

PIC Monolithic vs Hybrid

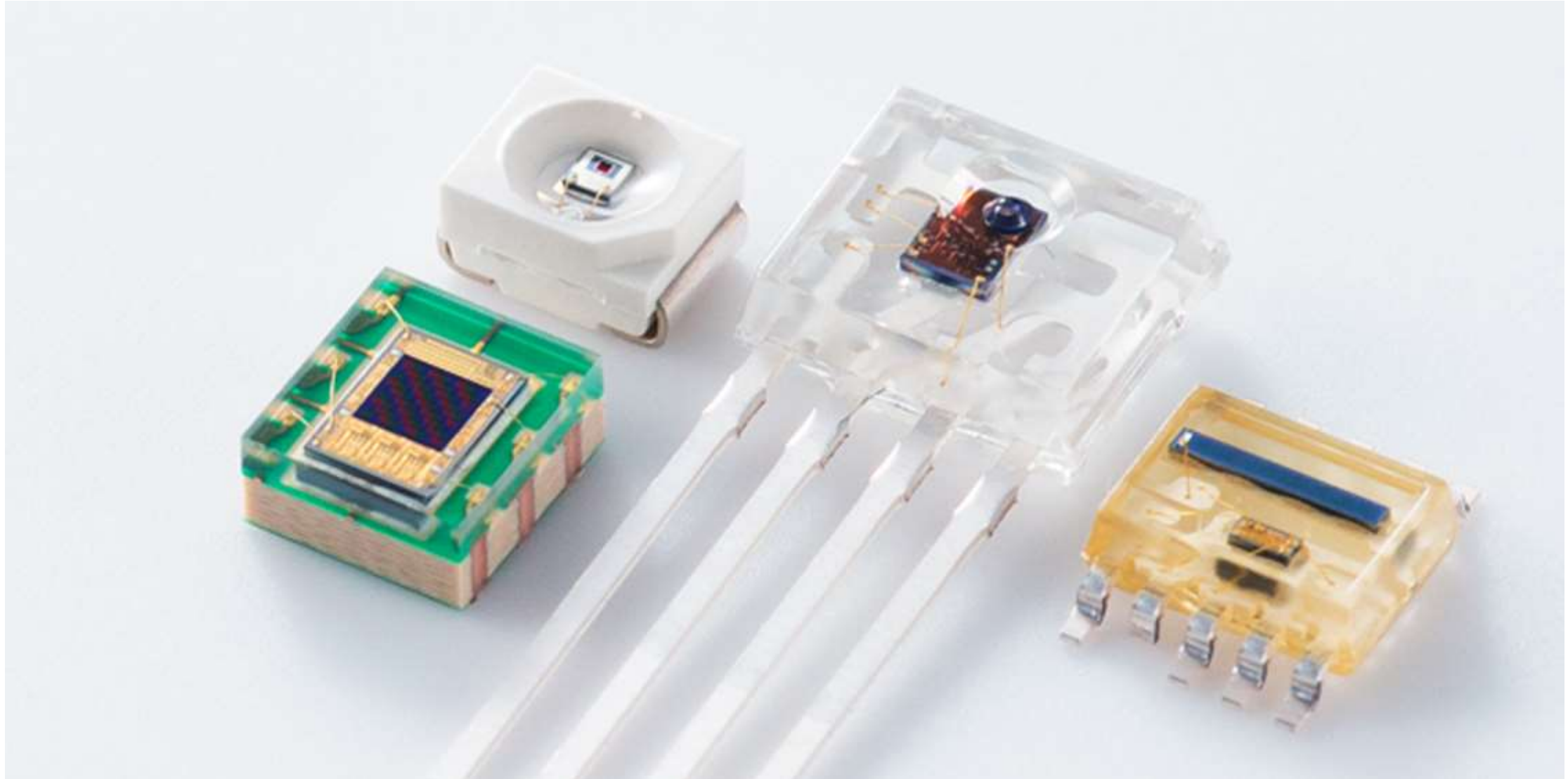
Marco Mayer
Hamamatsu Photonics
June 10th, 2021

Hamamatsu at a glance

Our technological capacity and scale by the numbers.



PIC by Hamamatsu

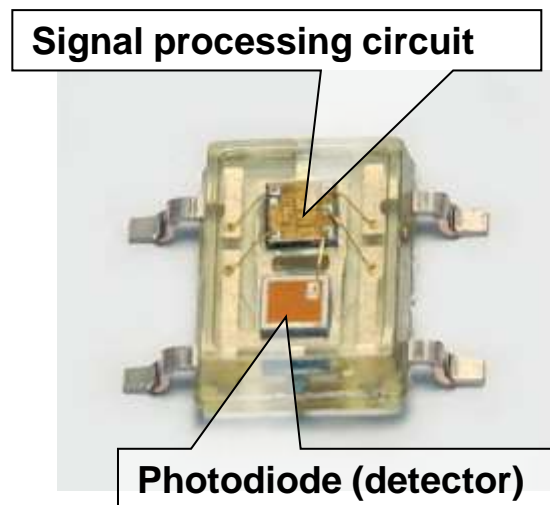


Configuration

■ Classification of Photo IC

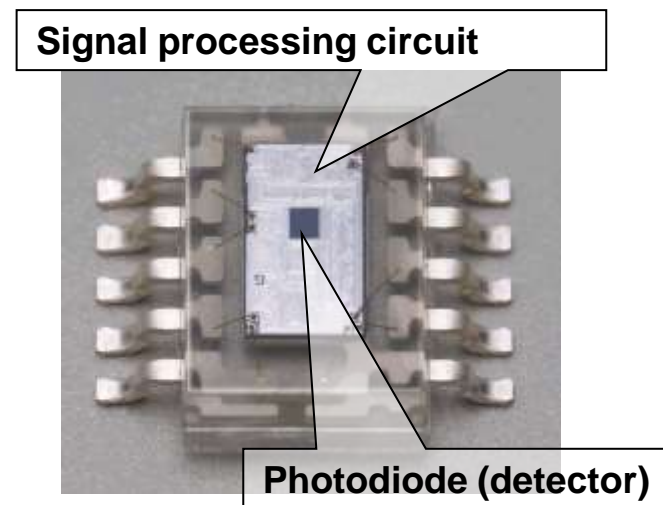
→ Construction : Hybrid type & Monolithic type

● Hybrid type Photo IC



2 chip on one package

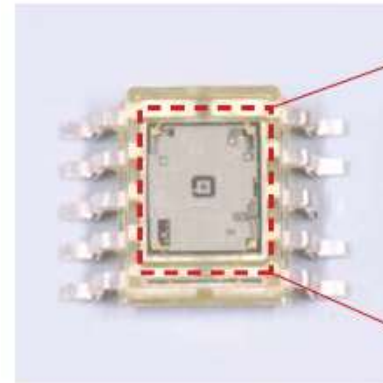
● Monolithic type Photo IC



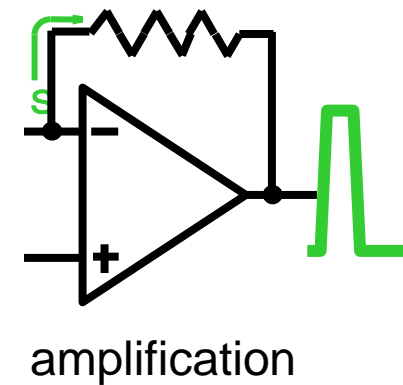
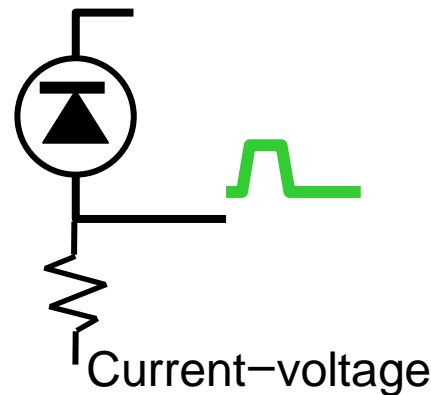
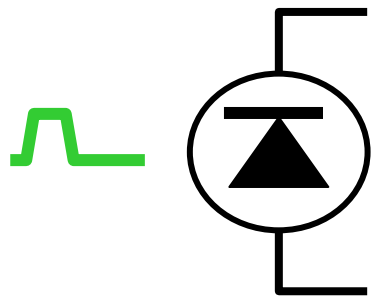
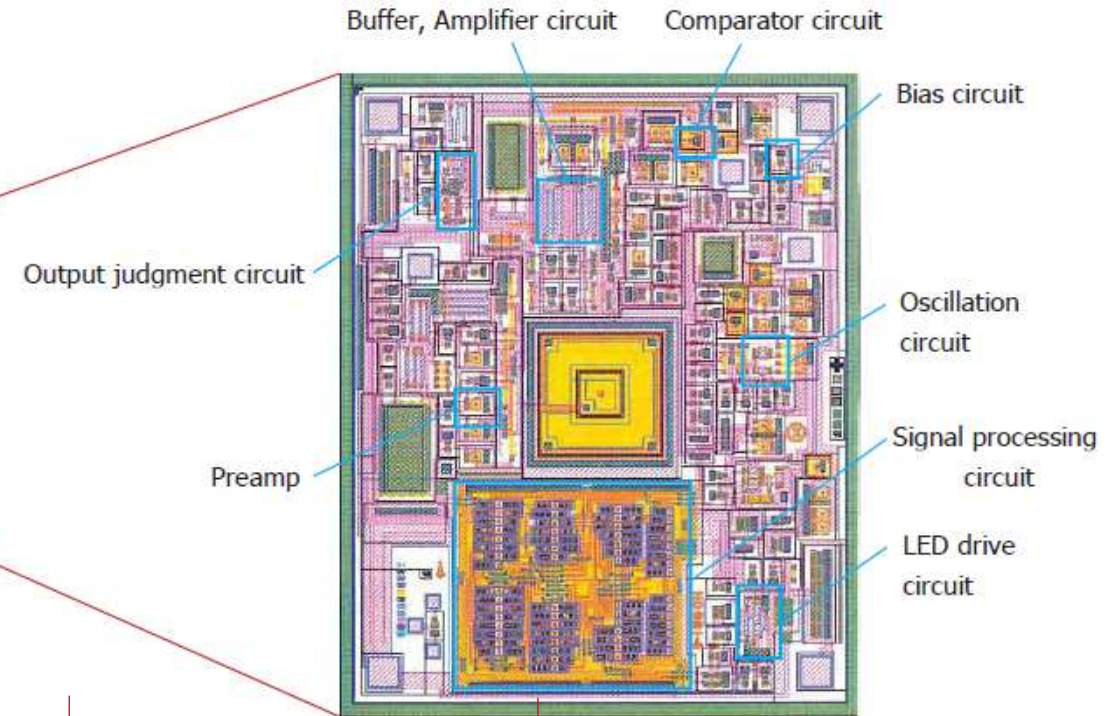
One chip on one package

What is a Photo IC

■ Configuration of signal circuit



S10053

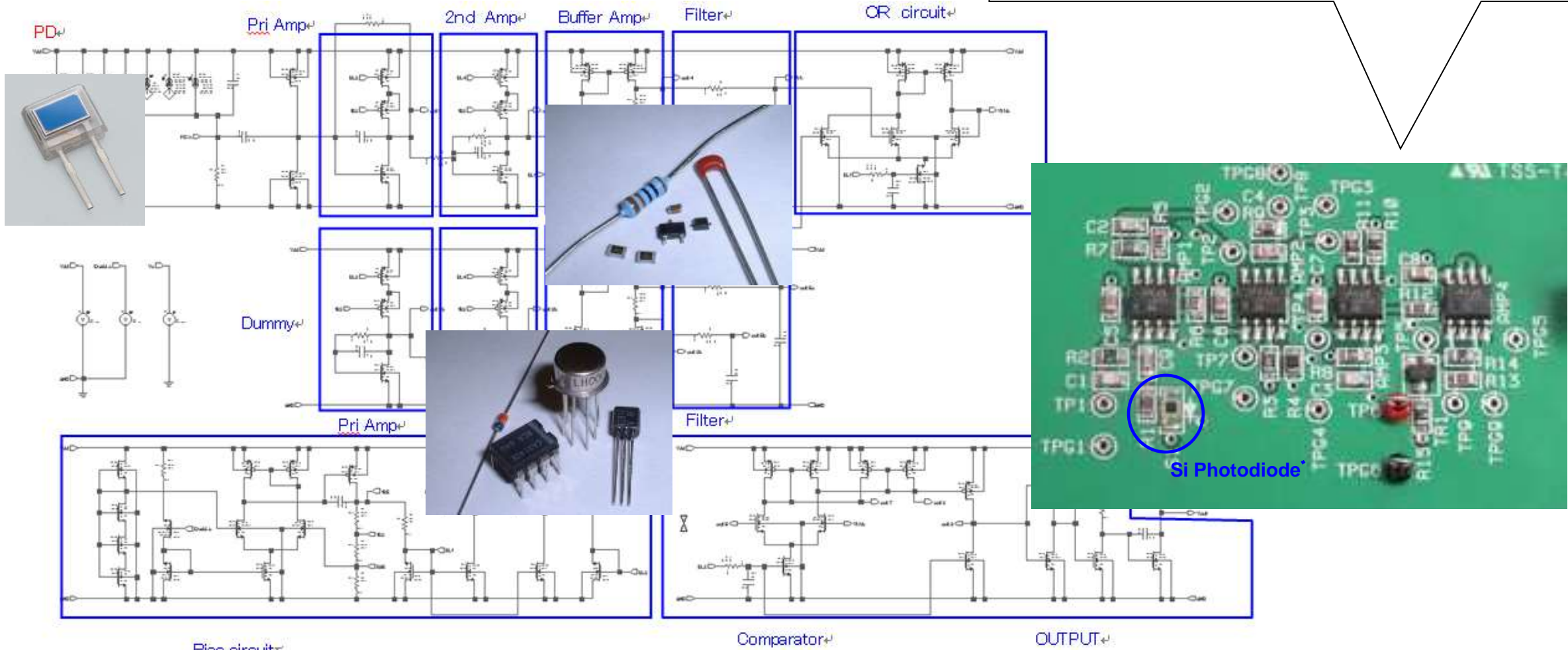


Various

What is Photo IC

FOR INTERNAL USE ONLY

Implemented all parts in PCB



It integrates a photodiode and a signal processing circuit.

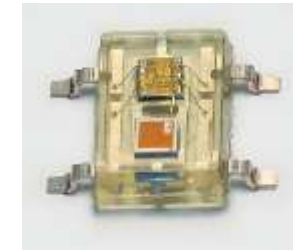
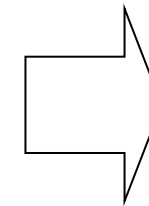
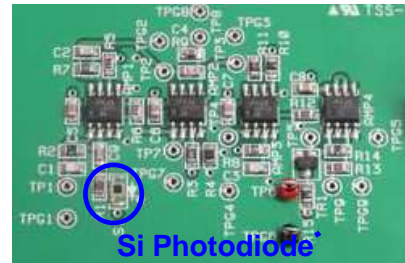
Features of Photo IC

FOR INTERNAL USE ONLY

Low Cost Small Size Light weight Low noise

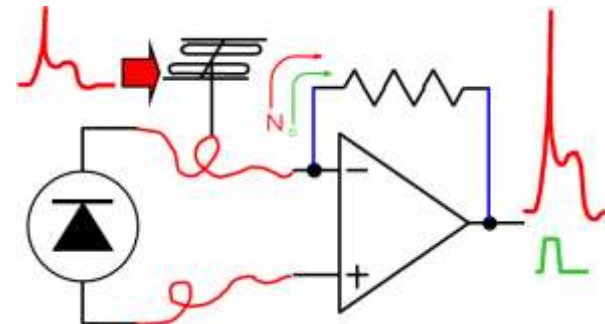
➤ **Main feature**

- Low cost
- Small size
- Light weight



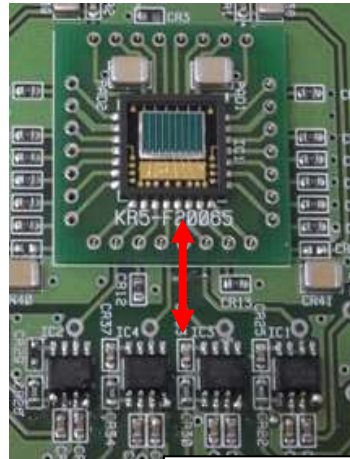
➤ **Advantage**

- Low noise



The explanation of Photo IC (Noise example)

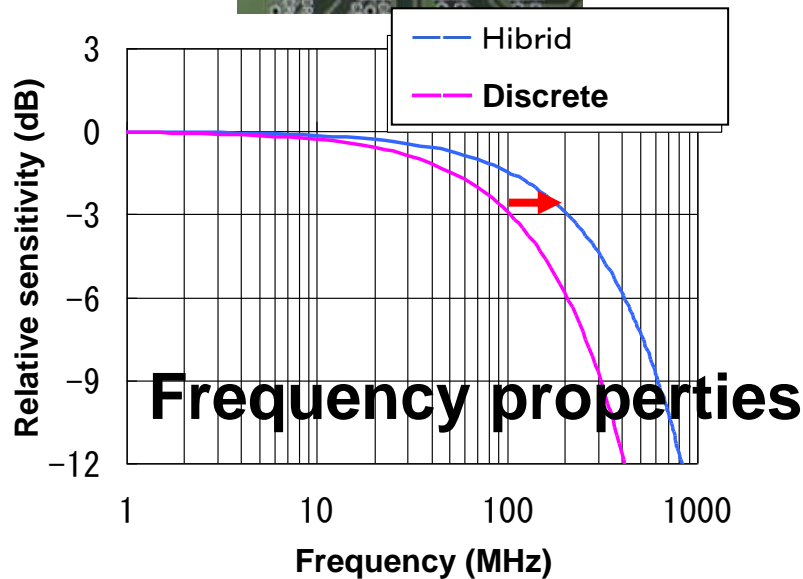
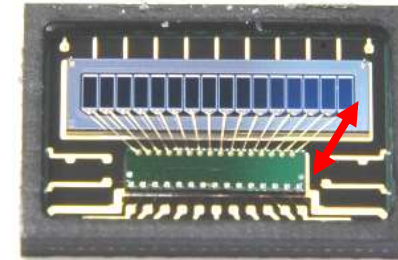
Discrete



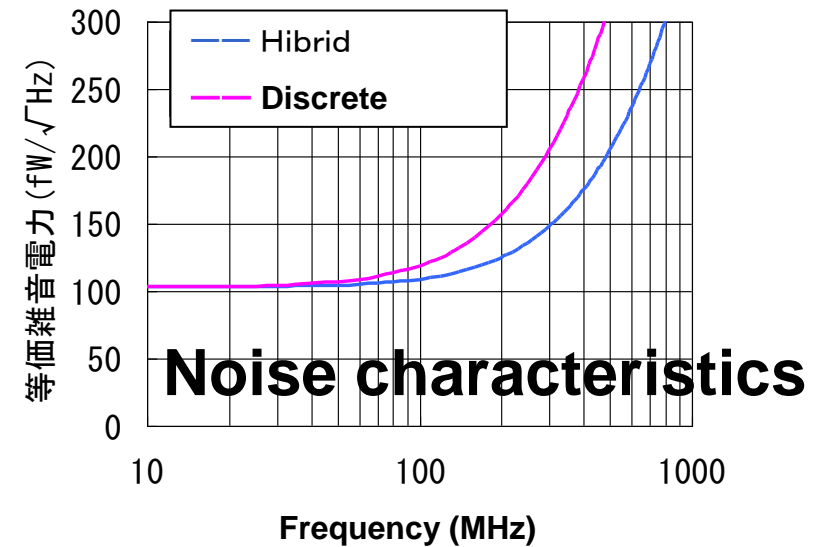
Distance shortening between PD and IC



Hibrid

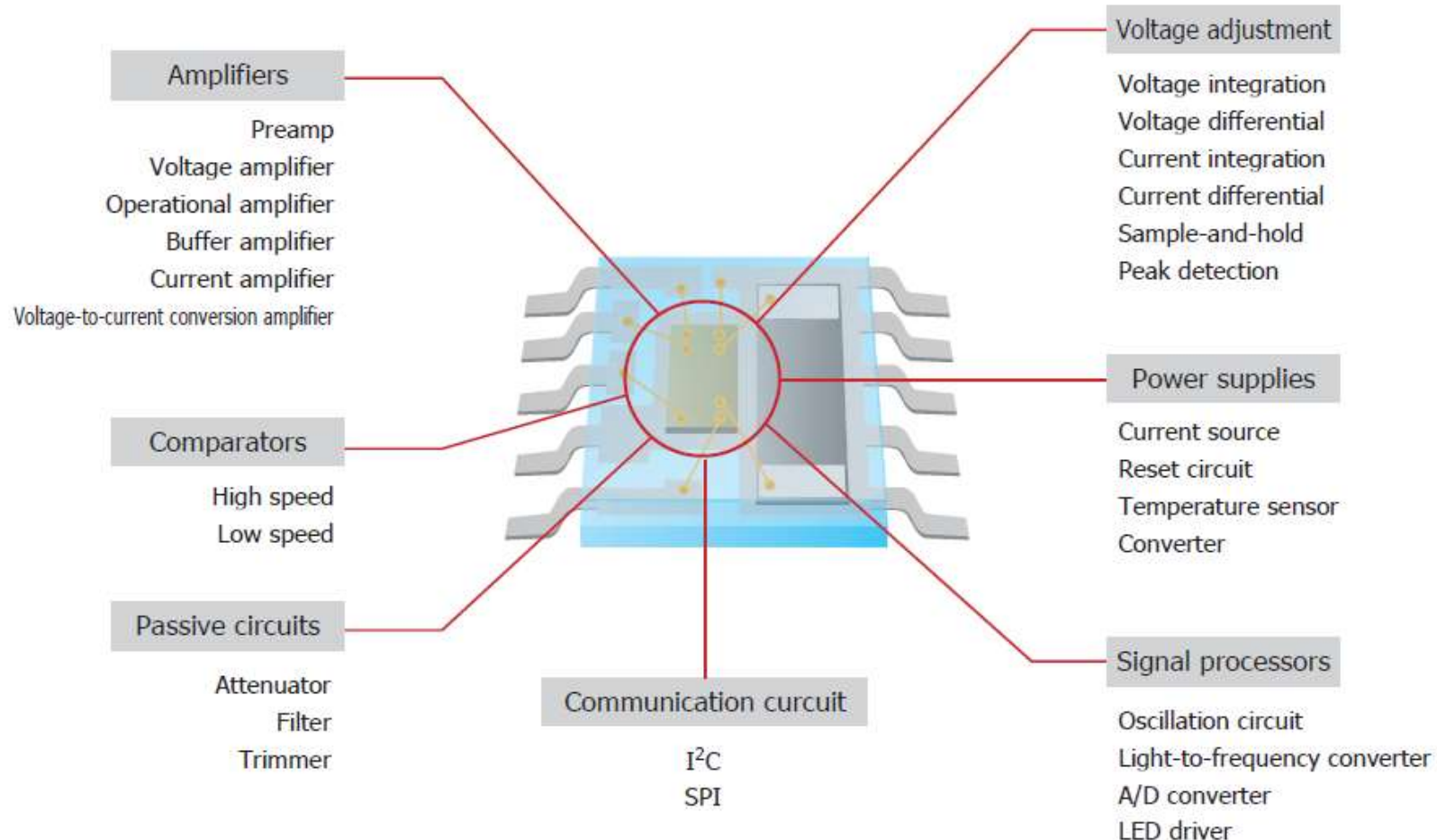


Noise equivalent power (fW/√Hz)



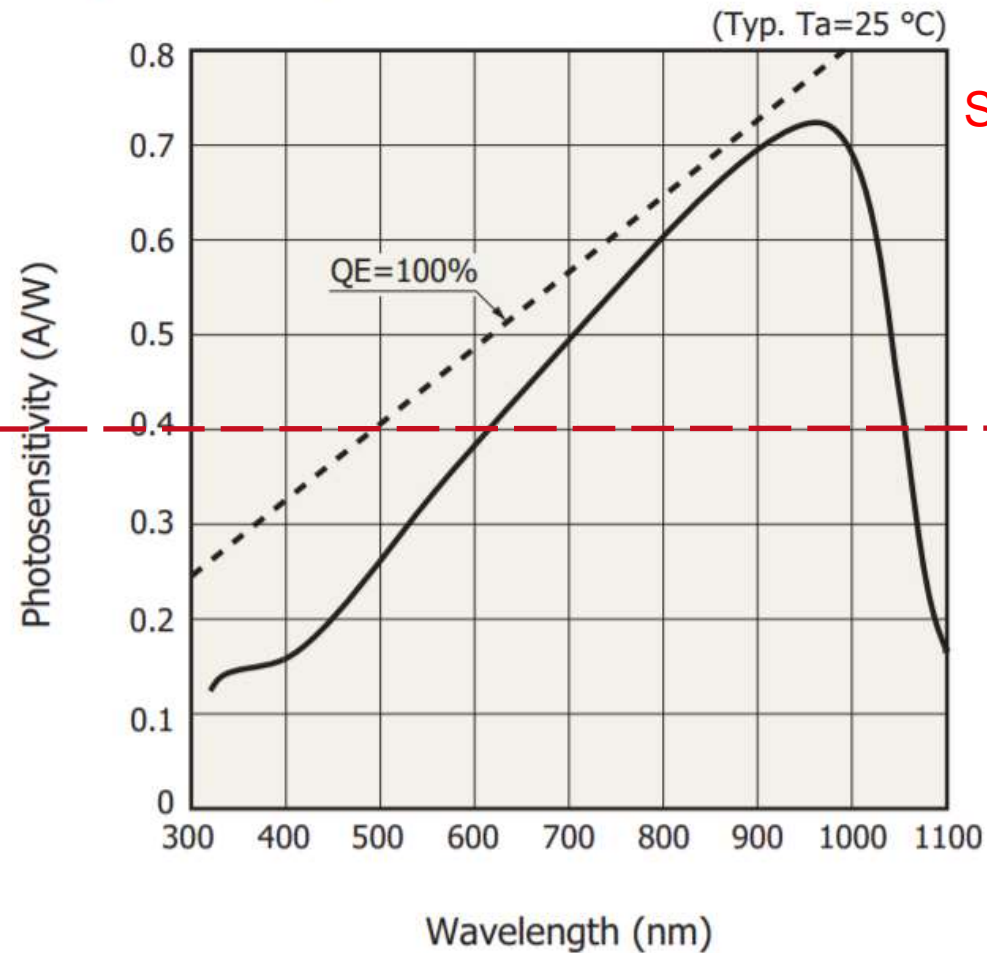
Circuit technology for Photo IC

Hamamatsu has analog circuit library so that it can contribute to quicker development and lower developmental cost.



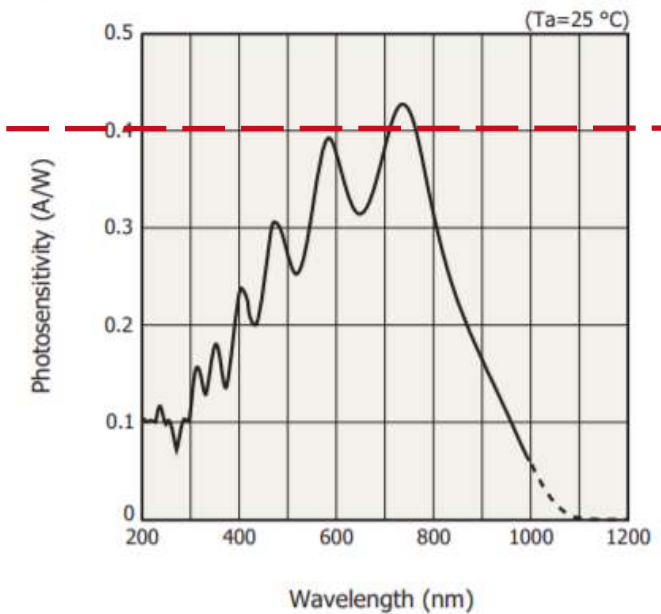
Why now separate the detector and the Circuit? Different Processes

▣ Spectral response

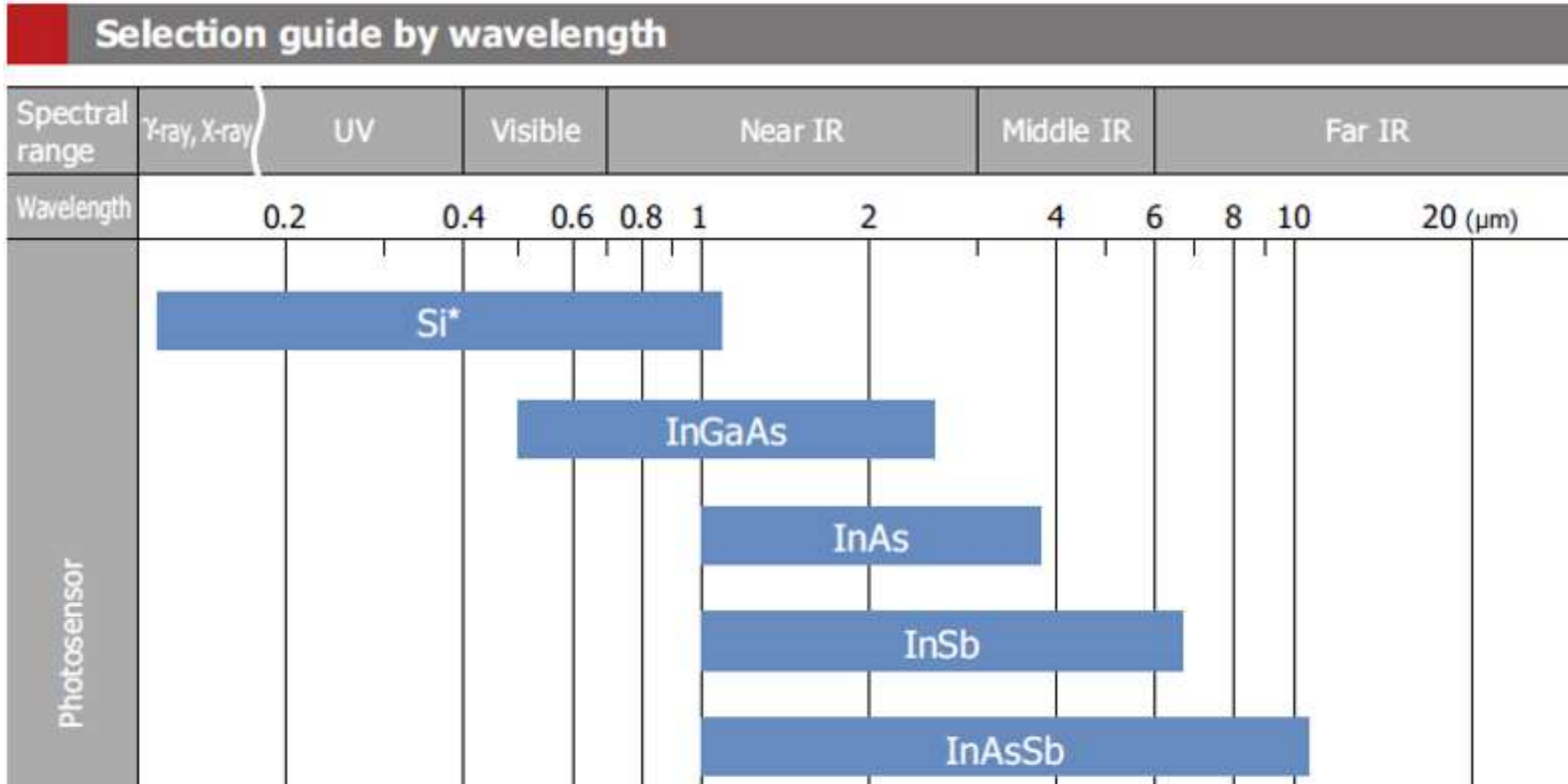


▣ Spectral response (typical example)

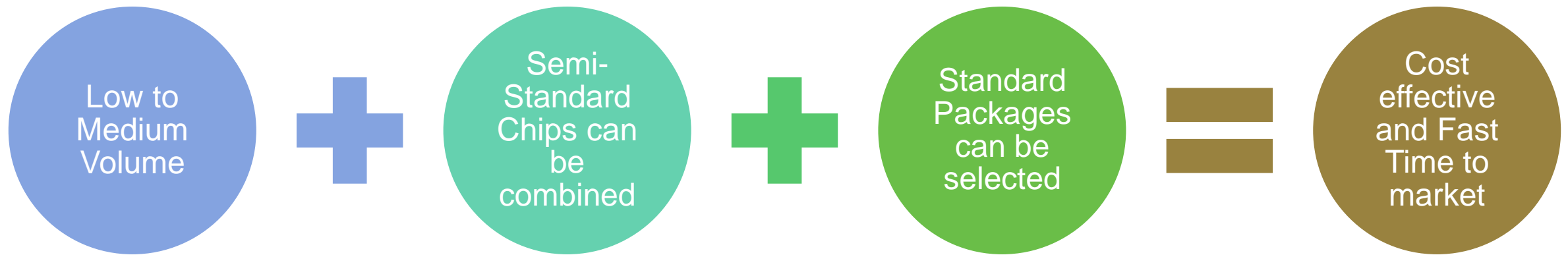
Standard CMOS



Why now separate the detector and the Circuit? Different Materials



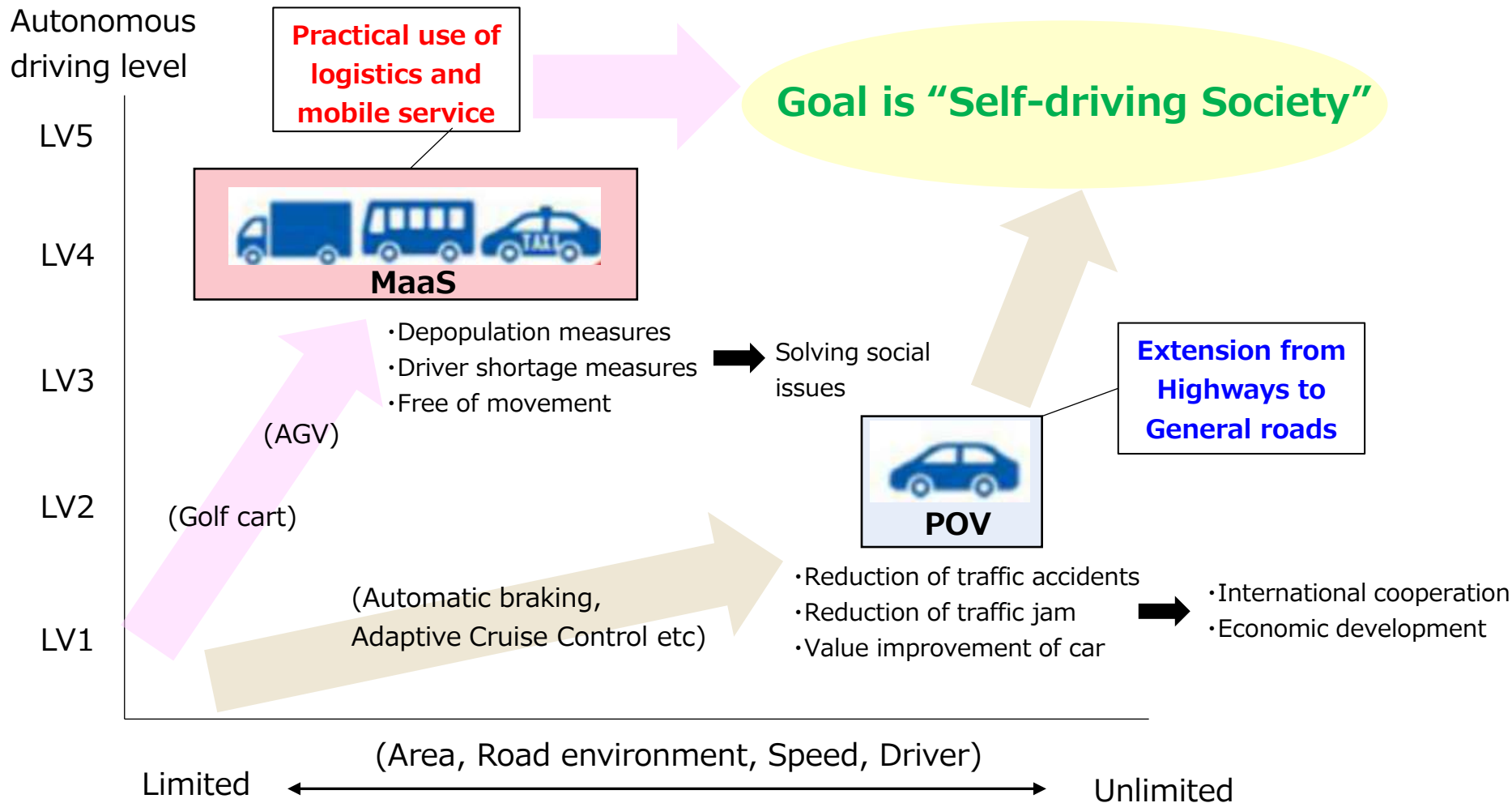
Why now separate the detector and the Circuit? Costs and Time



Application example / LiDAR

Category of future's mobility

Type	MaaS (Mobility As A Service) - Robo taxi -	POV (Personally Owned Vehicle) - ADAS -
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MaaS:

In order to provide continuous service, it is necessary to perform various evaluation, verifications, and extraction of issues on public roads are close to the actual operating environment

POV:

Aim to improve safety by early commercialization and popularization of safety driving support systems from highways

Lineup from wavelength and measurement distance

Emitter

Receiver

Wavelength

1550nm

1060nm

940nm

905nm

870nm

In-direct TOF

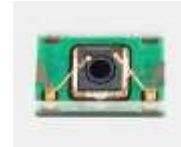
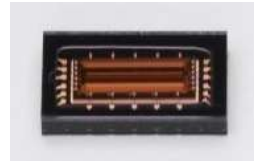
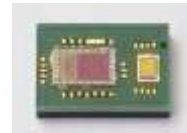
Direct TOF

InGaAs PIN PD
InGaAs APD



Distance: Near ---- Far

Si-PD Si-APD, Si-MPPC



870nm, 905nm
3-stacked Pulsed Laser Diode



1m

10m

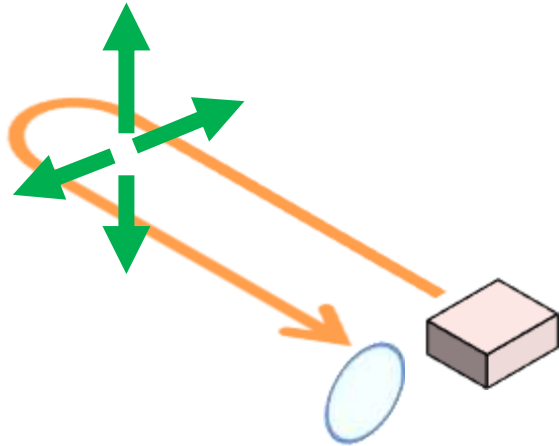
100m

1km

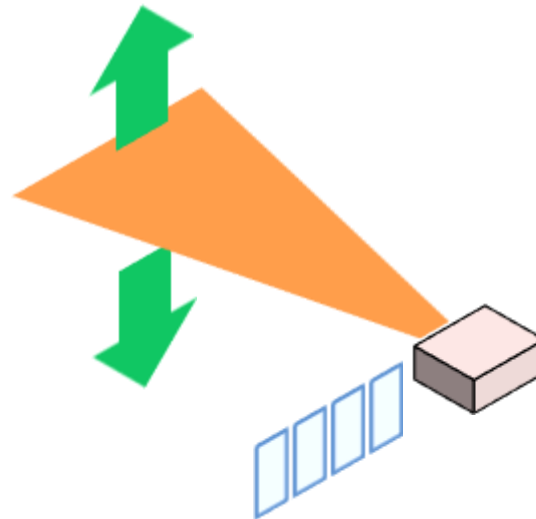
Measurement distance

Receiver shape required for LiDAR

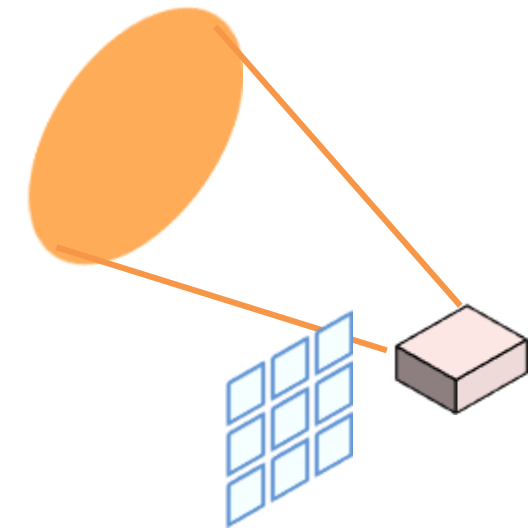
Point light
+ 2D scanner
+ Single detector



Fan beam
+ 1D scanner
+ 1D array detector



Diffuse light
+ 2D array detector



Mainly for long range
(Module size tends to be bigger because scan mechanism is necessary)



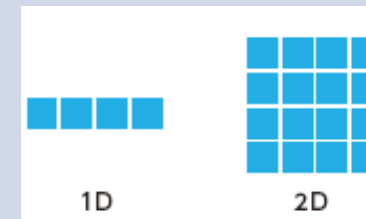
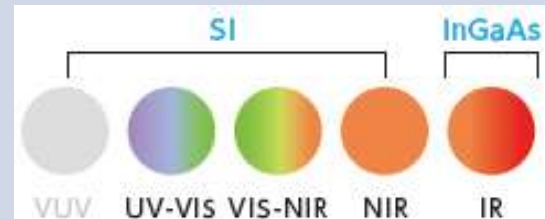
Mainly for short range
(Easier to minimize because scanner is not necessary. High sensitivity 2D detector is necessary)

Hybrid type Receiving detector with IC

Hamamatsu Hybrid type receiving detector

Design flexibility for both detector and IC

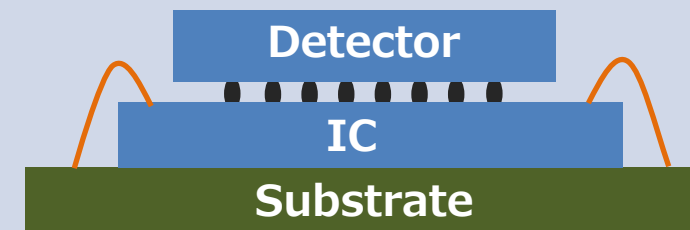
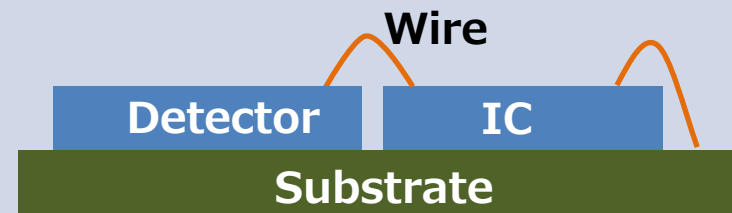
Customization of receiving detector based on necessary wavelength and the number of channels (1ch, 1D array, 2D array)







Customization of IC based on requirement




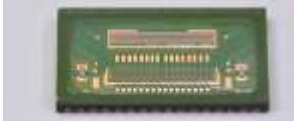
Package image



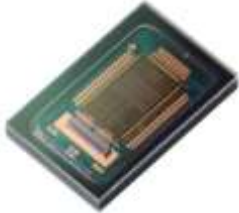

Lineup of Si APD+IC (TIA) Hybrid type

Parameter	S15597-01CT	S15658-01CT	S13645-01CR	S14137-01CR
Photo				
Built-in APD	1-element ($\phi 0.2\text{mm}$)	1-element ($\phi 0.5\text{mm}$)	16-element ($1.0 \times 0.4\text{mm}/\text{element}$)	16-element ($0.15 \times 0.43\text{mm}/\text{element}$)
Number of outputs	1	1	1 (Serial output)	16 (Parallel output)
Output type	Differential (high gain)	Differential (high gain)	Differential (high gain)	Single (without high gain)
Photosensitivity ($\lambda=905\text{nm}$)	3200 kV/W (high gain, M=100)	3200 kV/W (high gain, M=100)	900 kV/W (high gain, M=50)	36 kV/W (M=50)
High cutoff frequency	160 MHz (high gain)	150 MHz (high gain)	160 MHz (high gain)	180 MHz
Operating temperature range	-40 to +105 degC	-40 to +105 degC	-40 to +105 degC	-40 to +105 degC

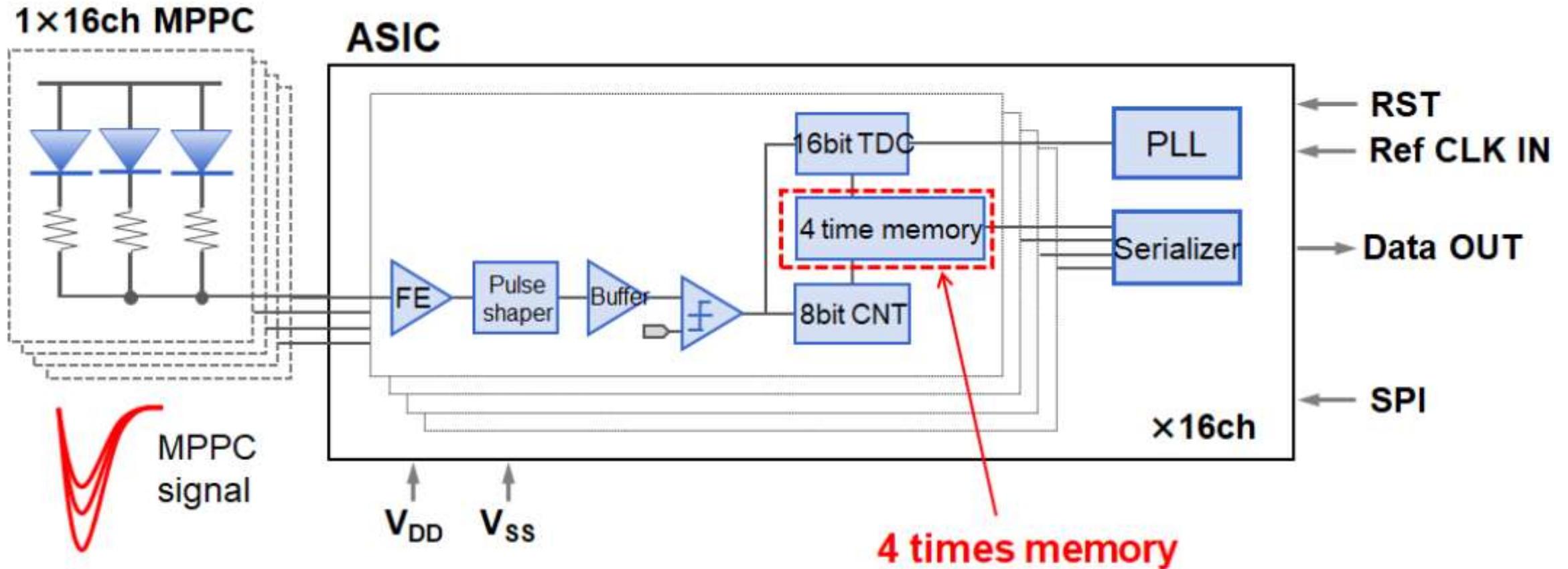
Lineup of InGaAs APD+IC (TIA) Hybrid type

Parameter	G15749 UNDER DEVELOPMENT	G15799 UNDER DEVELOPMENT
Photo		
Built-in InGaAs APD	1-element ($\phi 0.2\text{mm}$)	16-element ($0.15 \times 0.43\text{mm}/\text{element}$)
Number of outputs	1	16 (Parallel output)
TIA gain AC(0.1 μF) + 50ohm load	0.8kV/A	0.8kV/A
Higher cutoff frequency AC(0.1 μF) + 50ohm load	270MHz	200MHz
Operating temperature range	-40 to +105 degC	-40 to +105 degC

Photoncounting array with IC Hybrid type

Parameter	S15022-0225GL-01	S15013-0125NP-01	UNDER DEVELOPMENT
Photo			
Built-in MPPC	16ch front illuminated type MPPC (200x200um/Channel)	32 x 32ch back-illuminated type MPPC (100x100um/Channel)	
Number of pixel/Ch	64ch	12ch	
Pixel pitch	25um	25um	
PDE at 905nm	9%	6%	
Features	<ul style="list-style-type: none"> • Integrated TDC (Time-to-Digital Converter) • 4 times Multi-echo detection per measurement 	<ul style="list-style-type: none"> • 2D array with ASIC connected by Solder Bumps • Integrated TDC (Time-to-Digital Converter) on each pixel 	

Block diagram of S15022-0225GL-01



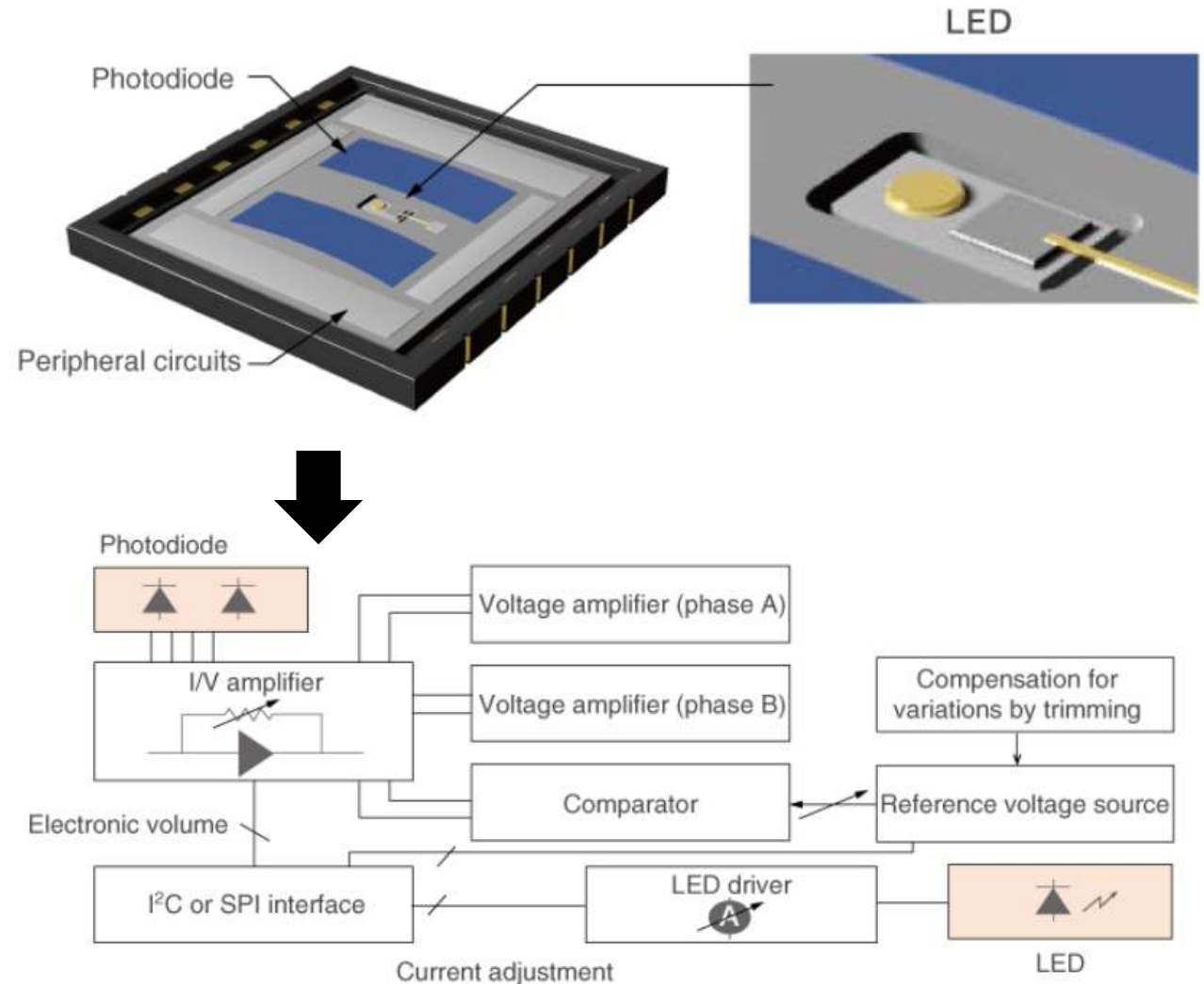
Application example / Optical encoder

Monolithic Photo IC for Reflective encoder

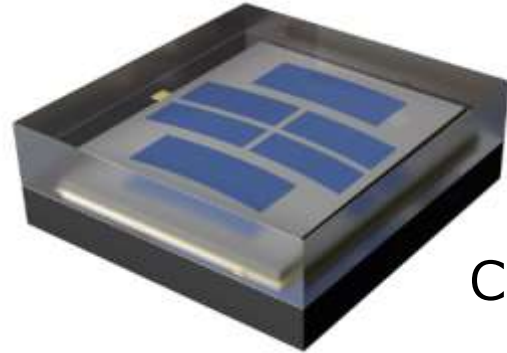
Photo IC Photodiode and LED are integrated with Peripheral circuits

■ Features

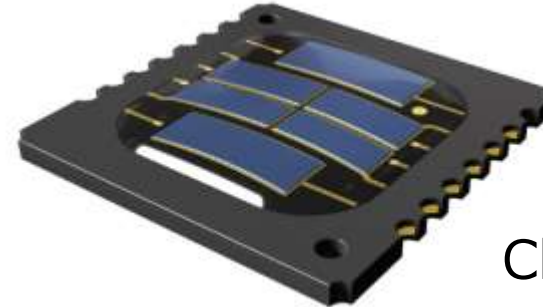
- Monolithic structure of PD and peripheral circuit
⇒ Helps reduce the number of parts and mounting space on the customer side
- Multi-functionalization using I2C
⇒ Enables multi-functionalization such as electron volume
- Built-in LED and LED driver
⇒ Photo IC including receiver and emitter with LED placed in the center of the chip
- Compensation for variations in reference values (current, voltage) by trimming



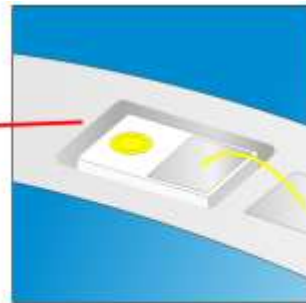
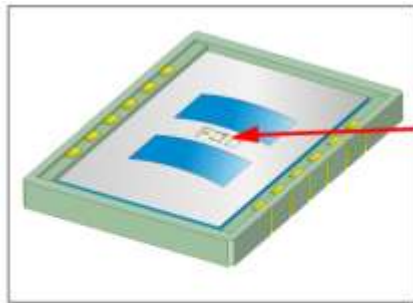
Package proposal for Encoder application



COB package

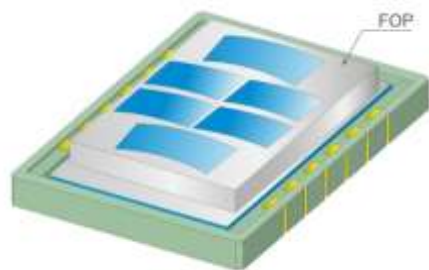


Chip carrier package



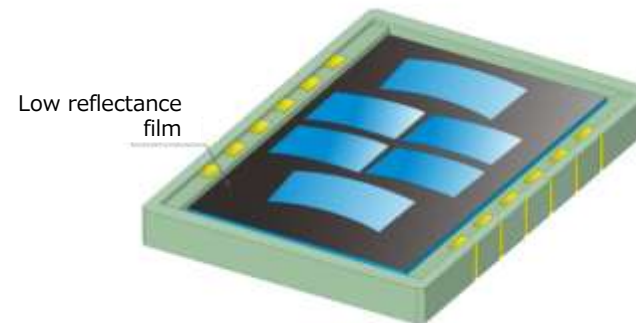
MEMS processing

In order to align the height between LED chip mounted in the center hole and PD chip, thickness of PD can be adjusted by the MEMS processing.



FOP (Fiber Optic Plate)

Combining the FOP with PD, focus of lens at the position where is thicker than PD active area surface is possible.



Low reflectance film

Due to lower reflectance at PD chip surface and metal wirings, it can contribute to better S/N.

Ichino factory

For wafer process like PD, APD, and CMOS



Miyakoda factory For compound semiconductor process



Shingai factory

For assembly process for high volume products



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