

KAI-43140

8040 (X) x 5360 (V) Interline CCD Image Sensor

Description

The KAI-43140 image sensor is a 43 megapixel Interline Transfer CCD in a 35 mm optical format. Leveraging a 4.5 μm pixel design that provides a 50% resolution increase compared to the KAI-29050 and KAI-29052 devices, the KAI-43140 provides excellent image uniformity and broad dynamic range. A flexible output architecture supports 1, 2, or 4 outputs for full resolution readout of up to 4 frames per second, and a true electronic shutter enables image capture without motion artifacts across a broad range of exposure times.

In addition to standard monochrome and Bayer Color configurations, the sensor is available in a Sparse CFA configuration which provides a 2x improvement in light sensitivity compared to the standard Bayer Color part. The sensor shares the same package as the KAI-29050 and KAI-29052 image sensors, simplifying camera design.

Table 1. GENERAL SPECIFICATIONS

| Parameter | Typical Value |
|--|---|
| Architecture | Interline CCD; Progressive Scan |
| Total Number of Pixels | 8160 (H) x 5480 (V) |
| Number of Effective Pixels | 8080 (H) x 5400 (V) |
| Number of Active Pixels | 8040 (H) x 5360 (V) |
| Pixel Size | 4.5 μm (H) x 4.5 μm (V) |
| Active Image Size | 36.18 mm (H) x 24.12 mm (V) 43.48 mm (Diag.), 35 mm Optical Format |
| Aspect Ratio | 3:2 |
| Number of Outputs | 1, 2, or 4 |
| Charge Capacity | 13,000 electrons |
| Output Sensitivity | 42 $\mu\text{V}/\text{e}^-$ |
| Quantum Efficiency Pan (-AXA, -QXA) R, G, B (-FXA, -QXA) | 45 % 27%, 34%, 37% |
| Read Noise (f = 60 MHz) | 13 electrons rms |
| Dark Current Photodiode VCCD | 7 electrons/s 50 electrons/s |
| Dynamic Range | 60 dB |
| Charge Transfer Efficiency | 0.999999 |
| Blooming Suppression | > 300 X |
| Smear | -98 dB |
| Image Lag | < 10 electrons |
| Maximum Pixel Clock Speed | 60 MHz |
| Maximum Frame Rates Quad Output Dual Output Single Output | 4 fps 2 fps 1 fps |
| Package | 72 pin PGA |
| Cover Glass | AR Coated, 2 Sides |

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



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Figure 1. KAI-43140 CCD Image Sensor

Features

- High Resolution Image Capture in 35 mm Optical Format
- True Electronic Shutter with Broad Exposure Latitude
- Low Noise Architecture
- Excellent Smear Performance
- Monochrome, Bayer Color, and Sparse CFA Configurations

Applications

- Industrial Imaging and Inspection
- Security and Surveillance

ORDERING INFORMATION

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

KAI-43140

ORDERING INFORMATION

Table 2. ORDERING INFORMATION

| Part Number | Description | Marking Code |
|---------------------|---|--------------------------------|
| KAI-43140-AXA-JD-B1 | Monochrome, Special Microlens, PGA Package, Sealed Clear Cover Glass with AR coating (both sides), Grade 1 | KAI-43140-AXA Serial Number |
| KAI-43140-AXA-JD-B2 | Monochrome, Special Microlens, PGA Package, Sealed Clear Cover Glass with AR coating (both sides), Grade 2 | |
| KAI-43140-AXA-JD-AE | Monochrome, Special Microlens, PGA Package, Sealed Clear Cover Glass with AR coating (both sides), Engineering Grade | |
| KAI-43140-AXA-JP-B1 | Monochrome, Special Microlens, PGA Package, Taped Clear Cover Glass (no coatings), Grade 1 | KAI-43140-AXA Serial Number |
| KAI-43140-AXA-JP-B2 | Monochrome, Special Microlens, PGA Package, Taped Clear Cover Glass (no coatings), Grade 2 | |
| KAI-43140-AXA-JP-AE | Monochrome, Special Microlens, PGA Package, Taped Clear Cover Glass (no coatings), Engineering Grade | |
| KAI-43140-FXA-JD-B1 | Gen2 Color (Bayer RGB), Special Microlens, PGA Package, Sealed Clear Cover Glass with AR coating (both sides), Grade 1 | KAI-43140-FXA Serial Number |
| KAI-43140-FXA-JD-B2 | Gen2 Color (Bayer RGB), Special Microlens, PGA Package, Sealed Clear Cover Glass with AR coating (both sides), Grade 2 | |
| KAI-43140-FXA-JD-AE | Gen2 Color (Bayer RGB), Special Microlens, PGA Package, Sealed Clear Cover Glass with AR coating (both sides), Engineering Grade | |
| KAI-43140-QXA-JD-B1 | Gen2 Color (Sparse CFA), Special Microlens, PGA Package, Sealed Clear Cover Glass with AR coating (both sides), Grade 1 | KAI-43140-QXA Serial Number |
| KAI-43140-QXA-JD-AE | Gen2 Color (Sparse CFA), Special Microlens, PGA Package, Sealed Clear Cover Glass with AR coating (both sides), Engineering Grade | |

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 40 dark reference rows at the top and 40 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 40 dark columns on the left or right side of the image sensor as a dark reference. Under normal circumstances use only the center 38 columns of the 40 column dark reference due to potential light leakage.

Dummy Pixels

Within each horizontal shift register there are 12 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

20 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. The 8 outer buffer pixels are less

sensitive than the inner buffer pixels. The inner buffer pixels have the same sensitivity as the 8040 by 5360 active pixels.

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 photo-site. 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.

KAI-43140

Bayer Color Filter

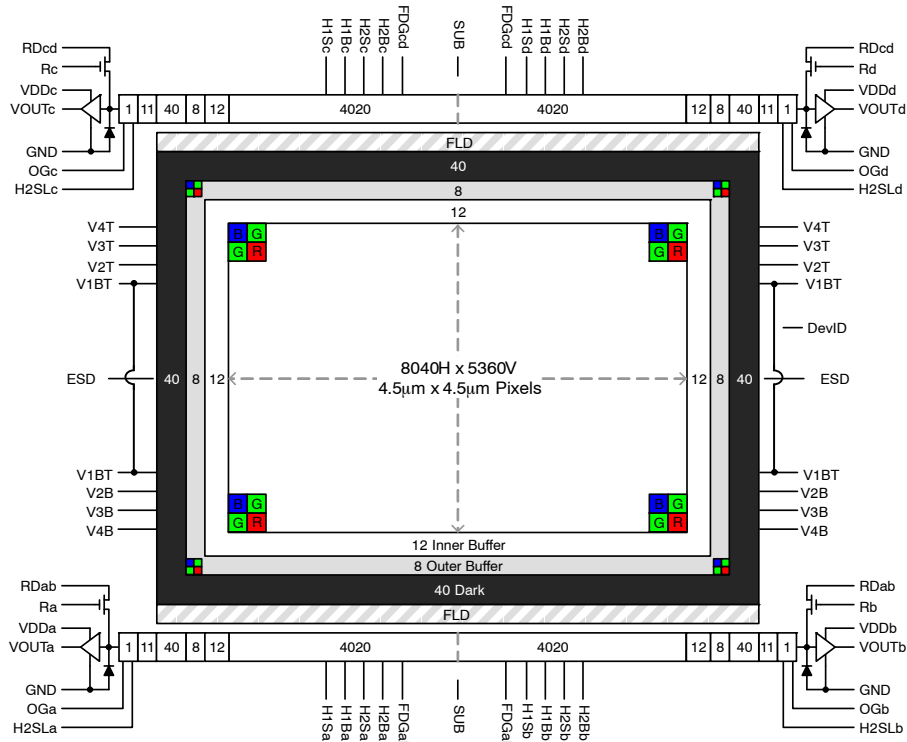


Figure 3. Bayer Color Filter Pattern

Sparse Color Filter

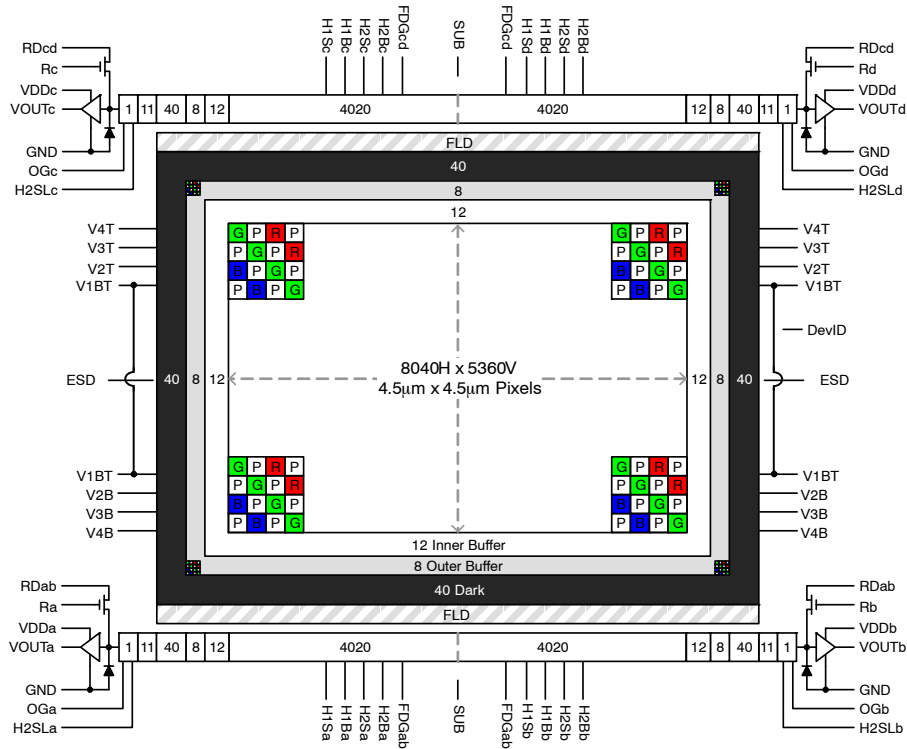


Figure 4. Sparse Color Filter Pattern

PHYSICAL DESCRIPTION

Pin Description and Device Orientation

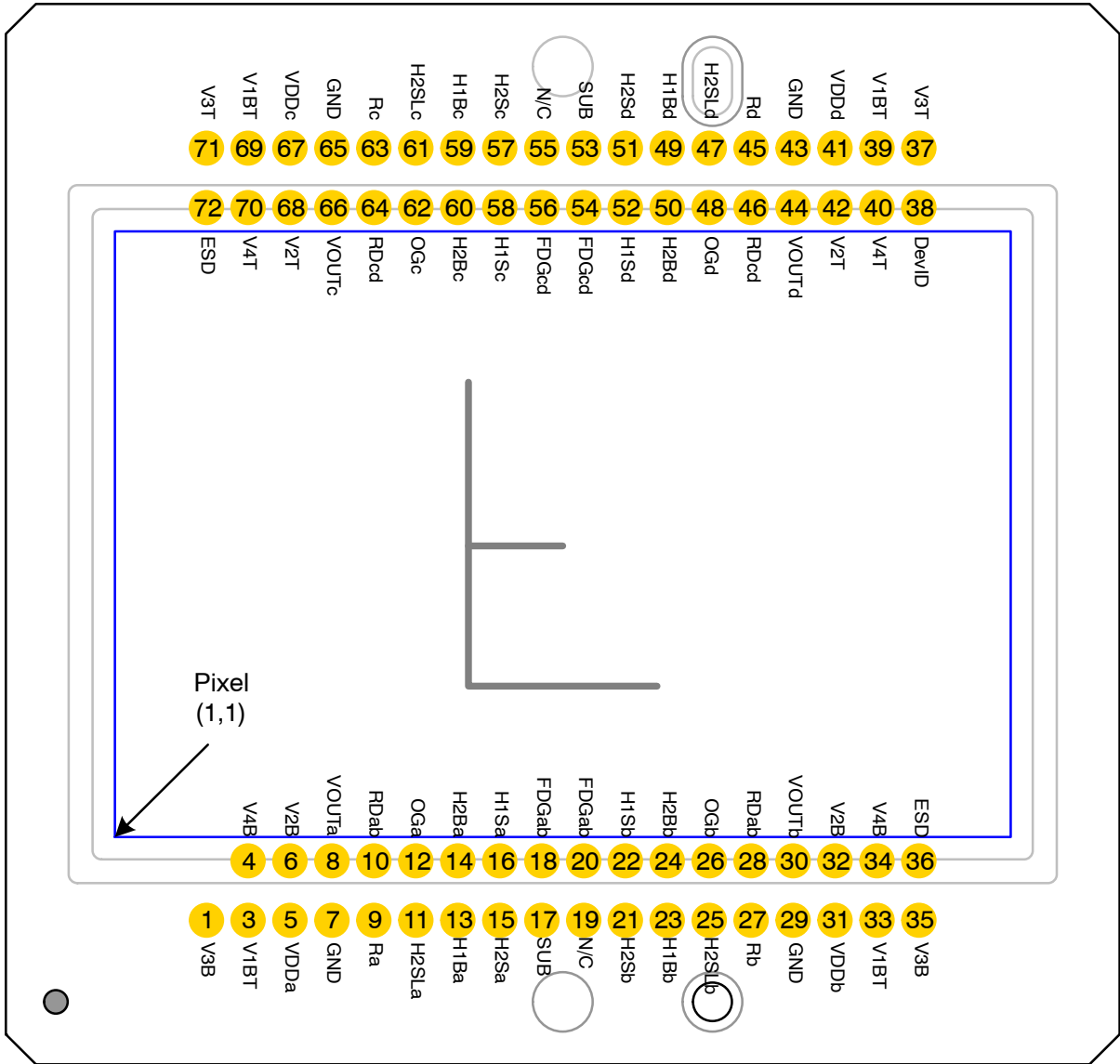


Figure 5. Package Pin Description – Top View

Table 3. PIN DESCRIPTION

| Pin | Name | Description |
|-----|-------|--|
| 1 | V3B | Vertical CCD Clock, Phase 3, Bottom |
| 3 | V1BT | Vertical CCD Clock, Phase 1, Bottom and Top |
| 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 | VOUa | Video Output, Quadrant a |
| 9 | Ra | Reset Gate, Quadrant a |
| 10 | RDab | Reset Drain, Quadrants a and b |
| 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 | SUB | Substrate |
| 18 | FDGab | Fast Line Dump Gate, Bottom |
| 19 | N/C | No Connect |
| 20 | FDGab | Fast Line Dump Gate, Bottom |
| 21 | H2Sb | Horizontal CCD Clock, Phase 2, Storage, Quadrant b |
| 22 | H1Sb | Horizontal CCD Clock, Phase 1, Storage, Quadrant b |
| 23 | H1Bb | Horizontal CCD Clock, Phase 1, Barrier, Quadrant b |
| 24 | H2Bb | Horizontal CCD Clock, Phase 2, Barrier, Quadrant b |
| 25 | H2SLb | Horizontal CCD Clock, Phase 2, Storage, Last Phase, Quadrant b |
| 26 | OGb | Output Gate, Quadrant b |
| 27 | Rb | Reset Gate, Quadrant b |
| 28 | RDab | Reset Drain, Quadrants a and b |
| 29 | GND | Ground |
| 30 | VOUa | Video Output, Quadrant a |
| 31 | VDDb | Output Amplifier Supply, Quadrant b |
| 32 | V2B | Vertical CCD Clock, Phase 2, Bottom |
| 33 | V1BT | Vertical CCD Clock, Phase 1, Bottom and Top |
| 34 | V4B | Vertical CCD Clock, Phase 4, Bottom |
| 35 | V3B | Vertical CCD Clock, Phase 3, Bottom |
| 36 | ESD | ESD Protection Disable |
| 37 | V3T | Vertical CCD Clock, Phase 3, Top |
| 38 | DevID | Device Identification |
| 39 | V1BT | Vertical CCD Clock, Phase 1, Bottom and Top |
| 40 | V4T | Vertical CCD Clock, Phase 4, Top |
| 41 | VDDd | Output Amplifier Supply, Quadrant d |
| 42 | V2T | Vertical CCD Clock, Phase 2, Top |

Table 3. PIN DESCRIPTION (continued)

| Pin | Name | Description |
|-----|-------|--|
| 43 | GND | Ground |
| 44 | VOUtd | Video Output, Quadrant d |
| 45 | Rd | Reset Gate, Quadrant d |
| 46 | RDcd | Reset Drain, Quadrants c and d |
| 47 | H2SLd | Horizontal CCD Clock, Phase 2, Storage, Last Phase, Quadrant d |
| 48 | OGd | Output Gate, Quadrant b |
| 49 | H1Bd | Horizontal CCD Clock, Phase 1, Barrier, Quadrant d |
| 50 | H2Bd | Horizontal CCD Clock, Phase 2, Barrier, Quadrant d |
| 51 | H2Sd | Horizontal CCD Clock, Phase 2, Storage, Quadrant d |
| 52 | H1Sd | Horizontal CCD Clock, Phase 1, Storage, Quadrant d |
| 53 | SUB | Substrate |
| 54 | FDGcd | Fast Line Dump Gate, Top |
| 55 | N/C | No Connect |
| 56 | FDGcd | Fast Line Dump Gate, Top |
| 57 | H2Sc | Horizontal CCD Clock, Phase 2, Storage, Quadrant c |
| 58 | H1Sc | Horizontal CCD Clock, Phase 1, Storage, Quadrant c |
| 59 | H1Bc | Horizontal CCD Clock, Phase 1, Barrier, Quadrant c |
| 60 | H2Bc | Horizontal CCD Clock, Phase 2, Barrier, Quadrant c |
| 61 | H2SLc | Horizontal CCD Clock, Phase 2, Storage, Last Phase, Quadrant c |
| 62 | OGc | Output Gate, Quadrant c |
| 63 | Rc | Reset Gate, Quadrant c |
| 64 | RDcd | Reset Drain, Quadrants c and d |
| 65 | GND | Ground |
| 66 | VOUtc | Video Output, Quadrant c |
| 67 | VDDc | Output Amplifier Supply, Quadrant c |
| 68 | V2T | Vertical CCD Clock, Phase 2, Top |
| 69 | V1BT | Vertical CCD Clock, Phase 1, Bottom and Top |
| 70 | V4T | Vertical CCD Clock, Phase 4, Top |
| 71 | V3T | Vertical CCD Clock, Phase 3, Top |
| 72 | ESD | ESD Protection Disable |

1. Like named pins are internally connected and should have a common drive signal.
2. N/C pins (19, 55) should be left floating

IMAGING PERFORMANCE

Table 4. TYPICAL OPERATION 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 | For monochrome sensor, only green LED used |
| Operation | Nominal operating voltages and timing | |

Table 5. PERFORMANCE PARAMETERS (Performance parameters are by design.)

| Description | Symbol | Nom. | Units | Notes | |
|---|----------------------|-------------------|----------------|-------|--|
| Maximum Photo-response Nonlinearity | NL | 2 | % | 4 | |
| Maximum Signal Error due to Nonlinearity Differences | ΔNL | 1 | % | 4 | |
| Horizontal CCD Charge Capacity | HNe | 40 | ke- | | |
| Vertical CCD Charge Capacity | VNe | 24 | ke- | | |
| Photodiode Charge Capacity | PNe | 13 | ke- | 5 | |
| Image Lag | Lag | < 10 | e- | | |
| Anti-blooming Factor | Xab | > 300X | | | |
| Vertical Smear | Smr | -98 | dB | 9 | |
| Read Noise | n_{e-T} | 13 | e-rms | 6 | |
| Dynamic Range | DR | 60 | dB | 6, 7 | |
| Output Amplifier DC Offset | Vodc | 8 | V | | |
| Output Amplifier Bandwidth | f-3db | 250 | MHz | 8 | |
| Output Amplifier Impedance | Rout | 127 | Ω | | |
| Output Amplifier Sensitivity | $\Delta V/\Delta N$ | 42 | $\mu V/e-$ | | |
| Peak Quantum Efficiency (KAI-43140-AXA and KAI-43140-QXA Configurations) | QE _{max} | 45 | % | | |
| Peak Quantum Efficiency (KAI-43140-FXA and KAI-43140-QXA Configurations) | Blue Green Red | QE _{max} | 37 34 27 | % | |

Table 6. PERFORMANCE SPECIFICATIONS

| Description | Symbol | Min. | Nom. | Max. | Units | Temperature Tested At (°C) | Notes |
|---|------------|----------|----------|------|-------|----------------------------|-------|
| Dark Field Global Non-Uniformity | DSNU | - | - | 5 | mVpp | 27, 40 | |
| Bright Field Global Non-Uniformity | BSNU | - | - | 5 | %rms | 27, 40 | 3 |
| Bright Field Global Peak to Peak Non-Uniformity | PRNU | - | - | 30 | %pp | 27, 40 | 3 |
| Maximum Gain Difference Between Outputs | ΔG | - | - | 10 | % | 27, 40 | 4 |
| Horizontal CCD Charge Transfer Efficiency | HCTE | 0.999995 | 0.999999 | - | | | |
| Vertical CCD Charge Transfer Efficiency | VCTE | 0.999995 | 0.999999 | - | | | |
| Photodiode Dark Current | lpd | - | 7 | 50 | e/p/s | 40 | |
| Vertical CCD Dark Current | lvd | - | 50 | 200 | e/p/s | 40 | |

3. Per color
4. Value is over the range of 10% to 90% of photodiode saturation.
5. The operating value of the substrate voltage, VAB, will be marked on the shipping container for each device. The value of VAB is set such that the photodiode charge capacity is 546 mV.
6. At 60 MHz
7. Uses $20 * \text{LOG} (P_{ne}/n_{e-T})$
8. Assumed 5 pF load.
9. Green LED illumination

TYPICAL PERFORMANCE CURVES

Quantum Efficiency



Figure 6. Monochrome with Microlens Quantum Efficiency



Figure 7. Gen2 Color (Bayer RGB) with Microlens Quantum Efficiency



Figure 8. Color (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.



Figure 9. Monochrome with Microlens Angular Quantum Efficiency

KAI-43140

Dark Current versus Temperature



Figure 10. Dark Current versus Temperature

Power



Figure 11. Power

Frame Rates



Figure 12. Frame Rates

DEFECT DEFINITIONS

Table 7. OPERATING CONDITIONS

| Description | Condition | Notes |
|--------------|---|---|
| Light Source | Continuous Red, Green, and/or Blue LED Illumination | For the monochrome sensor, only the green LED is used |
| Operation | Nominal Operating Voltages and Timing | |

Table 8. OPERATING PARAMETERS

| Description | 1 Output | 4 Outputs |
|----------------------|---------------|---------------|
| HCCD Clock Frequency | 20 MHz | 20 MHz |
| Pixels per Line | 8160 | 4080 |
| Lines per Frame | 5480 | 5480 |
| Line Time | 429.6 μ s | 225.6 μ s |
| Frame Time | 2354.3 ms | 618.2 ms |

Table 9. TIMING MODES

| Timing Mode | Conditions |
|-------------|---|
| Mode A | 1 Output, no electronic shutter used. Photodiode integration time is equal to the Frame Time |
| Mode B | 4 Outputs, no electronic shutter used. Photodiode integration time is equal to the Frame time |

Table 10. DEFECT DEFINITIONS

| Description | Definition | Grade 1 | Grade 2 (mono) | Grade 2 (color) |
|--------------------|--|-------------------|-------------------|-------------------|
| Column Defect | A group of more than 10 contiguous pixels along a single column that deviate from the neighboring columns by: <ul style="list-style-type: none"> more than 94 mV in the dark field using Timing Mode A at 40°C more than 94 mV in the dark field using Timing Mode A at 27°C more than -2% or +50% in the bright field using timing mode A at 27°C or 40°C | 0 | 7 | 27 |
| Cluster Defect | A group of 2 to N contiguous defective pixels, but no more than W adjacent defects horizontally, that deviate from the neighboring pixels by: <ul style="list-style-type: none"> more than 440 mV in the dark field using Timing Mode A at 40°C more than 236 mV in the dark field using Timing Mode A at 27°C more than -12% or +12% in the bright field using timing mode A at 27°C or 40°C | 30 W=4 N=19 | 70 W=5 N=38 | 70 W=5 N=38 |
| Major Point Defect | A single defective pixel that deviates from the neighboring pixels by: <ul style="list-style-type: none"> more than 440 mV in the dark field using Timing Mode A at 40°C more than 236 mV in the dark field using Timing Mode A at 27°C more than -12% or +50% in the bright field using timing mode A at 27°C or 40°C | 400 | 800 | 800 |
| Minor Point Defect | A single defective pixel that deviates from the neighboring pixels by: <ul style="list-style-type: none"> more than 220 mV in the dark field using Timing Mode A at 40°C | 4000 | 8000 | 8000 |

10. Bright field is define as where the average signal level of the sensor is 382 mV, with the substrate voltage set to the recommend VAB setting such that the capacity of the photodiodes is 546 mV (13,000 electrons)

11. For the color devices (KAI-43140-FXA or KAI-43140-QXA), a bright field defective pixel is with respect to pixels of the same color

12. Column and cluster defects are separated by no less than two (2) non-defective 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.

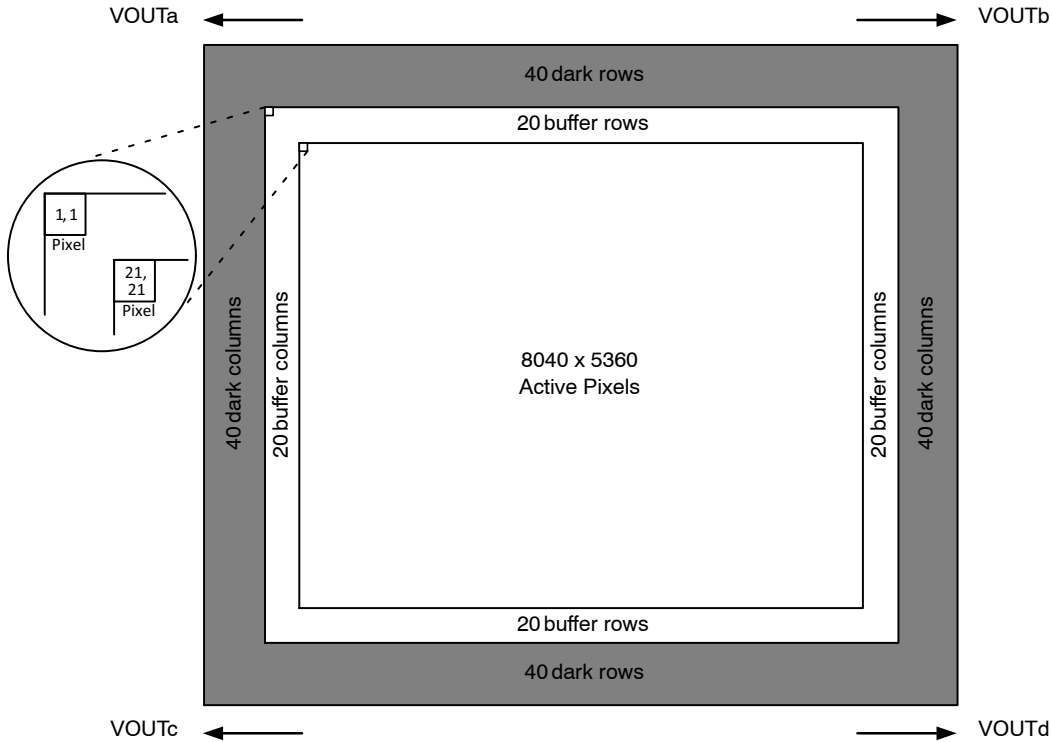


Figure 13. Pixel 1, 1 Location

OPERATION

Table 11. ABSOLUTE MAXIMUM RATINGS

| Description | Symbol | Minimum | Maximum | Units | Notes |
|-----------------------|--------|---------|---------|-------|--------|
| Operating Temperature | Top | -50 | +70 | °C | 13, 15 |
| Humidity | RH | 5 | 90 | % | 14, 15 |
| Output Bias Current | Iout | - | 60 | mA | 16 |
| Off-Chip Load | CL | - | 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.

13. Noise performance will degrade at higher temperatures.

14. T = 25 °C. Excessive humidity will degrade MTTF.

15. The KAI-43140 image sensors have epoxy sealed cover glass. The seal formed is non-hermetic, and may allow moisture ingress over time, depending on the storage environment. As a result, care must be taken to avoid cooling the device below the dew point inside the package cavity, since this may result in condensation on the sensor. For all KAI-43140 configurations, no warranty, expressed or implied, covers condensation.

16. 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 12. ABSOLUTE MAXIMUM VOLTAGE RATINGS BETWEEN PINS AND GROUND

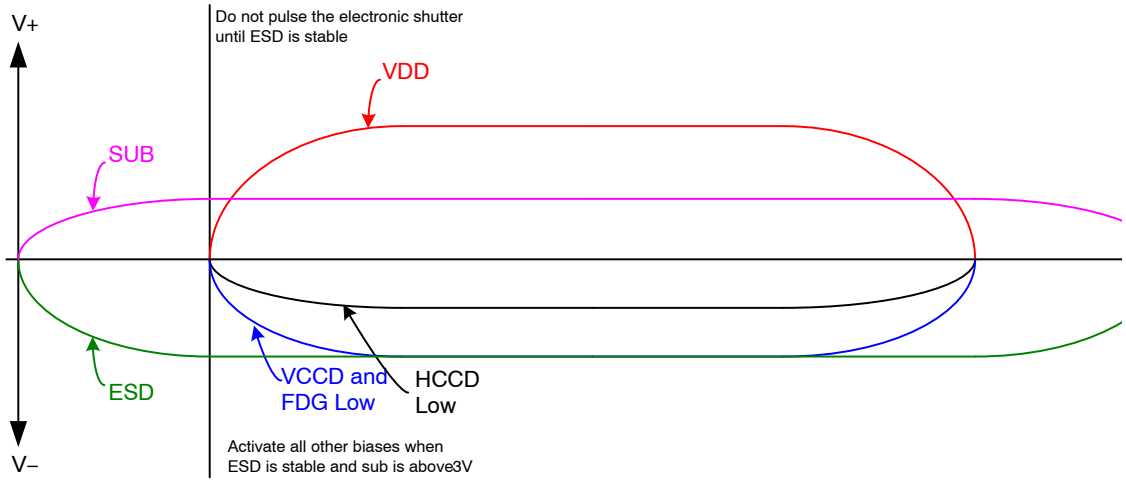
| Description | Minimum | Maximum | Units | Notes |
|--|-----------|------------|-------|-------|
| VDD α , VOUT α | -0.4 | +17.5 | V | 17 |
| RD α | -0.4 | +15.5 | V | 17 |
| V1TB | ESD - 0.4 | ESD + 24.0 | V | |
| V2B, V2T, V3B, V3T, V3B, V3T | ESD - 0.4 | ESD + 14.0 | V | |
| FDG α b, FDG α d | ESD - 0.4 | ESD + 15.0 | V | |
| H1 α , H2 α , H2L α | ESD - 0.4 | ESD + 14.0 | V | 17 |
| R α | ESD - 0.4 | ESD + 18.0 | V | 17 |
| ESD | -10 | 0.0 | V | |
| SUB | -0.4 | 40.0 | V | 18 |

17. α refers to a, b, c, or d.

18. 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:

- 19. Activate all other biases when ESD is stable and SUB is above 3 V.
- 20. Do not pulse the electronic shutter until ESD is stable.
- 21. The VCCD clock waveform must not have a negative overshoot more than 0.4 V below the ESD voltage. See Figure 15.
- 22. 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 Figure 16.

Figure 14. Power-Up and Power-Down Sequence



Figure 15. VCCD Clock Overshoots



Figure 16. External Diode Protection

Table 13. DC BIAS OPERATING CONDITIONS

| Description | Pins | Symbol | Minimum | Nominal | Maximum | Units | Max. DC Current | Notes |
|-------------------------|--------------|--------|---------|---------|---------|-------|-----------------|------------|
| Reset Drain | RD α | RD | +12.3 | +12.5 | +12.7 | V | 10 μ A | 23 |
| Output Gate | OG α | OG | +1.5 | +1.7 | +2.4 | V | 10 μ A | 23 |
| Output Amplifier Supply | VDD α | VDD | +14.5 | +15.0 | +15.5 | V | 11.0 mA | 23, 24 |
| Ground | GND | GND | +0.0 | +0.0 | +0.0 | V | -1.0 mA | |
| Substrate | SUB | VSUB | +5.0 | VAB | VDD | V | 50 μ A | 25, 30 |
| ESD Protection Disable | ESD | ESD | -9.2 | -9.0 | -8.8 | V | 50 μ A | 28, 29 |
| Output Bias Current | VOU α | Iout | -3.0 | -5.0 | -10.0 | mA | | 23, 26, 27 |

23. α denotes a, b, c or d

24. The maximum DC current is for one output. $I_{dd} = I_{out} + I_{ss}$. See Figure 17.

25. The operating value of the substrate voltage, VAB, will be marked on the shipping container for each device. The value of VAB is set such that the photodiode charge capacity is the nominal PNe (see Specifications).

26. An output load sink must be applied to each VOUT pin to activate each output amplifier.

27. Nominal value required for 60 MHz operation per output. May be reduced for slower data rates and lower noise.

28. Adherence to the power-up and power-down sequence is critical. See Power-Up and Power-Down Sequence section.

29. ESD maximum value must be less than or equal to V1_L - 0.4 V and V2_L - 0.4 V.

30. Refer to Application Note *Using Interline CCD Image Sensors in High Intensity Visible Lighting Conditions*.



Figure 17. Output Amplifier

AC OPERATING CONDITIONS

Table 14. CLOCK LEVELS

| Description | Pins (Note 31) | Symbol | Level | Min | Nom | Max | Units | Capacitance (Note 32) |
|---|----------------------------------|------------------|--------|----------|----------|-------|-------|--------------------------|
| Vertical CCD Clock, Phase 1 | V1B, V1T | V1_L | Low | -8.2 | -8.0 | -7.8 | V | 420 nF |
| | | V1_M | Mid | -0.2 | +0.0 | +0.2 | | |
| | | V1_H | High | +10.3 | +10.5 | +10.7 | | |
| Vertical CCD Clock, Phase 2 | V2B, V2T | V2_L | Low | -8.2 | -8.0 | -7.8 | V | 240 nF |
| | | 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 | 260 nF |
| | | 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 | 240 nF |
| | | V4_H | High | -0.2 | +0.0 | +0.2 | | |
| Horizontal CCD Clock, Phase 1 Storage | H1S α | H1S_L | Low | -0.2 | +0.0 | +0.2 | V | 650 pF |
| | | H1S_H | High | +3.8 | +4.0 | +5.2 | | |
| Horizontal CCD Clock, Phase 1 Barrier | H1B α | H1B_L | Low | -0.2 | +0.0 | +0.2 | V | 680 pF |
| | | H1B_H | High | +3.8 | +4.0 | +5.2 | | |
| Horizontal CCD Clock, Phase 2 Storage | H2S α | H2S_L | Low | -0.2 | +0.0 | +0.2 | V | 560 pF |
| | | H2S_H | High | +3.8 | +4.0 | +5.2 | | |
| Horizontal CCD Clock, Phase 2 Barrier | H2B α | H2B_L | Low | -0.2 | +0.0 | +0.2 | V | 460 pF |
| | | H2B_H | High | +3.8 | +4.0 | +5.2 | | |
| Horizontal CCD Clock, Last Phase (Note 33) | H2SL α | H2SL_L | Low | -0.2 | +0.0 | +0.2 | V | 20 pF |
| | | H2SL_H | High | +3.8 | +4.0 | +5.2 | | |
| Reset Gate | R α | R_L (Note 34) | Low | +2.0 | +3.0 | +3.2 | V | 20 pF |
| | | R_H | High | +6.8 | +7.0 | +7.2 | | |
| Electronic Shutter (Notes 35, 38) | SUB | VES | High | - | - | +40 | V | 12 nF |
| | | VES_Offset | Offset | VAB + 24 | VAB + 25 | - | | |
| Fast Line Dump Gate | FDG α , FDG α d | FDG_L | Low | -8.2 | -8.0 | -7.8 | V | 200 pF |
| | | FDG_H | High | +4.5 | +5.0 | +5.5 | | |

31. α denotes a, b, c or d.

32. Capacitance is total for all like named pins.

33. Use separate clock driver for improved speed performance.

34. Reset low should be set to +2.0 V for signal levels greater than 26,000 electrons.

35. Refer to Application Note *Using Interline CCD Image Sensors in High Intensity Visible Lighting Conditions*.

36. Capacitance values are estimated.

37. If the minimum horizontal clock low level is used (-0.2 V), then a 4 V clock amplitude should be used to create a -0.2 V to +3.8 V clock. For the maximum horizontal charge transfer efficiency performance a 5 volt clock amplitude may be used.

38. Figure 18 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. The VES_Offset is referenced to VSUB.



Figure 18. VSUB and VES Reference

Device Identification

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

Table 15. DEVICE IDENTIFICATION

| Description | Pins | Symbol | Minimum | Nominal | Maximum | Unit | Max. DC Current | Notes |
|-----------------------|-------|--------|---------|---------|---------|------|-----------------|------------|
| Device Identification | DevID | DevID | 230,000 | 260,000 | 300,00 | Ω | 50 μA | 39, 40, 41 |

39. Nominal value subject to verification and/or change during release of preliminary specifications.

40. If the Device Identification is not used, it may be left disconnected.

41. After Device Identification resistance has been read during camera initialization, it is recommended that the circuit be disabled to prevent localized heating of the sensor due to current flow through the R_DeviceID resistor.

Recommended Circuit

Note that V1 must be a different value than V2.



Figure 19. Device Identification Recommended Circuit

TIMING

Table 16. REQUIREMENTS AND CHARACTERISTICS

| Description | Symbol | Minimum | Nominal | Maximum | Units | Notes |
|------------------------|------------------|---------|---------|---------|---------------|------------------------|
| Photodiode Transfer | T_{PD} | 6 | – | – | μs | |
| VCCD Leading Pedestal | T_{3P} | 16 | – | – | μs | |
| VCCD Trailing Pedestal | T_{3D} | 16 | – | – | μs | |
| VCCD Transfer Delay | T_D | 4 | – | – | μs | |
| VCCD Transfer | T_V | 10 | – | – | μs | |
| VCCD Clock Cross-over | V_{VCR} | 75 | – | 100 | % | 42 |
| VCCD Rise, Fall Time | T_{VR}, T_{VF} | 5 | – | 10 | % | 42, 43 |
| FDG Delay | T_{FDG} | 5 | – | – | μs | |
| HCCD Delay | T_{HS} | 1 | – | – | μs | |
| HCCD Transfer | T_E | 16.6667 | – | – | ns | |
| Shutter Transfer | T_{SUB} | 1 | – | – | μs | |
| Shutter Delay | T_{HD} | 1 | – | – | 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} | 89.21 | – | – | μs | Dual/Quad HCCD Readout |
| | | 157.21 | – | – | | Single HCCD Readout |
| Frame Time | T_{FRAME} | 244.43 | – | – | ms | Quad HCCD Readout |
| | | 488.86 | – | – | | Dual HCCD Readout |
| | | 861.50 | – | – | | Single HCCD Readout |

42. Refer to Figure 24: VCCD Clock Rise Time, Fall Time and Edge Alignment

43. Relative to the pulse width

KAI-43140

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 20 and Figure 21. Contact ON Semiconductor Application Engineering for other readout modes.

Table 17. TIMING SEQUENCE

| Device Pin | Quad Readout | Dual Readout VOUTa, VOUTb | Dual Readout VOUTa, VOUTc | Single Readout VOUTa |
|-------------------------|--------------|---------------------------------------|---------------------------------------|---------------------------------------|
| V1BT | P1BT | P1BT | P1BT | P1BT |
| V2T | P2T | P4B | P2T | P4B |
| V3T | P3T | P3B | P3T | P3B |
| V4T | P4T | P2B | P4T | P2B |
| V1BT | P1BT | | | |
| V2B | P2B | | | |
| V3B | P3B | | | |
| V4B | P4B | | | |
| H1Sa | P5 | | | |
| H1Ba | | | | |
| H2Sa (Note 45) | P6 | | | |
| H2Ba | | | | |
| Ra | P7 | | | |
| H1Sb | P5 | | P5 | |
| H1Bb | | | P6 | |
| H2Sb (Note 45) | P6 | | P6 | |
| H2Bb | | | P5 | |
| Rb | P7 | | P7 ⁴⁴ or Off ⁴⁶ | P7 ⁴⁴ or Off ⁴⁶ |
| H1Sc | P5 | P5 ⁴⁴ or Off ⁴⁶ | P5 | P5 ⁴⁴ or Off ⁴⁶ |
| H1Bc | | | | |
| H2Sc (Note 45) | P6 | P6 ⁴⁴ or Off ⁴⁶ | P6 | P6 ⁴⁴ or Off ⁴⁶ |
| H2Bc | | | | |
| Rc | P7 | P7 ⁴⁴ or Off ⁴⁶ | P7 | P7 ⁴⁴ or Off ⁴⁶ |
| H1Sd | P5 | P5 ⁴⁴ or Off ⁴⁶ | P5 | P5 ⁴⁴ or Off ⁴⁶ |
| H1Bd | | | P6 | |
| H2Sd (Note 45) | P6 | P6 ⁴⁴ or Off ⁴⁶ | P6 | P6 ⁴⁴ or Off ⁴⁶ |
| H2Bd | | | P5 | |
| Rd | P7 | P7 ⁴⁴ or Off ⁴⁶ | P7 ⁴⁴ or Off ⁴⁶ | P7 ⁴⁴ or Off ⁴⁶ |
| | | | | |
| # Lines/Frame (Minimum) | 2740 | 5480 | 2740 | 5480 |
| # Pixels/Line (Minimum) | 4092 | | 8172 | |

44. 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.

45. H2SLx follows the same pattern as H2Sx For optimal speed performance, use a separate clock driver.

46. Off = R_H for the Reset Gate and H_H for the Horizontal CCD gates. 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 2740 or 5480 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 20. 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 4092 or 8172 minimum counts required.



Figure 21. Line and Pixel Timing

Pixel Timing Detail



Figure 22. Pixel Timing Detail

Frame/Electronic Shutter Timing

The SUB pin may be optionally clocked to provide electronic shuttering capability as shown below. The resulting photodiode integration time is defined from the falling edge of SUB to the falling edge of V1 (P1 pattern).

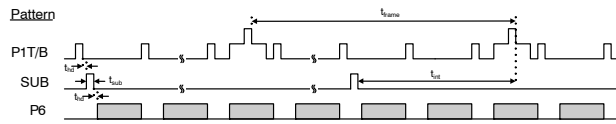


Figure 23. Electronic Shutter Timing

VCCD Clock Edge Alignment

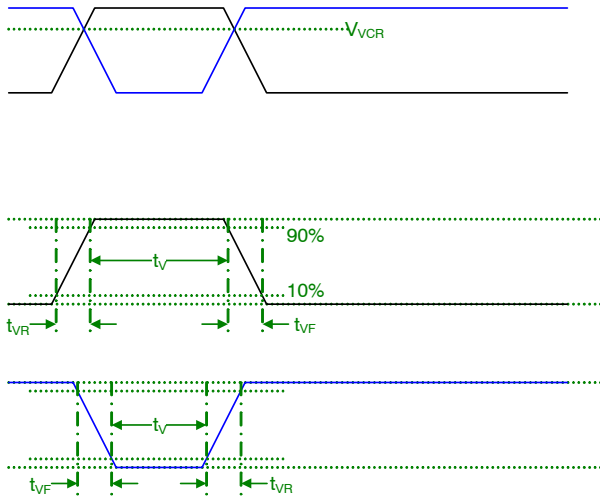


Figure 24. VCCD Clock Rise Time, Fall Time, and Edge Alignment

Line and Pixel Timing – Vertical Binning by 2



Figure 25. Line and Pixel Timing – Vertical Binning by 2

Fast Line Dump Timing

The FDG pins may be optionally clocked to efficiently remove unwanted lines in the image resulting for increased

frame rates at the expense of resolution. Below is an example of a 2 line dump sequence followed by a normal readout line.



Figure 26. Fast Line Dump Timing

STORAGE AND HANDLING

Table 18. STORAGE CONDITIONS

| Description | Symbol | Minimum | Maximum | Units | Notes |
|---------------------|-----------------|---------|---------|-------|-------|
| Storage Temperature | T _{AT} | -55 | +88 | °C | 47 |
| Humidity | RH | 5 | 90 | % | 48 |

47. Long term storage toward the maximum temperature will accelerate color filter degradation.

48. T = 25 °C. Excessive humidity will degrade MTF.

For information on ESD and cover glass care and cleanliness, please download the *Image Sensor Handling and Best Practices* Application Note (AN52561/D) from www.onsemi.com.

For information on soldering recommendations, please download the *Soldering and Mounting Techniques Reference Manual* (SOLDERRM/D) from www.onsemi.com.

For quality and reliability information, please download the *Quality & Reliability Handbook* (HBD851/D) from www.onsemi.com.

For information on device numbering and ordering codes, please download the *Device Nomenclature* technical note (TND310/D) from www.onsemi.com.

For information on Standard terms and Conditions of Sale, please download *Terms and Conditions* from www.onsemi.com.

MECHANICAL INFORMATION



NOTES:

- 49. Substrate = Schott D263T eco
- 50. Dust, Scratch, Inclusion Specification: 20 μm Max size in Zone A
- 51. MAR coated both sides
- 52. Spectral Transmission
 - 350–365 nm: T ≥ 88%
 - 365–405 nm: T ≥ 94%
 - 405–450 nm: T ≥ 98%
 - 450–650 nm: T ≥ 99%
 - 650–690 nm: T ≥ 98%
 - 690–770 nm: T ≥ 94%
 - 770–870 nm: T ≥ 88%
- 53. Units: IN [MM]

Figure 27. Cover Glass

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Figure 28. Cover Glass Transmission

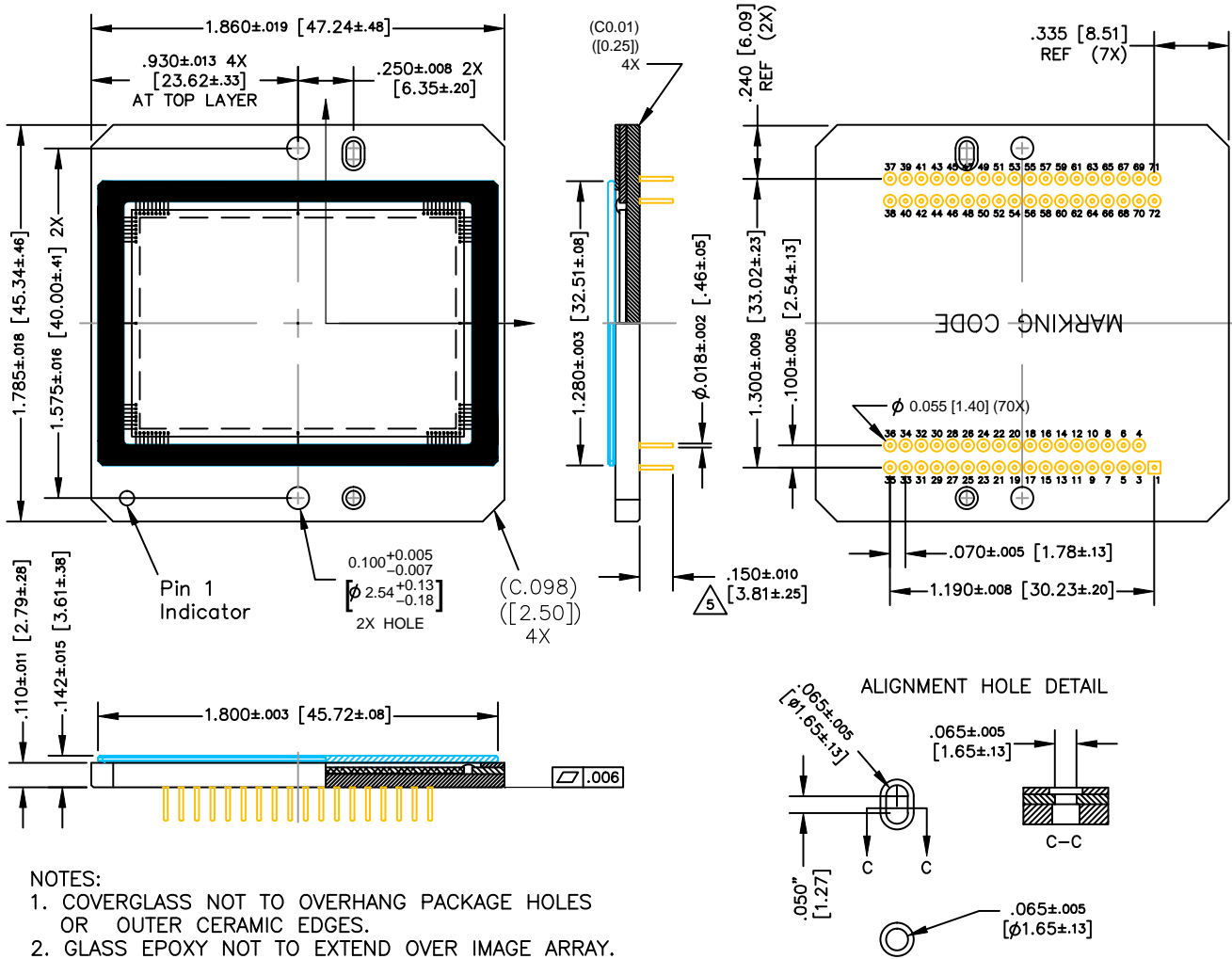
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NOTES:

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- GLASS EPOXY NOT TO EXTEND OVER IMAGE ARRAY.
- NO MATERIALS TO INTERFERE WITH CLEARANCE THROUGH PACKAGE HOLES.
- ALL PIN DISTANCES MEASURED AT PIN BASE.

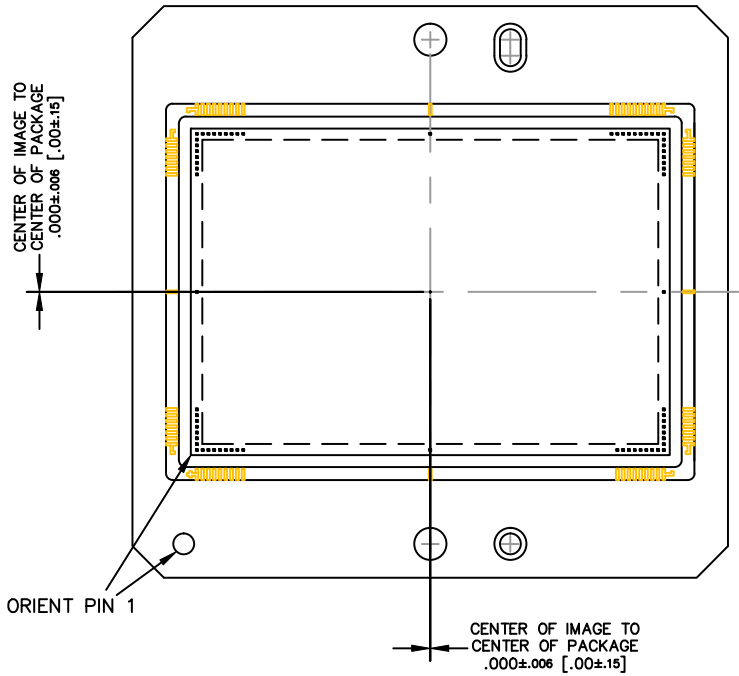
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