INTERNATIONAL IMAGE SENSOR SOCIETY

A 2.1µm High Dynamic Range CMOS Image Sensor with Sub-pixel and Lateral Overflow Integration Capacitor Architecture

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Outline

- Background and Concept
- Key Technology
- Sensor Characteristics
- Conclusion

Background

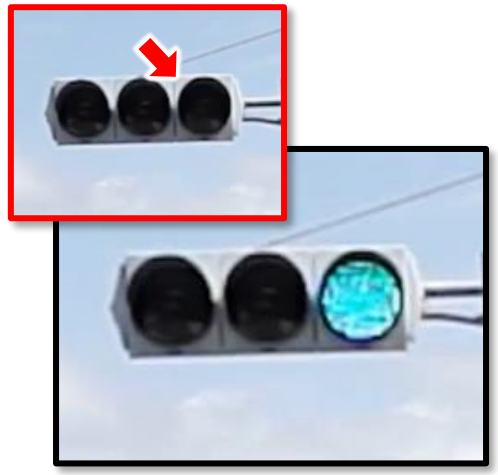
Many indicators required for automotive sensors

HDR

High Temp. SNR

High Sensitivity

LFM



We solve these issues with a new image sensor architecture

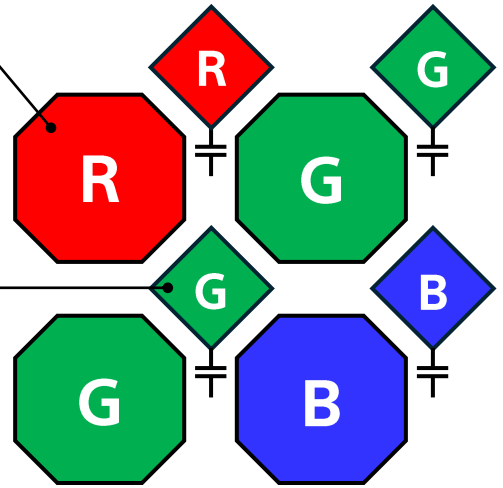
Concept

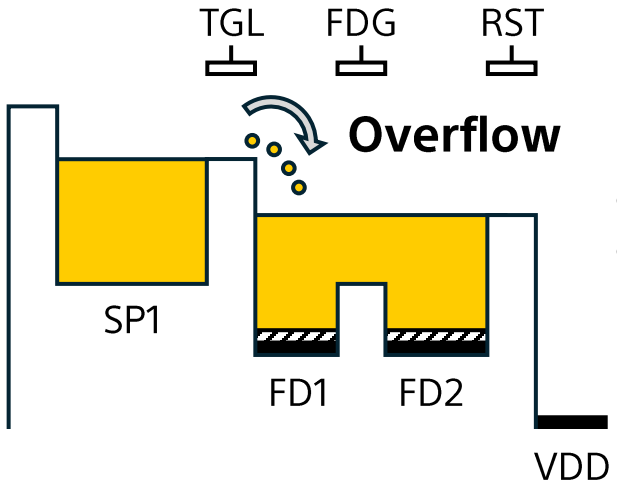
Combines Sub-pixel and LOFIC architecture to achieve HDR, High SNR, High sensitivity and LFM

Sub-pixel + **LOFIC**

Large PD (SP1)
- High sensitivity
- Low noise

Small PD (SP2)
- Low sensitivity
- High capacitance FC





- High capacitance EC
- Voltage controllable capacitor electrode

SP1 : Sub-pixel 1
SP2 : Sub-pixel 2
FC : Floating Capacitor

LOFIC : Lateral Overflow Integration Capacitor
EC : Extra Capacitor

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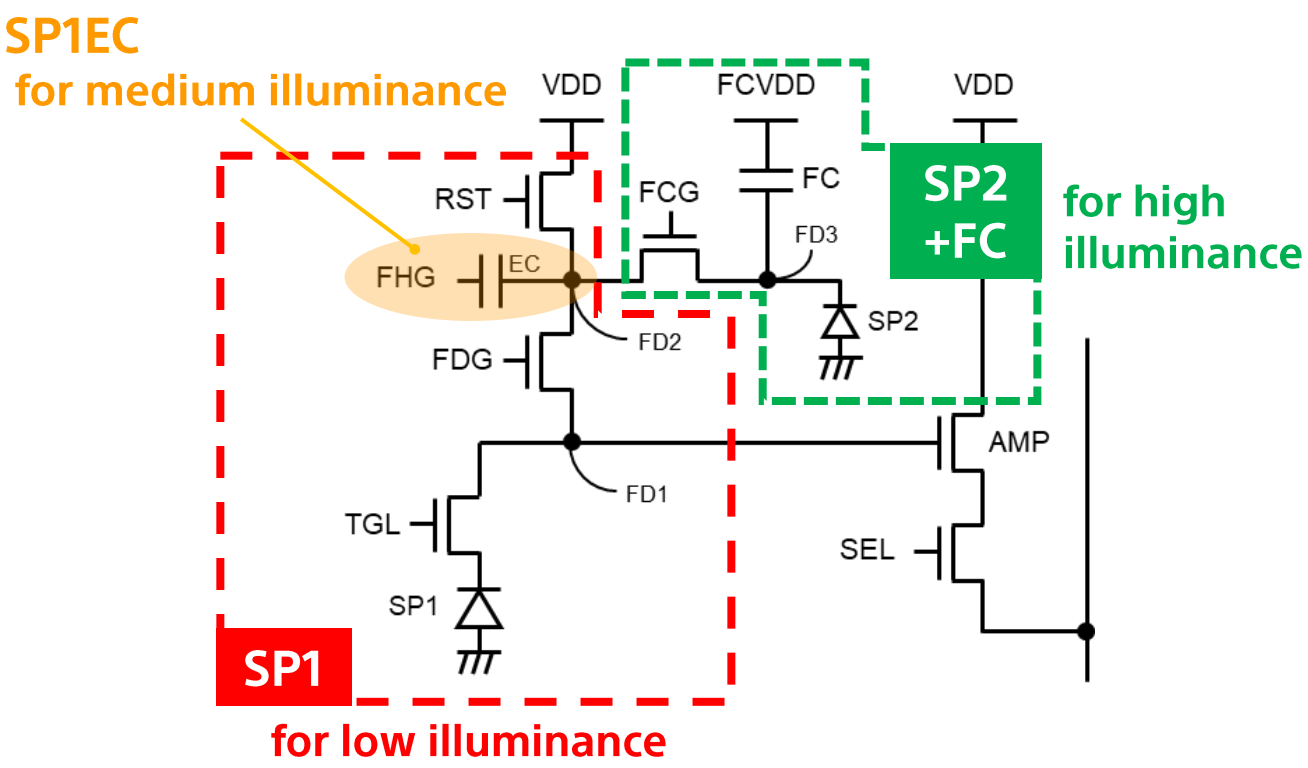
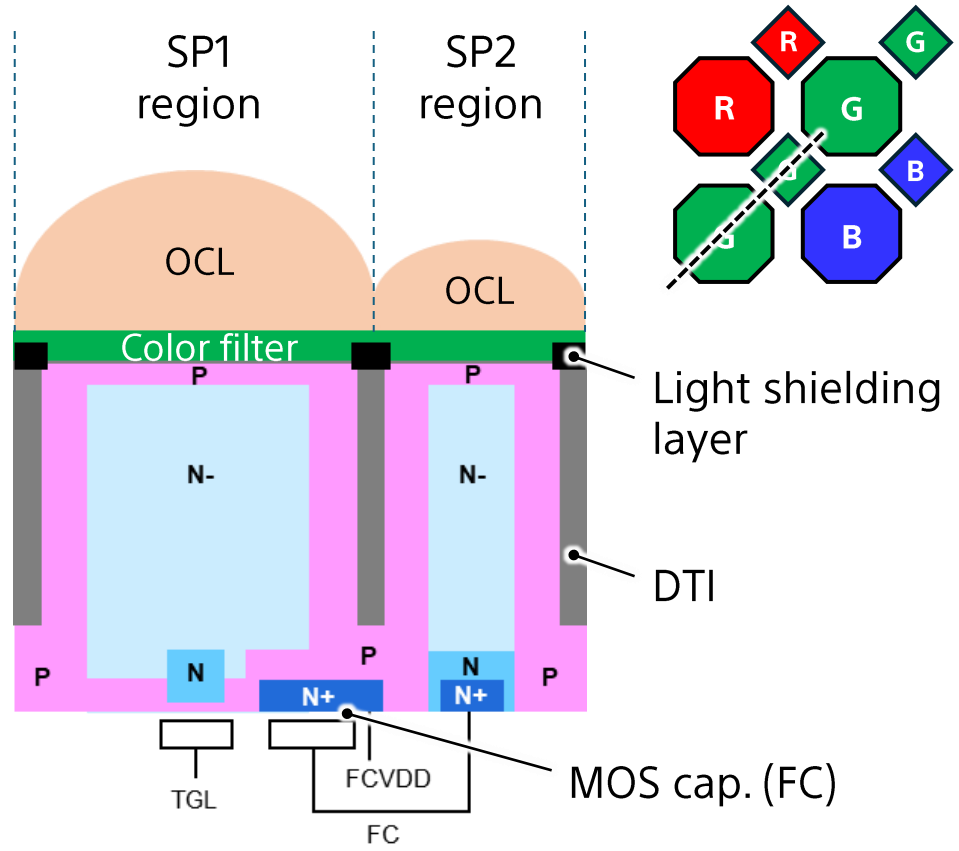
Key Technology : Pixel Architecture

Made up of Large pixel SP1 , SP1EC and Small pixel SP2 + FC

Pixel Circuit



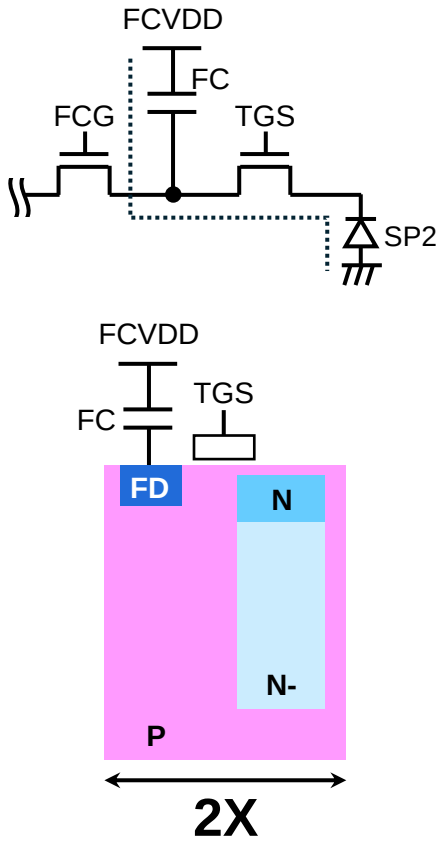
Pixel Structure



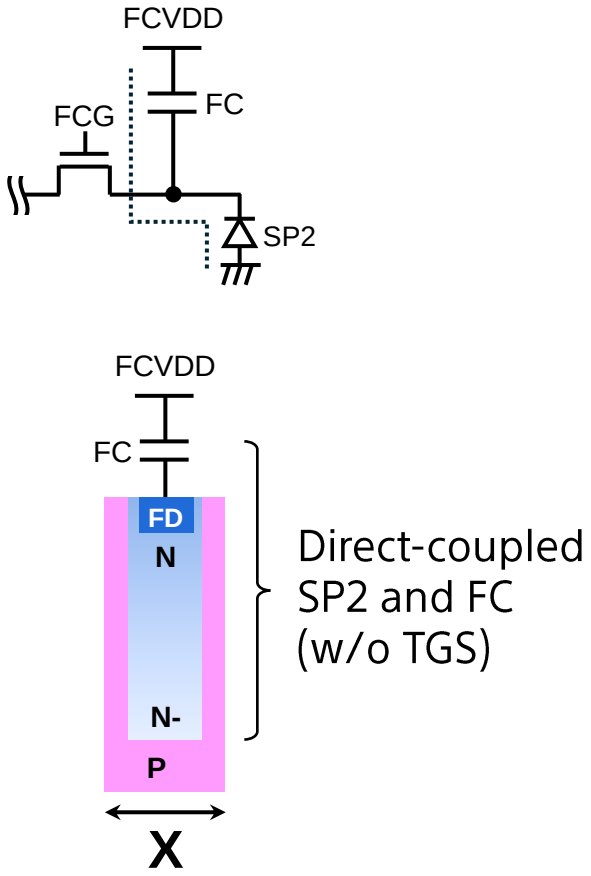
Key Technology : Small Photodiode(SP2) design

SP2 area minimizes to 50% with a direct-coupled technology

Conventional

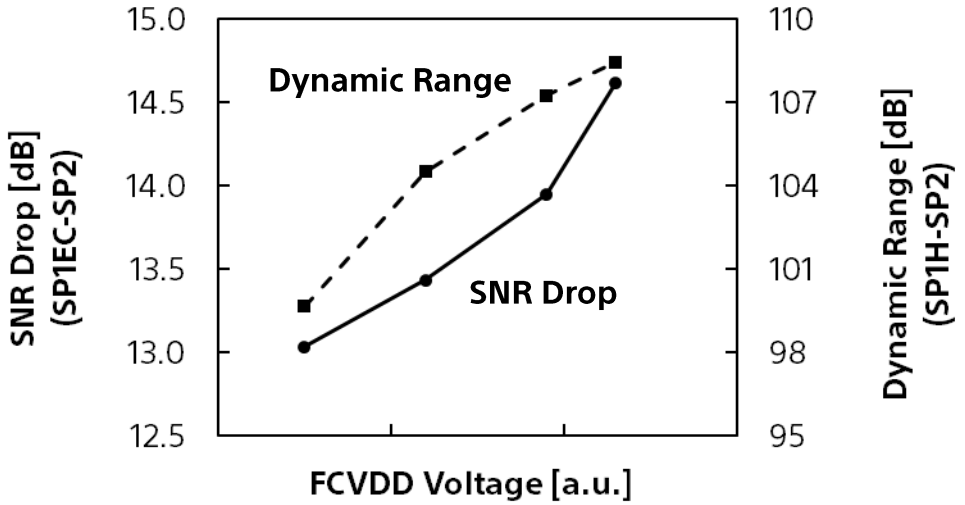


This work



Direct-coupled SP2 and FC (w/o TGS)

FCVDD dependency of SNR drop and Dynamic Range



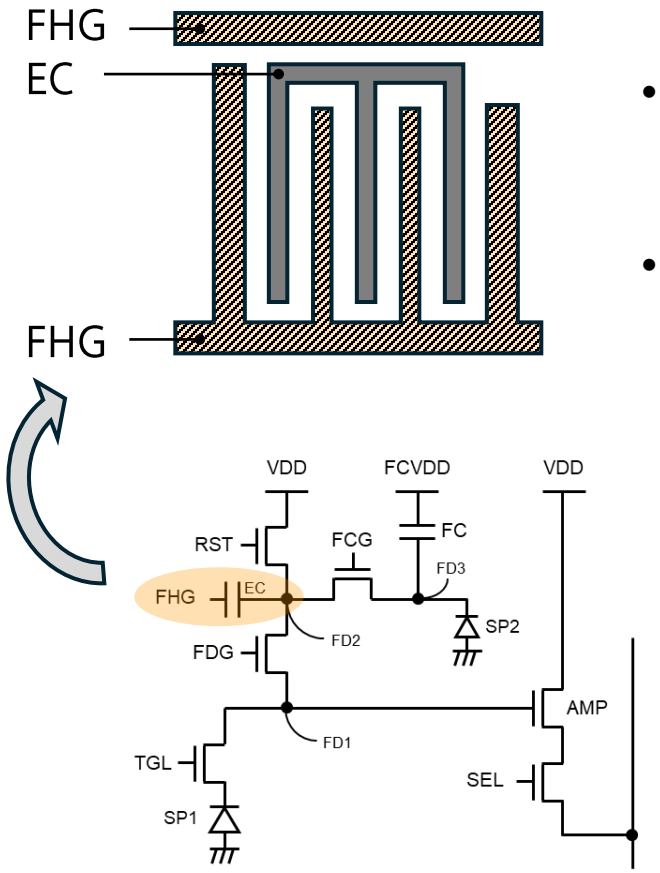
✓ Controlling voltage of FCVDD be able to optimize SNR Drop and Dynamic range

Key Technology : Extra Capacitor(EC) design

Comb-like wiring capacitor realizes a LOFIC drive

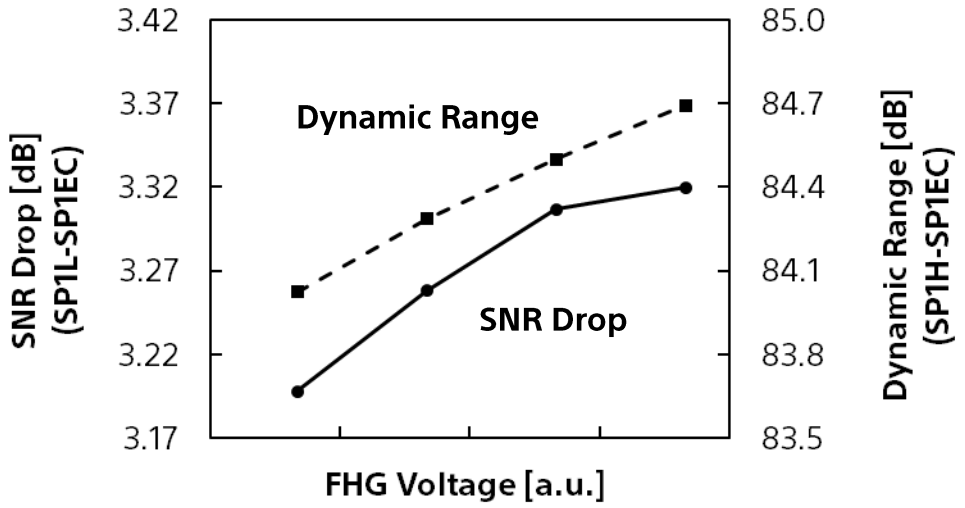
EC structure

(Top view)



- Large capacitance for LOFIC read-out
- Capacity adjustable by FHG voltage control

FHG dependency of SNR drop and Dynamic Range

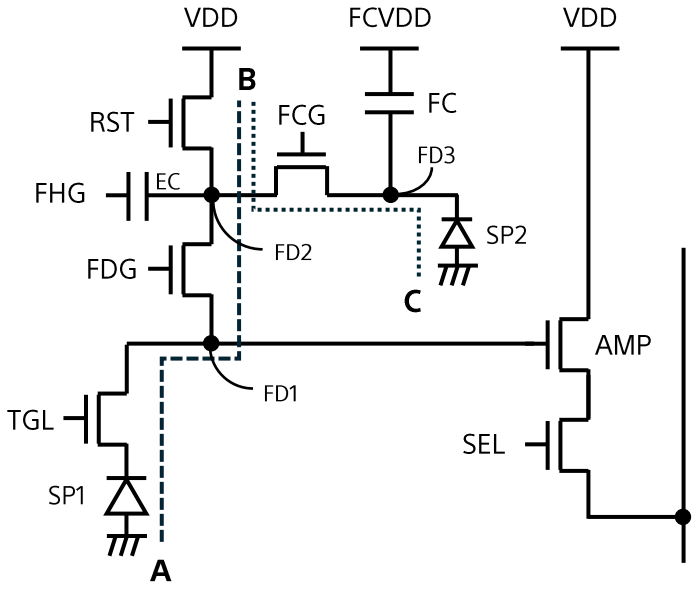


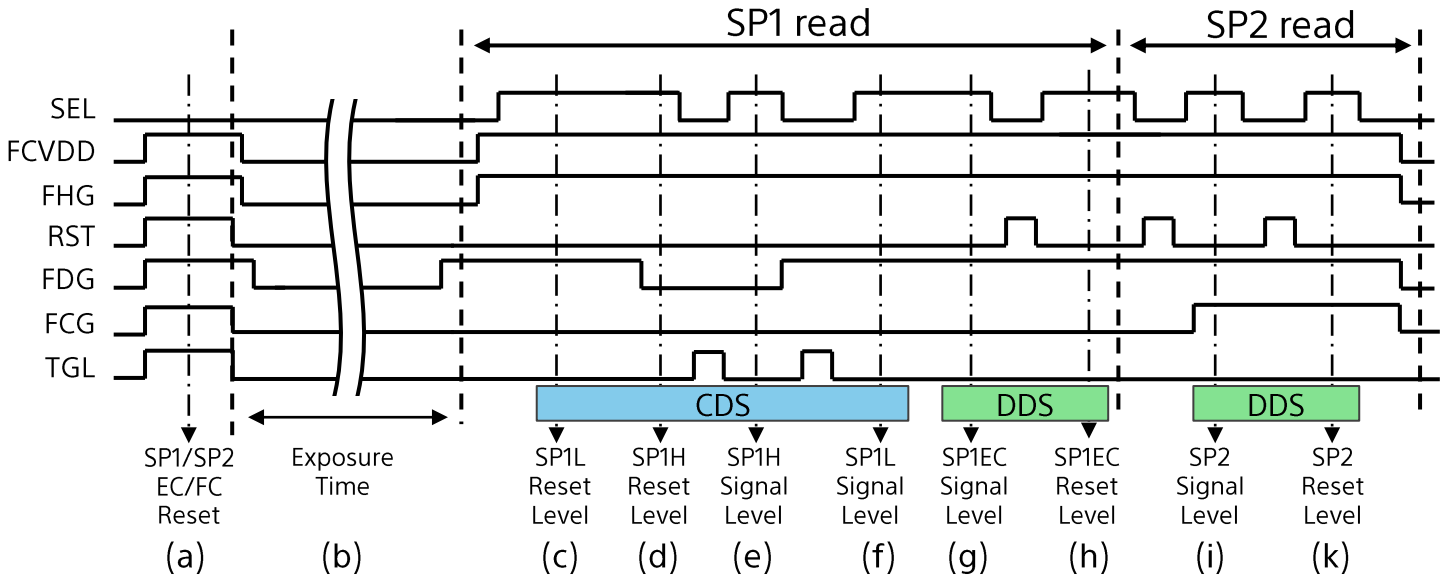
✓ Controlling voltage of FHG be able to optimize SNR Drop and Dynamic range

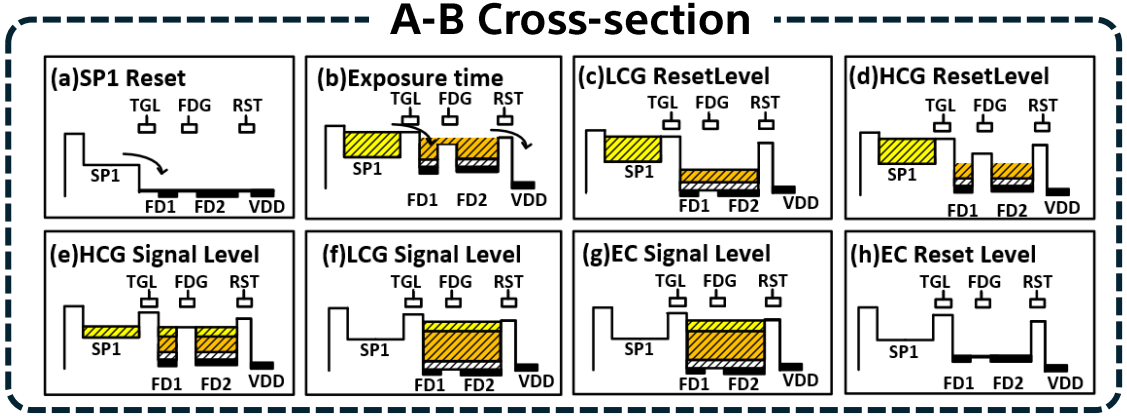
Key Technology : Pixel Potential Diagram

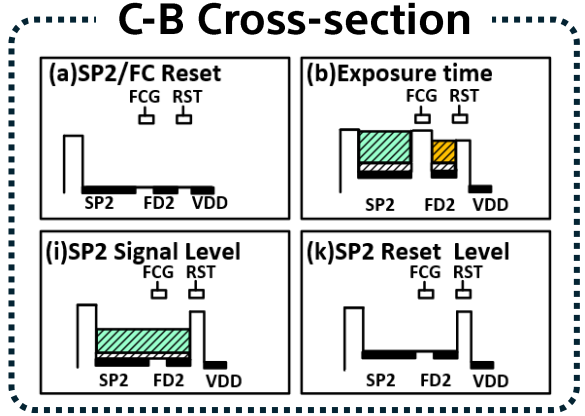
4 signals readout in a single exposure

- SP1H : SP1 High Conversion Gain (CDS)
- SP1L : SP1 Low Conversion Gain (CDS)
- SP1EC : SP1 LOFIC readout (DDS)
- SP2 : SP2 readout (DDS)



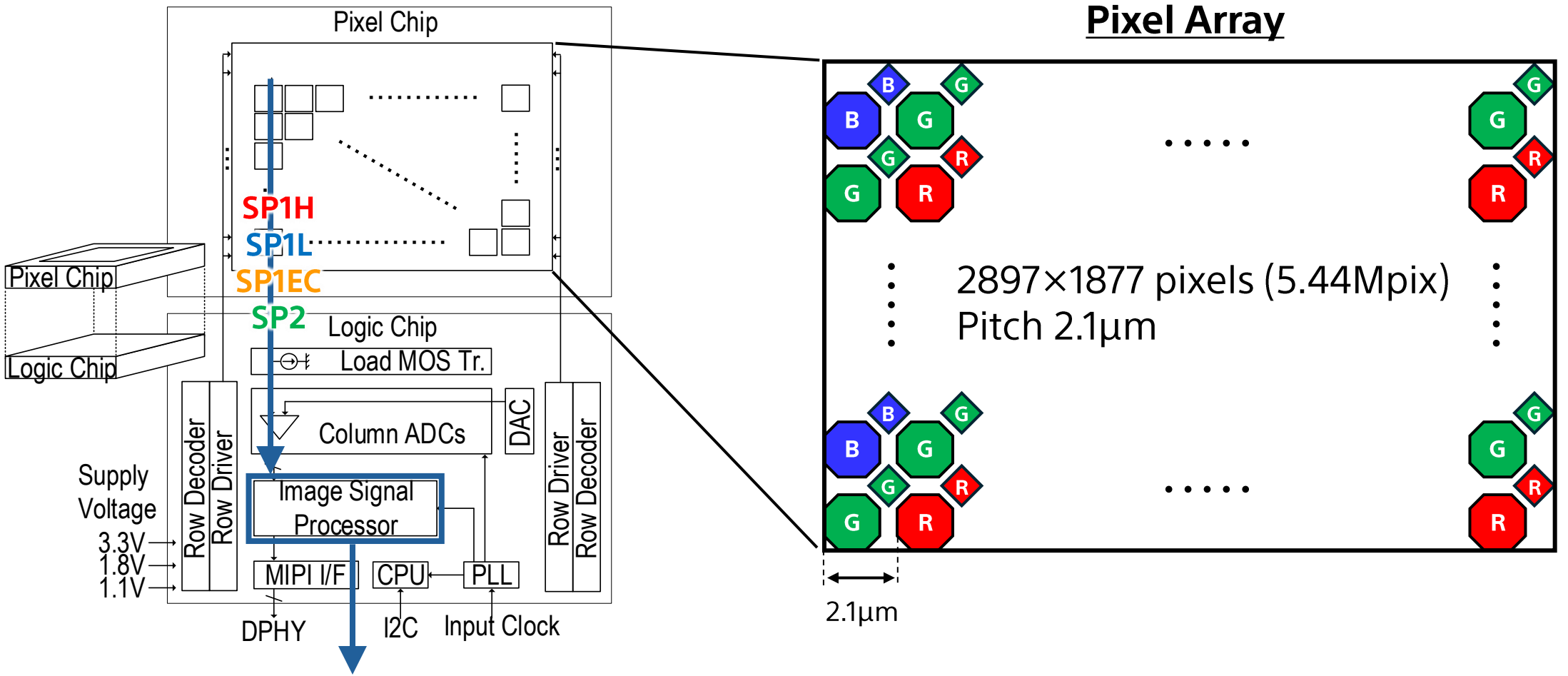






Key Technology : Sub-pixel Array

4 signals captured from single exposure are synthesized



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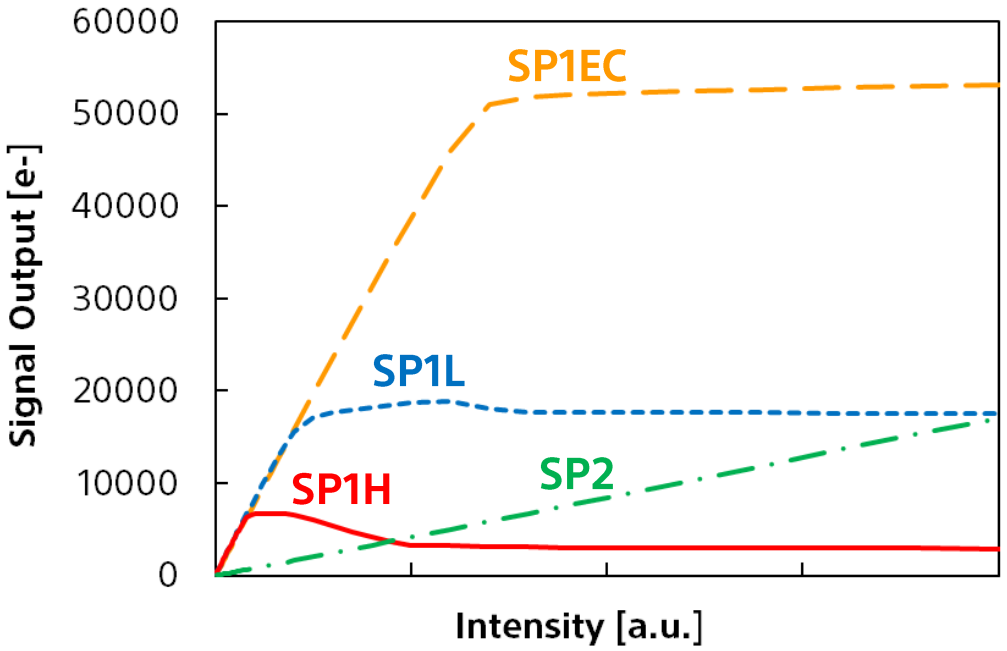
Sensor Characteristics : Response and SNR

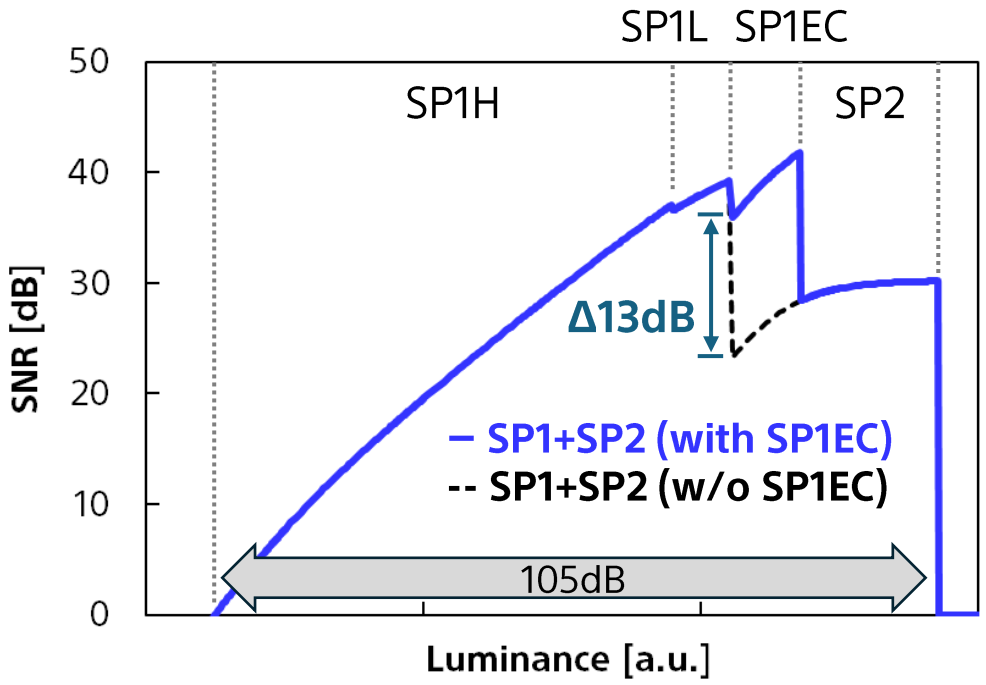
Improved SNR Drop Δ13dB with Sub-pixel and LOFIC

Photo response of SP1 and SP2



	SP1H	SP1L	SP1EC	SP2
Full-well Capacity [e-]	6700	16000	50500	58000
Sensitivity [e-/lx･s]	13200			1900

SNR curve



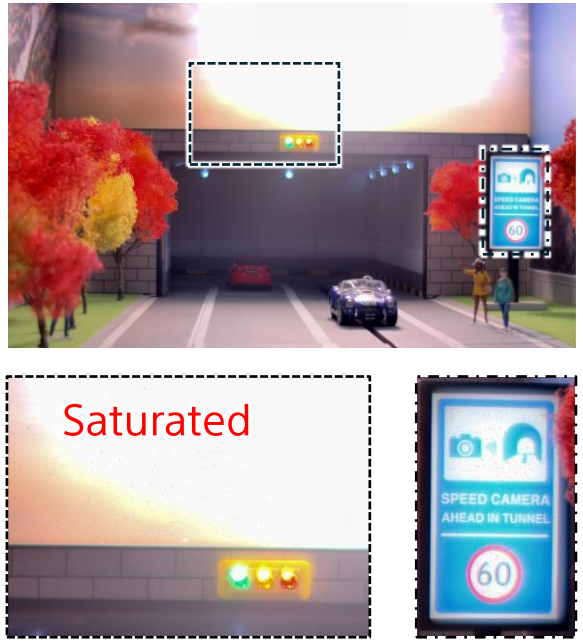
Exposure : 11ms
Temp. : Tj=85℃

Sensor Characteristics : Synthesized Image

Achieves both a HDR and High SNR in a single exposure, futher realizing LFM

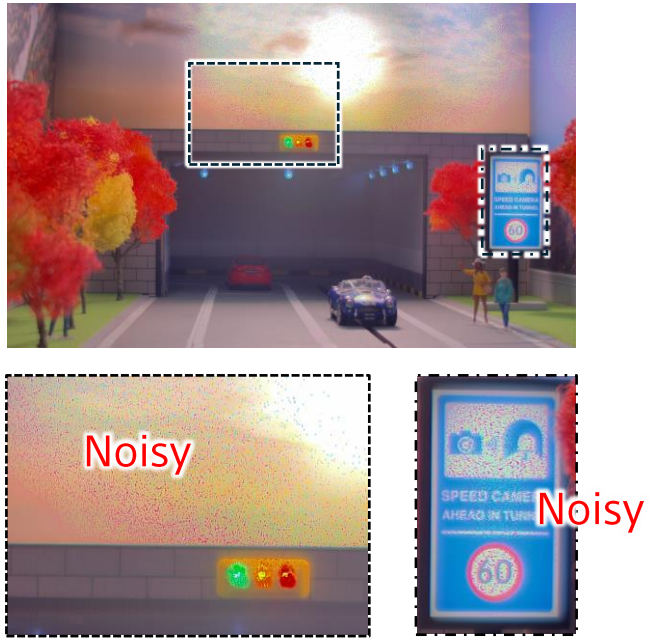
Exposure : 11ms
Temp. : Tj=85℃

SP1H - SP1L - SP1EC
(without SP2)



☹ **High-light object is Saturated**

SP1H - SP1L - SP2
(without SP1EC)



☹ **Mid-light object is Noisy**

SP1H - SP1L - SP1EC - SP2
(This work)

☺ ✓ **Able to capture High-lights**
✓ **Noise is Reduced**

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Conclusion

We have developed a “Sub-pixel and LOFIC architecture” with 105dB Dynamic Range and LED Flicker Mitigation

Sensor Performance

		Unit	Large PD (SP1)	LOFIC (SP1EC)	Small PD (SP2)
Power Supply		V	3.3 / 1.8 / 1.1		
Process Technology		-	Pixel : FE90nm / BE65nm 4Cu Logic : 40nm 6Cu 1AL		
Pixel Pitch		µm	2.1		
Pixel Array		pixel	2897(H) x 1877(V) = 5.44M		
Color		-	Red, Green, Blue		
HDR Technology	In-pixel Capacitor	-	MOM		MOS
	Sensitivity Ratio	times	1.0		8.5
Random Noise @ RT		e- rms	1.4	46.4	59.6
Sensitivity (3200K with IR cutfilter)		e-/lx・s	13200		1900
Full-well Capacity		e-	16000	50500	58000
Dynamic Range (Single Exp.)		dB	105		

Thank you so much for your kind attention