IEEE Xplore® Digital Library

ISCAS 2020
2020 IEEE International Symposium on Circuits and Systems
Virtual, October 10-21, 2020
CAS

A 1280x960 Dynamic Vision Sensor with a 4.95-μm Pixel Pitch and Motion Artifact Minimization

Yunjae Suh, Seungnam Choi, Masamichi Ito, Jeongseok Kim, Youngho Lee, Jongseok Seo, Heejae Jung, Dong-Hee Yeo, Seol Namgung, Jongwoo Bong, Sehoon Yoo, Seung-Hun Shin, Doowon Kwon, Pilkyu Kang, Seokho Kim, Hoonjoo Na, Kihyun Hwang, Changwoo Shin, Jun-Seok Kim, Paul K. J. Park, Joonseok Kim, Hyunsurk Ryu and Yongin Park

Samsung Electronics, South Korea

2020 IEEE International Symposium on Circuits and Systems
Virtual, October 10-21, 2020

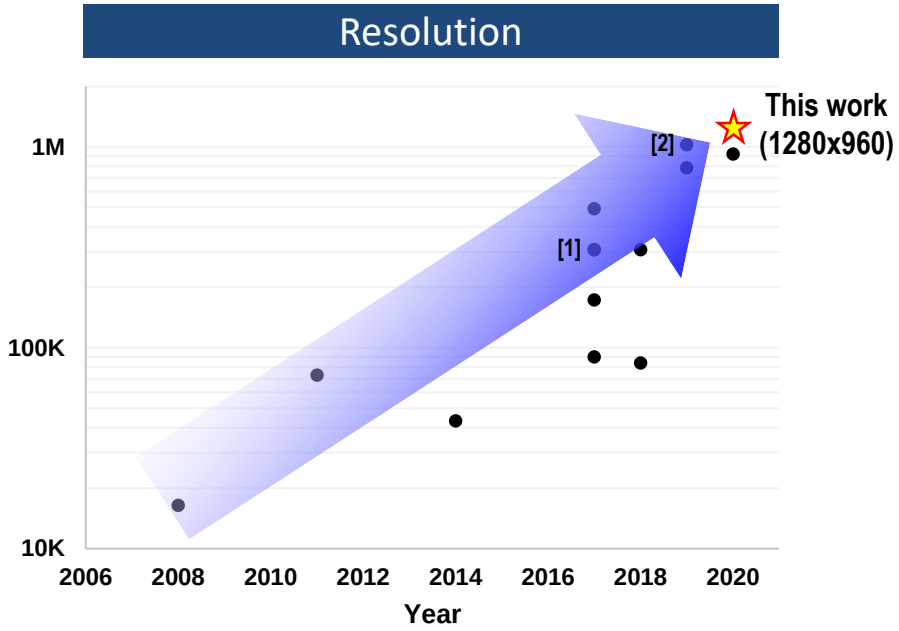
SAMSUNG

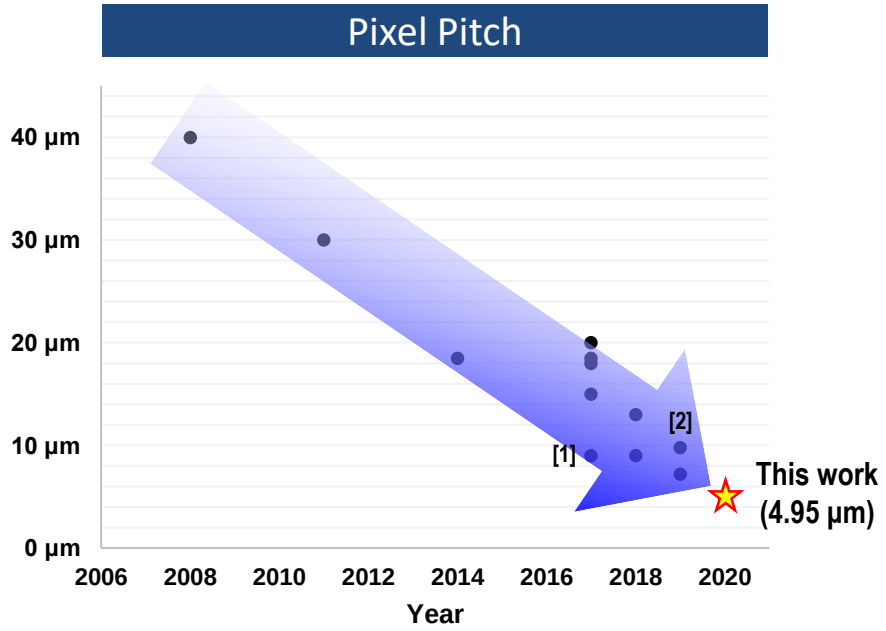
Outline

- ✓ Introduction
- ✓ Pixel Design
- ✓ Motion Artifact Minimization
- ✓ Performance Comparison
- ✓ Summary

Introduction

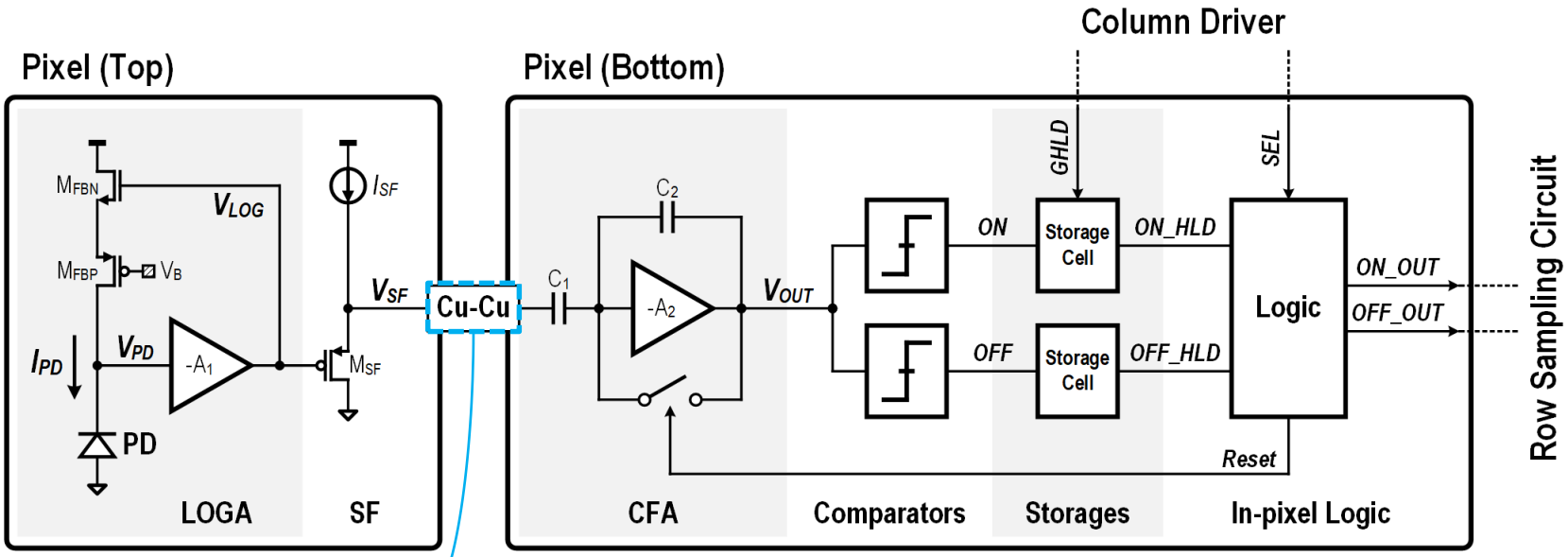
- **1280x960 (1.2M)** resolution and **4.95um** pixel pitch
- Pixel shrink is achieved by Cu-Cu wafer bonding technology.
- Side effects from scaled-down technology and motion artifacts are solved.

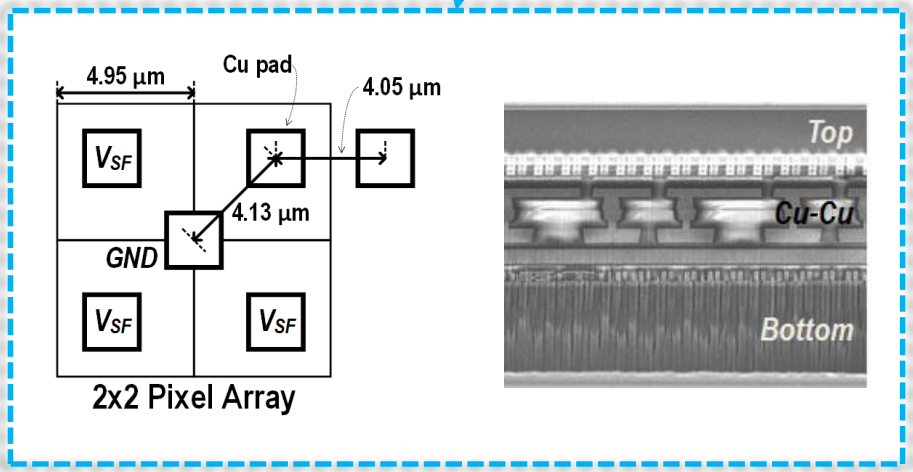




G. Gallego, et al., "Event-based Vision: A Survey," *IEEE Trans. Pattern Anal. Mach. Intell*, Early Access, Jul. 2020

Pixel Structure w/ Cu-Cu bonding





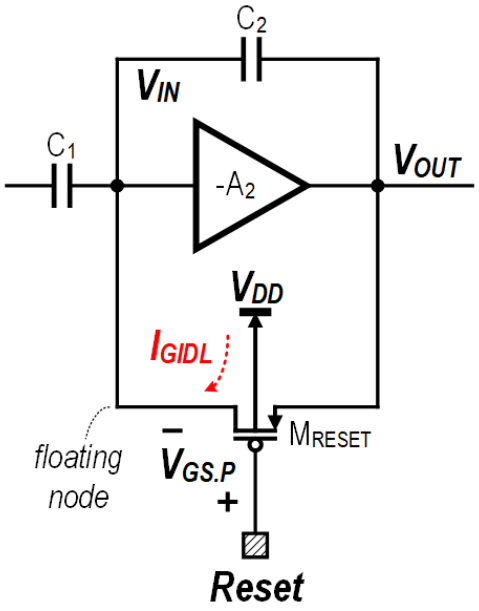
Pixel is composed of

- Photodiode (PD)
- Log Transimpedance Amplifier (LOGA)
- Source Follower (SF)
- Capacitive Feedback Amplifier (CFA)
- Comparators & Event Storages
- In-pixel Logic Circuitry

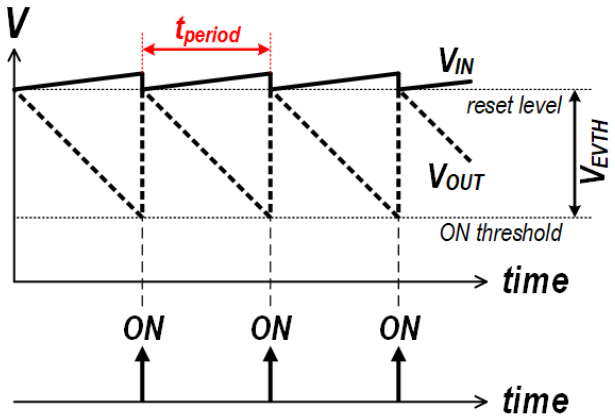
Periodic False Event Generation

- Leakage currents flowing into the floating node induces the periodic false event generation.
- GIDL of M_{RESET} is the dominant source of the leakage currents and it is derived from large $V_{GS.P}$ after reset operation finishes.

CFA w/ Conventional Reset Switch



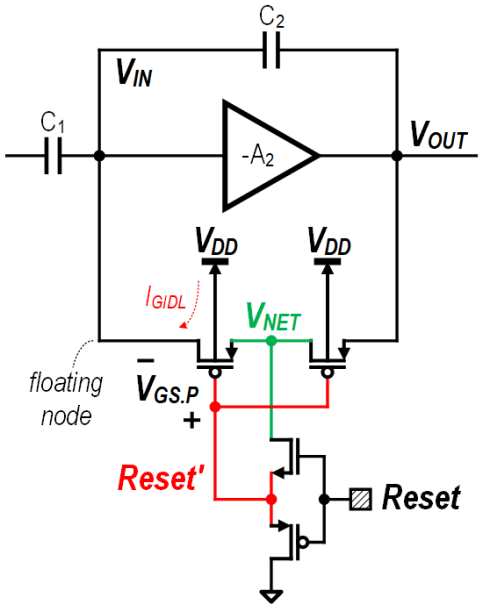
False ON-Event Generation

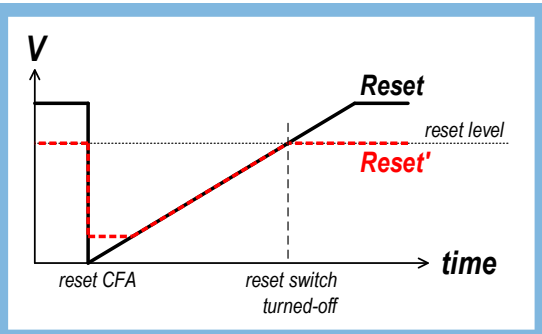


GIDL Suppression

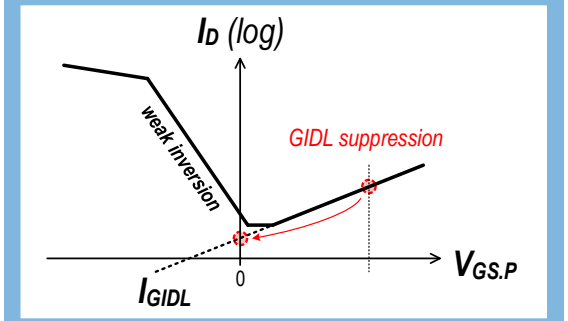
- **GIDL-suppressed reset switch** is newly designed to avoid the periodic false event generation.
- The switch adaptively samples its reset voltage pixel-by-pixel and time-to-time.
- Zero $V_{GS.P}$ after the reset operation finishes decreases GIDL, thus suppresses periodic false events.

GIDL-suppressed Switch



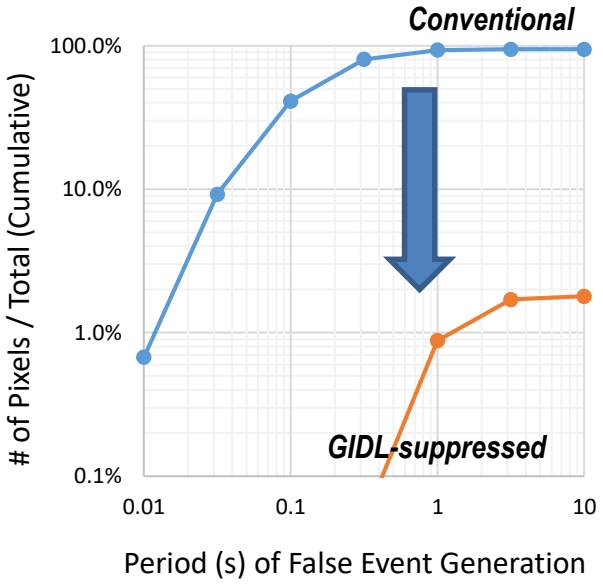


Timing Diagram at Reset



I-V Curve in Weak Inversion

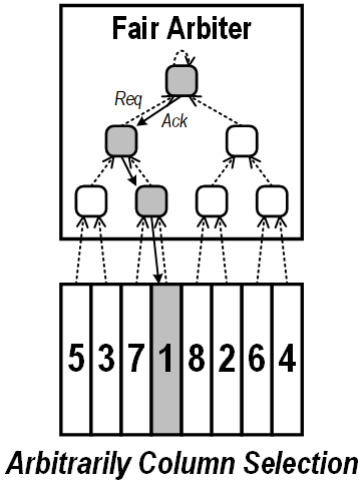
Measurement Result



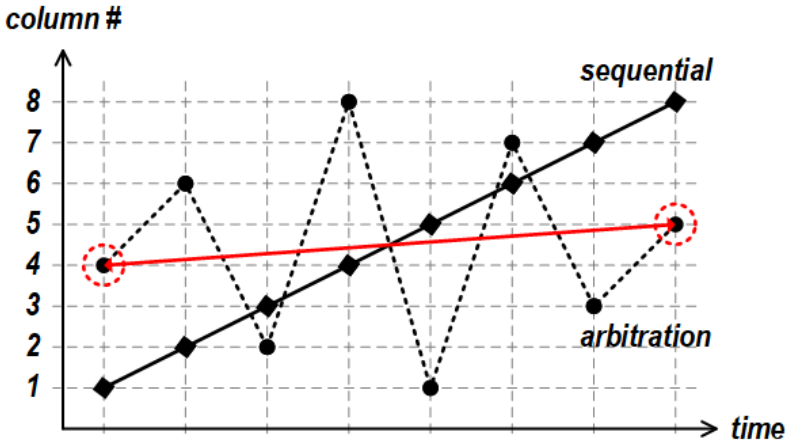
Motion Artifact Minimization (1/2)

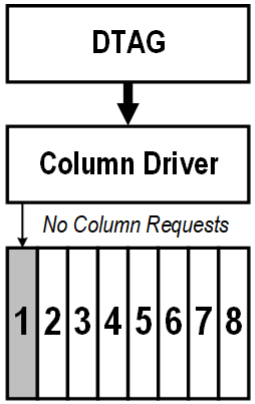
- **Sequential Column Readout** is employed to avoid the motion artifact which is introduced by the event-handling order of fair arbiter.

Arbitration VS Sequential Readout



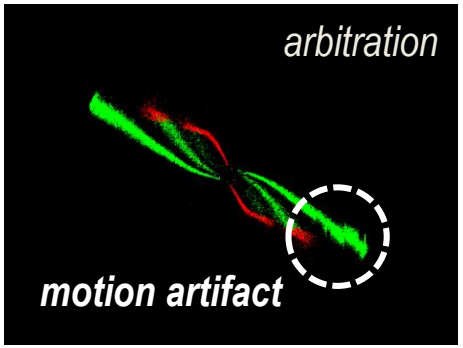
Arbitrarily Column Selection

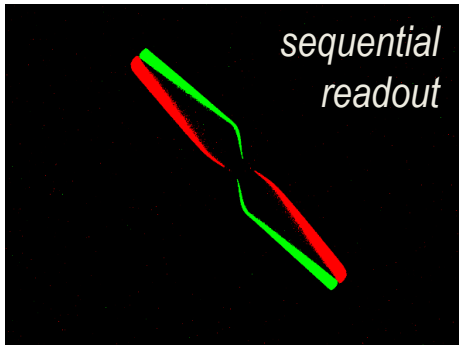




Sequential Column Selection

Captured Images (Rotating Fan)

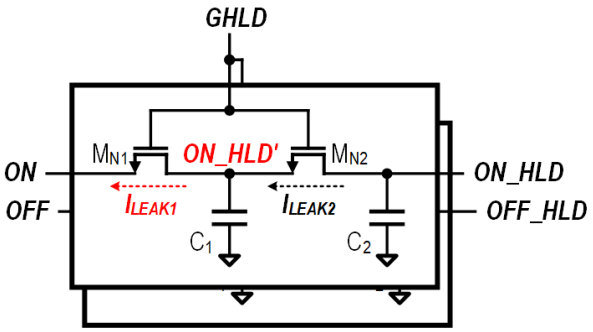




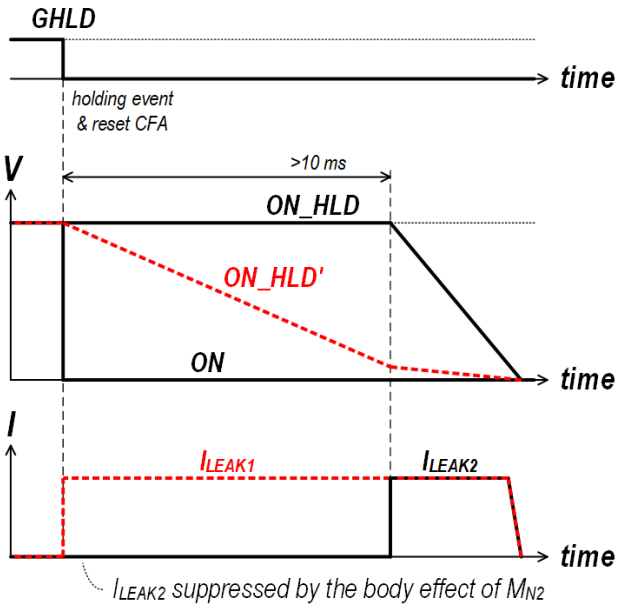
Motion Artifact Minimization (2/2)

- **Global Event-Holding Function** is implemented to avoid a jello effect.
- The cascaded structure of the in-pixel storage secures the sampled event voltage from the channel leakage.

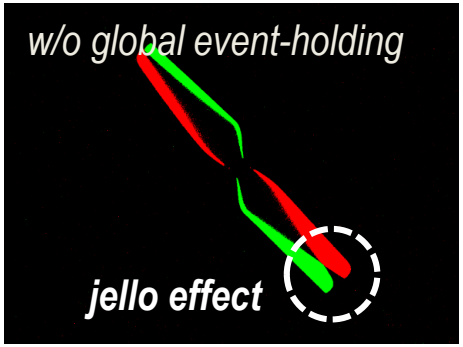
Cascaded Structure of in-pixel Storage

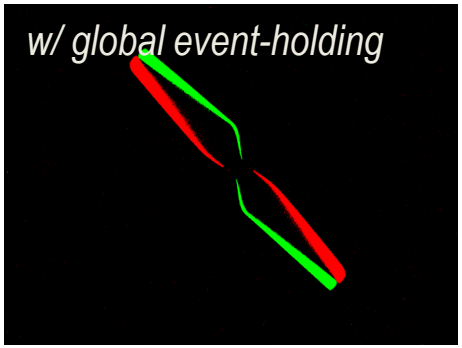


Leakage Prevention



Captured Images (Rotating Fan)

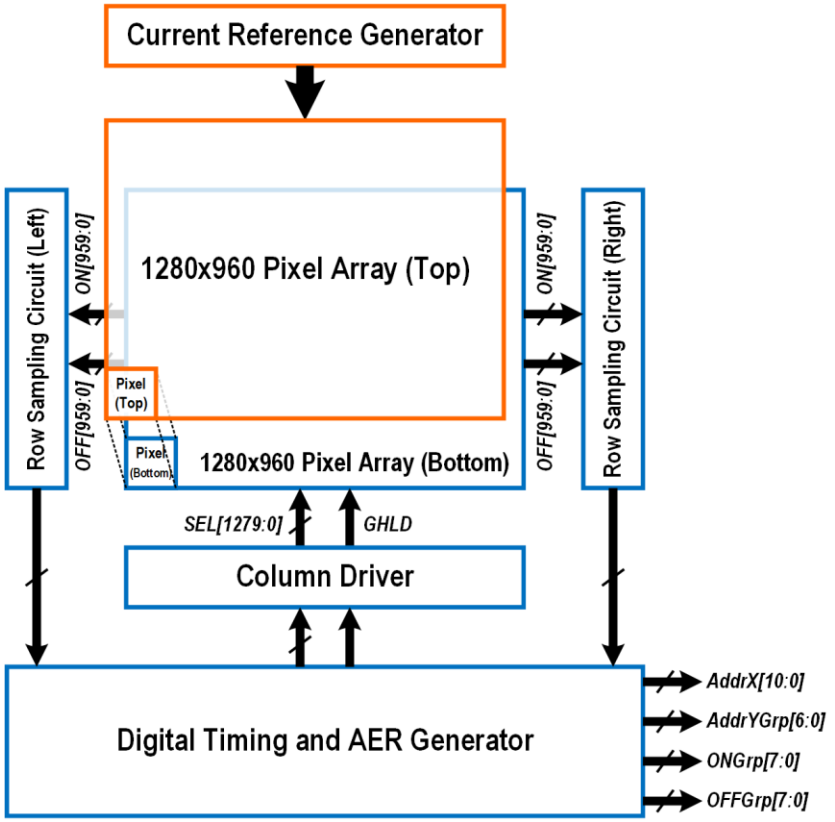




Top Block Diagram & Chip Photo

- Pixel array is divided into the top and the bottom wafers.
- 8.37 x 7.64 mm^2 sensor was fabricated in a 65 nm/28 nm stack process.

Top Block Diagram



Chip Photo

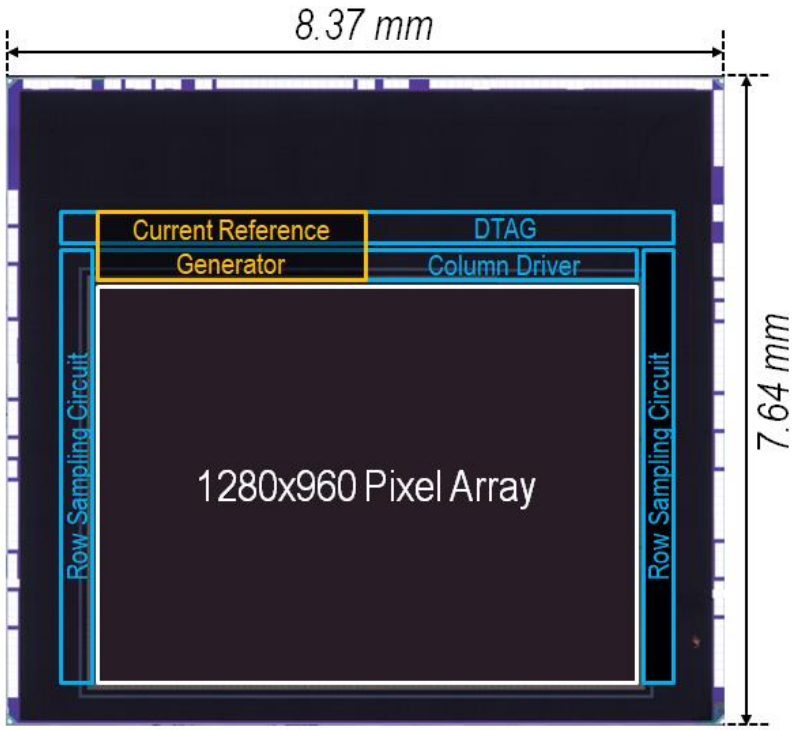
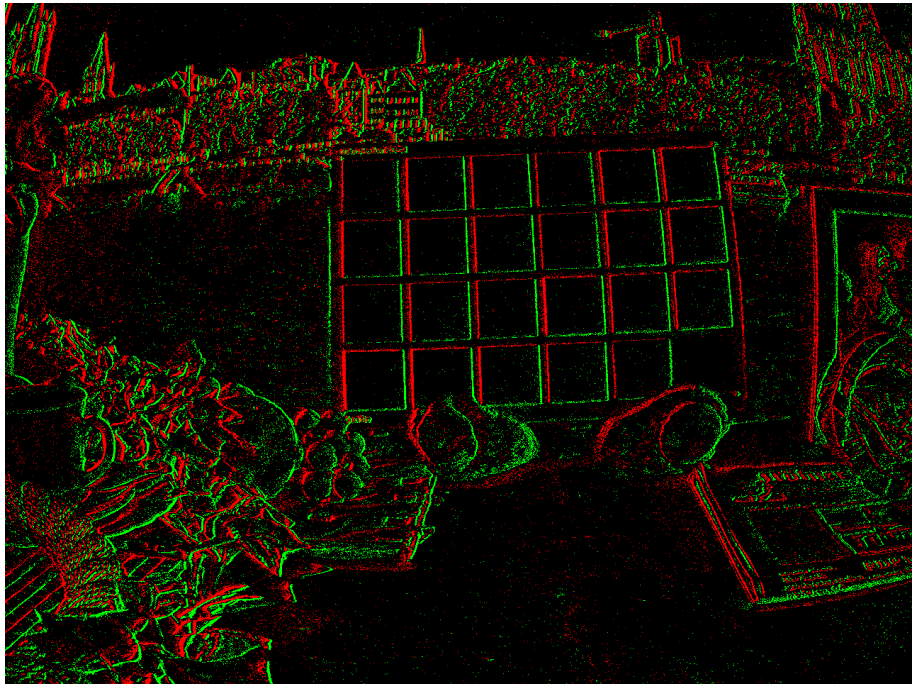


Image from Event Stream

- 1280x960 high-resolution image captured from event stream



A captured image from the event stream
(Green for ON event, Red for OFF event)

Original studio scene

Performance Comparison

- **The *highest* resolution** and **the *highest* event rate** were achieved.
- 2.5-Gbps 4-lane MIPI is integrated to transfer 1.3 x 10^9 events in a second.

		This work	ISSCC 2017 [1]	CVPR 2019 [2]	VLSI 2019 [6]	ISSCC 2020
Process		**65 nm 1P6M BSI / 28 nm 1P7M**	90 nm 1P5M BSI	65 nm CIS	65 nm 1P9M	90 nm BI CIS / 40 nm CMOS
Resolution		**1280x960**	640x480	1280x800	132x104	1280x720
Chip Area		**8.37x7.64 mm^2**	8.0x5.8 mm^2	-	2.0x2.0 mm^2	-
Pixel Pitch		**4.95 µm**	9 µm	9.8 µm	10 µm	4.86 µm
Fill Factor		**22%**	-	-	20%	>77%
Supply Voltages		**2.8 V, 1.8V, 1.0 V**	2.8 V, 1.2 V	-	1.2 V	2.5 V, 1.1 V
Power Consumption	Total[a]	**150 mW[c]**	50 mW[d]	400 mW[c]	4.9 mW[d]	84 mW[d]
	per Pixel[b]	**122 nW**	162 nW	391 nW	357 nW	91 nW
Max Event Rate		**1.3 Geps**	300 Meps	-	180 Meps	1.066 Geps
Readout		**Sequential**	Arbitration	-	Sequential	Arbitration
In-Pixel Storage		**Yes**	No	-	Yes	-
Interface		**MIPI**	MIPI	MIPI	Parallel	Parallel

a. At max event rate or under high activity condition

b. Normalized by resolution

c. Including power consumption at MIPI as I/O

d. Including power consumption at parallel interface as I/O

Summary

- 1280x960 resolution dynamic vision sensor
- 4.95-µm pixel pitch with in-pixel Cu-Cu bonding technology
- GIDL-suppressed switch
- Sequential column selection
- Global event-holding function
- The highest resolution (1.2Mpixels)
- The highest event rate (1.3 Geps)