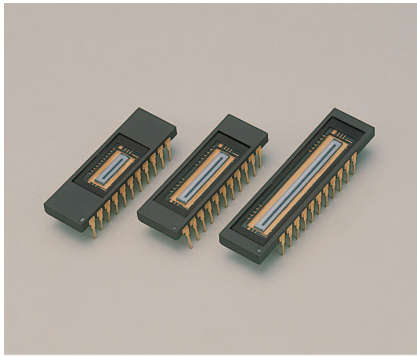


# NMOS linear image sensor



S3922/S3923 series

## Voltage output type with current-integration readout circuit and impedance conversion circuit

NMOS linear image sensors are self-scanning photodiode arrays designed specifically as detectors for multichannel spectroscopy. The scanning circuit is made up of N-channel MOS transistors, operates at low power consumption and is easy to handle. Each photodiode has a large active area, high UV sensitivity yet very low noise, delivering a high S/N even at low light levels. NMOS linear image sensors also offer excellent output linearity and wide dynamic range.

S3922/S3923 series have a current-integration readout circuit utilizing the video line and an impedance conversion circuit. The output is available in boxcar waveform allowing signal readout with a simple external circuit.

The photodiodes of S3922 series have a height of 0.5 mm and are arrayed in a row at a spacing of 50  $\mu\text{m}$ . The photodiodes of S3923 series also have a height of 0.5 mm but are arrayed at a spacing of 25  $\mu\text{m}$ . The photodiodes are available in 3 different pixel quantities for each series, 128 (S3922-128Q), 256 (S3922-256Q, S3923-256Q) and 512 (S3922-512Q, S3923-512Q) and 1024 (S3923-1024Q). Quartz glass is the standard window material.

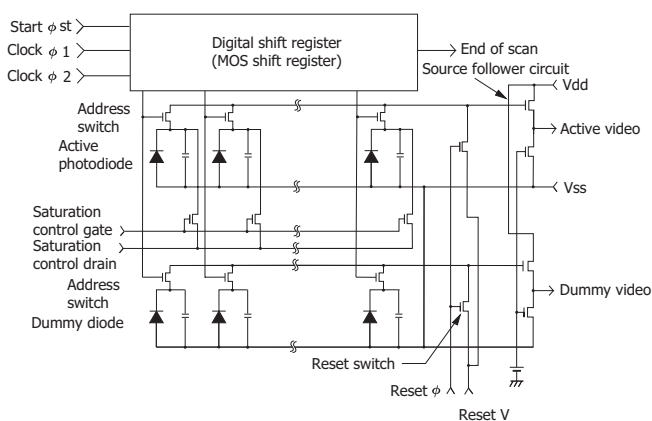
### Features

- Built-in current-integration readout circuit utilizing video line capacitance and impedance conversion circuit (boxcar waveform output)
- Wide active area  
Pixel pitch: 50  $\mu\text{m}$  (S3922 series)  
25  $\mu\text{m}$  (S3923 series)  
Pixel height: 0.5 mm
- High UV sensitivity with good stability
- Low dark current and high saturation charge allow a long integration time and a wide dynamic range at room temperature.
- Excellent output linearity and sensitivity spatial uniformity
- Low voltage, single power supply operation
- Start pulse, clock pulse and video line reset pulse are CMOS logic compatible.

### Applications

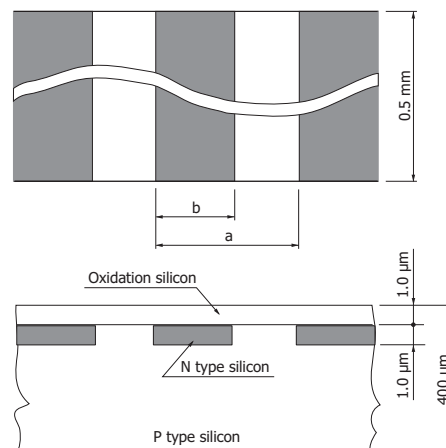
- Multichannel spectrophotometry
- Image readout system

### Equivalent circuit



KMPDC0019EA

### Active area structure



S3922 series: a=50  $\mu\text{m}$ , b=45  $\mu\text{m}$   
S3923 series: a=25  $\mu\text{m}$ , b=20  $\mu\text{m}$

**▣ Absolute maximum ratings**

Parameter	Symbol	Value	Unit
Supply voltage	Vdd	15	V
Input pulse ( $\phi_1$ , $\phi_2$ , $\phi_{st}$ , Reset $\phi$ ) voltage	V $\phi$	15	V
Power consumption*1	P	10	mW
Operating temperature*2	Topr	-40 to +65	°C
Storage temperature	Tstg	-40 to +85	°C

\*1: Vdd=5 V, Vr=2.5 V

\*2: No condensation

**▣ Shape specifications**

Parameter	S3922-128Q	S3922-256Q	S3922-512Q	S3923-256Q	S3923-512Q	S3923-1024Q	Unit
Number of pixels	128	256	512	256	512	1024	-
Package length	31.75		40.6	31.75		40.6	mm
Number of pin	22			22			-
Window material	Quartz			Quartz			-
Weight	3.0		3.5	3.0		3.5	g

**▣ Specifications (Ta=25 °C)**

Parameter	Symbol	S3922 series			S3923 series			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Pixel pitch	-	-	50	-	-	25	-	μm
Pixel height	-	-	0.5	-	-	0.5	-	mm
Spectral response range (10% of peak)	$\lambda$	200 to 1000			200 to 1000			nm
Peak sensitivity wavelength	$\lambda_p$	-	600	-	-	600	-	nm
Photodiode dark current*3	Id	-	0.08	0.15	-	0.04	0.08	pA
Photodiode capacitance*3	Cph	-	3.6	-	-	1.8	-	pF
Saturation exposure*3 *4	Esat	-	220	-	-	220	-	m $\lambda$ · s
Saturation charge*3	Qsat	-	10	-	-	5	-	pC
Saturation output voltage*3	Vsat	-	900 (-128Q)	-	-	420 (-256Q)	-	mV
		-	670 (-256Q)	-	-	280 (-512Q)	-	
		-	460 (-512Q)	-	-	160 (-1024Q)	-	
Photo response non-uniformity*5	PRNU	-	-	±3	-	-	±3	%

\*3: Reset V=2.5 V, Vdd=5.0 V, V $\phi$ =5.0 V

\*4: 2856 K, tungsten lamp

\*5: 50% of saturation, excluding the start pixel and last pixel

Electrical characteristics (Ta=25 °C)

Parameter	Symbol	Condition	S3922 series			S3923 series			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	
Clock pulse (φ1, φ2) voltage	High	Vφ1, Vφ2 (H)	4.5	5	10	4.5	5	10	V
	Low	Vφ1, Vφ2 (L)	0	-	0.4	0	-	0.4	V
Start pulse (φst) voltage	High	Vφst (H)	4.5	Vφ1	10	4.5	Vφ1	10	V
	Low	Vφst (L)	0	-	0.4	0	-	0.4	V
Reset pulse (Reset φ) voltage	High	Vrφ (H)	4.5	Vφ1	10	4.5	Vφ1	10	V
	Low	Vrφ (L)	0	-	0.4	0	-	0.4	V
Source follower circuit drain voltage	Vdd		4.5	Vφ	10	4.5	Vφ	10	V
Reset voltage (Reset V) <sup>*6 *7</sup>	Vr		2.0	Vφ - 2.5	Vφ - 2.0	2.0	Vφ - 2.5	Vφ - 2.0	V
Saturation control gate voltage	Vscg		-	0	-	-	0	-	V
Saturation control drain voltage <sup>*7</sup>	Vscd		-	Vr	-	-	Vr	-	V
Clock pulse (φ1, φ2) rise / fall time	trφ1, trφ2 tfφ1, tfφ2		-	20	-	-	20	-	ns
Clock pulse (φ1, φ2) pulse width	tpwφ1, tpwφ2		200	-	-	200	-	-	ns
Start pulse (φst) rise / fall time	trφst, tfφst		-	20	-	-	20	-	ns
Start pulse (φst) pulse width	tpwφst		200	-	-	200	-	-	ns
Reset pulse rise / fall time	trrφ, tfrφ		-	20	-	-	20	-	ns
Start pulse (φst) and clock pulse (φ2) overlap	tφov		200	-	-	200	-	-	ns
Clock pulse (φ2) and reset pulse (Reset φ) overlap	tφovr		660	-	-	660	-	-	ns
Clock pulse (φ2) and reset pulse (Reset φ) delay time	tdφr-2		50	-	-	50	-	-	ns
Clock pulse (φ1, φ2) space <sup>*8</sup>	X1, X2		trf - 20	-	-	trf - 20	-	-	ns
Clock pulse (φ2, Reset φ) space	tsφr-2		0	-	-	0	-	-	ns
Data rate <sup>*9</sup>	f		0.1	-	500	0.1	-	500	kHz
Video delay time	tvd	50% of saturation <sup>*9</sup>	-	100 (-128 Q)	-	-	100 (-256 Q)	-	ns
			-	150 (-256 Q)	-	-	150 (-512 Q)	-	ns
			-	200 (-512 Q)	-	-	200 (-1024 Q)	-	ns
Clock pulse (φ1, φ2) line capacitance	Cφ	5 V bias	-	21 (-128 Q)	-	-	27 (-256 Q)	-	pF
			-	36 (-256 Q)	-	-	50 (-512 Q)	-	pF
			-	67 (-512 Q)	-	-	100 (-1024 Q)	-	pF
Reset pulse (Reset φ) line capacitance	Cr	5 V bias	-	6	-	-	6	-	pF
Saturation control gate (Vscg) line capacitance	Cscg	5 V bias	-	12 (-128 Q)	-	-	12 (-256 Q)	-	pF
			-	20 (-256 Q)	-	-	24 (-512 Q)	-	pF
			-	35 (-512 Q)	-	-	45 (-1024 Q)	-	pF
Output impedance	Zo	Vdd=5 V Vr=2.5 V	-	200	-	-	200	-	Ω

\*6: Vφ is input pulse voltage. (refer to P.7 "Reset V voltage margin")

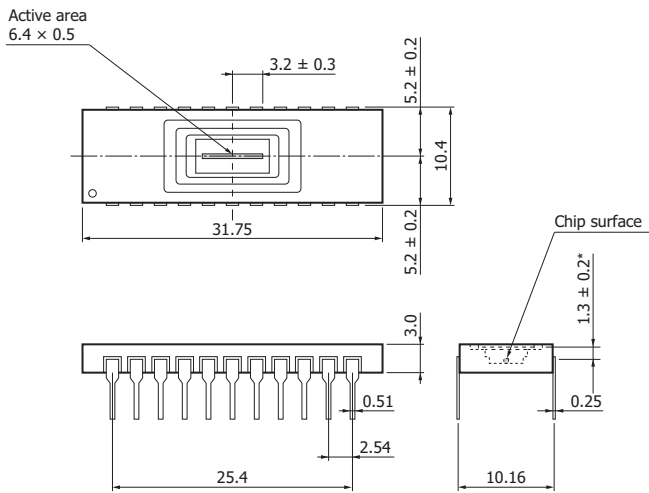
\*7: Terminal pin 7 is used for both Reset V and saturation control drain voltage.

\*8: trf is the clock pulse rise or fall time. A clock pulse space of "rise time/fall time - 20" ns or more should be input if the clock pulse rise or fall time is longer than 20 ns. (refer to P.7 "Timing chart for driver circuit")

\*9: Reset V=2.5 V, Vdd=5.0 V, Vφ =5.0 V

**Dimensional outlines (unit: mm)**

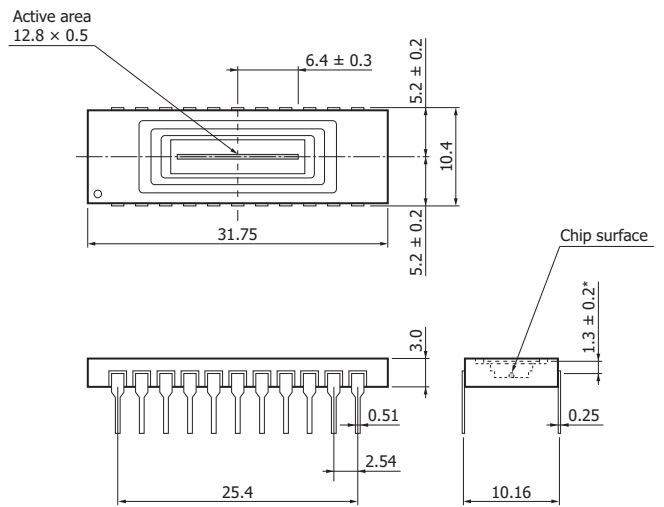
S3922-128Q, S3923-256Q



\* Optical distance from the outer surface of the quartz window to the chip surface

KMPDA0108EB

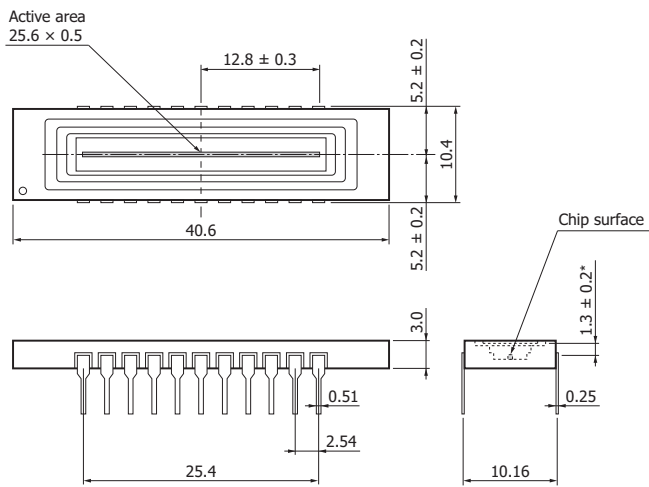
S3922-256Q, S3923-512Q



\* Optical distance from the outer surface of the quartz window to the chip surface

KMPDA0109EB

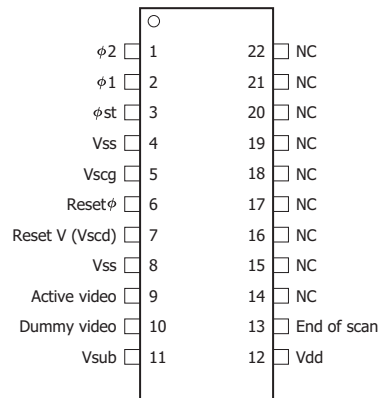
S3922-512Q, S3923-1024Q



\* Optical distance from the outer surface of the quartz window to the chip surface

KMPDA0110EB

**Pin connection**

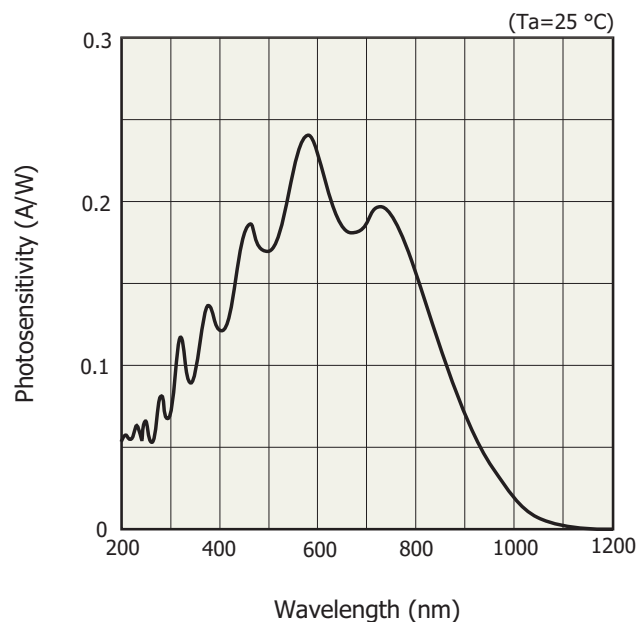


Vss, Vsub and NC should be grounded.

KMPDC0025EA

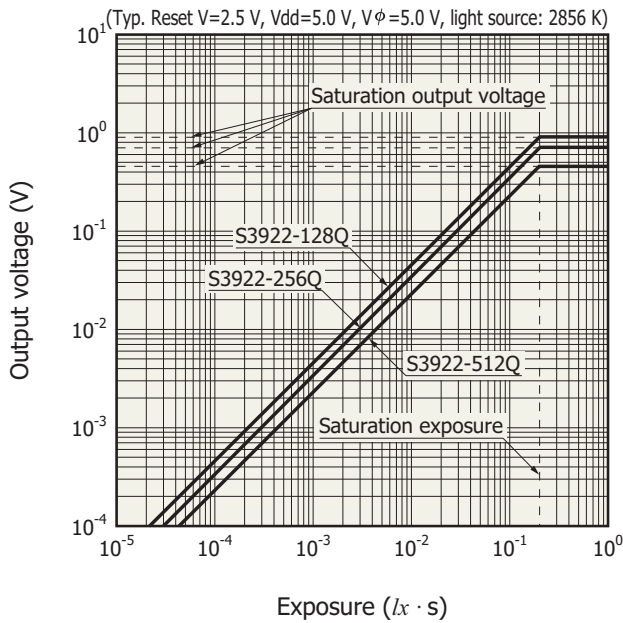
Terminal	Input or output	Description
$\phi 1, \phi 2$	Input (CMOS logic compatible)	Pulses for operating the MOS shift register. The video data rate is equal to the clock pulse frequency since the video output signal is obtained synchronously with the rise of $\phi 2$ pulse.
$\phi st$	Input (CMOS logic compatible)	Pulse for starting the MOS shift register operation. The time interval between start pulses is equal to the signal accumulation time.
Vss	-	Connected to the anode of each photodiode. This should be grounded.
Vscg	Input	Used for restricting blooming. This should be grounded.
Reset $\phi$	Input (CMOS logic compatible)	With Reset $\phi$ at high level, the video line is reset at the Reset V voltage.
Reset V	Input	The Reset V terminal connects to each photodiode cathode via the video line when the address turns on. A positive voltage should be applied to the Reset V terminal to use each photodiode at a reverse bias. Setting the Reset V voltage to 2.5 V is recommended when the amplitude of $\phi 1, \phi 2$ and Reset $\phi$ is 5 V. Terminal pin 7 is used for both Reset V and Vscd.
Vscd	Input	Used for restricting blooming. This should be biased at a voltage equal to Reset V.
Active video	Output	Low-impedance video output signal after internal current-voltage conversion. Negative-going output including DC offset.
Dummy video	Output	This has the same structure as the active video, but is not connected to photodiodes, so only DC offset is output. Leave this terminal open when not used.
Vsub	-	Connected to the silicon substrate. This should be grounded.
Vdd	Input	Supply voltage to the internal impedance conversion circuit. A voltage equal to the amplitude of each clock should be applied to this terminal.
End of scan	Output (CMOS logic compatible)	This should be pulled up at 5 V by using a 10 k $\Omega$ resistor. This is a negative going pulse that appears synchronously with the $\phi 2$ timing right after the last photodiode is addressed.
NC	-	Should be grounded.

**▣ Spectral response (typical example)**

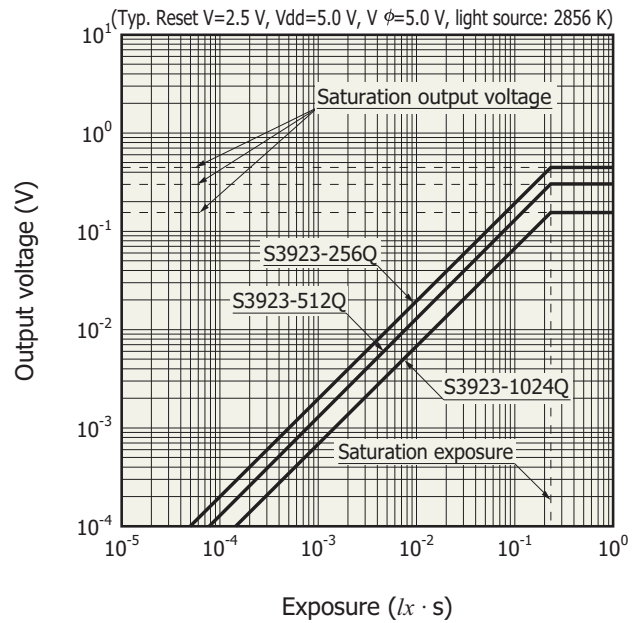


KMPDB0149EA

**Output voltage vs. exposure**



KMPDB0120EA



KMPDB0121EA

**Construction of image sensor**

The NMOS image sensor consists of a scanning circuit made up of MOS transistors, a photodiode array, and a switching transistor array that addresses each photodiode, all integrated onto a monolithic silicon chip. "Equivalent circuit" (see P.1) shows the circuit of a NMOS linear image sensor.

The MOS scanning circuit operates at low power consumption and generates a scanning pulse train by using a start pulse and 2-phase clock pulses in order to turn on each address sequentially. Each address switch is comprised of an NMOS transistor using the photodiode as the source, the video line as the drain and the scanning pulse input section as the gate.

The photodiode array operates in charge integration mode so that the output is proportional to the amount of light exposure (light intensity  $\times$  integration time).

Each cell consists of an active photodiode and a dummy diode, which are respectively connected to the active video line and the dummy video line via a switching transistor. Each of the active photodiodes is also connected to the saturation control drain via the saturation control gate, so that the photodiode blooming can be suppressed by grounding the saturation control gate. Applying a pulse signal to the saturation control gate triggers all reset. (See P.8 "Auxiliary functions".)

"Active area structure" (see P.1) shows the schematic diagram of the photodiode active area. This active area has a PN junction consisting of an N-type diffusion layer formed on a P-type silicon substrate.

A signal charge generated by light input accumulates as a capacitive charge in this PN junction. The N-type diffusion layer provides high UV sensitivity but low dark current.

**Driver circuit**

A start pulse  $\phi_{st}$  and 2-phase clock pulses  $\phi_1$ ,  $\phi_2$  are needed to drive the shift register. These start and clock pulses are positive going pulses and CMOS logic compatible.

The 2-phase clock pulses  $\phi_1$ ,  $\phi_2$  can be either completely separated or complementary. However, both pulses must not be "High" at the same time.

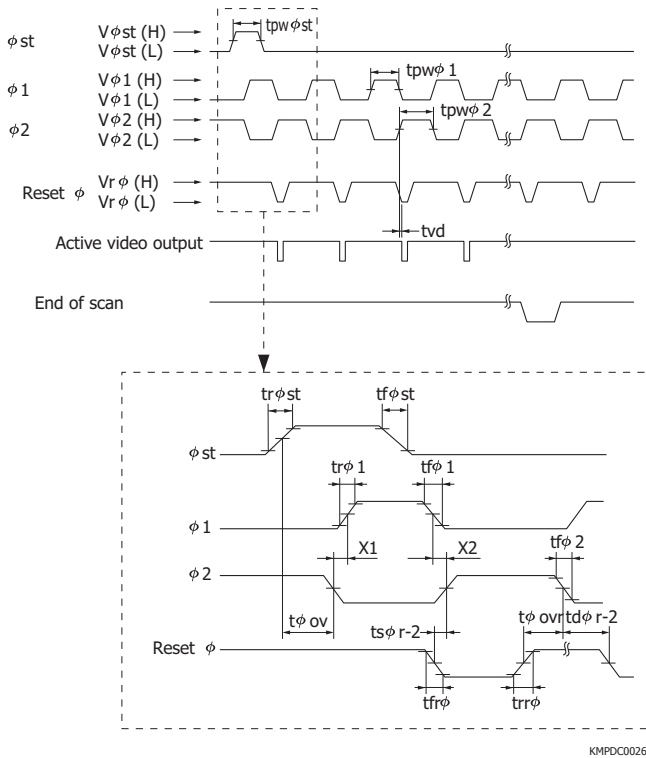
A clock pulse space [X1 and X2 in "Timing chart for driver circuit" (see P.7)] of a "rise time/fall time - 20" ns or more should be input if the rise and fall times of  $\phi_1$ ,  $\phi_2$  are longer than 20 ns. The  $\phi_1$  and  $\phi_2$  clock pulses must be held at "High" at least 200 ns. Since the photodiode signal is obtained at the rise of each  $\phi_2$  pulse, the clock pulse frequency will equal the video data rate.

The amplitude of start pulse  $\phi_{st}$  is the same as the  $\phi_1$  and  $\phi_2$  pulses. The shift register starts the scanning at the "High" level of  $\phi_{st}$ , so the start pulse interval is equal to signal accumulation time. The  $\phi_{st}$  pulse must be held "High" at least 200 ns and overlap with  $\phi_2$  at least for 200 ns. To operate the shift register correctly,  $\phi_2$  must change from the "High" level to the "Low" level only once during "High" level of  $\phi_{st}$ . The timing chart for each pulse is shown in "Timing chart for driver circuit".

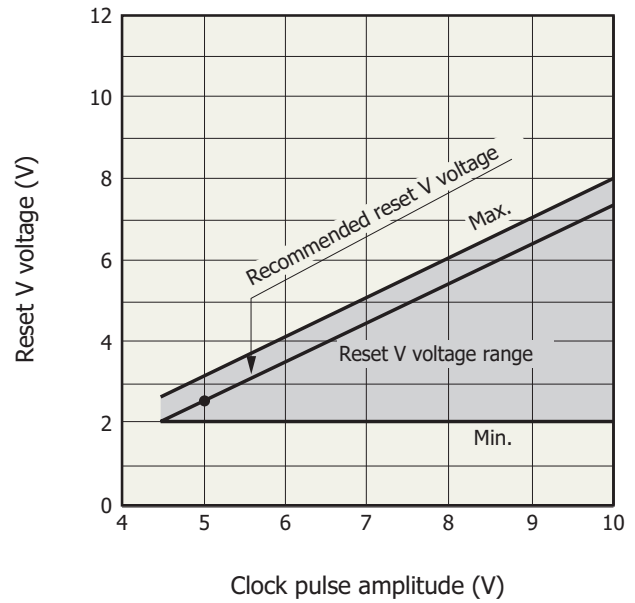
**End of scan**

The end of scan ( $\overline{EOS}$ ) signal appears in synchronization with the  $\phi_2$  timing right after the last photodiode is addressed, and the  $\overline{EOS}$  terminal should be pulled up at 5 V using a 10 k $\Omega$  resistor.

**Timing chart for driver circuit**



**Reset V voltage margin**



KMPD80047EA

**Signal readout circuit**

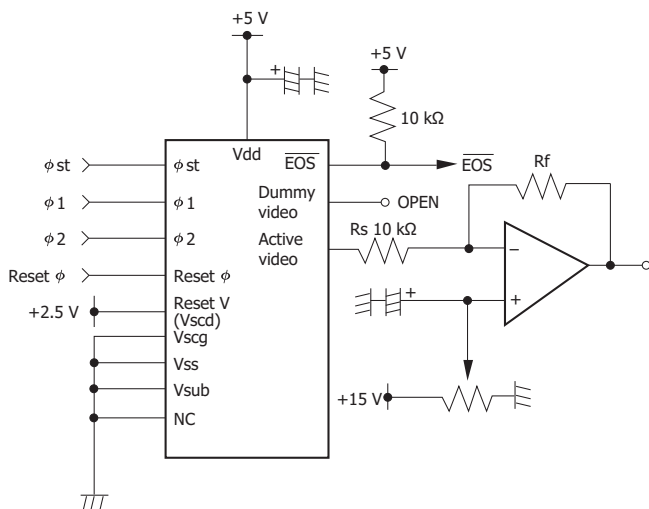
S3922/S3923 series include a current integration circuit utilizing the video line capacitance and an impedance conversion circuit. This allows signal readout with a simple external circuit. However, a positive bias must be applied to the video line because the photodiode anode of NMOS linear image sensors is at 0 V ( $V_{ss}$ ). This is done by adding an appropriate pulse to the  $\text{Reset } \phi$  terminal. The amplitude of the reset pulse should be equal to  $\phi_1$ ,  $\phi_2$  and  $\phi_{st}$ .

When the reset pulse is at the high level, the video line is set at the  $\text{Reset V}$  voltage. "Reset V voltage margin" shows the  $\text{Reset V}$  voltage margin. A higher clock pulse amplitude allows higher  $\text{Reset V}$  voltage and saturation charge. Conversely, if the  $\text{Reset V}$  voltage is set at a low level with a higher clock pulse amplitude, the rise and fall times of video output waveform can be shortened. Setting the  $\text{Reset V}$  voltage to 2.5 V is recommended when the amplitude of  $\phi_1$ ,  $\phi_2$ ,  $\phi_{st}$  and  $\text{Reset } \phi$  is 5 V.

To obtain a stable output, an overlap between the reset pulse ( $\text{Reset } \phi$ ) and  $\phi_2$  must be settled. ( $\text{Reset } \phi$  must rise while  $\phi_2$  is at the high level.) Furthermore,  $\text{Reset } \phi$  must fall while  $\phi_2$  is at the low level.

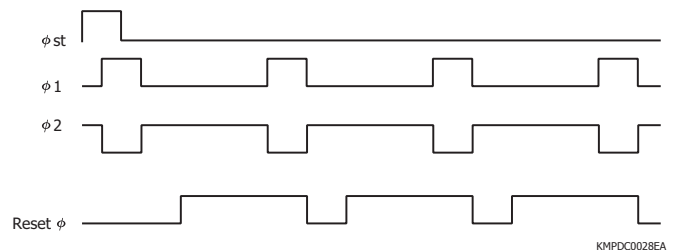
S3922/S3923 series provide output signals with negative-going boxcar waveform which include a DC offset of approximately 1 V when  $\text{Reset V}$  is 2.5 V. If you want to remove the DC offset to obtain the positive-going output, the signal readout circuit and pulse timing shown in "Readout circuit example" and "Timing chart" are recommended. In this circuit,  $R_s$  must be larger than 10 k $\Omega$ . Also, the gain is determined by the ratio of  $R_f$  to  $R_s$ , so choose the  $R_f$  value that suits your application.

**Readout circuit example**



KMPD80027EA

**Timing chart**



KMPD80028EA

■ **Anti-blooming function**

If the incident light intensity is higher than the saturation charge level, even partially, a signal charge in excess of the saturation charge cannot accumulate in the photodiode. This excessive charge flows out into the video line degrading the signal purity. To avoid this problem and maintain the signal purity, applying the same voltage as the Reset V voltage to the saturation control drain and grounding the saturation control gate are effective. If the incident light intensity is extremely high, a positive bias should be applied to the saturation control gate. The larger the voltage applied to the saturation control gate, the higher the function for suppressing the excessive saturation charge will be. However, this voltage also lowers the amount of saturation charge, so an optimum bias voltage should be selected.

■ **Auxiliary functions**

1) All reset

In normal operation, the accumulated charge in each photodiode is reset when the signal is read out. Besides this method that uses the readout line, S3922/S3923 series can reset the photodiode charge by applying a pulse to the saturation control gate. The amplitude of this pulse should be equal to the  $\phi_1$ ,  $\phi_2$ ,  $\phi_{st}$ , Reset  $\phi$  pulses and the pulse width should be longer than 5  $\mu$ s.

When the saturation control gate is set at the "High" level, all photodiodes are reset to the saturation control drain potential (equal to video bias). Conversely, when the saturation control gate is set at the "Low" level (0 V), the signal charge accumulates in each photodiode without being reset.

2) Dummy video

S3922/S3923 series have a dummy video line. Positive-polarity video signals with the DC offset remove can be obtained by differential amplification of the active video line and dummy video line outputs. When not needed, leave this unconnected.

■ **Precautions for using NMOS linear image sensors**

1) Electrostatic countermeasures

NMOS linear image sensors are designed to resist static electrical charges. However, take sufficient cautions and countermeasures to prevent damage from static charges when handling the sensors.

2) Window

If dust or grime sticks to the surface of the light input window, it appears as a black blemish or smear on the image. Before using the image sensor, the window surface should be cleaned. Wipe off the window surface with a soft cloth, cleaning paper or cotton swab slightly moistened with organic solvent such as alcohol, and then lightly blow away with compressed air. Do not rub the window with dry cloth or cotton swab as this may generate static electricity.

■ **Related information**

[www.hamamatsu.com/sp/ssd/doc\\_en.html](http://www.hamamatsu.com/sp/ssd/doc_en.html)

■ **Precautions**

- Disclaimer
- Image sensors

Information described in this material is current as of March 2017.

Product specifications are subject to change without prior notice due to improvements or other reasons. This document has been carefully prepared and the information contained is believed to be accurate. In rare cases, however, there may be inaccuracies such as text errors. Before using these products, always contact us for the delivery specification sheet to check the latest specifications.

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