

# KAF-6303

## 3072 (H) x 2048 (V) Full Frame CCD Image Sensor

### Description

The KAF-6303 Image Sensor is a high performance CCD (charge-coupled device) with 3072 (H) x 2048 (V) photo active pixels designed for a wide range of image sensing applications.

The sensor incorporates true two-phase CCD technology, simplifying the support circuits required to drive the sensor as well as reducing dark current without compromising charge capacity. The sensor also utilizes the TRUESENSE Transparent Gate Electrode to improve sensitivity compared to the use of a standard front side illuminated polysilicon electrode.

**Table 1. GENERAL SPECIFICATIONS**

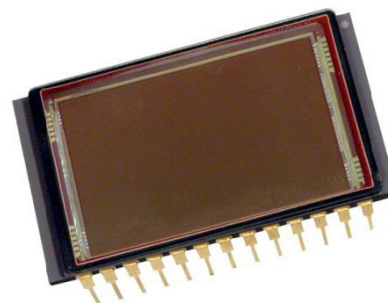
| Parameter                                       | Typical Value   |
|---|---|
| Architecture                                    | Full Frame CCD  |
| Total Number of Pixels                          | 3088 (H) x 2056 (V)   |
| Number of Active Pixels                         | 3072 (H) x 2048 (V) = approx. 6.3 Mp                                      |
| Pixel Size                                      | 9 $\mu\text{m}$ (H) x 9 $\mu\text{m}$ (V)                                 |
| Active Image Size                               | 27.65 mm (H) x 18.48 mm (V)<br>33.4 mm (Diagonal)<br>APS-H Optical Format |
| Chip Size                                       | 29.0 mm (H) x 19.1 mm (V)   |
| Saturation Signal                               | 100,000 $e^-$   |
| Output Sensitivity                              | 10 $\mu\text{V}/e^-$  |
| Quantum Efficiency<br>(450, 550, 650 nm)        | 40%, 52%, 65%   |
| Readout Noise (10 MHz)                          | 15 $e^-$ rms  |
| Dark Current<br>(Accumulation Mode)             | < 10 pA/cm <sup>2</sup>   |
| Dark Current Doubling Rate                      | 6°C   |
| Dynamic Range<br>(Saturation Signal/Dark Noise) | 76 dB   |
| Maximum Data Rate                               | 10 MHz  |
| Package   | CERDIP Package (Sidebrazed)   |
| Cover Glass                                     | Clear or AR Coated, 2 Sides   |

NOTE: Parameters above are specified at T = 25°C unless otherwise noted.



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**Figure 1. KAF-6303 Full Frame CCD Image Sensor**

### Features

- True Two Phase Full Frame Architecture
- TRUESENSE Transparent Gate Electrode for High Sensitivity
- 100% Fill Factor
- Low Dark Current

### Applications

- Medical Imaging
- Scientific Imaging

### ORDERING INFORMATION

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

# KAF-6303

## ORDERING INFORMATION

**Table 2. ORDERING INFORMATION – KAF-6303 IMAGE SENSOR**

| Part Number        | Description   | Marking Code                  |
|--------------------|---|-------------------------------|
| KAF-6303-AAA-CD-B2 | Monochrome, No Microlens, CERDIP Package (Sidebrazed), Clear Cover Glass with AR Coating (Both Sides), Grade 2            | KAF-6303-AAA<br>Serial Number |
| KAF-6303-AAA-CD-AE | Monochrome, No Microlens, CERDIP Package (Sidebrazed), Clear Cover Glass with AR Coating (Both Sides), Engineering Sample |                               |
| KAF-6303-AAA-CP-B2 | Monochrome, No Microlens, CERDIP Package (Sidebrazed), Taped Clear Cover Glass (No Coatings), Grade 2                     |                               |
| KAF-6303-AAA-CP-AE | Monochrome, No Microlens, CERDIP Package (Sidebrazed), Taped Clear Cover Glass (No Coatings), Engineering Sample          |                               |

**Table 3. ORDERING INFORMATION – EVALUATION SUPPORT**

| Part Number         | Description                     |
|---------------------|---------------------------------|
| KAF-6303-12-5-A-EVK | Evaluation Board (Complete Kit) |

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](http://www.onsemi.com).

## DEVICE DESCRIPTION

### Architecture

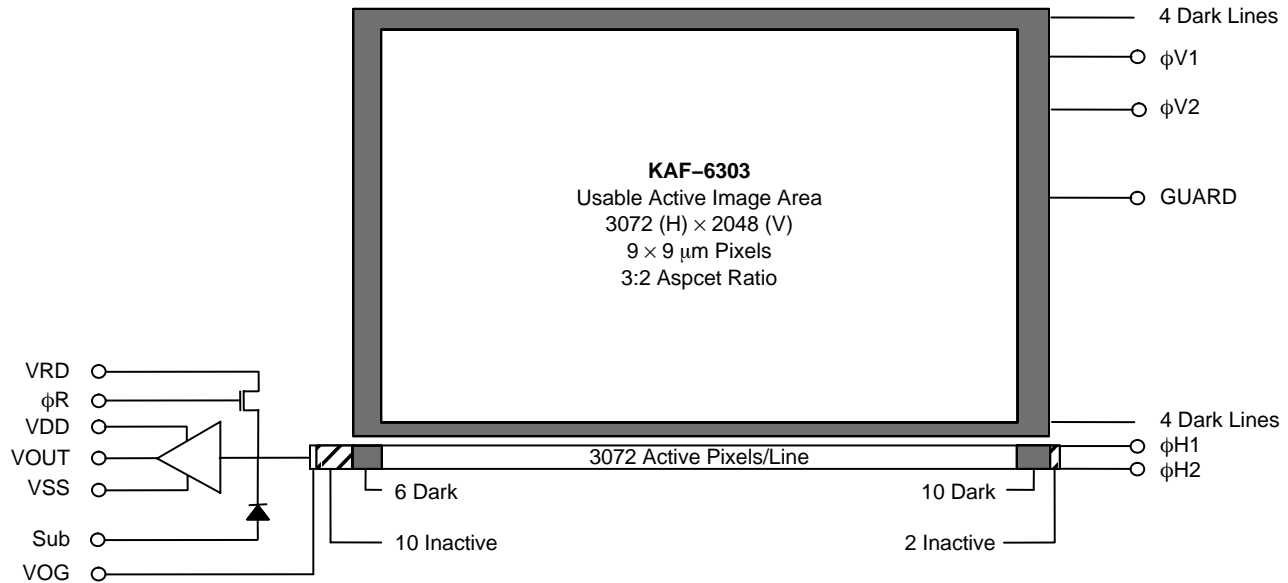


Figure 2. Block Diagram

The sensor consists of 3,088 parallel (vertical) CCD shift registers each 2,056 elements long. These registers act as both the photosensitive elements and as the transport circuits that allow the image to be sequentially read out of the sensor. The elements of these registers are arranged into a  $3,072 \times 2,048$  photosensitive array surrounded by a light shielded dark reference of 16 columns and 8 rows. The parallel (vertical) CCD registers transfer the image one line at a time into a single 3,100 element (horizontal) CCD shift register. The horizontal register transfers the charge to a single output amplifier. The output amplifier is a two-stage source follower that converts the photo-generated charge to a voltage for each pixel.

#### Dark Reference Pixels

Surrounding the peripheral of the device is a border of light shielded pixels. This includes 6 leading and 10 trailing pixels on every line excluding dummy pixels. There are also 4 full dark lines at the start of every frame and 4 full dark lines at the end of each frame. Under normal circumstances, these pixels do not respond to light. However, dark reference pixels in close proximity to an active pixel, or the outer bounds of the chip (including the first two lines out), can scavenge signal depending on light intensity and wavelength and therefore will not represent the true dark signal.

#### Dummy Pixels

Within the horizontal shift register are 10 leading and 2 trailing additional shift phases that are not associated with a column of pixels from the vertical register. These pixels

contain only horizontal shift register dark current signal and do not respond to light. A few leading dummy pixels may scavenge false signal depending on operating conditions.

#### Image Acquisition

An electronic representation of an image is formed when incident photons falling on the sensor plane create electron-hole pairs within the sensor. These photon-induced electrons are collected locally by the formation of potential wells at each photogate or pixel site. The number of electrons collected is linearly dependent on light level and exposure time and non-linearly dependent on wavelength. When the pixel's capacity is reached, excess electrons will leak into the adjacent pixels within the same column. This is termed blooming. During the integration period, the  $\phi V1$  and  $\phi V2$  register clocks are held at a constant (low) level. See Figure 8.

#### Charge Transport

Referring again to Figure 8, the integrated charge from each photogate is transported to the output using a two-step process. Each line (row) of charge is first transported from the vertical CCD's to the horizontal CCD register using the  $\phi V1$  and  $\phi V2$  register clocks. The horizontal CCD is presented a new line on the falling edge of  $\phi V2$  while  $\phi H1$  is held high. The horizontal CCD's then transport each line, pixel by pixel, to the output structure by alternately clocking the  $\phi H1$  and  $\phi H2$  pins in a complementary fashion. On each falling edge of  $\phi H2$ , a new charge packet is transferred onto a floating diffusion and sensed by the output amplifier.

## Horizontal Register

### Output Structure

Charge presented to the floating diffusion (FD) is converted into a voltage and current amplified in order to drive off-chip loads. The resulting voltage change seen at the output is linearly related to the amount of charge placed on FD. Once the signal has been sampled by the system

electronics, the reset gate ( $\phi_R$ ) is clocked to remove the signal and FD is reset to the potential applied by VRD. More signal at the floating diffusion reduces the voltage seen at the output pin. In order to activate the output structure, an off-chip load must be added to the VOUT pin of the device. See Figure 3.

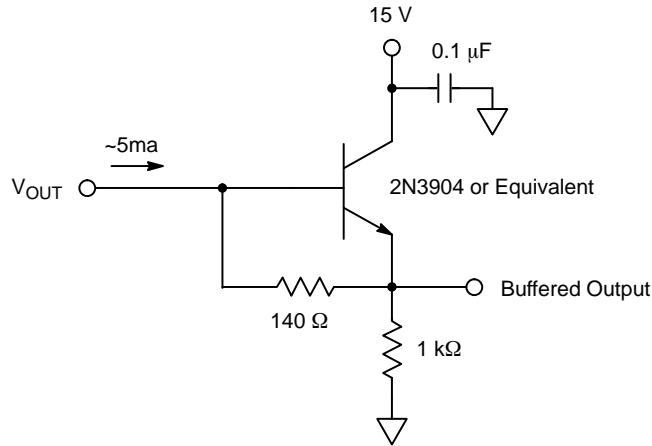
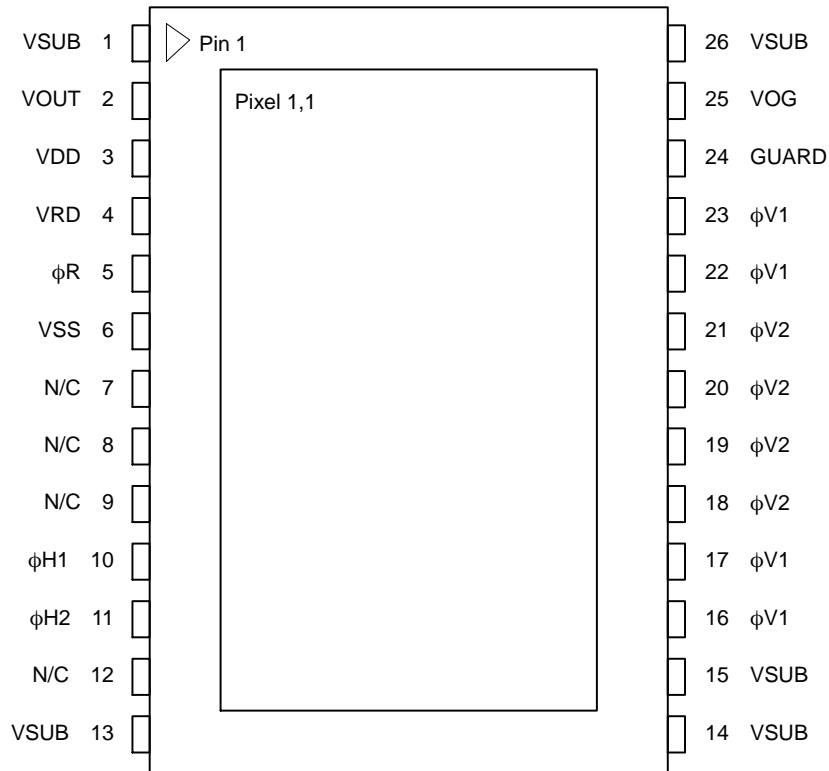


Figure 3. Typical Output Structure Load Diagram

# KAF-6303

## Physical Description

### Pin Description and Device Orientation



**Figure 4. Pinout Diagram**

NOTE: The KAF-1603 is mechanically the same and electrically identical to the KAF-0402 sensor. It is also mechanically the same as the KAF-0261 and KAF-3200 sensors. There are some electrical differences since the KAF-0261 has two outputs and two additional clock inputs. The KAF-3200 requires that pin 11 be a “No connect” and be electrically floating. Refer to their specifications for details.

**Table 4. PIN DESCRIPTION**

| Pin | Name | Description                    |
|-----|------|--------------------------------|
| 1   | VSUB | Substrate (Ground)             |
| 2   | VOUT | Video Output                   |
| 3   | VDD  | Amplifier Supply               |
| 4   | VRD  | Reset Drain                    |
| 5   | φR   | Reset Clock                    |
| 6   | VSS  | Amplifier Supply Return        |
| 7   | N/C  | No Connection (Open Pin)       |
| 8   | N/C  | No Connection (Open Pin)       |
| 9   | N/C  | No Connection (Open Pin)       |
| 10  | φH1  | Horizontal CCD Clock – Phase 1 |
| 11  | φH2  | Horizontal CCD Clock – Phase 2 |
| 12  | N/C  | No Connection (Open Pin)       |
| 13  | VSUB | Substrate (Ground)             |

| Pin | Name  | Description                  |
|-----|-------|------------------------------|
| 14  | VSUB  | Substrate (Ground)           |
| 15  | VSUB  | Substrate (Ground)           |
| 16  | φV1   | Vertical CCD Clock – Phase 1 |
| 17  | φV1   | Vertical CCD Clock – Phase 1 |
| 18  | φV2   | Vertical CCD Clock – Phase 2 |
| 19  | φV2   | Vertical CCD Clock – Phase 2 |
| 20  | φV2   | Vertical CCD Clock – Phase 2 |
| 21  | φV2   | Vertical CCD Clock – Phase 2 |
| 22  | φV1   | Vertical CCD Clock – Phase 1 |
| 23  | φV1   | Vertical CCD Clock – Phase 1 |
| 24  | GUARD | Guard Ring                   |
| 25  | VOG   | Output Gate                  |
| 26  | VSUB  | Substrate (Ground)           |

## IMAGING PERFORMANCE

**Table 5. SPECIFICATIONS**

(All values measured at 25°C, and nominal operating conditions. These parameters exclude defective pixels.)

| Description   | Symbol                  | Min.                         | Nom.                          | Max.                          | Unit  | Notes | Verification Plan    |
|---|-------------------------|------------------------------|-------------------------------|-------------------------------|---|-------|----------------------|
| Saturation Signal<br>Vertical CCD Capacity<br>Horizontal CCD Capacity<br>Output Node Capacity | $N_{SAT}$               | 85,000<br>170,000<br>190,000 | 100,000<br>200,000<br>220,000 | 120,000<br>240,000<br>240,000 | e <sup>-</sup> /Pixel                         | 1     | Design <sup>11</sup> |
| Quantum Efficiency<br>Red<br>Green<br>Blue  | $R_R$<br>$R_G$<br>$R_B$ | 52<br>42<br>30               | 65<br>52<br>40                | 75<br>62<br>48                | %QE   |       | Design <sup>11</sup> |
| Photoresponse Non-Linearity   | PRNL                    | -                            | 1.0                           | 2.0                           | %   | 2     | Design <sup>11</sup> |
| Photoresponse Non-Uniformity  | PRNU                    | -                            | 1.0                           | 3.0                           | %   | 3     | Die <sup>10</sup>    |
| Dark Signal   | $J_{DARK}$              | -<br>-                       | 15<br>3.5                     | 50<br>10                      | e <sup>-</sup> /Pix/Sec<br>pA/cm <sup>2</sup> | 4     | Die <sup>10</sup>    |
| Dark Signal Doubling Temperature  |                         | 5.0                          | 6.3                           | 7.5                           | °C  |       | Design <sup>11</sup> |
| Dark Signal Non-Uniformity  | DSNU                    | -                            | 10                            | 50                            | e <sup>-</sup> /Pix/Sec                       | 5     | Die <sup>10</sup>    |
| Dynamic Range   | DR                      | 70                           | 76                            | -                             | dB  | 6     | Design <sup>11</sup> |
| Charge Transfer Efficiency  | CTE                     | 0.99997                      | 0.99999                       | -                             |   |       | Die <sup>10</sup>    |
| Output Amplifier DC Offset  | $V_{ODC}$               | 9.5                          | 10.5                          | 11.5                          | V   | 7     | Die <sup>10</sup>    |
| Output Amplifier Bandwidth  | $f_{-3dB}$              | -                            | 45                            | -                             | MHz   | 8     | Design <sup>11</sup> |
| Output Amplifier Sensitivity  | $V_{OUT}/N_{e^-}$       | 9                            | 10                            | 11                            | μV/e <sup>-</sup>                             |       | Design <sup>11</sup> |
| Output Amplifier Output Impedance   | $Z_{OUT}$               | 175                          | 200                           | 2,520                         | Ω   |       | Design <sup>11</sup> |
| Noise Floor   | $n_{e^-}$               | -                            | 15                            | 20                            | e <sup>-</sup>                                | 9     | Die <sup>10</sup>    |

- For pixel binning applications, electron capacity up to 330,000 can be achieved with modified CCD inputs. Each sensor may have to be optimized individually for these applications. Some performance parameters may be compromised to achieve the largest signals.
- Worst-case deviation from straight line fit, between 1% and 90% of  $V_{SAT}$ .
- One Sigma deviation of a 128 × 128 sample when CCD illuminated uniformly.
- Average of all pixels with no illumination at 25°C.
- Average dark signal of any of 12 × 8 blocks within the sensor (each block is 128 × 128 pixels).
- 20Log ( $N_{SAT} / n_{e^-}$ ) at nominal operating frequency and 25°C.
- Video level offset with respect to ground.
- Last output amplifier stage only. Assumes 10 pF off-chip load.
- Output noise at 25°C, nominal operating frequency, and  $t_{INT} = 0$ .
- A parameter that is measured on every sensor during production testing.
- A parameter that is quantified during the design verification activity.

TYPICAL PERFORMANCE CURVES

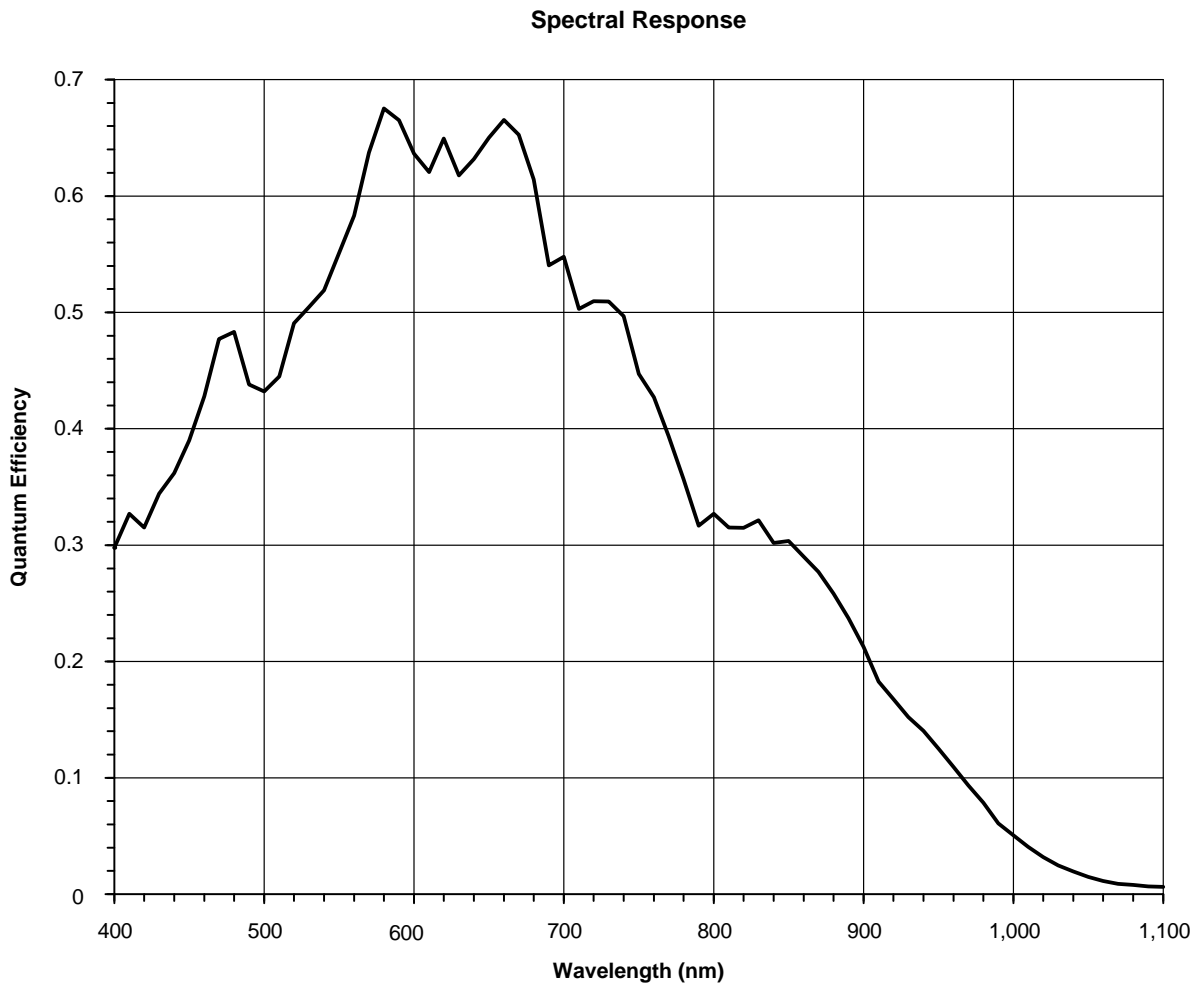


Figure 5. Typical Spectral Response

**DEFECT DEFINITIONS**

**Table 6. SPECIFICATIONS** (All tests performed at T = 25°C)

| Classification | Point Defect |        | Cluster Defect |        | Column Defect |        |
|----------------|--------------|--------|----------------|--------|---------------|--------|
|                | Total        | Zone A | Total          | Zone A | Total         | Zone A |
| C2             | ≤ 90         | ≤ 45   | ≤ 36           | ≤ 18   | 0             | 0      |

*Point Defects*

**Dark:** A pixel which deviates by more than 6% from neighboring pixels when illuminated to 70% of saturation.

**Bright:** A pixel with a dark current greater than 10,000 e<sup>-</sup>/pixel/sec at 25°C.

*Cluster Defect*

A grouping of not more than 5 adjacent point defects.

*Column Defect*

A grouping of > 5 contiguous point defects along a single column.

A column containing a pixel with dark current > 30,000 e<sup>-</sup>/pix/sec at 25°C (Bright column).

A column that does not meet the CTE specification for all exposures less than the specified Max sat. signal level and greater than 2 ke<sup>-</sup>.

A column that loses > 250 e<sup>-</sup> under 2 ke<sup>-</sup> illumination.

*Neighboring Pixels*

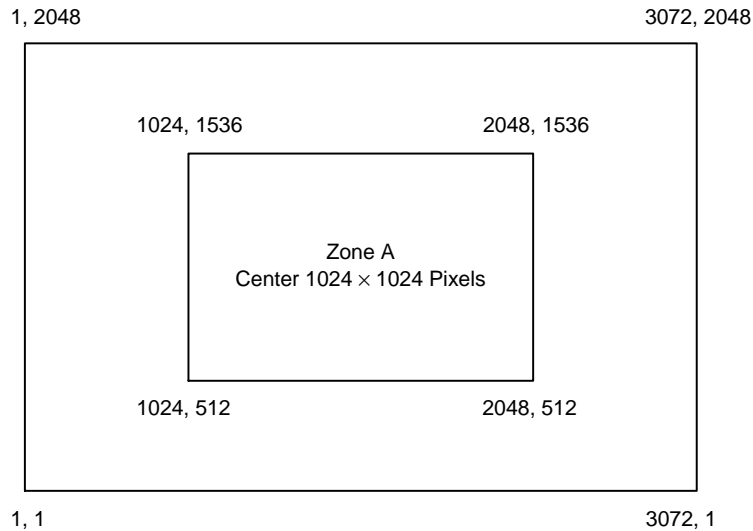
The surrounding 128 × 128 pixels or ±64 columns/rows.

*Defect Separation*

Column and cluster defects are separated by no less than two (2) pixels in any direction (excluding single pixel defects).

*Defect Region Exclusion*

Defect region excludes the outer two (2) rows and columns at each side/end of the sensor.



**Figure 6. Active Pixel Region**



## OPERATION

Table 7. ABSOLUTE MAXIMUM RATINGS

| Description                | Symbol      | Minimum | Maximum | Unit | Notes |
|----------------------------|-------------|---------|---------|------|-------|
| Diode Pin Voltages         | $V_{DIODE}$ | 0       | 20      | V    | 1, 2  |
| Gate Pin Voltages – Type 1 | $V_{GATE1}$ | -16     | 16      | V    | 1, 3  |
| Gate Pin Voltages – Type 2 | $V_{GATE2}$ | 0       | 16      | V    | 1, 4  |
| Inter-Gate Voltages        | $V_{g-g}$   | -       | 16      | V    | 5     |
| Output Bias Current        | $I_{OUT}$   | -       | -10     | mA   | 6     |
| Output Load Capacitance    | $C_{LOAD}$  | -       | 15      | pF   | 6     |
| Storage Temperature        | $T_{ST}$    | 0       | 70      | °C   |       |
| Humidity                   | RH          | 5       | 90      | %    | 7     |

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. Referenced to pin VSUB.
2. Includes pins: VRD, VDD, VSS, VOUT, GUARD.
3. Includes pins:  $\phi V1$ ,  $\phi V2$ ,  $\phi H1$ ,  $\phi H2$ .
4. Includes pins:  $\phi R$ , VOG.
5. Voltage difference between overlapping gates. Includes:  $\phi V1$  to  $\phi V2$ ,  $\phi H1$  to  $\phi H2$ ,  $\phi V2$  to  $\phi H1$ ,  $\phi H2$  to VOG.
6. Avoid shorting output pins to ground or any low impedance source during operation.
7. T = 25°C. Excessive humidity will degrade MTTF.

Table 8. DC BIAS OPERATING CONDITIONS

| Description             | Symbol    | Minimum | Nominal | Maximum | Unit | Maximum DC Current (mA) | Notes |
|-------------------------|-----------|---------|---------|---------|------|-------------------------|-------|
| Reset Drain             | $V_{RD}$  | 10.5    | 11.0    | 11.5    | V    | 0.01                    |       |
| Output Amplifier Return | $V_{SS}$  | 1.5     | 2.0     | 2.5     | V    | 0.45                    |       |
| Output Amplifier Supply | $V_{DD}$  | 14.5    | 15      | 15.5    | V    | $I_{OUT}$               |       |
| Substrate               | $V_{SUB}$ | 0       | 0       | 0       | V    | 0.01                    |       |
| Output Gate             | $V_{OG}$  | 3.75    | 4.0     | 5.0     | V    | 0.01                    |       |
| Guard Ring              | $V_{LG}$  | 8.0     | 10.0    | 12.0    | V    | 0.01                    |       |
| Video Output Current    | $I_{OUT}$ | -       | -5      | -10     | mA   | -                       | 1     |

1. An output load sink must be applied to VOUT to activate output amplifier – see Figure 3.

## AC Operating Conditions

Table 9. CLOCK LEVELS

| Description                    | Symbol    | Level | Min.  | Nom.  | Max. | Unit | Effective Capacitance       |
|--------------------------------|-----------|-------|-------|-------|------|------|-----------------------------|
| Vertical CCD Clock – Phase 1   | $\phi V1$ | Low   | -10.5 | -10   | -9.5 | V    | 82 nF (All $\phi V1$ Pins)  |
| Vertical CCD Clock – Phase 1   | $\phi V1$ | High  | 0.5   | 1.0   | 1.5  | V    | 82 nF (All $\phi V1$ Pins)  |
| Vertical CCD Clock – Phase 2   | $\phi V2$ | Low   | -10.5 | -10.0 | -9.5 | V    | 820 nF (All $\phi V2$ Pins) |
| Vertical CCD Clock – Phase 2   | $\phi V2$ | High  | 0.5   | 1.0   | 1.5  | V    | 820 nF (All $\phi V2$ Pins) |
| Horizontal CCD Clock – Phase 1 | $\phi H1$ | Low   | -6.0  | -3.0  | -3.0 | V    | 400 pF                      |
| Horizontal CCD Clock – Phase 1 | $\phi H1$ | High  | 4.0   | 7.0   | 7.0  | V    | 400 pF                      |
| Horizontal CCD Clock – Phase 2 | $\phi H2$ | Low   | -6.0  | -3.0  | -3.0 | V    | 400 pF                      |
| Horizontal CCD Clock – Phase 2 | $\phi H2$ | High  | 4.0   | 7.0   | 7.0  | V    | 400 pF                      |
| Reset Clock                    | $\phi R$  | Low   | -4.0  | -3.0  | -2.0 | V    | 10 pF                       |
| Reset Clock                    | $\phi R$  | High  | 3.5   | 4.0   | 5.0  | V    | 10 pF                       |

1. All pins draw less than 10  $\mu A$  DC current.
2. Capacitance values relative to VSUB.

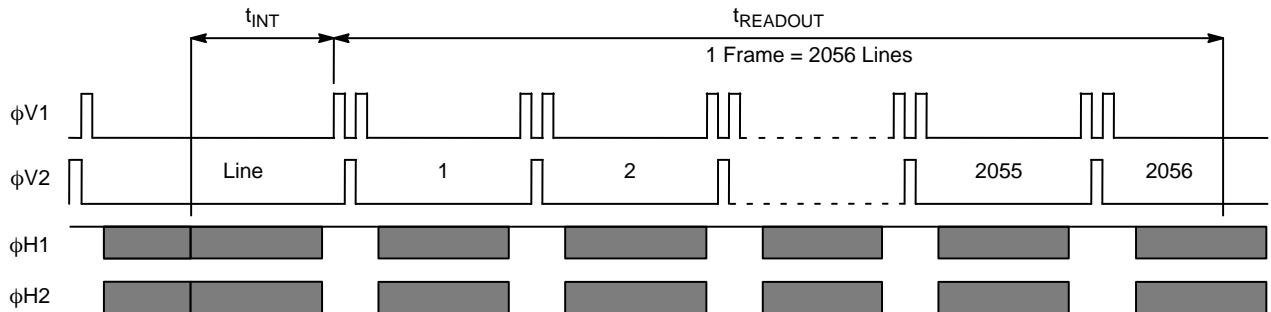
**TIMING**

**Table 10. REQUIREMENTS AND CHARACTERISTICS**

| Description                            | Symbol        | Minimum | Nominal | Maximum | Unit    | Notes   |
|--|---------------|---------|---------|---------|---------|---------|
| $\phi$ H1, $\phi$ H2 Clock Frequency   | $f_H$         | –       | 4       | 15      | MHz     | 1, 2, 3 |
| $\phi$ V1, $\phi$ V2 Clock Frequency   | $f_V$         | –       | 25      | 50      | kHz     | 1, 2, 3 |
| Pixel Period (1 Count)                 | $t_e$         | 67      | 250     | –       | ns      |         |
| $\phi$ H1, $\phi$ H2 Set-up Time       | $t_{\phi HS}$ | 0.5     | 1       | –       | $\mu$ s |         |
| $\phi$ V1, $\phi$ V2 Clock Pulse Width | $t_{\phi V}$  | 10      | 20      | –       | $\mu$ s | 2       |
| Reset Clock Pulse Width                | $t_{\phi R}$  | 10      | 20      | –       | ns      | 4       |
| Readout Time                           | $t_{READOUT}$ | 531     | 1,719   | –       | ms      | 5       |
| Integration Time                       | $t_{INT}$     | –       | –       | –       |         | 6       |
| Line Time                              | $t_{LINE}$    | 258.2   | 836     | –       | $\mu$ s | 7       |

1. 50% duty cycle values.
2. CTE may degrade above the nominal frequency.
3. Rise and fall times (10/90% levels) should be limited to 5–10% of clock period. Cross-over of register clocks should be between 40–60% of amplitude.
4.  $\phi$ R should be clocked continuously.
5.  $t_{READOUT} = (2056 \cdot t_{LINE})$ .
6. Integration time ( $t_{INT}$ ) is user specified. Longer integration times will degrade noise performance.
7.  $t_{LINE} = (3 \cdot t_{\phi V}) + t_{\phi HS} + 3100 + t_e$ .

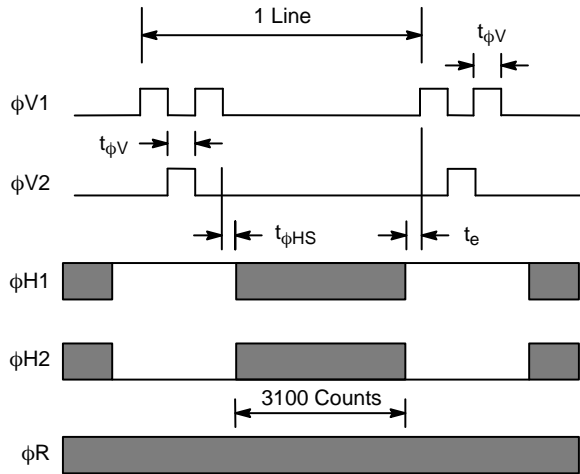
**Frame Timing**



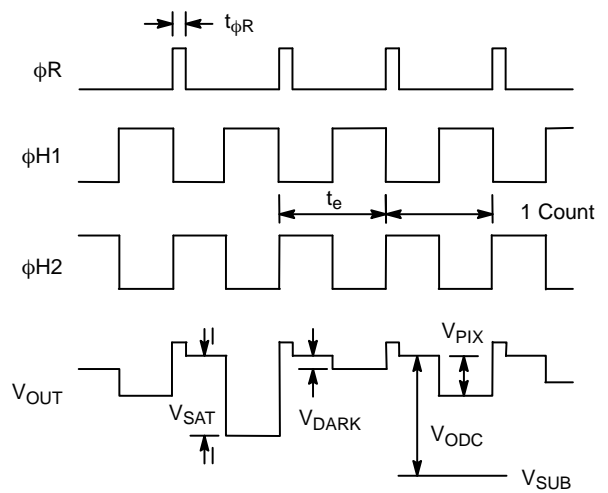
**Figure 7. Frame Timing**

Line Timing (Each Output)

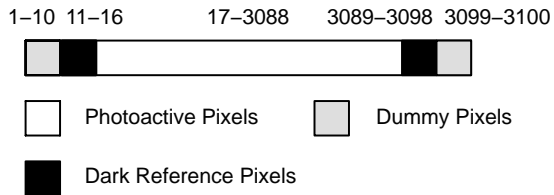
Line Timing Detail



Pixel Timing Detail



Line Content



- $V_{SAT}$  Saturated pixel video output signal
- $V_{DARK}$  Video output signal in no-light situation, not zero due to  $J_{DARK}$
- $V_{PIX}$  Pixel video output signal level, more electrons = more negative\*
- $V_{ODC}$  Video level offset with respect to  $V_{SUB}$
- $V_{SUB}$  Analog ground

\* See Image Acquisition section (Page 3).

Figure 8. Timing Diagrams

**STORAGE AND HANDLING**

**Table 11. STORAGE CONDITIONS**

| Description           | Symbol          | Minimum | Maximum | Unit | Notes |
|-----------------------|-----------------|---------|---------|------|-------|
| Storage Temperature   | T <sub>ST</sub> | 0       | 70      | °C   | 1     |
| Operating Temperature | T <sub>OP</sub> | -60     | 60      | °C   |       |

1. Storage toward the maximum temperature will accelerate color filter degradation.

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](http://www.onsemi.com).

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

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

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

For information on Standard terms and Conditions of Sale, please download [Terms and Conditions](#) from [www.onsemi.com](http://www.onsemi.com).

MECHANICAL INFORMATION

Completed Assembly

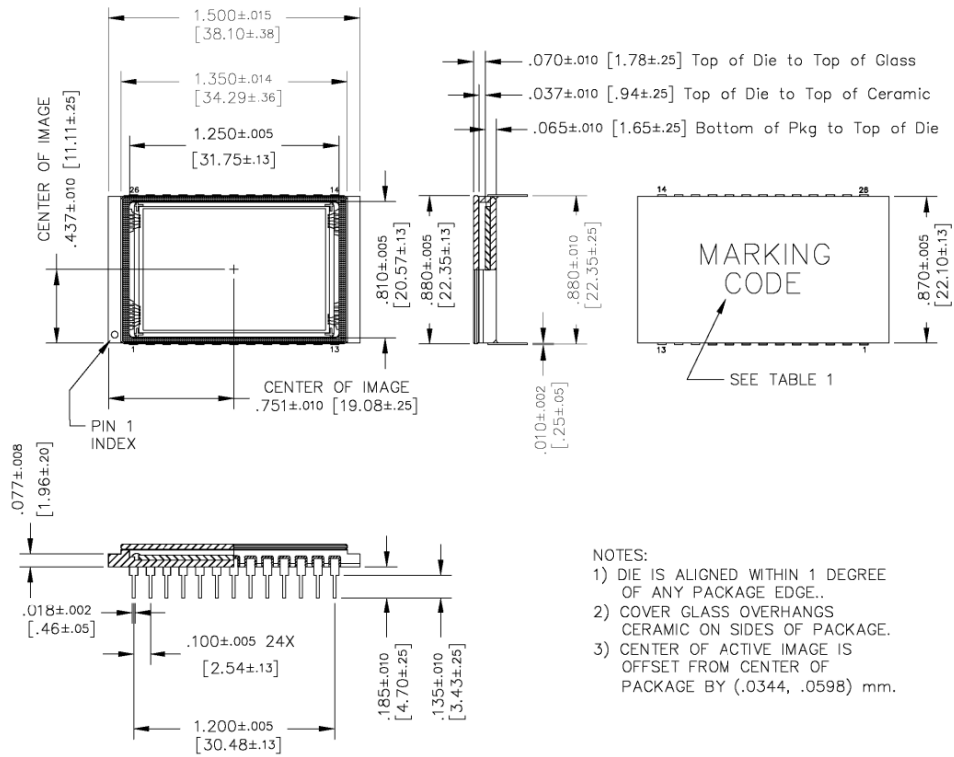
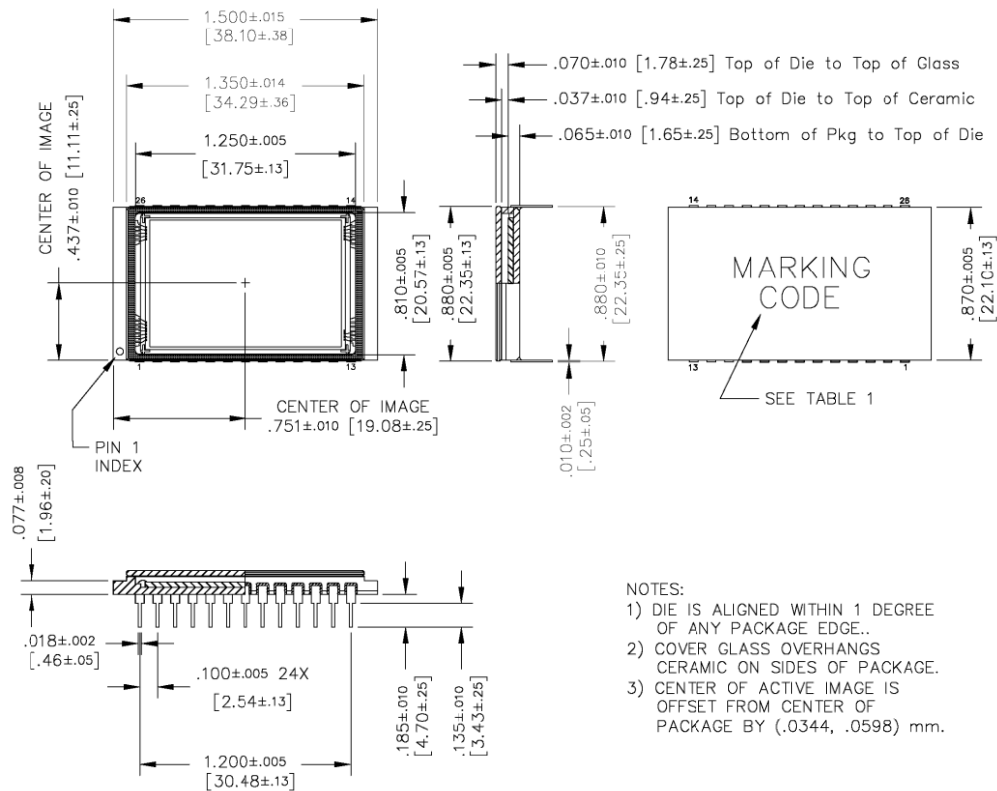



Figure 9. Completed Assembly (1 of 2)



- NOTES:
- 1) DIE IS ALIGNED WITHIN 1 DEGREE OF ANY PACKAGE EDGE..
  - 2) COVER GLASS OVERHANGS CERAMIC ON SIDES OF PACKAGE.
  - 3) CENTER OF ACTIVE IMAGE IS OFFSET FROM CENTER OF PACKAGE BY (.0344, .0598) mm.

Figure 10. Completed Assembly (2 of 2)

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