5 V. Note that there may be operating conditions (high temperature and/or very bright light sources) that will cause blooming from the unused c/d register into the image area.

Photodiode Transfer Timing

A row of charge is transferred to the HCCD on the falling edge of V1 as indicated in the P1 pattern below. Using this timing sequence, the leading dummy row or line is combined with the first dark row in the HCCD. The “Last Line” is dependent on readout mode – either 632 or 1264 minimum counts required. It is important to note that, in general, the rising edge of a vertical clock (patterns P1−P4) should be coincident or slightly leading a falling edge at the same time interval. This is particularly true at the point where P1 returns from the high (3rd level) state to the mid-state when P4 transitions from the low state to the high state.

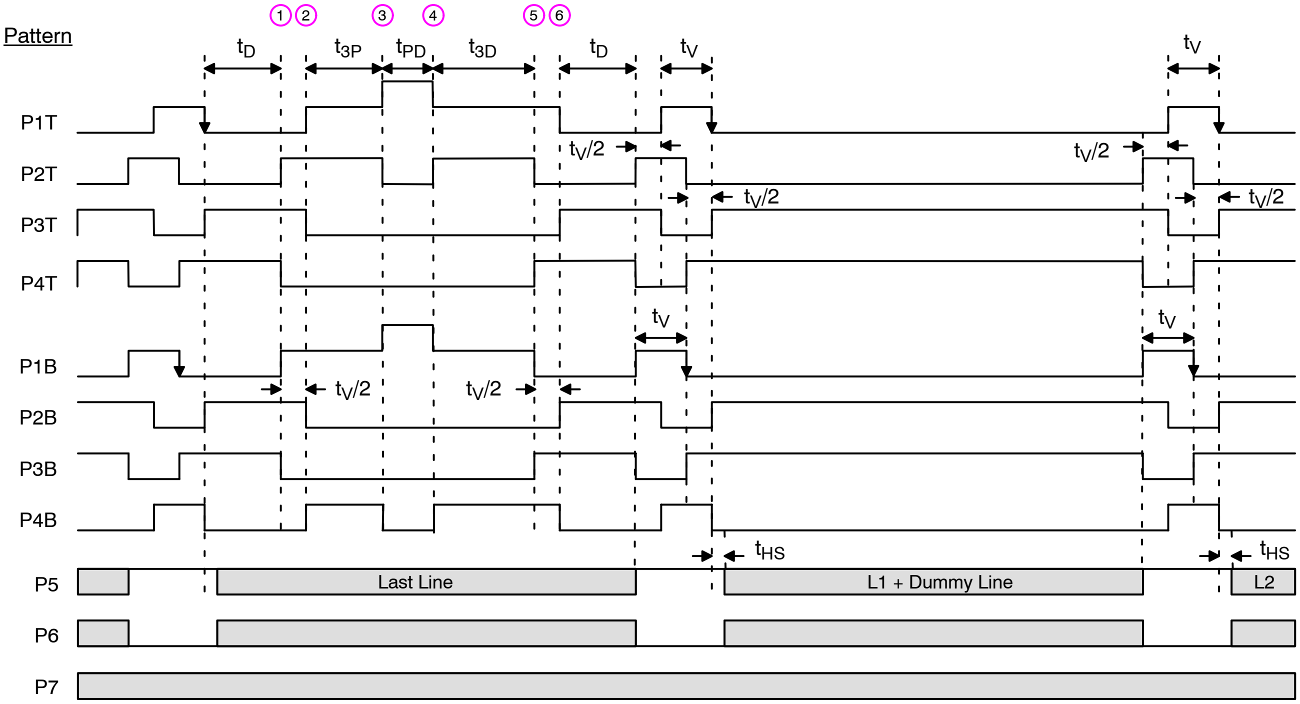


Figure 22. Photodiode Transfer Timing

Line and Pixel Timing

Each row of charge is transferred to the output, as illustrated below, on the falling edge of H2SL (indicated as P6 pattern). The number of pixels in a row is dependent on readout mode – either 1213 or 2426 minimum counts required.

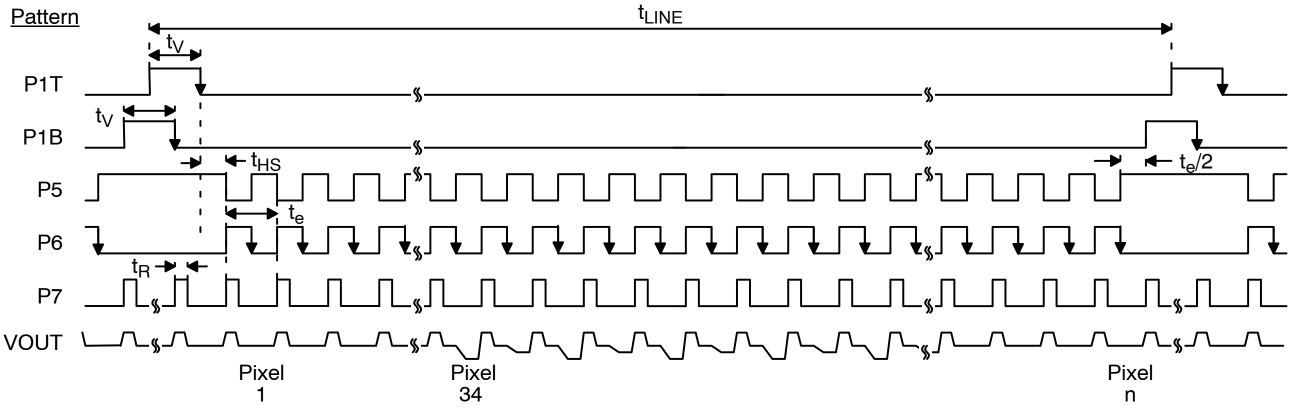


Figure 23. Line and Pixel Timing