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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 μ m (H) x 9 μ m (V)
Active Image Size	27.65 mm (H) x 18.48 mm (V) 33.4 mm (Diagonal) APS-H Optical Format
Chip Size	29.0 mm (H) x 19.1 mm (V)
Saturation Signal	100,000 e ⁻
Output Sensitivity	10 μ V/e ⁻
Quantum Efficiency (450, 550, 650 nm)	40%, 52%, 65%
Readout Noise (10 MHz)	15 e ⁻ rms
Dark Current (Accumulation Mode)	< 10 pA/cm ²
Dark Current Doubling Rate	6°C
Dynamic Range (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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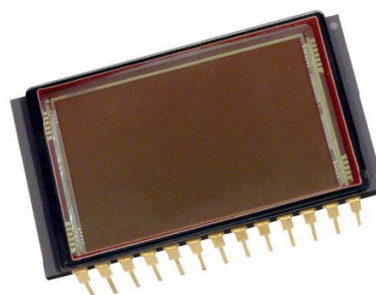


Figure 1. KAF-6303 Full Frame CCD Image Sensor

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 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.

KAF-6303

DEVICE DESCRIPTION

Architecture

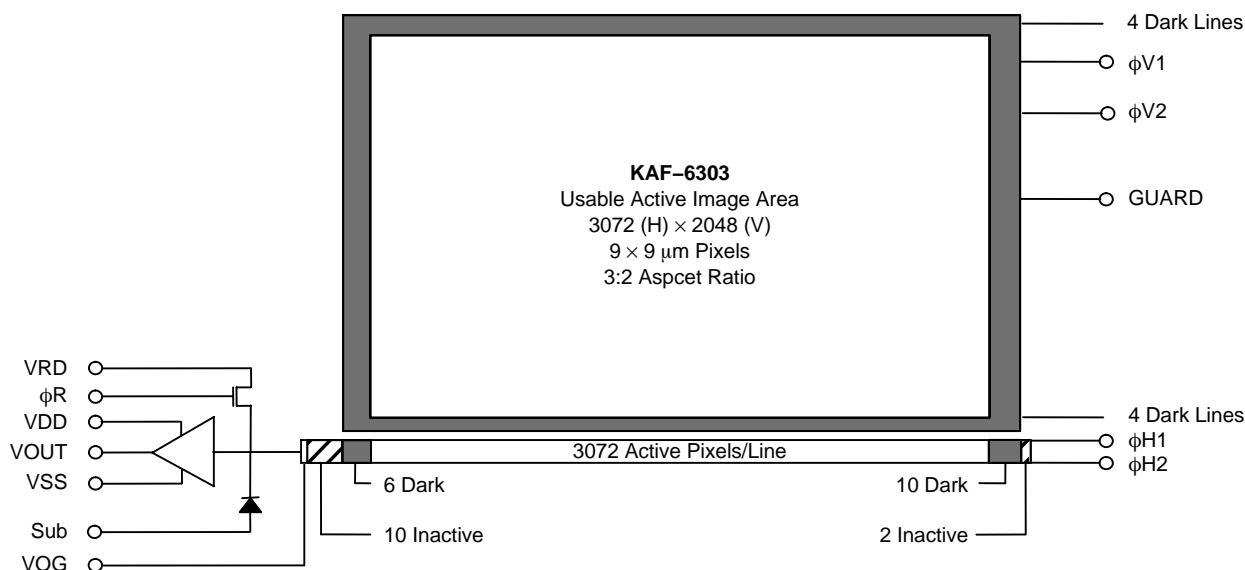


Figure 2. Block Diagram

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.

KAF-6303

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 (ϕ_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.

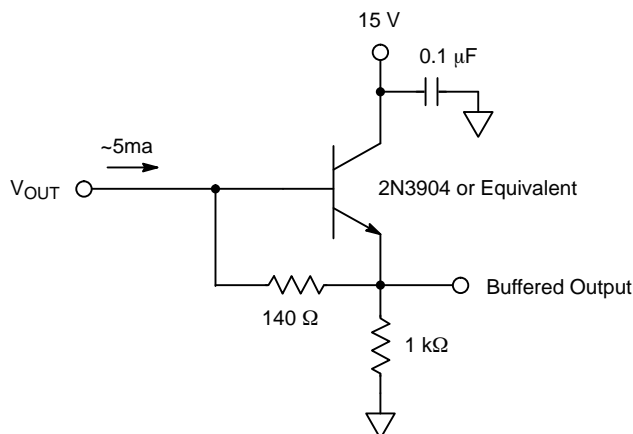


Figure 3. Typical Output Structure Load Diagram

KAF-6303

Physical Description

Pin Description and Device Orientation

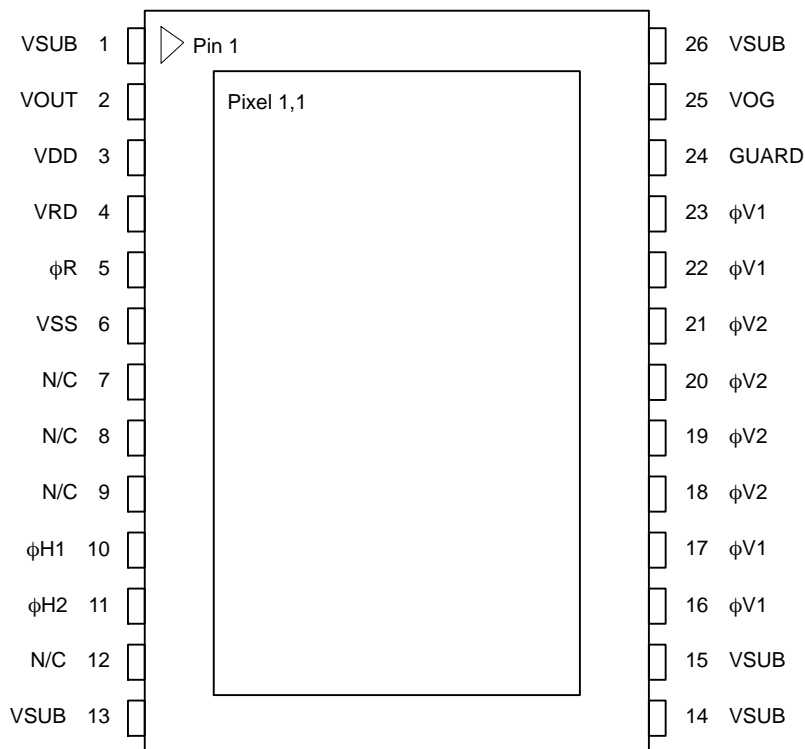


Figure 4. Pinout Diagram

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	$\phi H1$	Horizontal CCD Clock – Phase 1
11	$\phi H2$	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	$\phi V1$	Vertical CCD Clock – Phase 1
17	$\phi V1$	Vertical CCD Clock – Phase 1
18	$\phi V2$	Vertical CCD Clock – Phase 2
19	$\phi V2$	Vertical CCD Clock – Phase 2
20	$\phi V2$	Vertical CCD Clock – Phase 2
21	$\phi V2$	Vertical CCD Clock – Phase 2
22	$\phi V1$	Vertical CCD Clock – Phase 1
23	$\phi V1$	Vertical CCD Clock – Phase 1
24	GUARD	Guard Ring
25	VOG	Output Gate
26	VSUB	Substrate (Ground)

KAF-6303

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

1. 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.
2. Worst-case deviation from straight line fit, between 1% and 90% of V_{SAT} .
3. One Sigma deviation of a 128×128 sample when CCD illuminated uniformly.
4. Average of all pixels with no illumination at 25°C.
5. Average dark signal of any of 12×8 blocks within the sensor (each block is 128×128 pixels).
6. $20\text{Log}(N_{SAT} / n_{e^-})$ at nominal operating frequency and 25°C.
7. Video level offset with respect to ground.
8. Last output amplifier stage only. Assumes 10 pF off-chip load.
9. Output noise at 25°C, nominal operating frequency, and $t_{INT} = 0$.
10. A parameter that is measured on every sensor during production testing.
11. A parameter that is quantified during the design verification activity.

KAF-6303

TYPICAL PERFORMANCE CURVES

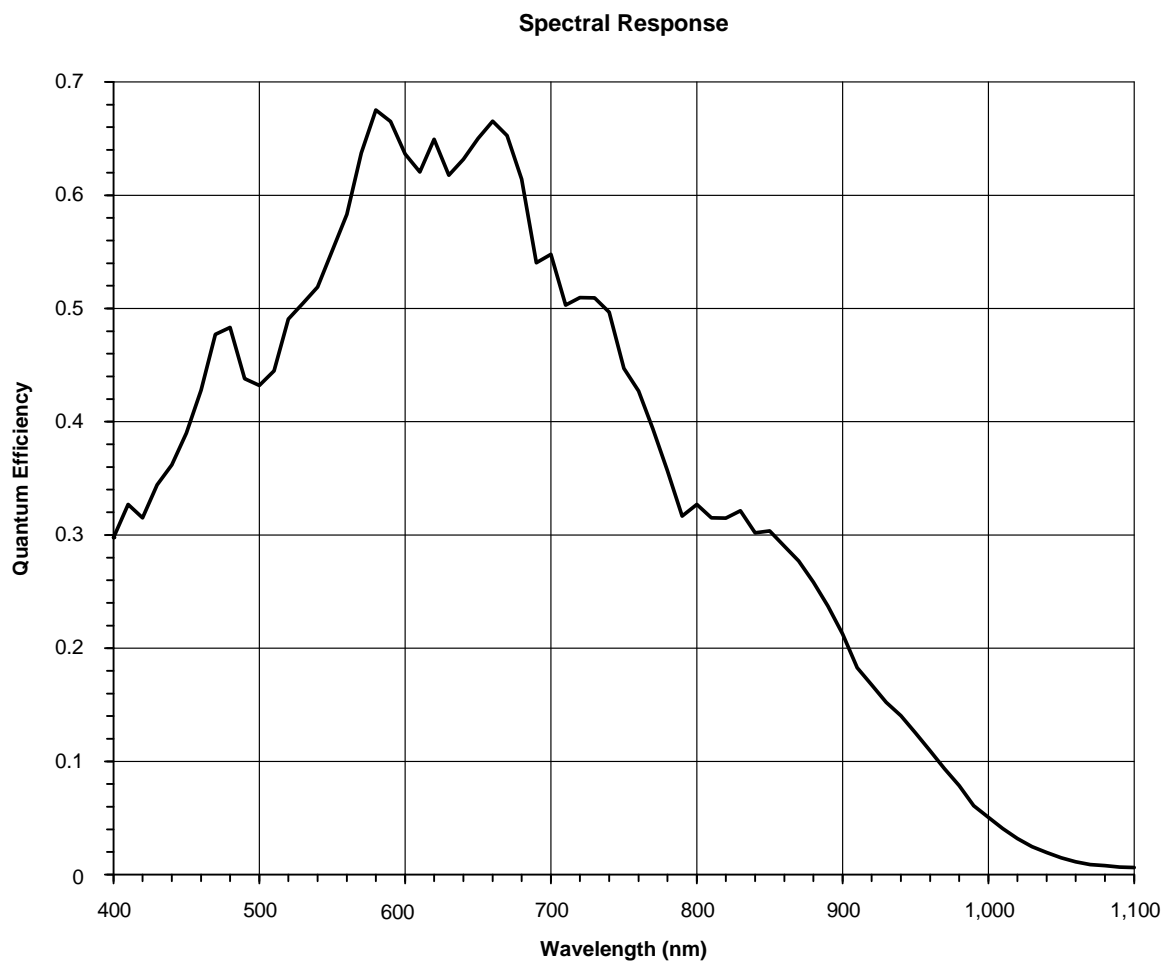


Figure 5. Typical Spectral Response

KAF-6303

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⁻/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⁻/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⁻.

A column that loses > 250 e⁻ under 2 ke⁻ 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.

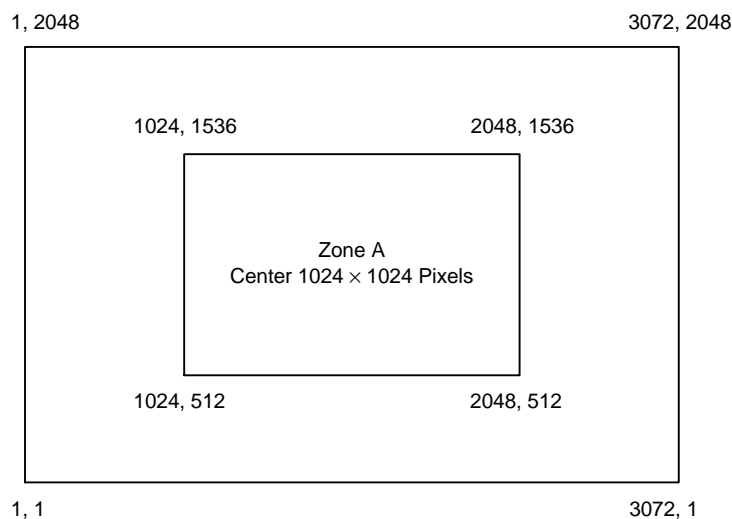


Figure 6. Active Pixel Region

KAF-6303

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: ϕR , 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	ϕR	Low	–4.0	–3.0	–2.0	V	10 pF
Reset Clock	ϕR	High	3.5	4.0	5.0	V	10 pF

1. All pins draw less than 10 μA DC current.
2. Capacitance values relative to V_{SUB}.

KAF-6303

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	–	μs	
$\phi V1$, $\phi V2$ Clock Pulse Width	$t_{\phi V}$	10	20	–	μs	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	–	μs	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. ϕR 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

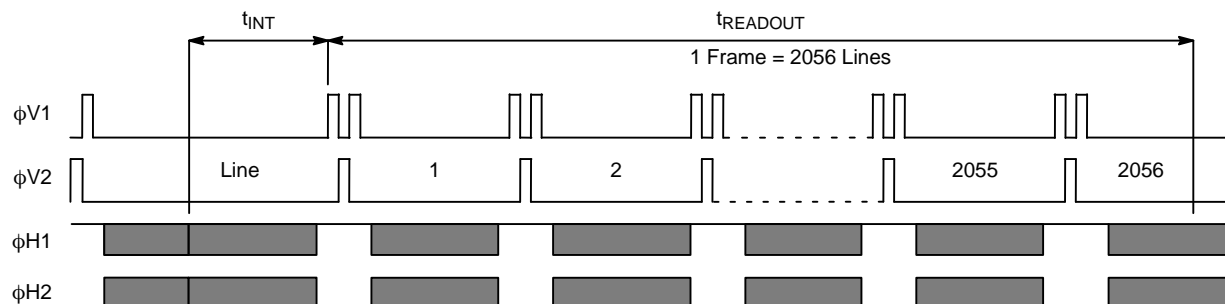
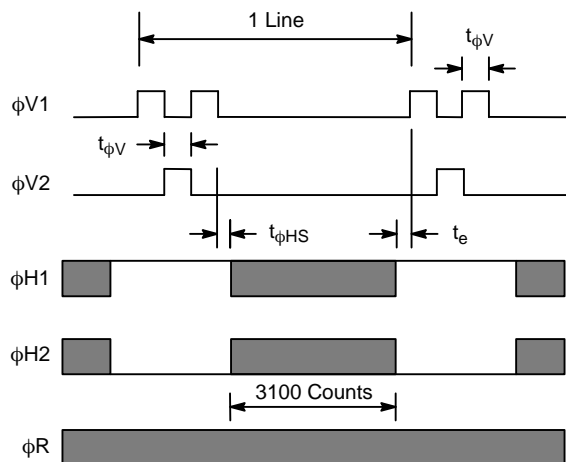


Figure 7. Frame Timing

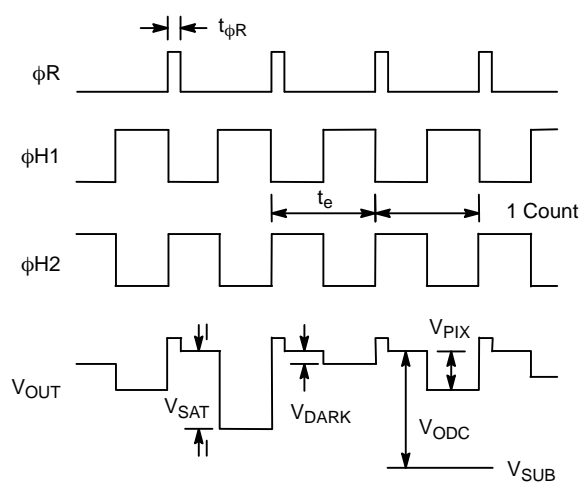
KAF-6303

Line Timing (Each Output)

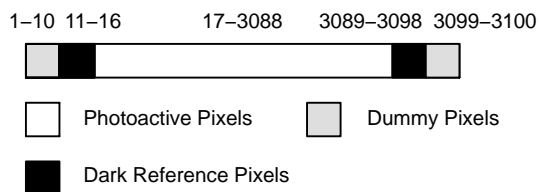
Line Timing Detail



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

KAF-6303

STORAGE AND HANDLING

Table 11. STORAGE CONDITIONS

Description	Symbol	Minimum	Maximum	Unit	Notes
Storage Temperature	T _{ST}	0	70	°C	1
Operating Temperature	T _{OP}	-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.

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.

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MECHANICAL INFORMATION

Completed Assembly

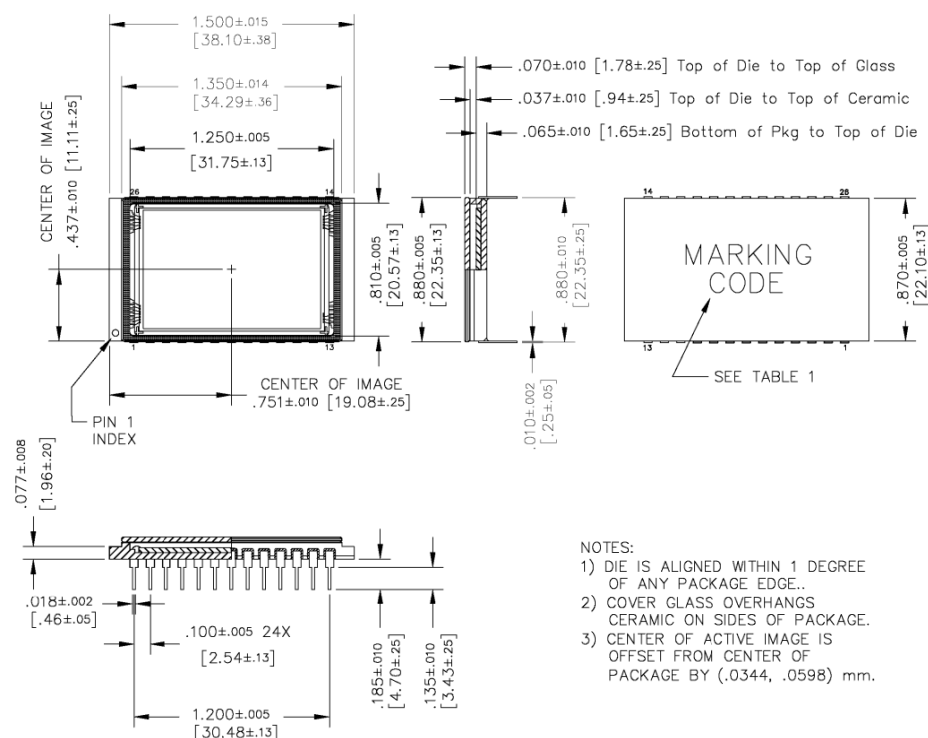


Figure 9. Completed Assembly (1 of 2)

KAF-6303

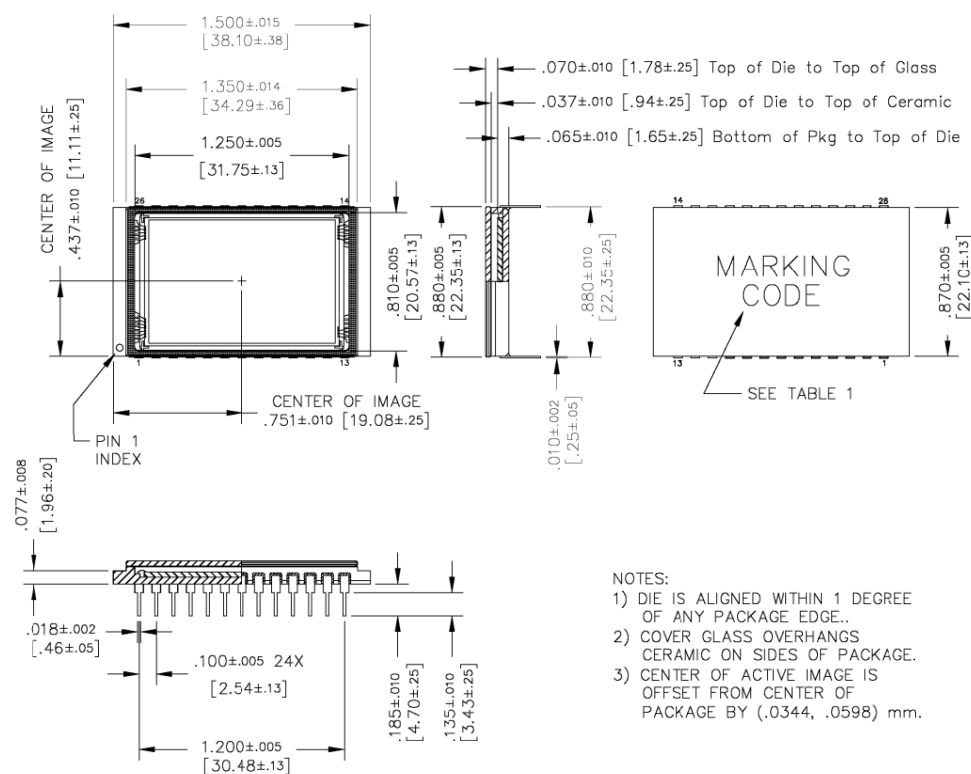



Figure 10. Completed Assembly (2 of 2)

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