Re: **United States Patent 8,513,102 *Forbes* , et al. August 20, 2013**
Reduction of random telegraph signal (RTS) and 1/f ***noise*** in silicon MOS devices, circuits, and sensors

The global image sensors market is estimated to be valued at $15,934.8 million in 2017 and is forecasted to witness a CAGR of 6.2% during 2018–2023.Rising demand for improved medical imaging solutions and increasing penetration of image sensing devices in the automobile sector are the key factors driving the growth of the image sensors market. Some of the key players in the global image sensors industry are Sony Corporation, Panasonic Corporation, Samsung Electronics Co. Ltd., OmniVision Technologies Inc., Canon Inc., STMicroelectronics N.V., Toshiba Corporation, SK Hynix Inc., ON Semiconductor Corporation, and Hamamatsu Photonics K.K.

Attached is a description of our patent, it is undoubtedly being used by all CMOS imaging companies, as a technique to minimize noise and increase sensitivity. More generally it is applicable to all CMOS integrated circuits being used in the world today to reduce bit errors in memory and logic circuits. This could provide you with tremendous leverage in your patent portfolio. Global revenue in the semiconductor industry stood at almost 340 billion U.S. dollars in 2014 and it is expected to grow further in the coming years. By 2016, the industry is projected to generate yearly revenue of over 350 billion U.S. dollars, representing a year-on-year growth of 4.3 percent.

TECHNIQUE TO REDUCE RANDOM TELEGRAPH SIGNAL(RTS) and l/f NOISE IN SILICON MOS DEVICES, CIRCUITS, AND SENSORS

INVENTORS

Given Names	Family Name	Residence	Mailing Address	Citizenship
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PRIORITY DATA

This application claims the benefit of U.S. Provisional Patent Application Serial No. 61411376, filed on November 8, 2010, and which is incorporated herein by reference.

ABSTRACT

The effects of random telegraph noise signal(RTS) or equivalently l/f noise on MOS or CMOS devices, circuits and sensors is described. Techniques are disclosed for minimizing this RTS and low frequency noise in MOS or CMOS devices, integrated circuits, and sensors by minimizing the number of ionized impurity atoms in the wafer, substrate, well, pillar or fin behind the channel of the CMOS transistors. This serves to reduce the errors in devices, sensors and analog integrated circuits and error rates in digital integrated circuits and memories.

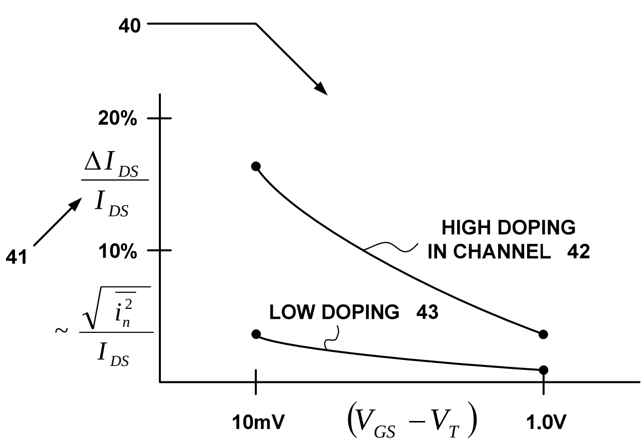

FIG. 4

US008513102B2

(12) **United States Patent**
Forbes et al.

(10) **Patent No.:** **US 8,513,102 B2**
(45) **Date of Patent:** **Aug. 20, 2013**

(54) **REDUCTION OF RANDOM TELEGRAPH SIGNAL (RTS) AND 1/F NOISE IN SILICON MOS DEVICES, CIRCUITS, AND SENSORS**

(76) Inventors: **Leonard Forbes**, Corvallis, OR (US); **Drake A. Miller**, Tigard, OR (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/317,522**

(22) Filed: **Oct. 20, 2011**

(65) **Prior Publication Data**

US 2012/0112251 A1 May 10, 2012

Related U.S. Application Data

(60) Provisional application No. 61/411,376, filed on Nov. 8, 2010.

(51) **Int. Cl.**
H01L 21/425 (2006.01)
H01L 21/336 (2006.01)

(52) **U.S. Cl.**
USPC **438/514**; 257/E21.409; 257/288

(58) **Field of Classification Search**
USPC 257/288, E21.409, E29.255; 438/292, 438/514
See application file for complete search history.

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Drake A. Miller, Panupat Poocharoen and Leonard Forbes, "Subthreshold leakage due to 1/f noise and RTS(random telegraph signals)," IEEE Workshop on Microelectronics and Electron Devices, Boise, Apr. 20, 2007, pp. 23-24.
Slavcheva G. et al., "Potential Fluctuations in metal-oxide-semiconductor field-effect transistors generated by randomly distributed impurities in the depletion layer," J. Appl. Phys., vol. 91, No. 7, pp. 4326-4324, 2002.

(Continued)

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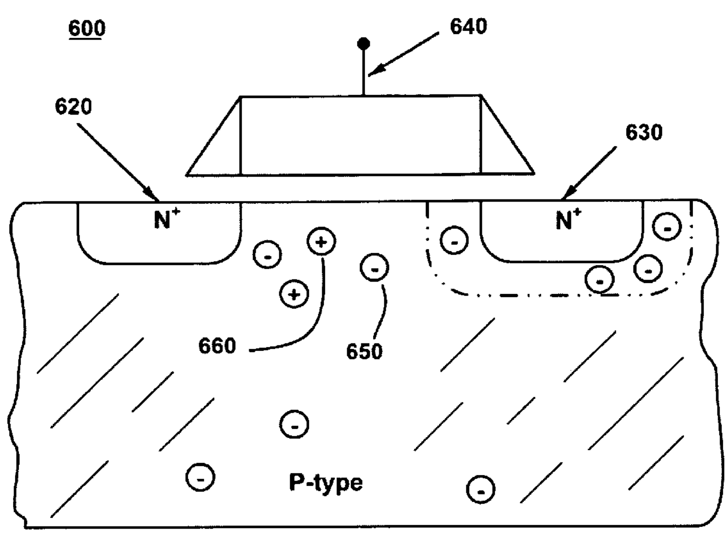
Assistant Examiner — Christine Enad

(57) **ABSTRACT**

The effects of random telegraph noise signal (RTS) or equivalently 1/f noise on MOS devices, circuits, and sensors is described. Techniques are disclosed for minimizing this RTS and low frequency noise by minimizing the number of ionized impurity atoms in the wafer, substrate, well, pillar, or fin behind the channel of the MOS transistors. This noise reduction serves to reduce the errors in devices, sensors, and analog integrated circuits and error rates in digital integrated circuits and memories.

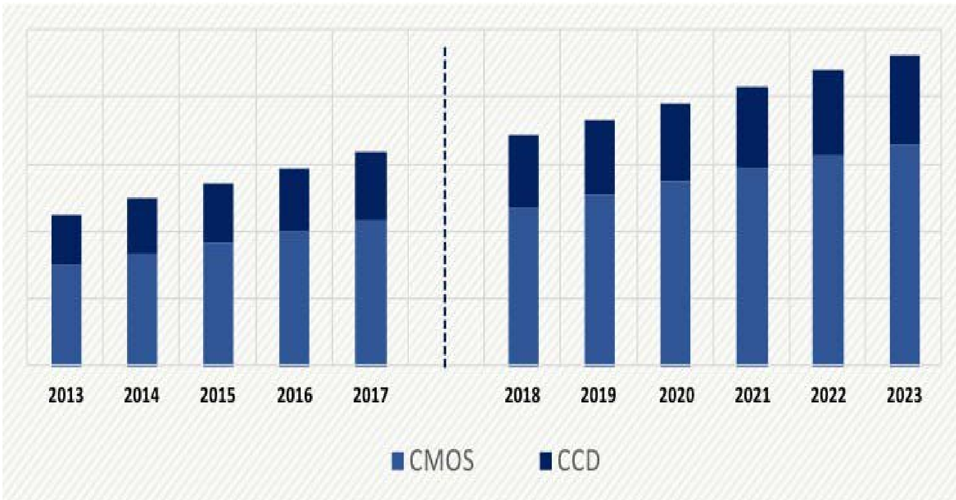
20 Claims, 6 Drawing Sheets



CMOS IMAGE SENSORS

https://www.psmarketresearch.com/market-analysis/image-sensors-market

in billions of US dollars (each division on the vertical axis is 5 billion dollars)



The global image sensors market is estimated to be valued at $15,934.8 million in 2017 and is forecasted to witness a CAGR of 6.2% during 2018–2023.Rising demand for improved medical imaging solutions and increasing penetration of image sensing devices in the automobile sector are the key factors driving the growth of the image sensors market.

Some of the key players in the global image sensors industry are Sony Corporation, Panasonic Corporation, Samsung Electronics Co. Ltd., OmniVision Technologies Inc., Canon Inc., STMicroelectronics N.V., Toshiba Corporation, SK hynix Inc., ON Semiconductor Corporation, and Hamamatsu Photonics K.K.

Results of Search in US Patent Collection db for: ABST/(rts AND noise)

1 10,044,962 T Solid-state imaging device, method of manufacturing solid-state imaging device, and electronic apparatus

2 9,912,891 T Solid-state imaging device, method of manufacturing solid-state imaging device, and electronic apparatus

3 9,762,832 T Solid-state imaging device, method of manufacturing solid-state imaging device, and electronic apparatus

4 9,723,578 T Random telegraph signal identification and measurement

5 9,531,968 T Imagers having image processing circuitry with error detection capabilities

6 9,479,717 T Image sensor array with external charge detection circuitry

7 9,380,234 T Reduced random telegraph signal noise CMOS image sensor and associated method

8 9,363,451 T Solid-state imaging device, method of manufacturing solid-state imaging device, and electronic apparatus

9 8,994,082 T Transistors, methods of manufacturing thereof, and image sensor circuits with reduced RTS noise

10 8,937,272 T Vertical JFET source follower for small pixel CMOS image sensors

11 8,785,986 T BCMD image sensor with junction gate for back side or front side illumination

12 **8,513,102** T **Reduction of random telegraph signal (RTS) and 1/f noise in silicon MOS devices, circuits, and sensors**

13 7,983,230 T Adaptive power and data rate control for ad-hoc mobile wireless systems

14 7,885,990 T Random telegraph signal noise as a source for random numbers

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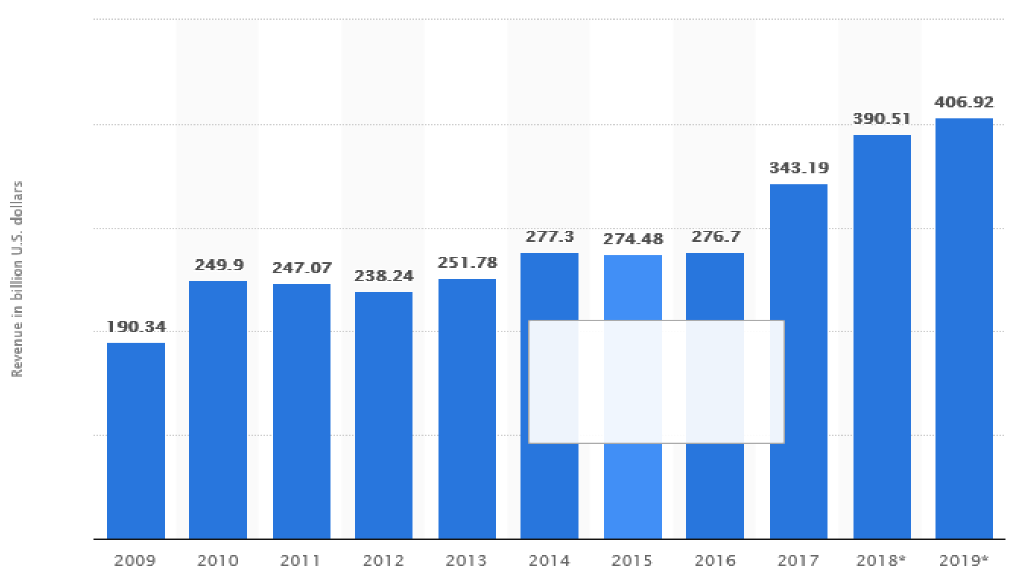
INTEGRATED CIRCUITS(mainly CMOS processors and memory, includes CMOS image sensors)

https://www.statista.com/statistics/519456/forecast-of-worldwide-semiconductor-sales-of-integrated-circuits/

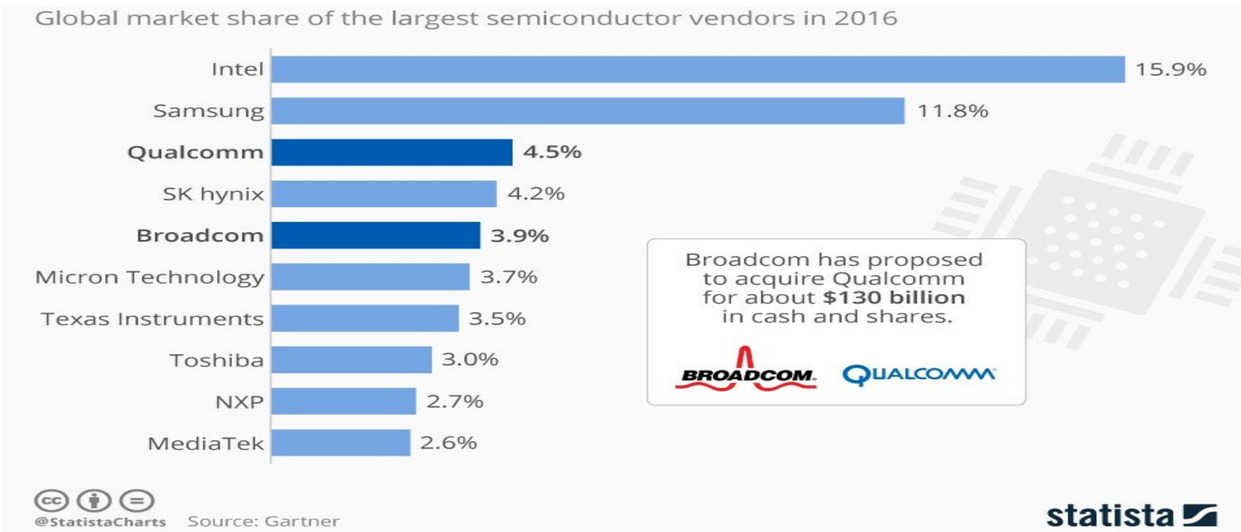
Integrated circuits semiconductor market size worldwide from 2009 to 2019 (in billion U.S. dollars)



This statistic shows the global revenue generated by the leading semiconductor vendors in the industry from 2009 to 2017. In 2017, Samsung was the leading semiconductor vendor with about 59.88 billion U.S. dollars in revenue. Intel was the leading vendor in the semiconductor industry in 2014 as the company generated revenue of over 50.8 billion U.S. dollars. This is a steady increase on the 33.4 billion U.S. dollar revenue it generated in 2009. In the same time period, Samsung Electronics, Intel's closest competitor, has seen its industry revenue increase from 17.7 billion U.S. dollars to over 35.28 billion U.S. dollars. Intel's overall market share of the semiconductor industry in 2014 stood at 15 percent, whilst Samsung Electronics held 10.4 percent of the market. Qualcomm was their nearest rival as the Californian company held a market share of 5.6 percent.

The revenue generated by Intel in the semiconductor industry marks a significant portion of the company's overall net revenue, which stood at 55.87 billion U.S. dollars in 2014. In 2013, some 9 billion U.S. dollars was generated domestically in the United States and a further 11 billion U.S. dollars was made in Singapore. In comparison, Samsung Electronics' 30 billion U.S. dollar revenue in the semiconductor industry represents less than 15 percent of the company's overall revenue, which was estimated at over 216 billion U.S. dollars in 2013. Around a third of this revenue was generated in the Americas and a further 23 percent in Europe.

Global revenue in the semiconductor industry stood at almost 340 billion U.S. dollars in 2014 and it is expected to grow further in the coming years. By 2016, the industry is projected to generate yearly revenue of over 350 billion U.S. dollars, representing a year-on-year growth of 4.3 percent.



Some of the above companies, like Qualcomm and Broadcom, and smaller companies not on the list utilize large foundry sites for manufacturing like: Taiwan Semiconductor Manufacturing Company, Ltd., Hsin-Chu, TW, with 48,000 employees ; United Microelectronics Corporation (UMC) Taiwan (HQ), Fab Operations Taiwan, Singapore and China, Employees Over 20,000 Worldwide, and GlobalFoundaries in New York with 17,000 employees.

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PROFESSOR (retired after 40 years), INVENTOR (over 1000 US patents)

EDUCATION

B.Sc (with Distinction) in Engineering Physics, 1962 University of Alberta,Edmonton; M.S. in Electrical Engineering, 1963 University of Illinois,Urbana; Ph.D. in Electrical Engineering, 1970 University of Illinois, Urbana,Thesis Advisor, Professor C.T. Sah, Minor in Physics.

Post-Doctoral Continuing Education 1974-Summer: Short Course on Integrated Optics University of California, Santa Barbara 1975-Summer: Short Course on Charge Transfer (Coupled) Devices University of Southern California,Los Angeles 1985-Summer: Organized Short Course on Defects in Silicon Portland Conference on Silicon Materials and Technology 1986-Summer: Organized Short Course on CMOS Technology Organized Short Course on GaAs Integrated Circuits Portland Conference on Silicon Materials and Technology 1987-Summer: TriQuintSemiconductor Chip Design Course, a week long course and follow-on projecton chip design and layout 1990-IEDM IEEE Short Course on Silicon-on-InsulatorTechnology 1996-IEDM IEEE Short Course on DRAMs; Aug. 2008 SPIE Short Course on Non-Imaging Optics, San Diego, CA; Feb. 2009 IEEE Short Course on Medical Imaging, San Francisco CA;

HONORS/PROFESSIONAL RECOGNITION

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1970-72 Staff Engineer, IBM Components Div., Fishkill N.Y. and Manassas,Virginia; 1973 Consultant to TELEX Computer Products, Tulsa, OK; 1974 Consultantto D.H. Baldwin, Fayetteville, AR; 1978 at Hewlett-Packard Labs., PaloAlto, California; 1979-81 Consultant to Hewlett-Packard, Santa Rosa, Calif.;1981-85 Consultant to Fairchild Semiconductor, Healdsburg, California;1988-1992 Consultant(Research Fellow)to Naval Ocean Systems Center, San Diego, California;1993 Consultant to Hewlett-Packard, Corvallis, OR; 1996-2007, Adjunct Research Fellow, Micron Advanced Research Institute, Boise, Idaho; 2008 Consultant to Advanced Pixel Research Lab., MagnaChip, Lake Oswego, OR.; 2009 ,2011, consultant to SiOnyx Beverly MA and Portland OR; 2010, 2012-present   L. Forbes and Associates LLC.

MILTARY SERVICE

Long Range Navigator, Royal Canadian Air Force,Ottawa, Ontario, Canada;1958 - 1966, Rank on release F/L (Captain) and stationed in Nova Scotia on long range maritime patrols over the North Atlantic. Lead navigator responsible for both long range and tactical command of an anti-submarineaircraft with a crew of twelve.