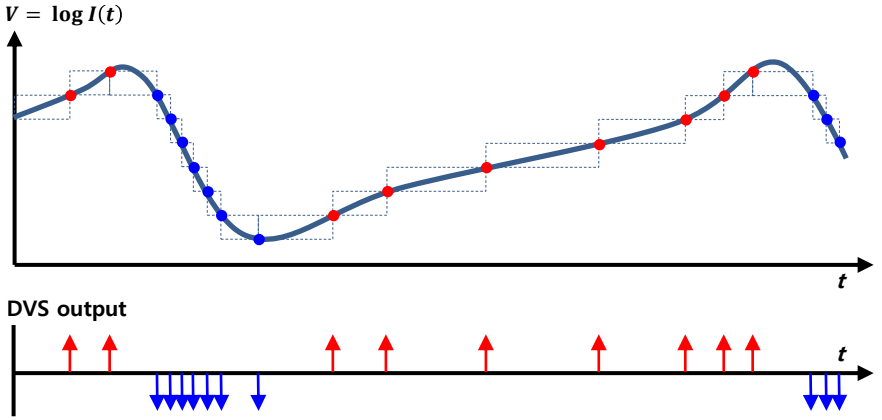
Dynamic Vision Sensor

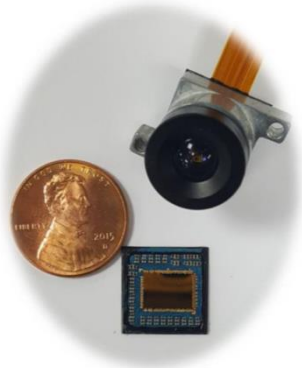
Samsung S.LSI

Dynamic Vision Sensor

Dynamic Vision Sensor (DVS)

- **Asynchronous vision sensor that responds to temporal change of light intensity**
- **Emits digital events that encode the identities of pixels that see these changes**

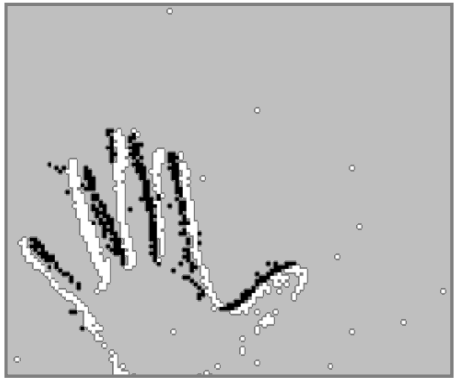




CIS image

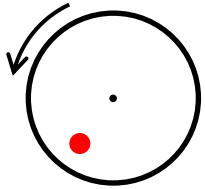
Wave gesture

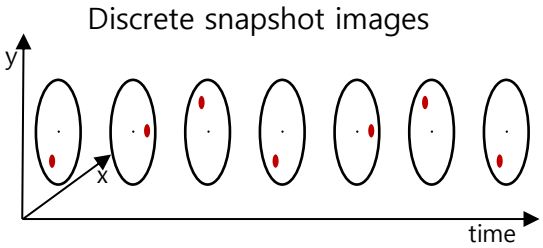
DVS image

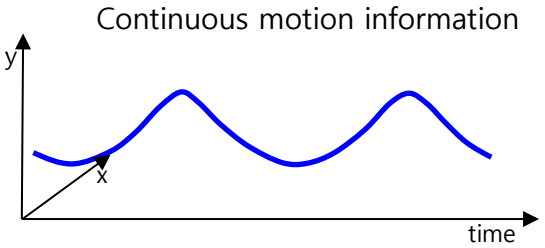


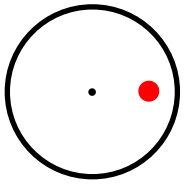
Comparison: DVS vs. Regular Image Sensor

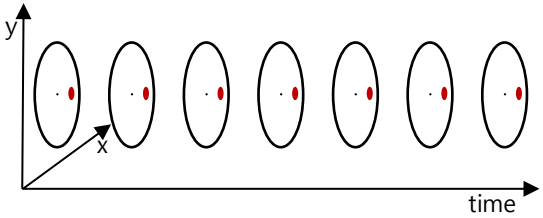
	Regular Image Sensor	DVS
Output data	Light intensity → shape	Temporal change of light intensity → motion
Output format	Framed images	Events stream
Timing	Synchronous	Asynchronous
Speed	Slow (>10msec)	Fast (≪1msec)
Dynamic range	Low	High (~100db)
Processing Power	High	Low (depends on the #of events)

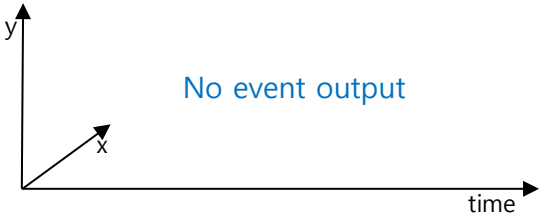










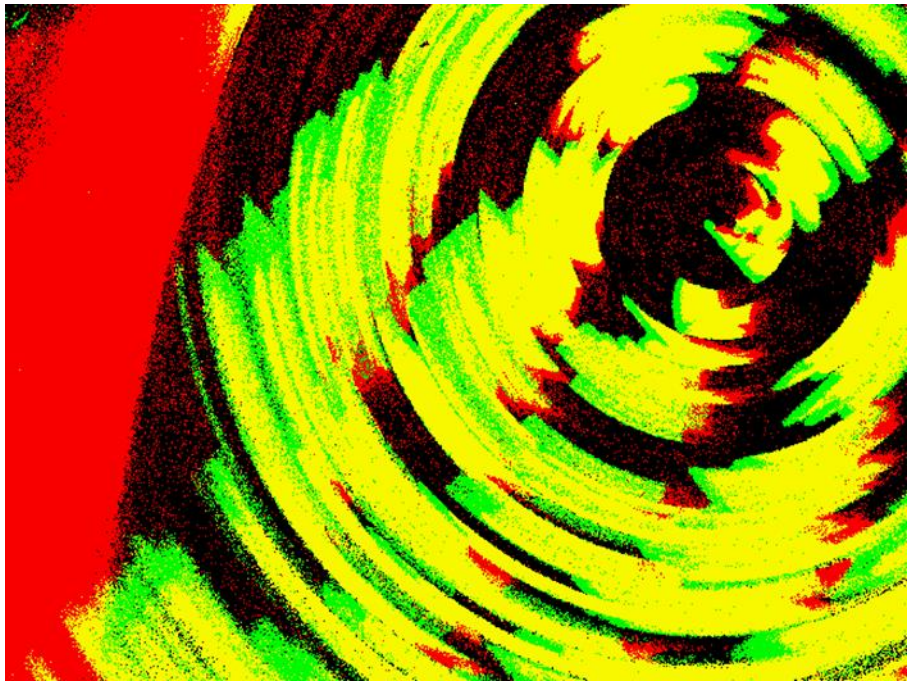


High Speed

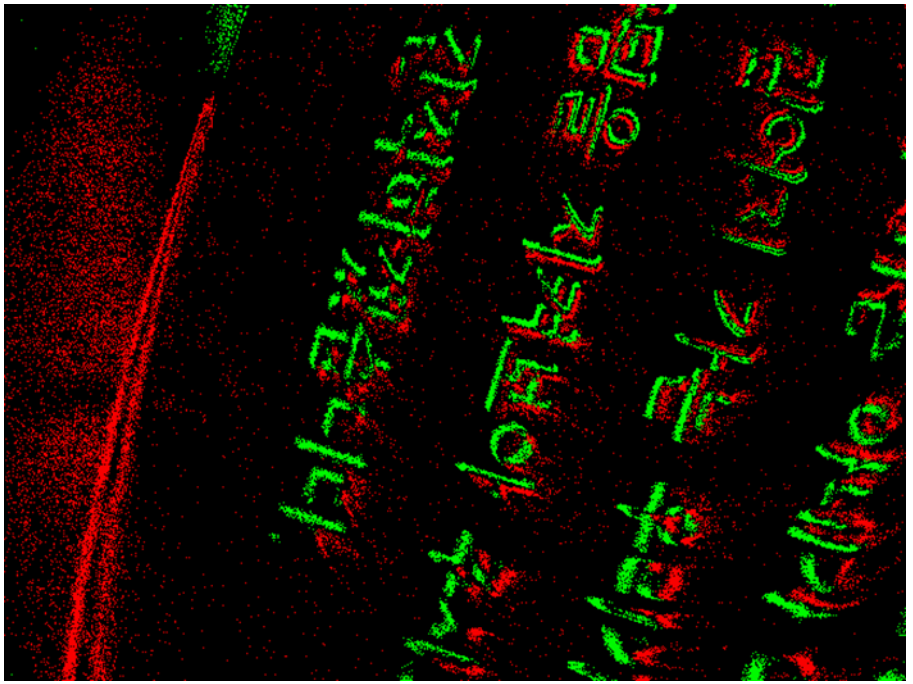
DVS Pseudo-frame

- Snapshot image can be easily reconstructed by accumulating events for a time window

20 msec/frame (50 fps)



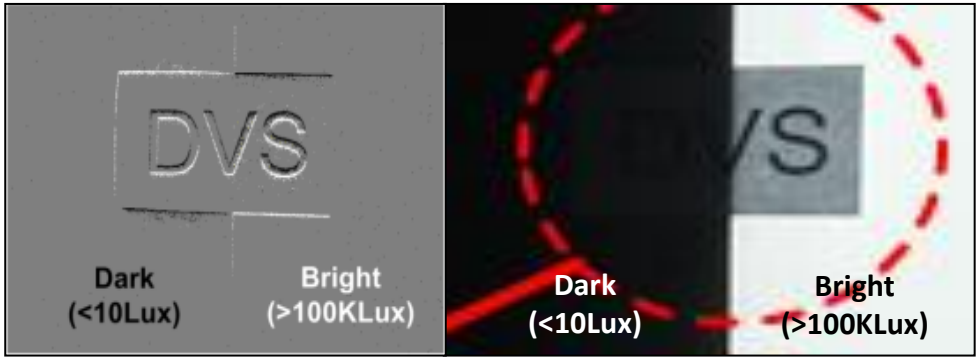
1 msec/frame (1000 fps)



Letters on a rotating disk

Wide Dynamic Range

DVS



CIS

DVS Specifications

DVS Gen2 Specifications

		Unit	DVS 2nd chip (Gen2) ('16.7)
Size		mm×mm	8.0 x 5.8
Resolution			640 x 480
Voltage	Analog	V	2.8 ±10%
	Bias	V	
	Digital	V	1.2 ±10%

Dynamic range		dB	90 (3~100,000 Lux)
Minimum Contrast Sensitivity		%	13
Stationary Noise Event per pixel	< 100Lux	EPS	0.03
	< 10,000Lux	EPS	

Peak Event Data Rate		MEPS*	50 (8 pixel On/Off events are reported as a single event)
Pixel Response Latency	10 Lux	μsec	65(On)/410(Off)
	1,000Lux	μsec	75(On)/410(Off)

*MEPS: Mega Event Per Second

Power Consumption	Monitoring Mode	mW	6~30
	Active Mode	mW	47~70 (MIPI)
Interface			Parallel for USB/FPGA, I²C, MIPI USB ready for FX3

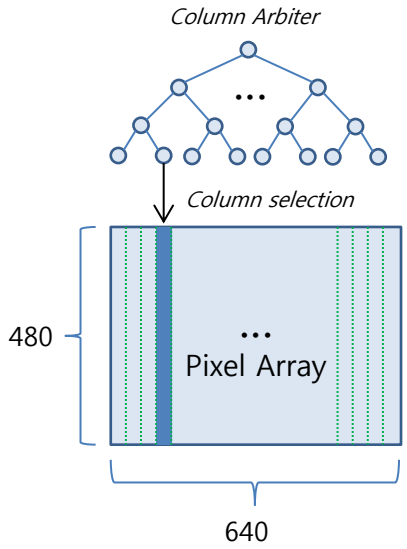
DVS Gen3 Target Specifications

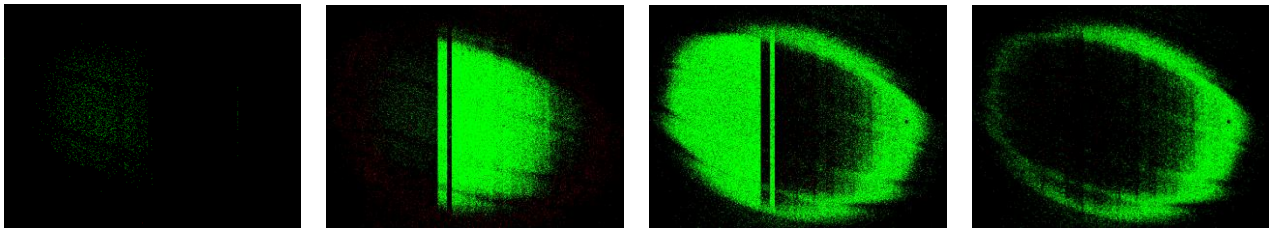
- **Key Features**
  1. Minimize motion artifacts
  2. Two chips : Half VGA, VGA version
  3. Lower light operating : 0.6 lux ~ 100,000 lux (@25°C)
  4. Externally triggered synchronization supported
  5. Operating Temperature : -40°C ~ 85°C

		Unit	Gen2 VGA	Gen3 hVGA	Gen3 VGA
Size		mm×mm	8.0 x 5.8	5.1 x 5.8	8.0 x 5.5
Resolution			640 x 480	320 x 480	640 x 480
Pixel Pitch		um	9	9	9
Voltage	Analog	V	2.8 ±10%		
	Digital	V	1.2 ±10%		
Temperature		°C	-30 ~ 50	-40 ~ 85	
Dynamic range		dB	3~100,000 Lux	0.6~100,000 Lux	
Effective Frame Rate		eFPS	> 1,000	> 2,000	> 2,000(MIPI)
AER		usec	Tree Arbiter	Global shutter / Full scanning	
Minimum Contrast Sensitivity		%	13	< 13	
Stationary Noise Event per pixel		EPS	0.03	0.03	
Operation Mode			Presence Detection, Subsampling, etc	Enhanced Presence Detection, Noise Reduction, etc	
Interface			MIPI (1Gbps 2-Lane), Parallel for USB/FPGA, I^2C, etc		MIPI (1Gbps 4-Lane) , I^2C, etc

DVS Pixel Readout

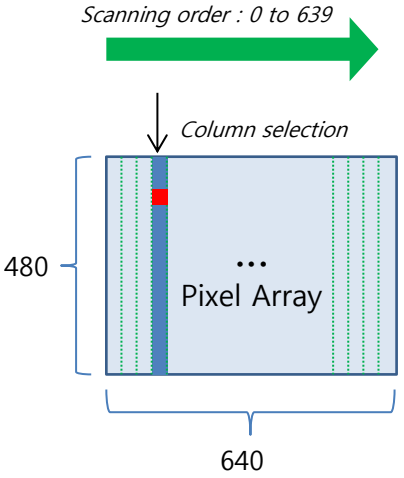
Gen2
unfair arbitration

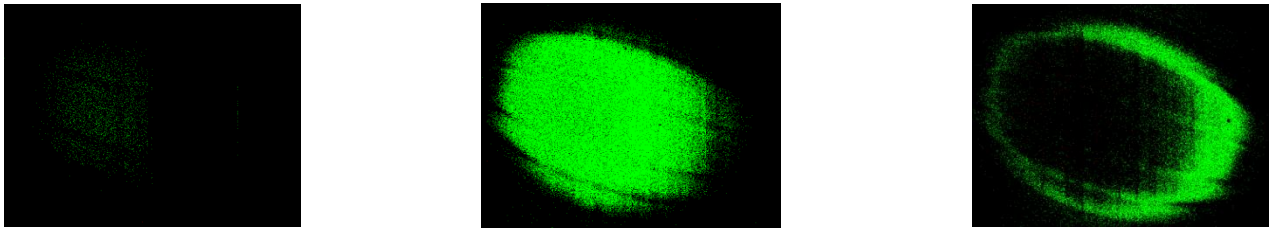




Unfair arbitration scheme

Gen3
scanning scheme





Fast scanning, Global Shutter(all pixels in PA)

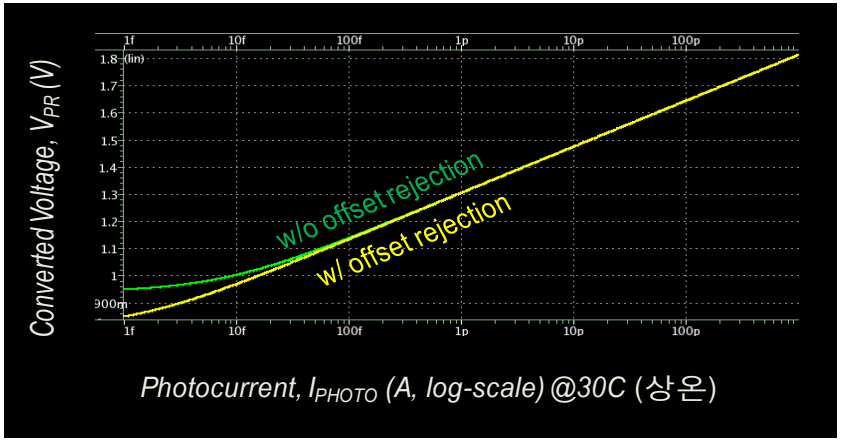
DVS Gen3 Dynamic Range Improvement (Simulation)

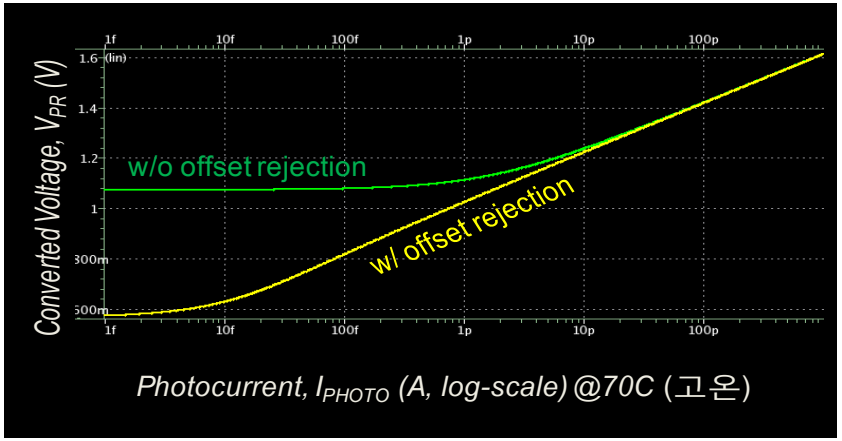
Changes in Pixel Design

	Gen2	Gen3
Power-gating Transistor	O	X
In-Pixel Memory	X	O
Refractory Period	10 μs ~ 1 ms	100 μs + global reset
Dynamic Range	3 ~ 100K Lux @25℃	0.6 ~ 100K Lux @25℃

Better Performance for low intensity

3,000 photons/pixel → 600photons / pixel

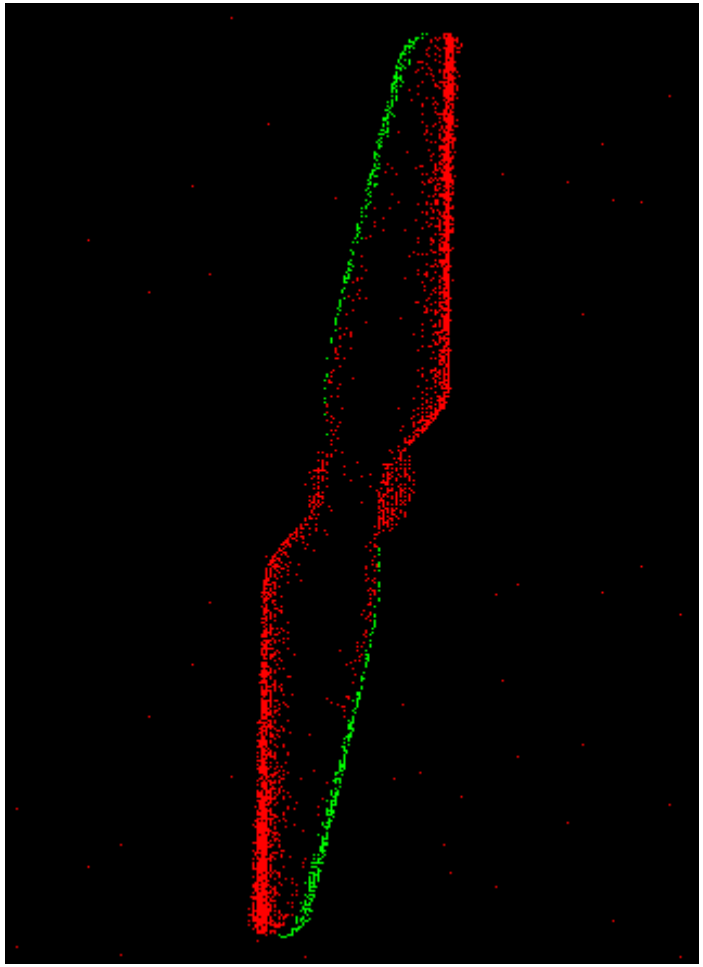




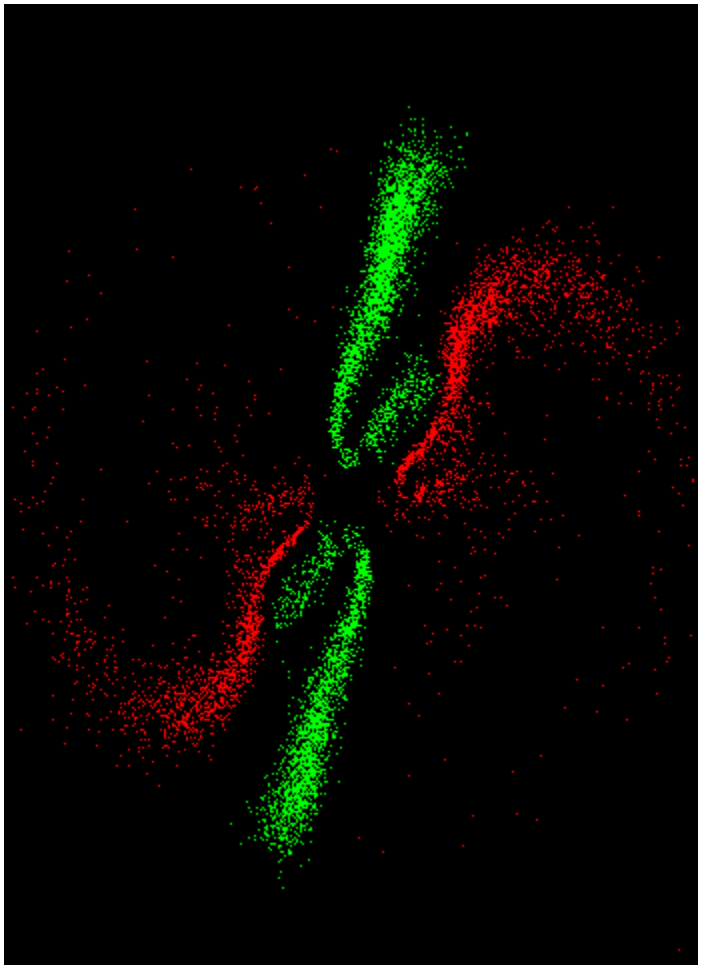
Comparison: DVS Gen3 vs. Gen2

High bandwidth of pixel + fast readout → clear event output

Gen3 (0.35msec/frame)



Gen2 (0.5msec/frame)



Rotating fan @ 8,000rpm