United States Patent [19]

Lyon

[11] **3,956,622**

[45] **May 11, 1976**

[54] **TWO'S COMPLEMENT PIPELINE MULTIPLIER**

[75] Inventor: **Richard Francis Lyon,** Stanford, Calif.

[73] Assignee: **Bell Telephone Laboratories, Incorporated,** Murray Hill, N.J.

[22] Filed: **Dec. 20, 1974**

[21] Appl. No.: **534,765**

[52] **U.S. Cl.** **235/164**

[51] **Int. Cl.²** **G06F 7/54**

[58] **Field of Search** 235/156, 164

[56] **References Cited**

UNITED STATES PATENTS

3,582,634	6/1971	Bartlett	235/164
3,627,999	12/1971	Iverson	235/164
3,737,638	6/1973	Esteban	235/164
3,761,699	9/1973	Sather	235/164 X
3,805,043	4/1974	Clary	235/164

OTHER PUBLICATIONS

L. B. Jackson et al., "An Approach to the Implementation of Digital Filters" IEEE Trans. on Audio & Electroacoustics, Vol. AU-16, No. 3, 9-1968, pp. 413-421.

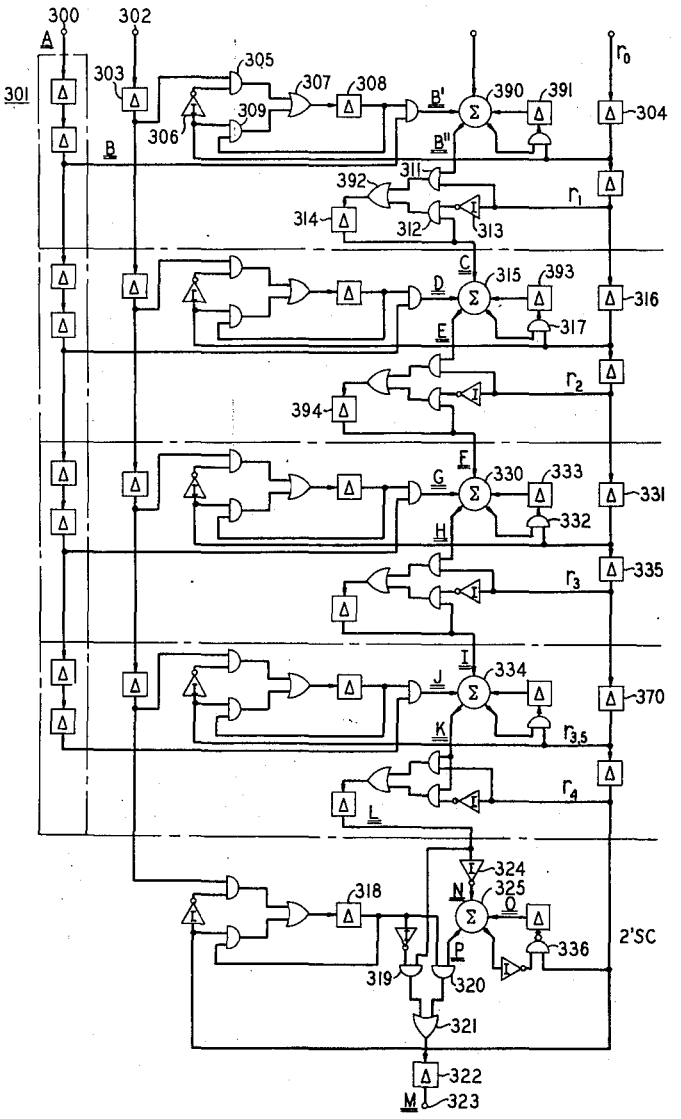
Digital Computer Design Fundamentals, Published 1962, pp. 444-447.

Primary Examiner—Malcolm A. Morrison
Assistant Examiner—Jerry Smith
Attorney, Agent, or Firm—R. A. Ryan

[57] **ABSTRACT**

The present invention includes a substantially modular pipeline multiplier for directly forming the correct final product of a 2's complement data word and a sign and magnitude coefficient word. In particular, the present invention includes circuitry for inserting logic 1 signals into the computations as sign extensions during multiplication whenever the data word is a negative 2's complement number.

4 Claims, 5 Drawing Figures



United States Patent [19]

Bell et al.

[11] **Patent Number: 4,494,021**

[45] **Date of Patent: Jan. 15, 1985**

[54] **SELF-CALIBRATED CLOCK AND TIMING SIGNAL GENERATOR FOR MOS/VLSI CIRCUITRY**

[75] Inventors: **Alan G. Bell; Richard F. Lyon; Gaetano Borriello,** all of Palo Alto, Calif.

[73] Assignee: **Xerox Corporation,** Stamford, Conn.

[21] Appl. No.: **412,490**

[22] Filed: **Aug. 30, 1982**

[51] **Int. Cl.**[3] **H03K 5/06;** H03K 17/284; H03L 7/08

[52] **U.S. Cl.** **307/591;** 307/481; 307/526; 307/601; 307/606; 331/25

[58] **Field of Search** 307/443, 453, 480–481, 307/519, 523, 526, 591, 597, 601, 605–606, 269; 331/25

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,953,674	4/1976	Fletcher et al.	375/87
3,996,481	12/1976	Chu et al.	307/481 X
4,011,402	3/1977	Koike et al.	307/481 X
4,103,251	7/1978	Glick	307/480 X
4,185,273	1/1980	Gowan	340/347 DD
4,344,041	8/1982	Maine	329/50
4,358,741	11/1982	Nardin	331/25 X
4,388,537	6/1983	Kanuma	307/297

OTHER PUBLICATIONS

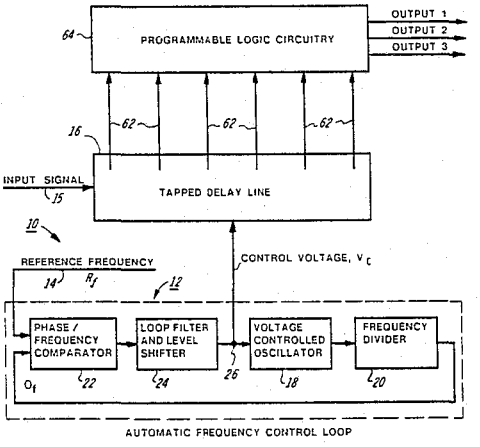
Mead and Conway, Introduction to VLSI Systems, Addison-Wesley Pub. Co., Menlo Park, CA, 1980, pp. 17–18, 67, 229–236.

Primary Examiner—Stanley D. Miller
Assistant Examiner—David R. Hudspeth
Attorney, Agent, or Firm—W. Douglas Carothers, Jr.

[57] **ABSTRACT**

A self-calibrated clock and timing signal generator provides reliable and continuous arbitrary digital waveforms of preselectable edge resolution. The generator comprises a multistage means to produce a time delayed signal of preselectable edge resolution and having a plurality of outputs or taps between a plurality of series connected delay stages comprising the multistage means. The delay per stage is substantially identical so that the selection of any one of the outputs is representative of a predetermined amount of delay provided to an input signal to the multistage means. Calibrating means is integrally included to develop a control signal which is coupled to each of the stages of the multistage means to continuously maintain the predetermined amount of delay per stage. In the embodiment described, the calibrating means takes the form of an automatic frequency control (AFC) loop wherein the frequency of a voltage controlled oscillator (VCO) is regulated to be equal to that of a reference frequency. The VCO comprises a plurality of series connected delay stages. The control voltage is applied to each stage to control the period of frequency of the VCO. The control voltage developed to adjust the VCO frequency is also employed to regulate the delay of the stages comprising the multistage means. The stages of the delay line are identical in construction to the stages of the VCO.

8 Claims, 10 Drawing Figures



United States Patent [19]

Borriello et al.

[11] **Patent Number: 4,513,427**

[45] **Date of Patent: Apr. 23, 1985**

[54] **DATA AND CLOCK RECOVERY SYSTEM FOR DATA COMMUNICATION CONTROLLER**

[75] Inventors: **Gaetano Borriello; Richard F. Lyon; Alan G. Bell,** all of Palo Alto, Calif.

[73] Assignee: **Xerox Corporation,** Stamford, Conn.

[21] Appl. No.: **412,637**

[22] Filed: **Aug. 30, 1982**

[51] **Int. Cl.**[3] **H04L 7/06**

[52] **U.S. Cl.** **375/110;** 375/87; 370/108

[58] **Field of Search** ..... 375/87, 110; 360/39-44, 51; 340/347 DD; 329/50, 104, 122; 328/56; 370/108

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,953,674	4/1976	Fletcher et al.	375/87
3,996,481	12/1976	Chu et al.	307/262
4,011,402	3/1977	Koike et al.	358/213
4,063,220	12/1977	Metcalfe et al.	370/85
4,103,251	7/1978	Glick	331/1 A
4,185,273	1/1980	Gowan	340/347 DD
4,282,512	8/1981	Boggs et al.	340/147.037
4,287,596	9/1981	Chari	375/49
4,344,041	8/1982	Maine	329/50
4,358,741	11/1982	Nardin	331/2
4,363,002	12/1982	Fuller	331/1 A
4,388,537	6/1983	Kanuma	307/297

OTHER PUBLICATIONS

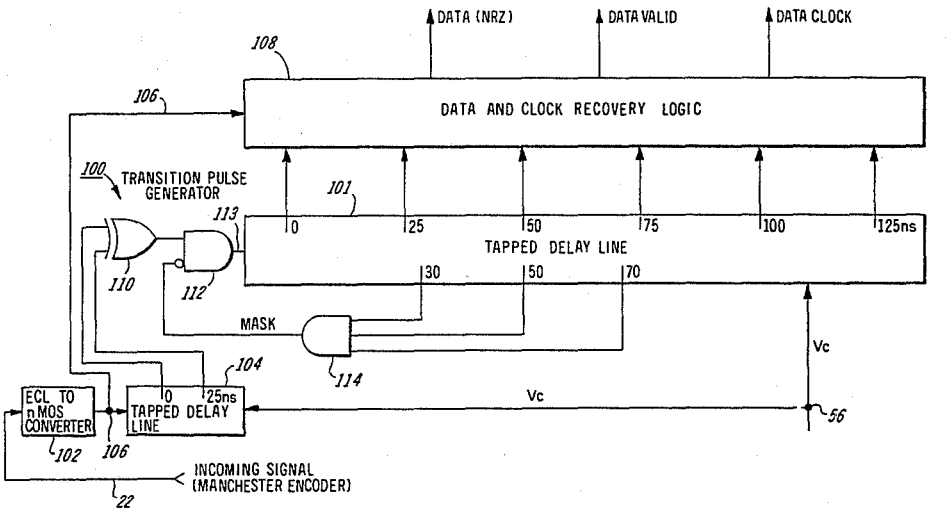
Mead & Conway, Introduction to VLSI Systems, Addison-Wesley Pub. Co., pp. 17-18, 67, 229-236 (1980).

Primary Examiner—Benedict V. Safourek
Assistant Examiner—Stephen Chin
Attorney, Agent, or Firm—W. Douglas Carothers, Jr.

[57] **ABSTRACT**

A data and clock recovery system is provided in the signal handling receiver (SHRx) stage of an integrated MOS circuit data communication controller to provide accurate sampling of an incoming data packet for recovery of the data and data clock, regardless of differences in the electrical and environmentally affected characteristics of the circuit elements comprising the integrated MOS/VLSI semiconductor chip. The system comprises a delay means including a plurality of delay stages to generate a transition pulse for every transition in the data packet, a similar delay means to apply a predetermined amount of unit delay to all of the transition pulses, both data transition pulses and between bit transition pulses, means to develop a mask from the delayed transition pulses representative of the time occurrence of any between bit transitions, means to apply the mask to the incoming data packet whereby the extraneous between bit transition pulses are removed therefrom, and means coupled to the delay means to calibrate the delay means by ensuring that each of its delay stages continuously impose a predetermined unit delay per stage.

8 Claims, 16 Drawing Figures



United States Patent [19]

Lyon

[11] **Patent Number: 4,521,772**

[45] **Date of Patent: Jun. 4, 1985**

[54] **CURSOR CONTROL DEVICE**

[75] Inventor: **Richard F. Lyon**, Palo Alto, Calif.

[73] Assignee: **Xerox Corporation**, Stamford, Conn.

[21] Appl. No.: **457,805**

[22] Filed: **Jan. 13, 1983**

Related U.S. Application Data

[62] Division of Ser. No. 296,947, Aug. 28, 1981.

[51] **Int. Cl.**[3] **G09G 1/00**

[52] **U.S. Cl.** **340/710**; 340/794; 235/472; 382/50; 382/68; 365/49

[58] **Field of Search** 350/3.70, 3.78; 365/49, 365/234, 235, 215, 127; 235/472, 435, 454, 458–460, 470; 340/710, 709, 707, 794, 706; 382/50, 68

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,145,368	8/1964	Hoover, Jr.	340/794
3,201,751	8/1965	Rabinow	382/68
3,304,434	2/1967	Koster	250/231
3,473,036	10/1969	Marcus	250/219
3,496,364	2/1970	Foskett et al.	250/219
3,524,067	8/1970	West	250/219
3,541,521	11/1970	Koster	340/172.5
3,541,541	11/1970	Engelbart	340/324
3,572,881	3/1971	Nishida et al.	365/49
3,701,095	10/1972	Yamaguchi	340/146.3 MA
3,835,464	9/1974	Rider	340/324 A
3,868,655	2/1975	Filipazzi	365/49
3,892,963	7/1975	Hawley et al.	250/231 R
3,906,465	9/1975	Moriwaki et al.	350/3.78
3,949,235	4/1976	Miyazaki et al.	350/3.78
3,987,685	10/1976	Opocensky	74/471 R
4,114,034	9/1978	Hunka	250/202
4,149,269	4/1979	Abe et al.	365/234
4,180,704	12/1979	Pettit	250/237 G
4,260,979	4/1981	Smith	235/472
4,329,684	5/1982	Monteath et al.	340/794
4,364,035	12/1982	Kirsch	340/710
4,390,873	6/1983	Kirsch	340/710

FOREIGN PATENT DOCUMENTS

54-126426	10/1979	Japan	340/710

OTHER PUBLICATIONS

The Hologram Tablet—A New Graphic Input Device, Sakaguchi et al., 1970 Fall Joint Computer Conf., pp. 653–658.

The Optical Mouse . . . , Lyon, CMU Conf. on VLS/Systems & Computations, pp. 1–19, 10/81.

C. Tassell et al.: "Photodiode Arrays—Characteristics & Applications," Microelectronics Journal, vol. 10(1), pp. 35–44 (1979).

B. E. Bliss et al., "Ball-Joint Position Trandsucers" IBM Technical Disclosure Bulletin, vol. 13(9), p. 2620 (Feb. 1981).

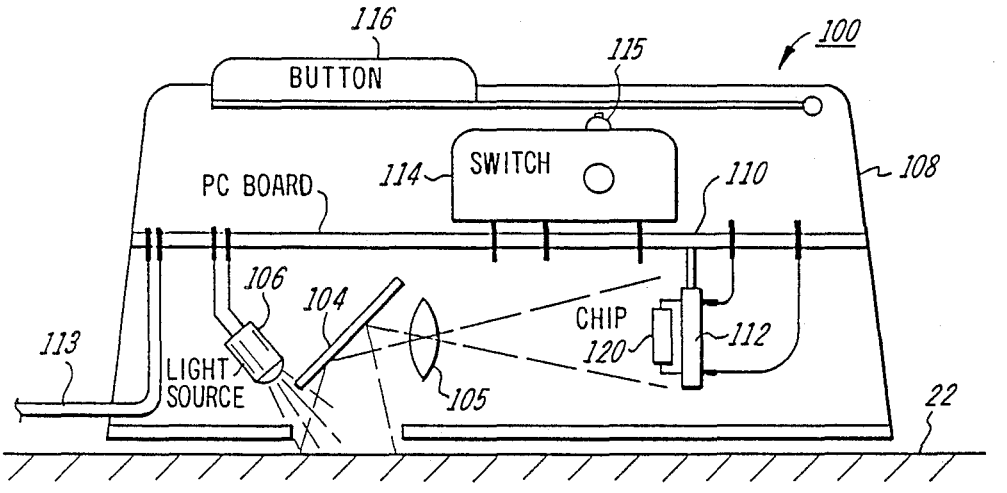
Primary Examiner—Marshall M. Curtis

Attorney, Agent, or Firm—W. Douglas Carothers, Jr.

[57] **ABSTRACT**

A cursor control device or "optical mouse" for use with an interactive display oriented computer system to provide movement for a visible cursor from position to position on a display screen of such a system. The device includes an IC chip that contains an optical sensor array and circuitry to bring about detectable bitmaps based upon a plurality of sensor cells making up the array. The distinguishable bitmaps are employed as a means for comparison to provide an output indicative of the direction and amount of movement of the cursor control device relative to an optical contrasting input to the array, the output is employed as a means to move the visible cursor from position to position on a display screen.

58 Claims, 43 Drawing Figures



United States Patent [19]

Lyon

[11] **Patent Number: 4,521,773**

[45] **Date of Patent: Jun. 4, 1985**

[54] **IMAGING ARRAY**

[75] Inventor: **Richard F. Lyon**, Palo Alto, Calif.

[73] Assignee: **Xerox Corporation**, Stamford, Conn.

[21] Appl. No.: **296,947**

[22] Filed: **Aug. 28, 1981**

[51] **Int. Cl.**[3] **G09G 1/00**

[52] **U.S. Cl.** **340/710**; 340/794; 382/50; 382/68; 235/472; 365/49

[58] **Field of Search** 350/3.70, 3.78; 365/49, 365/234, 235, 127, 215; 235/472; 340/710, 709, 707, 706, 794; 382/50, 68

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,145,368	8/1964	Hoover, Jr.	340/794
3,201,751	8/1965	Rabinow	382/68
3,304,434	2/1967	Koster	250/231
3,473,036	10/1969	Marcus	250/219
3,496,364	2/1970	Foskett et al.	250/219
3,524,067	8/1970	West	250/219
3,541,521	11/1970	Koster	340/172.5
3,541,541	11/1970	Engelbart	340/324
3,701,095	10/1972	Yamaguchi	340/146.3 MA
3,835,464	9/1974	Rider	340/324 A
3,868,655	2/1975	Filipazzi	365/49
3,892,963	7/1975	Hawley et al.	250/231 R
3,906,465	9/1975	Moriwaki et al.	350/3.78
3,949,235	4/1976	Miyazaki et al.	350/3.78
3,987,685	10/1976	Opocensky	74/471 R
4,114,034	9/1978	Hunka	250/202
4,180,704	12/1979	Pettit	250/237 G
4,260,979	4/1981	Smith	235/472
4,329,684	5/1982	Monteath et al.	340/794
4,364,035	12/1982	Kirsch	340/710
4,390,873	6/1983	Kirsch	340/710

FOREIGN PATENT DOCUMENTS

54-126426	10/1979	Japan	340/710

OTHER PUBLICATIONS

The Hologram Tablet–A New Graphic Input Device, Sakaguchi et al., 1970, Fall Joint Computer Conf., pp. 653–658.

C. Tassell et al.: "Photodiode Arrays–Characteristics and Applications" Microelectronics Journal, vol. 10, (1), pp. 35–44, (1979).

B. E. Bliss et al., "Ball–Joint Position Transducers" IBM Technical Disclosure Bulletin, vol. 13, (9), p. 2620, (Feb. 1981).

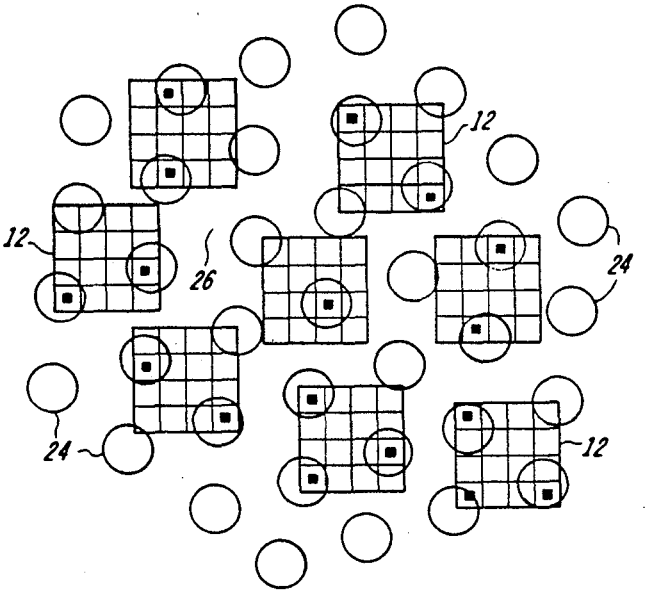
Primary Examiner—Marshall M. Curtis

Attorney, Agent, or Firm—W. Douglas Carothers, Jr.

[57] **ABSTRACT**

An imaging array provides a plurality of distinguishable bitmap images and comprises an array of sensor cells capable of sensing radiation. The cells are connected in a manner to form distinguishable bitmap images through a pattern of correspondence among the cells. Each bitmap image formed comprises a combination of one or more cells indicative of detecting an image pixel within a field of array cells that have been nonindicative of such detection. The pattern of correspondence may be one of inhibition of the operation of other cells in the array or one of indication of operation to other cells in the array. Various patterns of correspondence can be created among the cells creative of bitmap images. Bitmap images may consist of combinations of responsive cells within a field of nonresponsive cells in the array. For example, each bitmap image may comprise radiation responsive array cells that have sensed a sufficient quantity of radiation within a field of cells which have not sensed radiation or have been inhibited from sensing radiation. On the other hand, each bitmap image may comprise array cells that have not sensed a sufficient quantity of radiation within a field of cells that have sensed a sufficient quantity of radiation. An application of the imaging array is in an IC chip for a cursor control device or an "optical mouse" for use with an interactive display oriented computer system to provide movement for a visible cursor from position to position on a display screen of such a system.

63 Claims, 43 Drawing Figures



United States Patent [19]

Lyon

[11] **Patent Number: 4,536,844**

[45] **Date of Patent: Aug. 20, 1985**

[54] **METHOD AND APPARATUS FOR SIMULATING AURAL RESPONSE INFORMATION**

[75] Inventor: **Richard F. Lyon**, Palo Alto, Calif.

[73] Assignee: **Fairchild Camera and Instrument Corporation**, Mountain View, Calif.

[21] Appl. No.: **488,886**

[22] Filed: **Apr. 26, 1983**

[51] **Int. Cl.**[3] **A61N 1/36**

[52] **U.S. Cl.** ..... **364/487**; 128/419 R; 179/107 FD

[58] **Field of Search** ..... 128/746, 784–786, 128/789, 419 R, 421; 181/129–135; 381/68; 179/107 R, 107 PC, 107 BC, 107 E, 107 FD; 328/105; 364/578, 487

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,428,377 1/1984 Zollner et al. ..... 128/419 R

FOREIGN PATENT DOCUMENTS

2811120 9/1978 Fed. Rep. of Germany ... 128/419 R
WO83/00999 3/1983 PCT Int'l. Appl. 128/784

OTHER PUBLICATIONS

Merzenich et al., "Cochlear Implant Prosthesis: Strategies and Progress", *Annals of Biomed. Engr.*, vol. 8, 1980, pp. 361–368.

White, "Review of Current Status of Cochlear Prostheses", *IEEE Trans. on Biomed. Engr.*, vol. BME-29, No. 4, 4–1982, pp. 233–238.

Dillier et al., "Computer-Controlled Test System for Electrical Stim. of the Auditory Nerve of Deaf Patients w/Impl. Microelect.", *Scand. Audiol. Suppl. II*, 1980, pp. 163–170.

Forster, "Theor. Des. and Implementation of a Transcut, Multichannel Stimulator For Nevr. Prosthesis Applic.", J. Biomed. Engng, vol. 3, No. 2, 4–1981, pp. 107–120.

Allen, J. B., "Cochlear Modeling–1980", ICASSP 81, pp. 766–789, Atlanta, 1981.

Nilsson, H. G., "A Comparison of Models for Sharpening of Frequency Selectivity in the Cochlea", Biological Cypernetics 28, pp. 177–181, 1978.

Schroeder et al., "Model for Mechanical to Neural Transduction of the Auditory Receptor", JASA 55, pp. 1055–1060, 1974.

Kim et al., "A Population Study of Cochlear Nerve Fibers: Comparison of Spatial Distributions of Average-Rate and Phase Locking Measures of Responses to Single Tones", Journal of Neuro-Physiology 42, pp. 16–30, 1979.

Zwislocki, J. J., "Sound Analysis in the Ear: A History of Discoveries", American Scientist, 69, pp. 184–192, 1981.

Zweig et al., "The Cochlear Compromise", JASA 59, pp. 975–982, 1976.

Schroeder, M. R., "An Integrable Model for the Basilar Membrane", JASA 53, pp. 429–434, 1973.

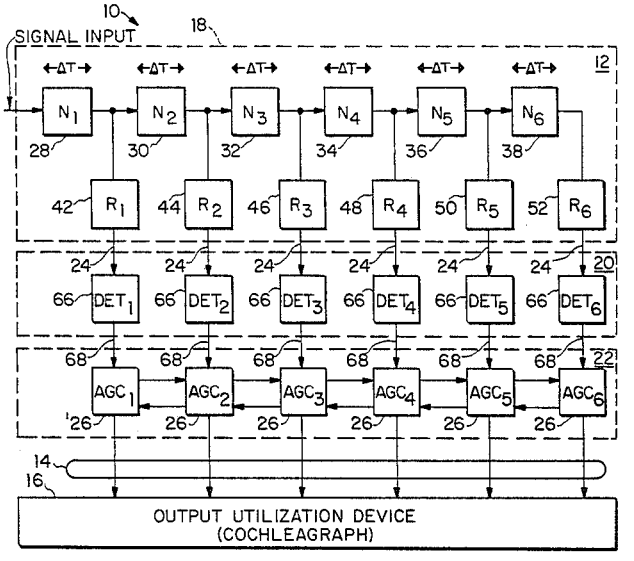
Zweig, "Basilar Membrane Motion", Cold Spring Harbor Symposia on Quantitative Biology, vol. XL, pp. 619–633 (Cold Spring Harbor Laboratory, 1976).

Primary Examiner—Lee S. Cohen
Assistant Examiner—Angela D. Sykes
Attorney, Agent, or Firm—Townsend and Townsend

[57] **ABSTRACT**

Speech and like signals are analyzed based on a model of the function of the human hearing system. The model of the inner ear is expressed as signal processing operations which map acoustic signals into neural representations. Specifically, a high order transfer function is modeled as a cascade/parallel filterbank network of simple linear, time-invariant second-order filter sections. Signal transduction and compression are based on a half-wave rectification with a non-linearly coupled, variable time constant automatic gain control network. The result is a simple device which simulates the complex signal transfer function associated with the human ear. The invention lends itself to implementation in digital circuitry for real-time or near real-time processing of speech and other sounds.

19 Claims, 8 Drawing Figures



United States Patent [19]

Lyon

[11] **Patent Number: 4,740,894**

[45] **Date of Patent: Apr. 26, 1988**

[54] **COMPUTING PROCESSOR WITH MEMORYLESS FUNCTION UNITS EACH CONNECTED TO DIFFERENT PART OF A MULTIPORTED MEMORY**

[75] Inventor: **Richard F. Lyon**, Los Altos Hills, Calif.

[73] Assignee: **Schlumberger Systems and Services, Inc.**, Palo Alto, Calif.

[21] Appl. No.: **844,468**

[22] Filed: **Mar. 26, 1986**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 781,231, Sep. 27, 1985, abandoned, which is a continuation of Ser. No. 927,147, Aug. 18, 1983, abandoned.

[51] **Int. Cl.**[4] **G06F 15/00**; G06F 15/31; G06F 12/00

[52] **U.S. Cl.** **364/200**; 364/736; 364/724

[58] **Field of Search** ..... 364/724, 736, 200 MS File, 364/900 MS File

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,970,993	7/1976	Finnila	364/200
3,979,728	9/1976	Reddaway	364/200
3,993,890	11/1976	Peled et al.	235/152
4,128,880	12/1978	Cray, Jr.	364/200
4,149,242	10/1979	Pirz	364/200
4,164,787	8/1979	Aranguren	364/200
4,181,956	1/1980	Schwab et al.	364/521
4,215,401	7/1980	Holsztynski et al.	364/200
4,302,818	11/1981	Niemann	364/736
4,302,819	11/1981	Ware	364/737
4,304002	12/1981	Hunt	371/48
4,380,046	4/1983	Frosch	364/200
4,435,765	3/1984	Uchida et al.	364/200
4,450,533	3/1984	Petit	364/724
4,466,125	8/1984	Kanayama	455/56
4,470,109	9/1984	McNally	364/200
4,484,349	11/1984	McCubbrey	382/48
4,550,437	10/1985	Kobayashi et al.	364/200
4,553,203	11/1985	Ran et al.	364/200
4,580,215	4/1986	Morton	364/200
4,636,942	1/1987	Chen et al.	364/200

FOREIGN PATENT DOCUMENTS

1445714	8/1976	United Kingdom .
1536933	12/1978	United Kingdom .
2020458	11/1979	United Kingdom .
2037042	7/1980	United Kingdom .

OTHER PUBLICATIONS

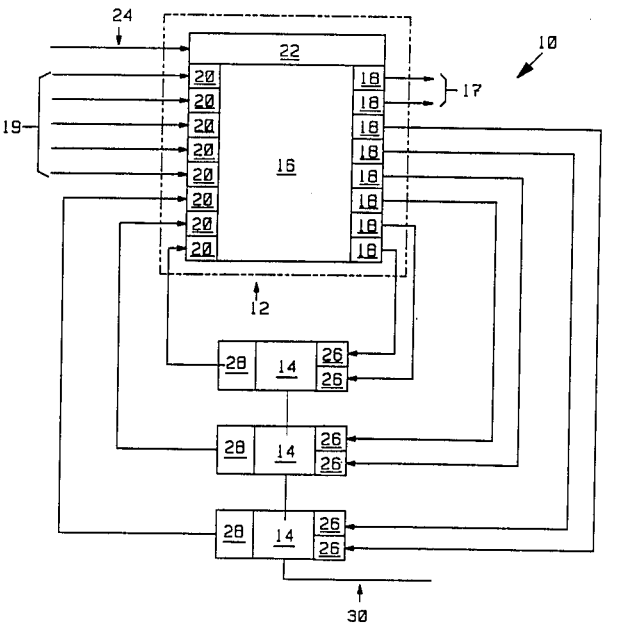
Richard F. Lyon, "MSSP: A Bit-Serial Multiprocessor for Signal Processing", VLSI Signal Processing, 11/1984, pp. 64–75.

Primary Examiner—Raulfe B. Zache
Assistant Examiner—Thomas C. Lee
Attorney, Agent, or Firm—Fitch, Even, Tabin & Flannery

[57] **ABSTRACT**

A processing element may be used either separately or in an array of similar processing elements for performing concurrent data processing calculations. The processing element includes a multiported memory unit for storing data to be processed by any of a plurality of function units which are connected to the multiported memory unit. The multiported memory unit includes a number of data storage slots for storing data words to be processed and the results of said processing. Each function unit performs a calculation having as its inputs one or or more data words from the multiported memory unit. The result of this calculation is stored back in the multiported memory unit. The transfer of data to and from the function units is accomplished by use of the ports on said multiported memory unit. The data manipulated by the processing element is controlled by specifying a correspondence between data storage slots, memory input ports and memory output ports.

11 Claims, 4 Drawing Sheets



United States Patent [19]

Mead et al.

[11] **Patent Number: 4,771,196**

[45] **Date of Patent: Sep. 13, 1988**

[54] **ELECTRONICALLY VARIABLE ACTIVE ANALOG DELAY LINE**

[75] Inventors: **Carver A. Mead**, Pasadena; **Richard F. Lyon**, Los Altos, both of Calif.

[73] Assignee: **California Institute of Technology**, Pasadena, Calif.

[21] Appl. No.: **81,861**

[22] Filed: **Aug. 5, 1987**

[51] **Int. Cl.**[4] **H03K 5/159**; H03K 5/00; H03K 5/13; G06G 7/12

[52] **U.S. Cl.** **307/605**; 328/127; 328/55; 307/590; 307/595; 307/597; 307/602; 307/603; 307/608; 307/490; 307/493; 307/497

[58] **Field of Search** 307/590, 593, 595, 597, 307/602, 603, 605, 606, 608, 490, 493, 491, 497, 552, 553, 264, 555, 558, 562; 328/172, 173, 209, 221, 175, 55, 191, 192, 193, 127, 128

[56] **References Cited**

U.S. PATENT DOCUMENTS

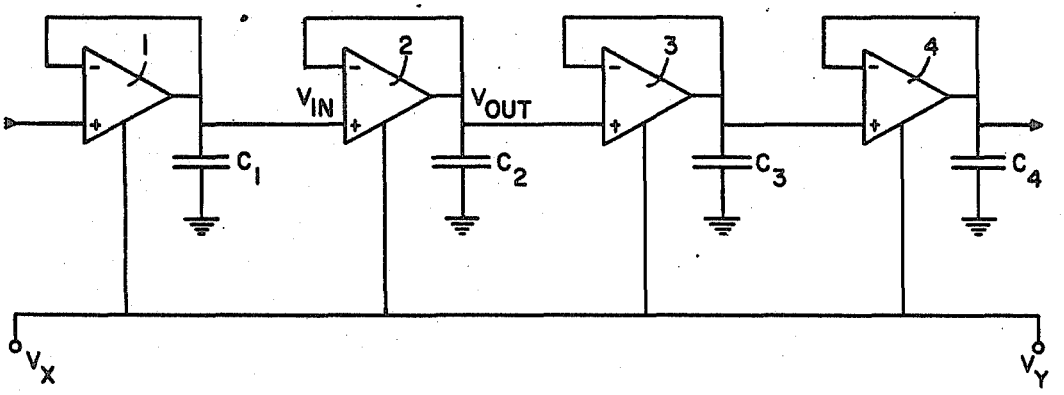
3,622,809	11/1971	Williams	328/55
3,633,043	1/1972	Anthony	307/562
4,641,048	2/1987	Pollock	328/128

Primary Examiner—Stanley D. Miller
Assistant Examiner—Trong Q. Phan
Attorney, Agent, or Firm—Freilich, Hornbaker, Rosen & Fernandez

[57] **ABSTRACT**

An electronically variable active analog delay line utilizes cascaded differential transconductance amplifiers with integrating capacitors and negative feedback from the output to the input of each noninverting amplifier. The delay of each section may be controlled through a conductor having distributed resistance connected at distributed points to the transconductance control terminal of the amplifiers with a controllable voltage gradient between the two ends of the conductor. Signals may be coupled in and added to a propagating signal using capacitors, or transconductance amplifiers which may also be of the differential transconductance type, particularly when coupling signals from a second delay line having substantially the same propagation velocity. The differential transconductance amplifiers may be arranged in pairs, each pair with positive feedback from the output terminal of the second to the input terminal of the first amplifier of the pair through a third differential amplifier with positive feedback from its own output terminal. The transconductances of the cascaded amplifiers are controlled in each section to produce the desired time-constant (delay) of the section, and the transconductance of the positive feedback amplifier is controlled for stable operation and gain control of the section.

17 Claims, 11 Drawing Sheets



United States Patent [19]

Lyon et al.

[11] **Patent Number: 4,796,227**

[45] **Date of Patent: Jan. 3, 1989**

[54] **COMPUTER MEMORY SYSTEM**

[75] Inventors: **Richard F. Lyon**, Los Altos; **Richard R. Schediwy**, Mountain View, both of Calif.

[73] Assignee: **Schlumberger Systems and Services, Inc.**, Palo Alto, Calif.

[21] Appl. No.: **27,218**

[22] Filed: **Mar. 17, 1987**

[51] **Int. Cl.**[4] **G11C 11/40**; G11C 13/00

[52] **U.S. Cl.** **365/154**; 365/190

[58] **Field of Search** 365/154, 189, 190, 202, 365/227

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,703,710	11/1972	Masaharu et al.	365/190
4,120,047	10/1978	Varadi	365/227
4,442,509	4/1984	Herndon	365/154
4,554,644	11/1985	Chen et al.	365/226
4,604,729	8/1986	Kimoto	365/190

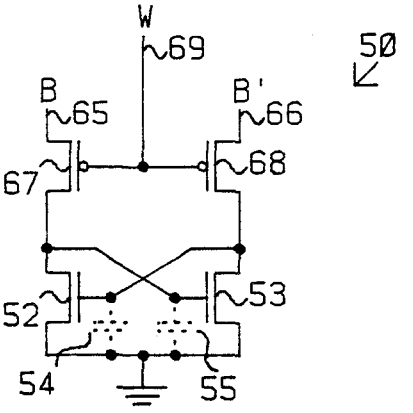
Primary Examiner—Terrell W. Fears

Attorney, Agent, or Firm—Fitch, Even, Tabin & Flannery

[57] **ABSTRACT**

An improved computer memory system based on a novel four transistor memory cell and an improved address decoder circuit is disclosed. The memory cell can be fabricated using currently available logic fabrication processes and requires a silicon area less than that required by prior art static memory cells. The improved decoder can be fabricated in significantly less silicon area than existing NOR gate decoder arrays and is faster than existing NOR gate decoder arrays.

16 Claims, 15 Drawing Sheets



US005319268A

United States Patent [19]

Lyon et al.

[11] Patent Number: 5,319,268

[45] Date of Patent: Jun. 7, 1994

[54] **CIRCUITS FOR WIDE INPUT RANGE ANALOG RECTIFICATION AND CORRELATION**

[75] Inventors: **Richard F. Lyon**, Los Altos; **Tobias Delbruck**, Pasadena; **Carver A. Mead**, Pasadena, all of Calif.

[73] Assignee: **California Institute of Technology**, Pasadena, Calif.

[21] Appl. No.: **978,210**

[22] Filed: **Nov. 18, 1992**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 854,223, Mar. 20, 1992, abandoned, which is a continuation of Ser. No. 591,728, Oct. 2, 1990, Pat. No. 5,099,156.

[51] **Int. Cl.**[5] **H03B 19/00**

[52] **U.S. Cl.** **307/529**; 307/355; 307/490; 307/498; 364/819

[58] **Field of Search** 307/201, 296.8, 350, 307/355, 446, 448, 490, 497, 498, 529, 304; 328/158, 160; 364/819

[56] **References Cited**

U.S. PATENT DOCUMENTS

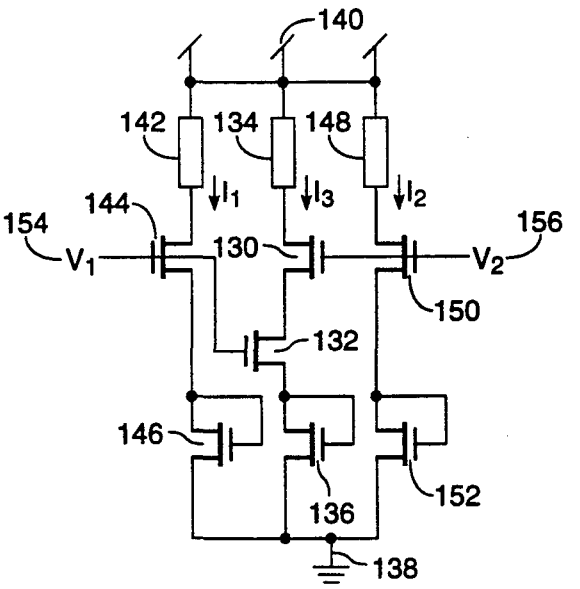
4,375,039	2/1983	Yamauchi	307/355
4,399,374	8/1983	Boeke	307/296.8
4,460,837	7/1984	Anderson, Jr.	307/355
4,464,588	8/1984	Wieser	307/491
4,634,894	1/1987	Shu et al.	307/491
4,724,344	2/1988	Watanabe	307/355
4,941,027	7/1990	Beason	307/307
5,065,043	11/1991	Bartling et al.	307/296.8

Primary Examiner—William L. Sikes
Assistant Examiner—Terry D. Cunningham
Attorney, Agent, or Firm—D'Alessandro, Frazzini & Ritchie

[57] **ABSTRACT**

A first and a second MOS transistor of the same conductivity type are connected in series between a load and a fixed voltage source. The gates of the first and second MOS transistors are connected to sources of input voltage which are of a magnitude smaller than the threshold voltages of the two MOS transistors. The first MOS transistor located next to the load is kept in saturation. A related circuit includes a first and a second MOS transistor of the same conductivity type are connected in series between a load and a fixed voltage source. The first MOS transistor located next to the load is kept in saturation. The gates of the first and second MOS transistors are connected to the gates of third and fourth diode-connected MOS transistors of the same conductivity type as the first and second MOS transistors. The third MOS transistor is connected between a first input current node and a fixed voltage source. The fourth MOS transistor is connected between a second input current node and a fixed voltage source. The third and fourth MOS transistors may alternatively be connected to first and second input transistors and a bias transistor arranged as in a differential amplifier. At least one diode-connected transistor is included in series with at least one of the transistors which has a gate connected to an input voltage.

10 Claims, 10 Drawing Sheets



US005355329A

United States Patent [19]

Lyon

[11] Patent Number: 5,355,329

[45] Date of Patent: Oct. 11, 1994

[54] **DIGITAL FILTER HAVING INDEPENDENT DAMPING AND FREQUENCY PARAMETERS**

[75] Inventor: **Richard F. Lyon**, Los Altos, Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[21] Appl. No.: **990,666**

[22] Filed: **Dec. 14, 1992**

[51] **Int. Cl.**[5] **G06F 15/31**

[52] **U.S. Cl.** **364/724.17**

[58] **Field of Search** 364/724.17, 724.03, 364/724.01

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,337,518	6/1982	Ohnishi et al.	364/724.17
4,356,559	10/1982	Candy et al.	364/724.17
5,170,369	12/1992	Rossum	364/724.17

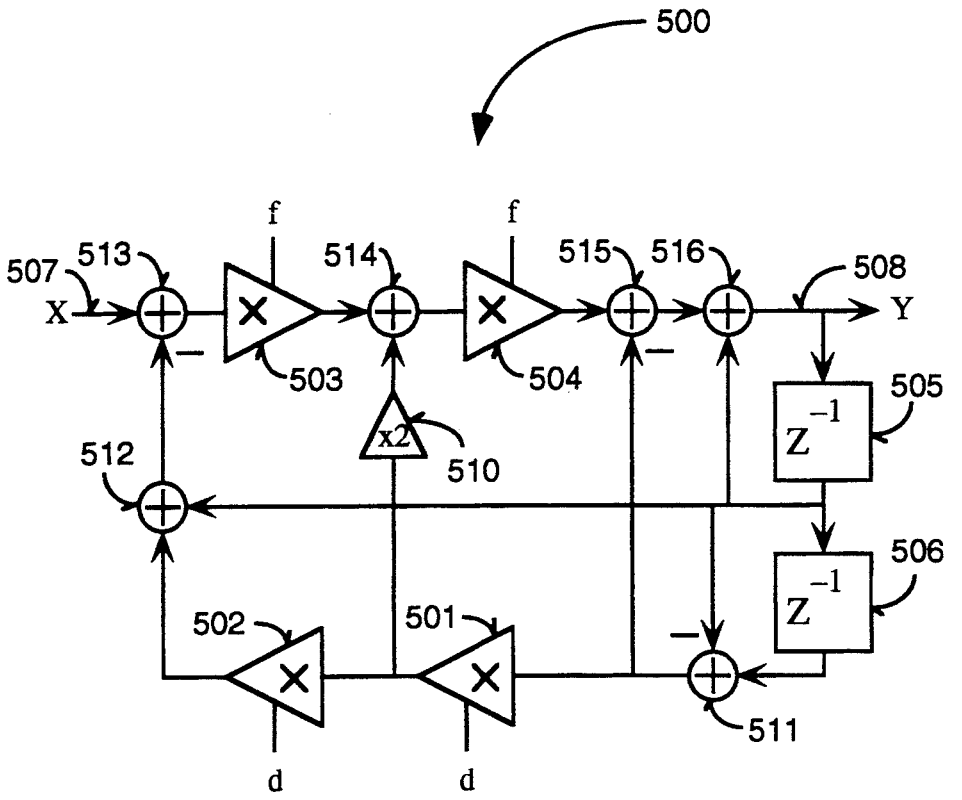
Primary Examiner—Tan V. Mai

Attorney, Agent, or Firm—Blakely, Sokoloff, Taylor & Zafman

[57] **ABSTRACT**

A filter capable of having its damping and frequency parameters independently varied. The filter can be represented in either a digital or an analog computation network. The network comprises four multipliers for multiplying by a frequency term twice and a damping factor twice. In addition, the network comprises two unit delay blocks for temporarily storing previous signal input values for zeros or output values for poles. These stored values are used in computing subsequent outputs. The multipliers are configured with adders and subtractors to compute a next output value as a combination of a current input, a weight $-2+2df+f^2-wd^2f^2$ times the most recent saved value and a weight $1-2df+wd^2f^2$ times the previous saved value. Moreover, unity gain at DC can be achieved.

11 Claims, 15 Drawing Sheets



US005440243A

United States Patent [19]

Lyon

[11] Patent Number: 5,440,243

[45] Date of Patent: Aug. 8, 1995

[54] **APPARATUS AND METHOD FOR ALLOWING A DYNAMIC LOGIC GATE TO OPERATION STATICALLY USING SUBTHRESHOLD CONDUCTION PRECHARGING**

[75] Inventor: **Richard F. Lyon**, Los Altos, Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[21] Appl. No.: **295,157**

[22] Filed: **Aug. 24, 1994**

Related U.S. Application Data

[63] Continuation of Ser. No. 124,820, Sep. 21, 1993, abandoned.

[51] **Int. Cl.**[6] **H03K 19/003**

[52] **U.S. Cl.** **326/33**; 326/34; 326/98

[58] **Field of Search** 307/443, 451, 452–453, 307/481, 269; 365/203; 326/21, 31, 33–34, 93, 95, 98

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,570,084	2/1986	Griffin et al.	307/452
4,796,227	1/1989	Lyon et al. .	
5,015,882	5/1991	Houston et al.	307/452
5,065,048	11/1991	Asai et al.	307/481 X
5,191,554	3/1993	Lee	365/203 X
5,293,342	3/1994	Casper et al.	365/203
5,317,204	5/1994	Yetter et al.	307/443

OTHER PUBLICATIONS

Pretorius et al, "Charge Redistribution and Noise Margins in Domino CMOS Logic", *IEEE TCAS*, vol. CA-S-33, No. 8, Aug. 1986, pp. 786–793.

Geiger, Randall L. Allen, Phillip E. and Stader, Noel R., "VLSI Design Techniques for Analog and Digital Circuits", pp. 815–821, McGraw-Hill, New York, 1990.

Glasser, Lance A. and Dobberpuhl, Daniel W., "The Design and Analysis of VLSI Circuits", pp. 331–343, 375–385, Addison-Wesley, Reading Mass., 1985.

Hodges, David A. Jackson, Horace G., "Analysis and Design of Digital Integrated Circuits" 2nd edition, pp. 98–102, 340–345, 398–407 312–316, 399–404, McGraw-Hill, New York.

(List continued on next page.)

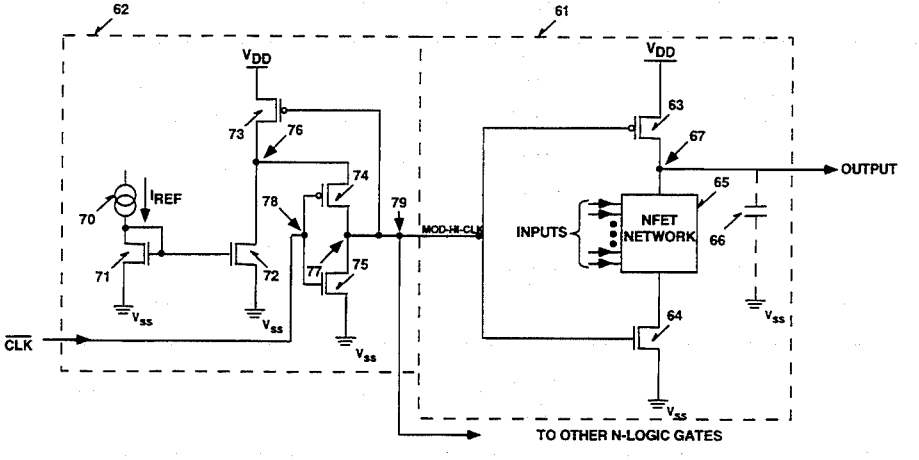
Primary Examiner—David R. Hudspeth

Attorney, Agent, or Firm—Blakely, Sokoloff, Taylor & Zafman

[57] **ABSTRACT**

A statically operated dynamic CMOS logic gate that includes an FET logic network for performing a predefined logic function with respect to its logic inputs, an output node, a precharge transistor, and in some embodiments an evaluate transistor. During operation, the precharge transistor is first turned on by a clock signal during a precharge phase to precharge an output node of the dynamic logic gate to a first voltage state. During the precharge phase, the evaluate transistor is turned off by the clock signal. An evaluate phase typically follows the precharge phase, and during the evaluation phase, the evaluate transistor is turned on by the control signal to allow the logic network to perform the predefined logic function with respect to its inputs, and the logic network selectively charges or discharges the output node to a second voltage state via the evaluate transistor in accordance with the predefined logic function given to the logic inputs to the logic gate. A driver circuit is provided for applying a bias voltage to the gate of the precharge transistor when the precharge transistor is not precharging the output node (e.g. the evaluate phase). The bias voltage has a voltage level that differs from the first voltage state by less than the magnitude of the threshold voltage of the precharge transistor in order for the precharge transistor to operate in a subthreshold conduction region so as to ensure the logic gate's output node to be at the first voltage state when the logic network does not discharge the output node to the second voltage state through the evaluate transistor as a result of the predetermined logic function. In this way, the dynamic logic gate circuit can operate statically with substantially minimized power consumption.

31 Claims, 22 Drawing Sheets



US005473759A

United States Patent [19]

Slaney et al.

[11] **Patent Number: 5,473,759**

[45] **Date of Patent: Dec. 5, 1995**

[54] **SOUND ANALYSIS AND RESYNTHESIS USING CORRELOGRAMS**

[75] Inventors: **Malcolm Slaney**, Los Altos Hills; **Richard F. Lyon**, Los Altos; **Daniel Naar**, Hayward, all of Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[21] Appl. No.: **20,785**

[22] Filed: **Feb. 22, 1993**

[51] **Int. Cl.**[6] **G10L 5/10**

[52] **U.S. Cl.** **395/2.75**; 395/2.67; 395/2.26; 395/2.72

[58] **Field of Search** 395/2.25, 2.29, 395/2.46, 2.26, 2.67, 2.72, 2, 2.27, 2.78, 2.75

[56] **References Cited**

PUBLICATIONS

Classification of Whale and Ice Sounds with a cochlear Model Parks et al. IEEE/Mar. 1992.

A Comparison of DFT, PLP and Cochleagram for Alphabet Recognition Fanty et al. IEEE/Nov. 1991.

Speaker–Independent Vowel Recognition: Spectograms versus Cochleagrams Muthesamy et al. IEEE/Apr. 1990.

A Temporal Representation of Sound Slanley et al. John Wiley 1992.

Auditory Representations of Acoustic Signals Yang et al. IEEE/Mar. 1992.

Mellinger, David K., "Feature–Map Methods for Extracting Sound Frequency Modulation", *IEEE Computer Society Press,* 1991, pp. 795–799.

Hukin, R. W., "Testing an Auditory Model by Resynthesis", *European Conference on Speech Communication and Technology,* Sep. 26–29, 1989, pp. 243–246.

Yang, X., et al, "Auditory Representations of Acoustic Signals", *IEEE Transactions of Information Theory,* vol. 38, No. 2, Mar. 1992, pp. 824–839.

Lyon, R., "CCD Correlators for Auditory Models", *Proceedings of the Twenty–Fifth Asilomar Conference on Signals, Systems and Computers,* Nov. 4–6, 1991, pp. 785–789.

Griffin, D., et al, "Signal Estimation From Modified Short–Time Fourier Transform", *IEEE Transactions on Acoustics, Speech and Signal Processing,* vol. ASSP–32, No. 2, Apr. 1984, pp. 236–243.

Summerfield, C., et al, "ASIC Implementation of the Lyon Cochlea Model", *Proceedings of the 1992 International Conference on Acoustics, Speech and Signal Processing,* IEEE, vol. V, 1992, pp. 673–676.

Roucos, S., et al, "High Quality Time–Scale Modification for Speech", *Proceedings of the 1985 IEEE Conference on Acoustics, Speech and Signal Processing,* 1985, pp. 493–496.

R. Lyon, "A Computational Model of Binaural Localization and Separation", *Proceedings of IEEE International Conference on Acoustics, Speech and Signal Processing,* Apr. 1983, pp. 1148–1151.

Rabiner, L., et al., *Digital Processing of Speech Signals,* Prentice Hall, pp. 274–277.

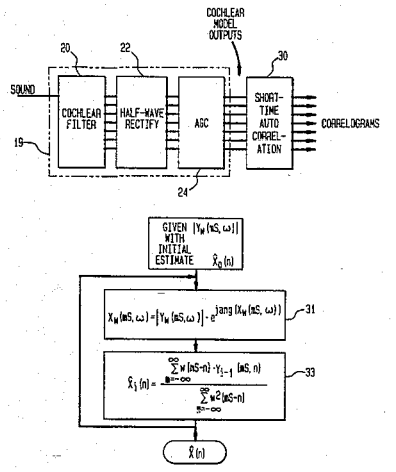
Slaney M., et al, "On the Importance of Time—A Temporal Representation of Sound", *Visual Representation of Speech Signals,* edited by Martin Cooke, Steve Beet and Malcolm Crawford, 1993, John Wiley & Sons Ltd.

Primary Examiner—Allen R. MacDonald
Assistant Examiner—Richemond Dorvic
Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis

[57] **ABSTRACT**

A system for reconstructing a signal waveform from a correlogram is based upon the recognition that the information in each channel of the correlogram is equivalent to the magnitude of the Fourier transform of a signal. By estimating a signal on the basis of its Short-Time Fourier Transform Magnitude, each channel of information from a cochlear model can be reconstructed. Once this information is retrieved, a signal waveform can be resynthesized through inversion of the cochlear model. The process for reconstructing the cochlear model data can be optimized with the use of techniques for improving the initial estimate of the signal from the magnitude of its Fourier Transform, and by employing information that is known apriori about the signal during the estimation process, such as the characteristics of sound signals.

28 Claims, 8 Drawing Sheets



US005502663A

United States Patent [19]

Lyon

[11] Patent Number: 5,502,663

[45] Date of Patent: Mar. 26, 1996

[54] **DIGITAL FILTER HAVING INDEPENDENT DAMPING AND FREQUENCY PARAMETERS**

[75] Inventor: **Richard F. Lyon**, Los Altos, Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[21] Appl. No.: **319,524**

[22] Filed: **Oct. 7, 1994**

Related U.S. Application Data

[62] Division of Ser. No. 990,666, Dec. 14, 1992, Pat. No. 5,355,329.

[51] **Int. Cl.**[6] **G06F 15/31**

[52] **U.S. Cl.** **364/724.01**

[58] **Field of Search** 364/724.01, 724.17, 364/724.19; 375/103

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,146,931	3/1979	Delforge	364/724.17
4,185,325	1/1980	Appel	364/724.17
4,337,518	7/1982	Ohnishi et al. .	
4,356,559	10/1982	Candy et al. .	
4,803,647	2/1989	Dieterich	364/724.17
5,031,132	7/1991	Dolazza	364/724.12
5,170,369	12/1992	Rossum .	
5,315,621	5/1994	Lucioni et al.	364/724.19

OTHER PUBLICATIONS

"*ASIC Implementation of the Lyon Cochlea Model*" by C. D. Summerfield and R. F. Lyon, in Proc. International Conference on Acoustics, Speech, and Signal Processing, IEEE, 1992.

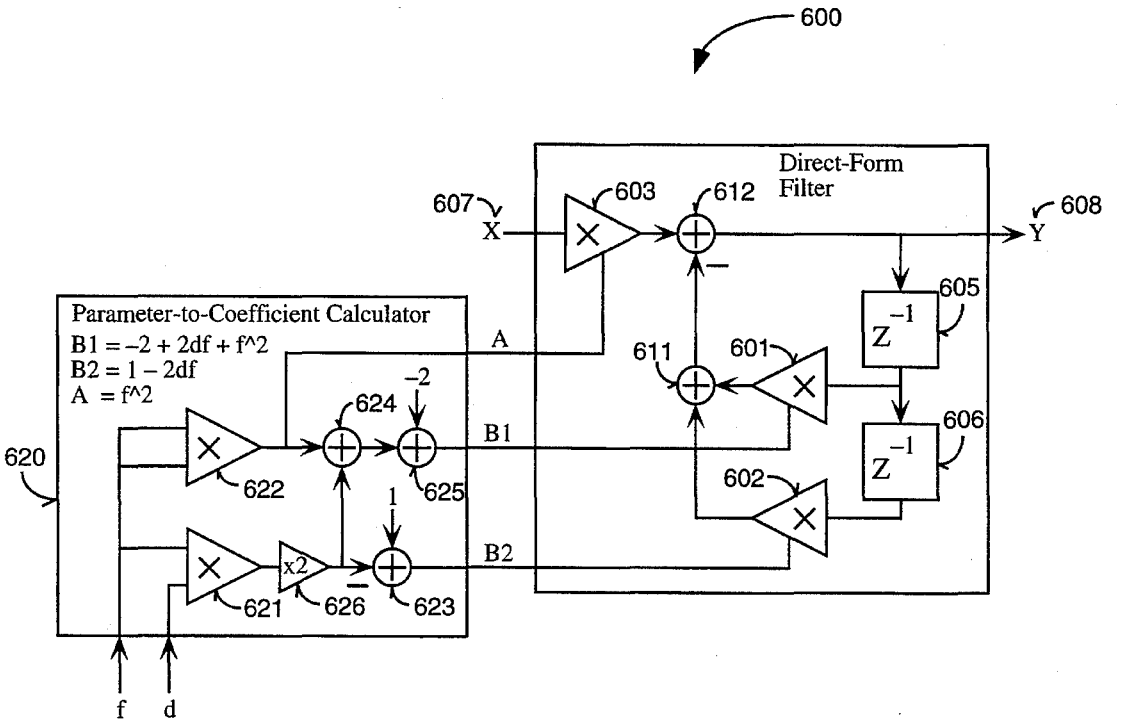
Primary Examiner—Tan V. Mai

Attorney, Agent, or Firm—Blakely, Sokoloff, Taylor & Zafman

[57] **ABSTRACT**

A filter capable of having its damping and frequency parameters independently varied. The filter can be represented in either a digital or an analog computation network. The network comprises four multipliers for multiplying by a frequency term twice and a damping factor twice. In addition, the network comprises two unit delay blocks for temporarily storing previous signal input values for zeros or output values for poles. These stored values are used in computing subsequent outputs. The multipliers are configured with adders and subtractors to compute a next output value as a combination of a current input, a weight $-2+2df+f^2-wd^2f^2$ times the most recent saved value and a weight $1-2df+wd^2f^2$ times the previous saved value. Moreover, unity gain at DC can be achieved.

14 Claims, 15 Drawing Sheets



US005550487A

United States Patent [19]

Lyon

[11] Patent Number: 5,550,487

[45] Date of Patent: *Aug. 27, 1996

[54] **APPARATUS AND METHOD FOR ALLOWING A SYNAMIC LOGIC GATE TO OPERATE STATICALLY**

[75] Inventor: **Richard F. Lyon**, Los Altos, Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,440,243.

[21] Appl. No.: **482,671**

[22] Filed: **Jun. 7, 1995**

Related U.S. Application Data

[63] Continuation of Ser. No. 295,157, Aug. 24, 1994, Pat. No. 5,440,243, which is a continuation of Ser. No. 124,820, Sep. 21, 1993, abandoned.

[51] **Int. Cl.**[6] **H03K 19/003**

[52] **U.S. Cl.** **326/33**; 326/21; 326/98

[58] **Field of Search** 326/21, 31, 33–34, 326/93, 95, 98

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,051,620	9/1991	Burgin	307/452
5,440,243	8/1995	Lyon	326/33

FOREIGN PATENT DOCUMENTS

8200740 3/1982 WIPO .

OTHER PUBLICATIONS

Charles M. Lee and Ellen W. Szeto, "Zipper CMOS," 1986, pp. 10–16.

Hery Fuchs, "1985 Chapel Hill Conference on Very Large Scale Integration", (Computer Science Press), pp. 88–94.

Jiren Yan and Christopher Sevensson, "High-Speed CMOS Circuit Technique," vol. 24, No. 1, Feb. 1989, pp. 62–70.

Marco Annaratone, "Digital CMOS Circuit Design," Kluwer Academic Publishers, pp. 103–124, Boston, 1986.

Fabricus, Eugene D., "Introduction to VLSI Design," pp. 196–218, McGraw–Hill, New York, 1990.

Mukherjee, Amar, "Introduction to NMOS and CMOS VLSI Systems Design," pp. 96–107, Prentice–Hall, Englewood Cliffs, NJ, 1986.

(List continued on next page.)

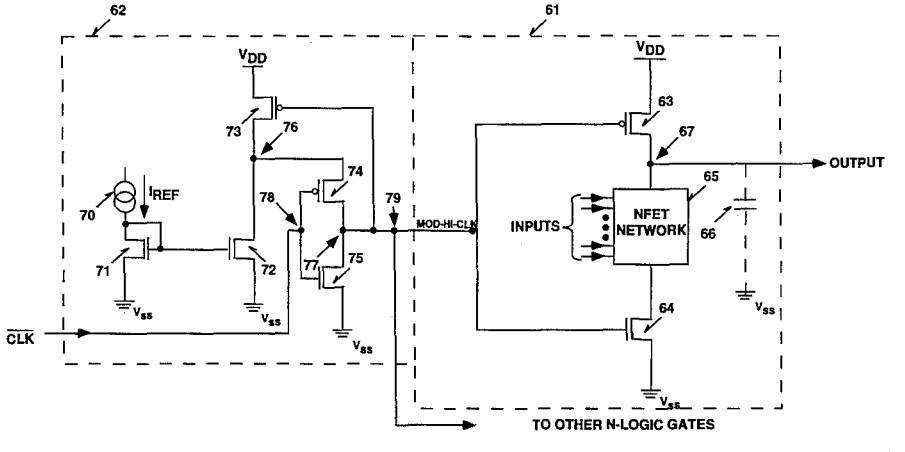
Primary Examiner—David R. Hudspeth

Attorney, Agent, or Firm—Blakely, Sokoloff, Taylor & Zafman

[57] **ABSTRACT**

A statically operated dynamic CMOS logic gate that includes an FET logic network for performing a predefined logic function with respect to its logic inputs, an output node, a precharge transistor, and in some embodiments an evaluate transistor. During operation, the precharge transistor is first turned on by a clock signal during a precharge phase to precharge an output node of the dynamic logic gate to a first voltage state. During the precharge phase, the evaluate transistor is turned off by the clock signal. An evaluate phase typically follows the precharge phase, and during the evaluation phase, the evaluate transistor is turned on by the control signal to allow the logic network to perform the predefined logic function with respect to its inputs, and the logic network selectively charges or discharges the output node to a second voltage state via the evaluate transistor in accordance with the predefined logic function given to the logic inputs to the logic gate. A driver circuit is provided for applying a bias voltage to the gate of the precharge transistor when the precharge transistor is not precharging the output node (e.g. the evaluate phase). The bias voltage has a voltage level that differs from the first voltage state by less than the magnitude of the threshold voltage of the precharge transistor in order for the precharge transistor to operate in a subthreshold conduction region so as to ensure the logic gate's output node to be at the first voltage state when the logic network does not discharge the output node to the second voltage state through the evaluate transistor as a result of the predetermined logic function. In this way, the dynamic logic gate circuit can operate statically with substantially minimized power consumption.

39 Claims, 22 Drawing Sheets



US005675665A

United States Patent [19]

Lyon

[11] Patent Number: 5,675,665

[45] Date of Patent: Oct. 7, 1997

[54] **SYSTEM AND METHOD FOR WORD RECOGNITION USING SIZE AND PLACEMENT MODELS**

[75] Inventor: **Richard F. Lyon**, Los Altos, Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[21] Appl. No.: **315,886**

[22] Filed: **Sep. 30, 1994**

[51] **Int. Cl.**[6] **G06K 9/72**; G06K 9/34

[52] **U.S. Cl.** **382/229**; 382/177; 382/187; 382/200; 382/206

[58] **Field of Search** 382/159, 177, 382/184, 185, 187, 195, 199, 200, 203, 229, 230

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,610,025	9/1986	Blum et al.	382/177
4,727,588	2/1988	Fox et al.	382/177
4,850,025	7/1989	Abe	382/177
4,972,496	11/1990	Sklarew	382/187
5,052,043	9/1991	Gaborski	382/157
5,210,704	5/1993	Husseiny	364/551.01
5,239,592	8/1993	Kameyama et al.	382/177
5,261,009	11/1993	Bokser	382/230
5,434,929	7/1995	Beernik et al.	382/187
5,517,578	5/1996	Altman et al.	382/200
5,528,743	6/1996	Tou et al.	382/181

OTHER PUBLICATIONS

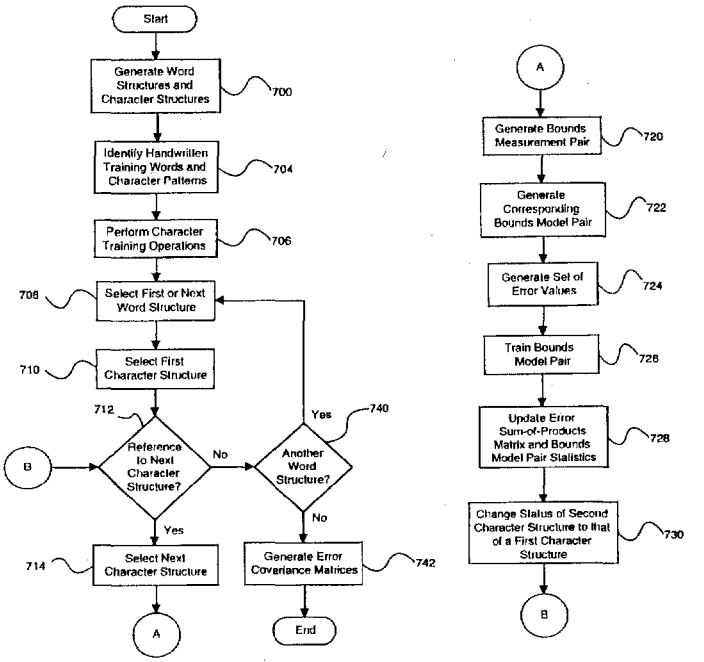
Parizeau and Plamondon, Allograph Adjacency Constraints for Cursive Script Recognition, Pre–Proceedings IWFHR III, 1993, 252–61.

Primary Examiner—Leo Boudreau
Assistant Examiner—Bipin Shalwala
Attorney, Agent, or Firm—Carr, DeFilippo & Ferrell

[57] **ABSTRACT**

A bounds evaluation unit generates a bounds measurement pair corresponding to a character pattern pair determined from a handwritten word. Within the bounds measurement pair, a first bounds measurement corresponds to a first character pattern, and a second bounds measurement corresponds to a second character pattern. The first and second bounds measurements are each a bounding box that defines a left-most, a right-most, a top-most, and a bottom-most extent of the corresponding character pattern. The bounds measurement pair is compared against one or more bounds model pairs, where each bounds model pair corresponds to a hypothesized character identifier pair in which each individual hypothesized character identifier has been determined by a character recognition unit. Each bounds model pair indicates the expected size and position of a character pattern pair corresponding to the hypothesized character identifier pair. Bounds model pairs are trained based upon size and positional relationships between character pattern pairs within handwritten training words. The comparison of the bounds measurement pair against a given bounds model pair produces a set of error values. The error values are used in conjunction with an error covariance matrix that has also been trained with handwritten training words to determine a pairwise cost value associated with the hypothesized character identifier pair. A word recognition unit incorporates individual character cost values and each pairwise cost value in a conventional minimum-cost path search method to determine the identity of the handwritten word.

14 Claims, 17 Drawing Sheets



US005739820A

United States Patent [19]

Lyon

[11] Patent Number: 5,739,820

[45] Date of Patent: Apr. 14, 1998

[54] METHOD AND APPARATUS FOR SPECULAR REFLECTION SHADING OF COMPUTER GRAPHIC IMAGES

[75] Inventor: **Richard F. Lyon**, Los Altos, Calif.

[73] Assignee: **Apple Computer Inc.**, Cupertino, Calif.

[21] Appl. No.: **984,180**

[22] Filed: **Nov. 19, 1992**

[51] **Int. Cl.**[6] **G06T 15/50**

[52] **U.S. Cl.** **345/426**; 345/427

[58] **Field of Search** 395/126, 127; 364/729

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,728,528	4/1973	Walters	364/720
3,789,203	1/1974	Catherall et al.	364/723
4,855,935	8/1989	Lien et al.	395/142
4,899,302	2/1990	Nakayama	364/729
4,901,064	2/1990	Deering	395/126
4,905,158	2/1990	Seki et al.	364/474.29
4,943,938	7/1990	Aoshima et al.	395/126 X
4,956,799	9/1990	Nakayama	364/729
5,046,108	9/1991	Inoue et al.	395/126 X
5,063,375	11/1991	Lien et al.	395/126 X
5,109,481	4/1992	Lathrop et al.	395/133
5,119,444	6/1992	Nishihara	382/263
5,125,073	6/1992	Lien et al.	395/142
5,163,126	11/1992	Einkauf et al.	395/126 X
5,179,659	1/1993	Lien et al.	395/513
5,222,202	6/1993	Koyamada	395/123
5,253,339	10/1993	Wells et al.	395/126
5,369,737	11/1994	Gholizadeh et al.	395/126
5,500,907	3/1996	Kunitake et al.	382/240

FOREIGN PATENT DOCUMENTS

0456408	5/1991	European Pat. Off.	G06F 15/72

OTHER PUBLICATIONS

Brinkmann et al, Linear Algebra And Analytic Geometry, 1971, pp. 345–351.

Foley et al, Computer Graphics: Principles and Practice, 1990, pp. 721–741, 1094–1099.

Schildt, Using Turbo C++, 1990, p. 392.

Beyer, Standard Mathematical Tables, 1978, pp. 169, 388.

Bui Tuong-Phong, "Illumination for computer-generated images," University of Utah, Jul. 1973, pp. 29–51.

Bui Tuong Phong, "Illumination for Computer Generated Pictures," Jun. 1975, vol. 18, No. 6, pp. 311–317.

James F. Blinn, "Models of Light Reflection For Computer Synthesized Pictures," ACM Siggraph 1977 Proceedings, pp. 192–198.

Gary Bishop; David M. Weimer, "Fast Phong Shading," ACM Siggraph 1986 Proceedings, vol. 20, No. 4, pp. 103–106.

A.A.M. Kujik; E.H. Blake, "Faster Phong Shading via Angular Interpolation," Computer Graphics Forum, 1989, vol. 8, pp. 315–324.

Ute Claussen, "On Reducing the Phong Shading Method," Eurographics 1989, pp. 333–344.

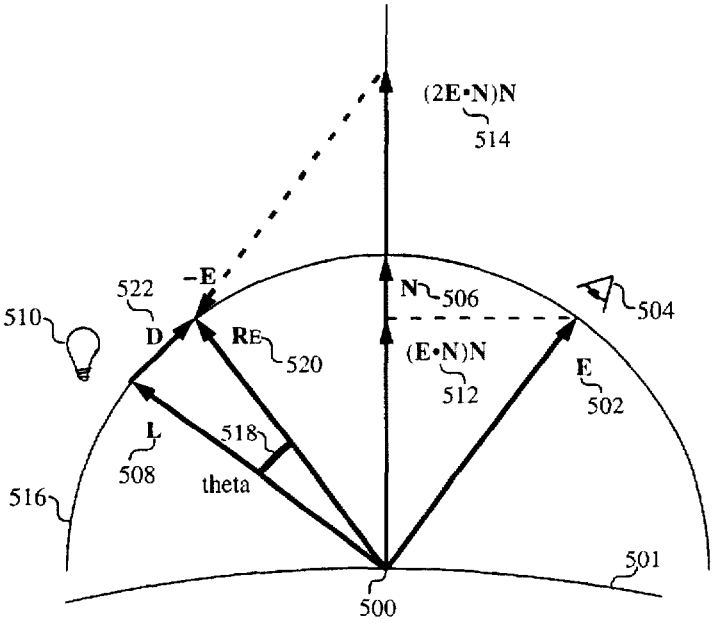
Primary Examiner—Anton W. Fetting

Attorney, Agent, or Firm—Carr, DeFilippo & Ferrell

[57] **ABSTRACT**

A method and system for approximating a Phong shading calculation for 3D renderings of realistic graphic images. The new method uses only a modest number of multiplies and adds to approximate a calculation that required divides, square roots and powers. The approximation uses approximate normalization, vector differences, and a shape function to simplify the processing and to improve performance significantly while still generating a graphic rendering that is very realistic.

6 Claims, 14 Drawing Sheets



US005796863A

United States Patent [19]

Lyon

[11] Patent Number: 5,796,863

[45] Date of Patent: Aug. 18, 1998

[54] **METHOD FOR TRAINING AN ADAPTIVE STATISTICAL CLASSIFIER TO BALANCE UNIGRAM PRIOR FACTORS**

[75] Inventor: **Richard F. Lyon**, Los Altos, Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[21] Appl. No.: **512,329**

[22] Filed: **Aug. 8, 1995**

[51] **Int. Cl.**[6] **G06T 1/40**

[52] **U.S. Cl.** **382/157**; 382/160; 382/228; 395/23

[58] **Field of Search** 382/156, 157, 382/159, 160, 161, 228; 395/20, 23, 24

[56] **References Cited**

U.S. PATENT DOCUMENTS

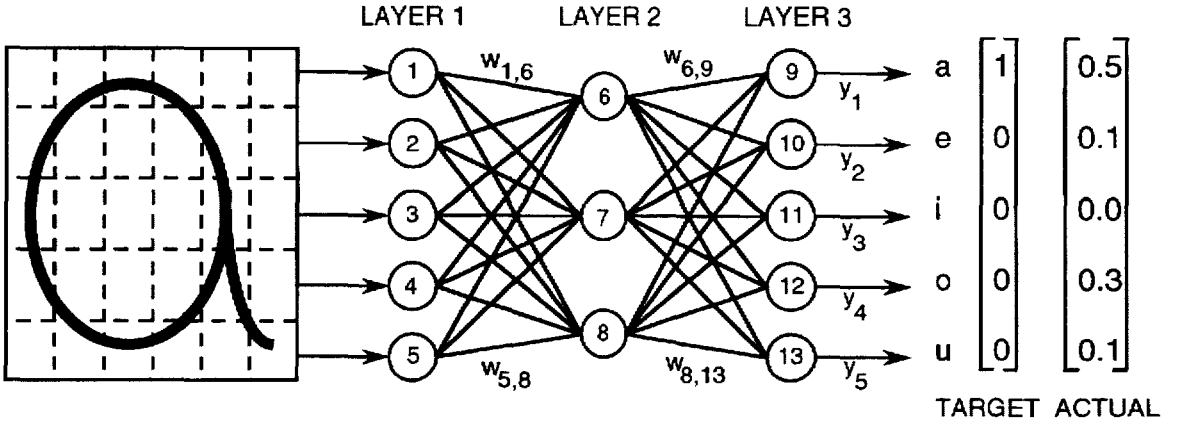
4,479,574	10/1984	Glier et al.	395/23
4,975,975	12/1990	Filipski	382/159
5,325,445	6/1994	Herbert	382/228
5,544,257	8/1996	Bellegarda et al.	382/228
5,559,929	9/1996	Wasserman	395/23

Primary Examiner—Leo Boudreau
Assistant Examiner—Christoper S. Kelly
Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis, L.L.P.

[57] **ABSTRACT**

A statistical classifier is trained in a manner to remove biasing due to unequal frequencies of unigram priors. The relative frequencies of all classes in a training set of sample patterns is determined. Training patterns are then selected from the set and skipped or repeated in dependence upon the relative frequency of the class to which they belong. In this manner, the presentation of samples is balanced across the classes.

15 Claims, 2 Drawing Sheets



US005805730A

United States Patent [19]

Yaeger et al.

[11] Patent Number: 5,805,730

[45] Date of Patent: Sep. 8, 1998

[54] **METHOD FOR TRAINING AN ADAPTIVE STATISTICAL CLASSIFIER WITH IMPROVED LEARNING OF DIFFICULT SAMPLES**

[75] Inventors: **Larry S. Yaeger**, Los Gatos; **Richard F. Lyon**, Los Altos, both of Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[21] Appl. No.: **512,296**

[22] Filed: **Aug. 8, 1995**

[51] **Int. Cl.**[6] **G06K 9/62**; G06K 9/74; G06K 9/00; G06K 9/72

[52] **U.S. Cl.** **382/228**; 382/187; 382/229; 382/225; 382/157

[58] **Field of Search** 382/182, 185–188, 382/215, 220, 225, 227, 228–229, 224, 155–157, 159–161, 137; 364/276.6, 972.7; 395/21, 23, 761, 792

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,161,204	11/1992	Hutcheson et al.	382/157
5,204,914	4/1993	Mason et al.	382/161
5,337,371	8/1994	Sato et al.	382/224
5,392,363	2/1995	Fujisaki et al.	382/187
5,555,317	9/1996	Anderson	382/159
5,577,166	11/1996	Mizuno	382/159

Primary Examiner—Bipin Shalwala

Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis, L.L.P.

[57] **ABSTRACT**

A statistical classifier that can be used for pattern recognition is trained to recognize negative, or improper patterns as well as proper patterns that are positively associated with desired output classes. A set of training samples includes both the negative and positive patterns, and target output values for the negative patterns are set so that no recognized class is indicated. The negative patterns are selected for training with less frequency than the positive patterns, and their effect on training is also modified, so that training is focused more heavily on improper patterns.

5 Claims, 2 Drawing Sheets

PATTERN	TYPE	PROB. OF USAGE CORRECT/INCORRECT		ERROR FACTOR LABEL CLASS/OTHER	
cl	POSITIVE	0.5	1.0	1.0	0.1
o	POSITIVE	0.5	1.0	1.0	0.1
g	POSITIVE	0.5	1.0	1.0	0.1
c	NEGATIVE	0.18		0.3	
clo	NEGATIVE	0.18		0.3	
l	NEGATIVE	0.18		0.3	
lo	NEGATIVE	0.18		0.3	
og	NEGATIVE	0.18		0.3	

US005805731A

United States Patent [19]

Yaeger et al.

[11] Patent Number: 5,805,731

[45] Date of Patent: Sep. 8, 1998

[54] **ADAPTIVE STATISTICAL CLASSIFIER WHICH PROVIDES RELIABLE ESTIMATES OR OUTPUT CLASSES HAVING LOW PROBABILITIES**

[75] Inventors: **Larry S. Yaeger**, Los Gatos; **Richard F. Lyon**, Los Altos, both of Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[21] Appl. No.: **512,328**

[22] Filed: **Aug. 8, 1995**

[51] **Int. Cl.**[6] **G06K 9/62**; G06K 9/74; G06K 9/68; G06K 9/70

[52] **U.S. Cl.** **382/228**; 382/157; 382/159; 382/220; 382/227

[58] **Field of Search** 382/182, 185–188, 382/215, 220, 227, 228, 229, 155–157, 159–161, 137; 364/276.6, 972.4; 395/21, 22

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,161,204	11/1992	Hutcheson et al.	382/157
5,204,914	4/1993	Mason et al.	382/161
5,337,371	8/1994	Sato et al.	382/229
5,392,363	2/1995	Fujisaki et al.	382/187
5,555,317	9/1996	Anderson	382/159
5,577,166	11/1996	Mizuno	382/159

Primary Examiner—Bipin Shalwala

Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis, L.L.P.

[57] **ABSTRACT**

A statistical classifier for pattern recognition, such as a neural network, produces a plurality of output signals corresponding to the probabilities that a given input pattern belongs in respective classes. The classifier is trained in a manner such that low probabilities which pertain to classes of interest are not suppressed too greatly. This is achieved by modifying the amount by which error signals, corresponding to classes which are incorrectly identified, are employed in the training process, relative to error signals corresponding to the correct class. As a result, output probabilities for incorrect classes are not forced to a low value as much as probabilities for correct classes are raised.

3 Claims, 2 Drawing Sheets

PATTERN	TYPE	PROB. OF USAGE CORRECT/INCORRECT		ERROR FACTOR LABEL CLASS/OTHER	
cl	POSITIVE	0.5	1.0	1.0	0.1
o	POSITIVE	0.5	1.0	1.0	0.1
g	POSITIVE	0.5	1.0	1.0	0.1
c	NEGATIVE	0.18		0.3	
clo	NEGATIVE	0.18		0.3	
l	NEGATIVE	0.18		0.3	
lo	NEGATIVE	0.18		0.3	
og	NEGATIVE	0.18		0.3	

US005903884A

United States Patent [19]

Lyon et al.

[11] Patent Number: 5,903,884

[45] Date of Patent: May 11, 1999

[54] **METHOD FOR TRAINING A STATISTICAL CLASSIFIER WITH REDUCED TENDENCY FOR OVERFITTING**

[75] Inventors: **Richard F. Lyon**, Los Altos; **William Stafford**, Burlingame, both of Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[21] Appl. No.: **08/512,361**

[22] Filed: **Aug. 8, 1995**

[51] **Int. Cl.**[6] **G06F 15/18**; G06K 9/46

[52] **U.S. Cl.** **706/25**; 706/20; 382/155; 382/157; 382/190

[58] **Field of Search** 395/23, 20; 382/155, 382/156, 157, 159, 160, 170, 190; 706/25, 20

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,058,180	10/1991	Khan	382/158
5,239,594	8/1993	Yoda	706/20
5,276,771	1/1994	Manukian et al.	706/25
5,297,237	3/1994	Masuoka et al.	706/25
5,299,284	3/1994	Roy	706/20
5,333,210	7/1994	Spirkovska et al.	382/156
5,359,699	10/1994	Tong et al.	706/20
5,390,285	2/1995	Wood	706/25
5,469,528	11/1995	Douglas et al.	706/20
5,504,780	4/1996	Alspector et al.	706/22
5,546,503	8/1996	Abe et al.	706/25
5,572,628	11/1996	Denker et al.	706/25
5,590,218	12/1996	Ornstein	706/20
5,640,468	6/1997	Hsu	382/190

OTHER PUBLICATIONS

M. Caudill, "Neural Network Training Tips and Techniques," AI Expert, pp. 56–61, Jan. 1991.

D. Whitley and N. Karunanithi, "Generalization in Feed Forward Neural Networks," Int'l. Joint Conf. on Neural Networks, vol. 2, pp. 77–82, Jul. 1991.

P. Koistinen and L. Holmstrom, "Kernel regression and backpropagation training with noise," 1991 IEEE Int'l. Joint Conf. on Neural Networks, vol. 1, pp. 367–372, Nov. 1991.

Z.M.V. Kovacs and R. Guerrieri, "A Generalization Technique for Nearest–Neighbor Classifiers," 1991 IEEE Int'l. Joint Conf. on Neural Networks, vol. 2, pp. 1782–1788, Nov. 1991.

L. Holmstrom and P. Koistinen, "Using Additive Noise in Back–Propagation Training," IEEE Trans. on Neural Networks, vol. 3(1), pp. 24–38, Jan. 1992.

R.D. Clay and C.H. Sequin, "Fault Tolerance Tranining Improves Generalization and Robustness," Int'l. Joint Conf. on Neural Networks, vol. 1, pp. 769–774, Jun. 1992.

R. Aloni–Lavi, et al., "A BP Variant with Improved Convergence and Generalization," Int'l. Joint Conf. on Neural Networks, vol. 1, pp. 932–937, Jun. 1992.

R. Reed, et al., "An Equivalence Between Sigmoidal Gain Scaling and Training with Noisy (jittered) input data," RNNS/IEEE Symp. on Neuroinformatics and Neurocomputers, vol. 1, pp. 120–127, Oct. 1992.

C.A. Hernandez, et al., "Effects of Training Data Distribution on Backpropagation Generalization," 1993 IEEE Int'l. Symp. on Circuits and Systems, vol. 4, pp. 2148–2151, May 1993.

(List continued on next page.)

Primary Examiner—Robert W. Downs

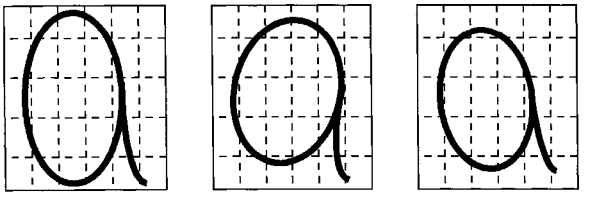
Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis, L.L.P.

[57] **ABSTRACT**

To prevent overfitting a neural network to a finite set of training samples, random distortions are dynamically applied to the samples each time they are applied to the network during a training session. A plurality of different types of distortions can be applied, which are randomly selected each time a sample is applied to the network. Alternatively, a combination of two or more types of distortion can be applied each time, with the amount of distortion being randomly varied for each type.

24 Claims, 2 Drawing Sheets

PHASE	EPOCHS	LEARNING RATE	CORRECT TRAIN PROB	NEGATIVE TRAIN PROB
1	25	1.0 - 0.5	0.1	0.05
2	25	0.5 - 0.1	0.25	0.1
3	50	0.1 - 0.01	0.5	0.18
4	30	0.01 - 0.001	1.0	0.3



US005946410A

United States Patent [19]

Lyon

[11] Patent Number: 5,946,410

[45] Date of Patent: Aug. 31, 1999

[54] **ADAPTIVE CLASSIFIER FOR COMPOUND CHARACTERS AND OTHER COMPOUND PATTERNS**

[75] Inventor: **Richard F. Lyon**, Los Altos, Calif.

[73] Assignee: **Apple Computer, Inc.**, Cupertino, Calif.

[21] Appl. No.: **08/586,233**

[22] Filed: **Jan. 16, 1996**

[51] **Int. Cl.**[6] **G06K 9/66**

[52] **U.S. Cl.** **382/157**; 382/158; 382/224

[58] **Field of Search** 382/156, 157, 382/159, 161, 224, 306, 227, 228, 229, 185, 158; 706/15

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,710,321	1/1973	Rubenstein	382/226
4,611,346	9/1986	Bednar et al.	382/174
4,754,489	6/1988	Bokser	382/230
5,373,566	12/1994	Murdock	382/156
5,425,108	6/1995	Hwang et al.	382/159

OTHER PUBLICATIONS

Ohtomo et al. "Two–Stage Recognition Method of Hand–Written Chinese Characters Using an Integrated Neural Network Model." Denshi Joohoo Tsuushin Gakkai Ronbunshi, D–II, vol. J74–D–II, No. 2, pp. 158–165 (with English translation), Feb. 1991.

Kuo et al. "A Radical–Partitioned coded Block Adaptive Neural Network Structure for Large–Volume Chinese Characters Recognition." Neural Networks 1992, IJCNN, Jun. 1992.

Kuo et al. "A Radical–Partitioned Neural Network System Using a Modified Sigmoid Function and a Weight–Dotted Radical Selector for Large–Volume Chinese Character Recognition VLSI." IEEE Int. Symp. Circuits and Systems, Jun. 1994.

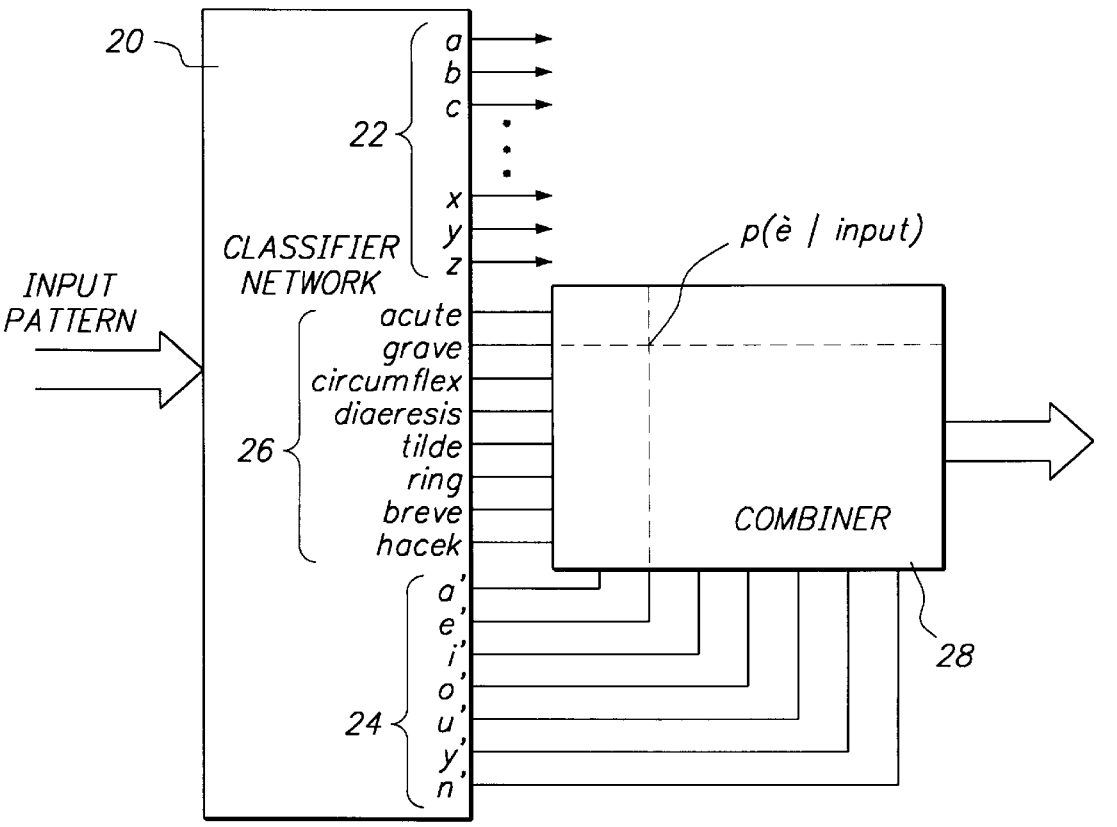
Primary Examiner—Jon Chang

Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis, L.L.P.

[57] **ABSTRACT**

A statistical classifier utilizes combined output values to determine posterior probabilities for certain output classes. In the field of handwriting recognition, compound characters are factored into classes of base letter forms and diacritical marks. A separate output activation value is produced for each base letter form and each diacritical mark. Pairs of output values, comprised of one value for a base letter form and one value for a diacritical mark, are combined to produce a posterior probability for every possible compound character, without requiring a network output for each possible class.

21 Claims, 2 Drawing Sheets



US006054704A

United States Patent [19]

Pritchard et al.

[11] **Patent Number: 6,054,704**

[45] **Date of Patent: Apr. 25, 2000**

[54] **DRIVEN CAPACITOR STORAGE PIXEL SENSOR AND ARRAY**

[75] Inventors: **J. Orion Pritchard**, San Francisco; **Richard B. Merrill**, Woodside; **Richard F. Lyon**, Los Altos, all of Calif.

[73] Assignee: **Foveon, Inc.**, Santa Clara, Calif.

[21] Appl. No.: **09/108,110**

[22] Filed: **Jun. 30, 1998**

[51] **Int. Cl.**[7] **H04N 3/14**

[52] **U.S. Cl.** ..... **250/208.1**; 250/214 R; 348/302

[58] **Field of Search** ..... 250/208.1, 214 R; 348/294, 300–302, 308, 311

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,988,619	10/1976	Malaviya et al.	307/311
4,002,824	1/1977	Petrocelli et al.	358/108
4,654,714	3/1987	Hurst, Jr. et al.	358/213
4,809,075	2/1989	Akimoto et al.	358/213
4,839,735	6/1989	Kyomasu et al.	358/213.31
4,942,473	7/1990	Zeevi et al.	358/213.26
5,262,871	11/1993	Wilder et al.	358/213.11
5,428,390	6/1995	Cooper et al.	348/240
5,471,245	11/1995	Cooper et al.	348/302
5,541,402	7/1996	Acklane et al.	250/208.1
5,576,763	11/1996	Acklane et al.	348/308
5,631,704	5/1997	Dickinson et al.	348/308
5,739,562	4/1998	Ackland et al.	257/291

FOREIGN PATENT DOCUMENTS

0777379	6/1997	European Pat. Off.	H04N 3/15

OTHER PUBLICATIONS

R. Panicacci, et al. 1/4–Inch CMOS Active Pixel Sensor with Smart on–Chip Functions and Full Digital Interface, Aug. 25–26, 1997 pp: 41–53, Hot Chips IX, Stanford California.

S. Decker, et al. A 256x256 CMOS Imaging Array with Wide Dynamic Range Pixels and Column–Parallel Digital Output, 1998 IEEE International Solid–State Circuits Conference; pp: 176–177.

Tobi Delbruck, et al. Analog VLSI Adaptive, Logarithmic, Wide–Dynamic–Range Photoreceptor, IEEE London, May 1994, Dept. Of Computation and Neural Systems California Institute of Technology Pasadena, CA.

T. Delbruck, et al. Analog VLSI Phototransduction by continuous–time, adaptive, logarithmic photoreceptor circuits, Apr. 2, 1996, CNS Memo No. 30, cover, pp: 1–23, index.

Eric R. Fossum, Active Pixel Sensors: Are CCD's Dinosaure?, Jet Propulsion Laboratory, California Institute of Technology, 2/SPIE vol. 1900. pp. 2–14.

Sunetra K. Mendis, et al. A 128x128 CMOS Active Pixel Image Sensor for Highly Intergrated Imaging Systems, 1993 IEEE, IEDM 93–583, pp. 22.6.1–66.6.4.

Yoshiaki Hagiwara, Member IEEE, High–Density and High–Quality Frame Transfer CCD Imager with Very Low Smear, Low Dark Current, and Very High Blue Senitivity, 1996 IEEE, IEEE Transaction of Electron Devices, vol. 43 No. 12, Dec. 1996, pp. 2122–2130.

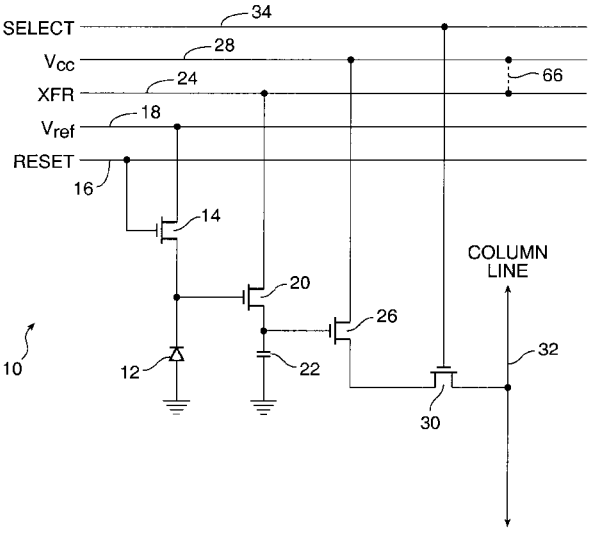
(List continued on next page.)

Primary Examiner—Stephone B. Allen
Attorney, Agent, or Firm—Sierra Patent Group. Ltd.

[57] **ABSTRACT**

A storage pixel sensor comprises a photosensor selectively connectable to a reset potential; a switched buffer amplifier having a control terminal coupled to said photosensor, a first terminal connected to a source of a transfer signal, and a second terminal; a storage capacitor coupled to said second terminal of said switched buffer amplifier; and an amplifier coupled to said storage capacitor.

29 Claims, 7 Drawing Sheets



US006078429A

United States Patent [19]

Lyon

[11] Patent Number: 6,078,429

[45] Date of Patent: Jun. 20, 2000

[54] **COLOR SEPARATING PRISM HAVING VIOLET LIGHT COMPONENT IN RED CHANNEL**

[75] Inventor: **Richard F. Lyon**, Los Altos, Calif.

[73] Assignee: **Foveon, Inc.**, Santa Clara, Calif.

[21] Appl. No.: **09/121,227**

[22] Filed: **Jul. 22, 1998**

[51] **Int. Cl.**[7] **G02B 27/14**; G02B 1/10

[52] **U.S. Cl.** **359/634**; 359/583

[58] **Field of Search** 359/634, 583, 359/629

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,602,637	8/1971	Katsuta et al.	178/5.4 ST
3,653,748	4/1972	Athey	350/171
3,659,918	5/1972	Tan	350/166
3,922,069	11/1975	Kishikawa et al.	350/173
4,268,119	5/1981	Hartmann	350/173
4,547,074	10/1985	Hinoda et al.	356/405

OTHER PUBLICATIONS

Blanksby et al, *Noise Performance of a Color CMOS Photogate Image Sensor*, IEDM 97–205 pp.8.6.1–8.6.4 (1997).

Juenger, Andrew K., *Color Sensitivity Selection for Electronics Still Cameras Based on Noise Considerations in Photographic Speed Maximization*, IS&T's 1998 PICS Conference.

Hunt, R. W. G., *The Reproduction of Colour*, Fifth Edition, Fountain Press, Kingston–upon–Thames, 1995 (Ch. 19, especially 19.12 and figure 19.9).

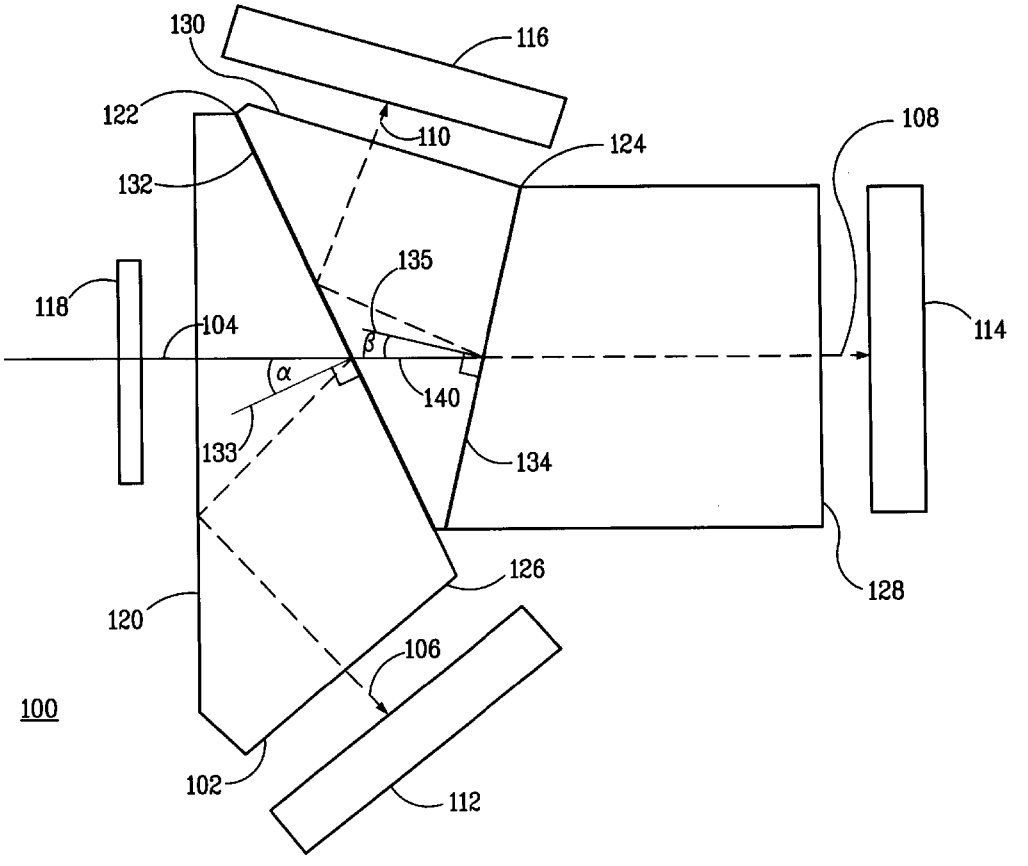
Primary Examiner—Ricky Mack

Attorney, Agent, or Firm—Carr & Ferrell LLP

[57] **ABSTRACT**

A color separating prism is disclosed for use in an electronic imaging systems such as a video or digital still-image camera. The prism separates an incoming light beam into red, green and blue light components and directs the separated light components onto adjacent imaging sensors. Beam-splitting interfaces of the prism are optically configured to admit approximately ten to twenty percent of a violet light contained in the incoming light beam into the red color channel. The prism may beneficially be optically coupled to a light-rejecting filter or mirror which rejects undesired far-red, far-violet and blue-green components of the light beam. In this manner, the resultant red, green and blue channels approximate a set of substantially non-negative color matching functions to facilitate highly colorimetrically accurate color imaging and thereby reduce or eliminate the need for post-imaging color correction.

15 Claims, 7 Drawing Sheets



US006097022A

United States Patent [19]

Merrill et al.

[11] **Patent Number: 6,097,022**

[45] **Date of Patent: Aug. 1, 2000**

[54] **ACTIVE PIXEL SENSOR WITH BOOTSTRAP AMPLIFICATION**

[75] Inventors: **Richard B. Merrill**, Woodside; **Richard F. Lyon**, Los Altos, both of Calif.

[73] Assignee: **Foveon, Inc.**, Santa Clara, Calif.

[21] Appl. No.: **09/099,116**

[22] Filed: **Jun. 17, 1998**

[51] **Int. Cl.**[7] **H04N 3/14**

[52] **U.S. Cl.** **250/208.1**; 348/300

[58] **Field of Search** 250/208.1; 348/300–302, 348/308, 311

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,866,067	2/1975	Amelio	307/311
3,934,161	1/1976	Caywood	307/311
4,363,963	12/1982	Ando	358/213.18
4,395,736	7/1983	Fraleux	358/213.31
4,499,590	2/1985	Bluzer	377/60
4,704,633	11/1987	Matsumoto	358/213.27
4,839,735	6/1989	Kyomasu et al.	358/213.31
4,901,129	2/1990	Hynecek	357/30
4,908,651	3/1990	Fujino et al.	354/434
5,117,292	5/1992	Matsunaga	358/213.19
5,227,887	7/1993	Dohi et al.	358/213.27
5,276,521	1/1994	Mori	358/213.31
5,317,174	5/1994	Hynecek	257/222
5,335,015	8/1994	Cooper et al.	348/302
5,341,008	8/1994	Hynecek	257/231
5,424,223	6/1995	Hynecek	437/3
5,471,245	11/1995	Cooper et al.	348/302
5,625,210	4/1997	Lee et al.	257/292
5,712,682	1/1998	Hannah	348/255

FOREIGN PATENT DOCUMENTS

0777379	6/1997	European Pat. Off.	H04N 3/15

OTHER PUBLICATIONS

Abbas El Garmal, et al. "Modeling and Estimation of FPN Components in CMOS Image Sensors" Information Systems Laboratory, Stanford University, pp. 1–10, 1987.

Andrew J. Blanksby, et al. "Noise Performance of a color CMOS Photogate Image Sensor" IEEE pp. 205–208, 1997.

Bernward Rossler "Electrically Erasable and Reprogrammable Read–Only Memory Using the n–Channel SIMOS One–Transistor Cell" IEEE Transactions on Electron Devices vol. ED–24, No. 5 pp. 606–610 May 1977.

S. Decker et, al. "A 256×256 CMOS Imaging Array with Wide Dynamic Range Pixels and Column–Parallel Digital Output" IEEE International Solid–State Circuits Conference pp. 176–177 1998.

S.M. Sze "Physics of Semiconductor Devices" Wiley–Interscience pp. 526–533 1969.

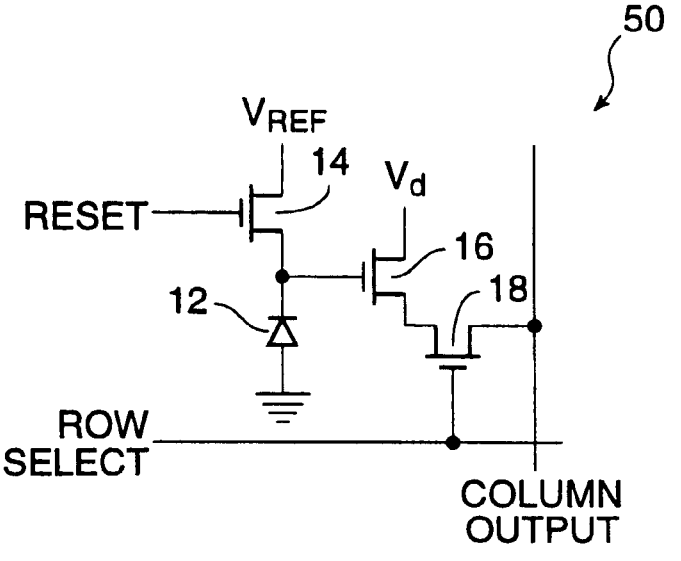
Primary Examiner—Stephone B. Allen

Attorney, Agent, or Firm—Sierra Patent Group

[57] **ABSTRACT**

In a first embodiment an active pixel sensor includes a photodiode for capturing photocharge, a reset transistor for resetting the photodiode to a reset potential, and a readout transistor, and in a second embodiment an active pixel sensor includes a photodiode for capturing photocharge, a reset transistor for resetting the photodiode to a reset potential, a transfer transistor for transferring captured photocharge, and a readout transistor. In both embodiments, the readout transistor has a drain that is coupled to a first supply voltage during integration of photocharge and a second supply voltage during readout of the photocharge. Accordingly, the sensitivity of an active pixel sensor is increased by increasing the fill factor, the noise an active pixel sensor is reduced by increasing the relative size of the readout transistor, and the gain is compressive as the relative light intensity in an active pixel sensor increases.

6 Claims, 6 Drawing Sheets



US006211510B1

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

(10) **Patent No.: US 6,211,510 B1**
(45) **Date of Patent: *Apr. 3, 2001**

(54) **ACTIVE PIXEL SENSOR WITH BOOTSTRAP AMPLIFICATION**

(75) Inventors: **Richard B. Merrill**, Woodside; **Richard F. Lyon**, Los Altos, both of CA (US)

(73) Assignee: **Foveon, Inc.**

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

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/491,462**

(22) Filed: **Jan. 26, 2000**

Related U.S. Application Data

(63) Continuation of application No. 09/099,116, filed on Jun. 17, 1998.

(51) **Int. Cl.**[7] **H04N 3/14**
(52) **U.S. Cl.** **250/208.1**; 348/302
(58) **Field of Search** 250/208.1, 214.1; 348/294, 300–302, 308, 311; 327/514

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,866,067 * 2/1975 Amelio 327/514
4,395,736 * 7/1983 Fraleax 250/214.1
5,335,015 * 8/1994 Cooper et al. 348/302
5,471,245 * 11/1995 Cooper et al. 348/302

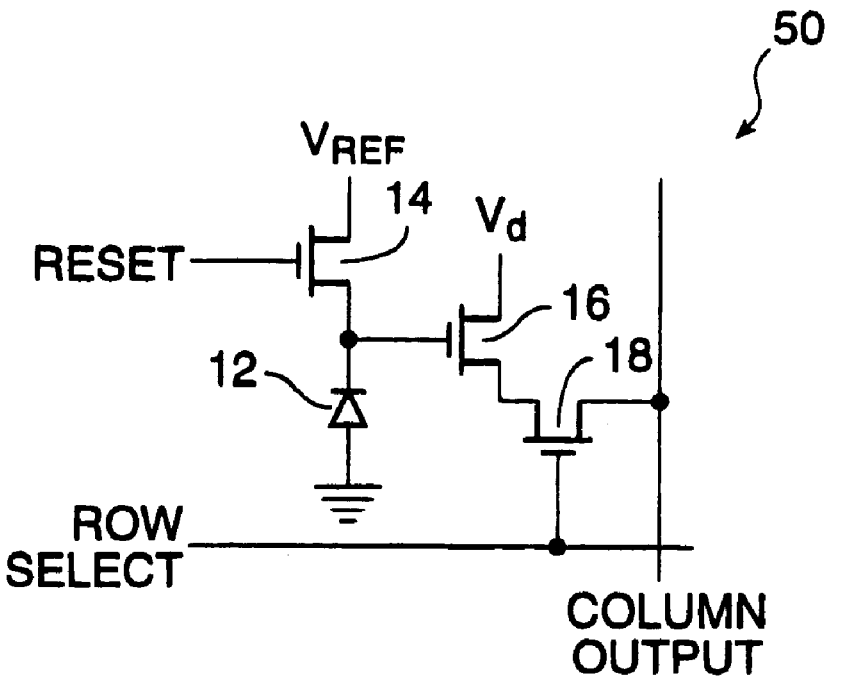
* cited by examiner

Primary Examiner—Stephone B. Allen
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

In a first embodiment an active pixel sensor includes a photodiode for capturing photocharge, a reset transistor for resetting the photodiode to a reset potential, and a readout transistor, and in a second embodiment an active pixel sensor includes a photodiode for capturing photocharge, a reset transistor for resetting the photodiode to a reset potential, a transfer transistor for transferring captured photocharge, and a readout transistor. In both embodiments, the readout transistor has a drain that is coupled to a first supply voltage during integration of photocharge and a second supply voltage during readout of the photocharge. Accordingly, the sensitivity of an active pixel sensor is increased by increasing the fill factor, the noise an active pixel sensor is reduced by increasing the relative size of the readout transistor, and the gain is compressive as the relative light intensity in an active pixel sensor increases.

6 Claims, 6 Drawing Sheets



US006330113B1

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

(10) **Patent No.: US 6,330,113 B1**
(45) **Date of Patent: Dec. 11, 2001**

(54) **COLOR SEPARATION PRISM WITH ADJUSTABLE PATH LENGTHS**

(75) Inventors: **Timothy M. Slagle**, Menlo Park; **Richard F. Lyon**, Los Altos, both of CA (US); **Mitchell C. Ruda**; **Tilman W. Stuhlinger**, both of Tucson, AZ (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **09/676,192**

(22) Filed: **Sep. 28, 2000**

(51) **Int. Cl.**[7] **G02B 27/14**; H04N 9/07
(52) **U.S. Cl.** **359/634**; 348/337; 348/338
(58) **Field of Search** 359/583, 634; 348/336, 337, 338, 339

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,134,468		7/1992	Ohmuro	358/50
5,777,674	*	7/1998	Ohmuro	348/338
6,238,051	*	5/2001	Huang	353/81

FOREIGN PATENT DOCUMENTS

02000266915A * 9/2000 (JP) G02B/5/04

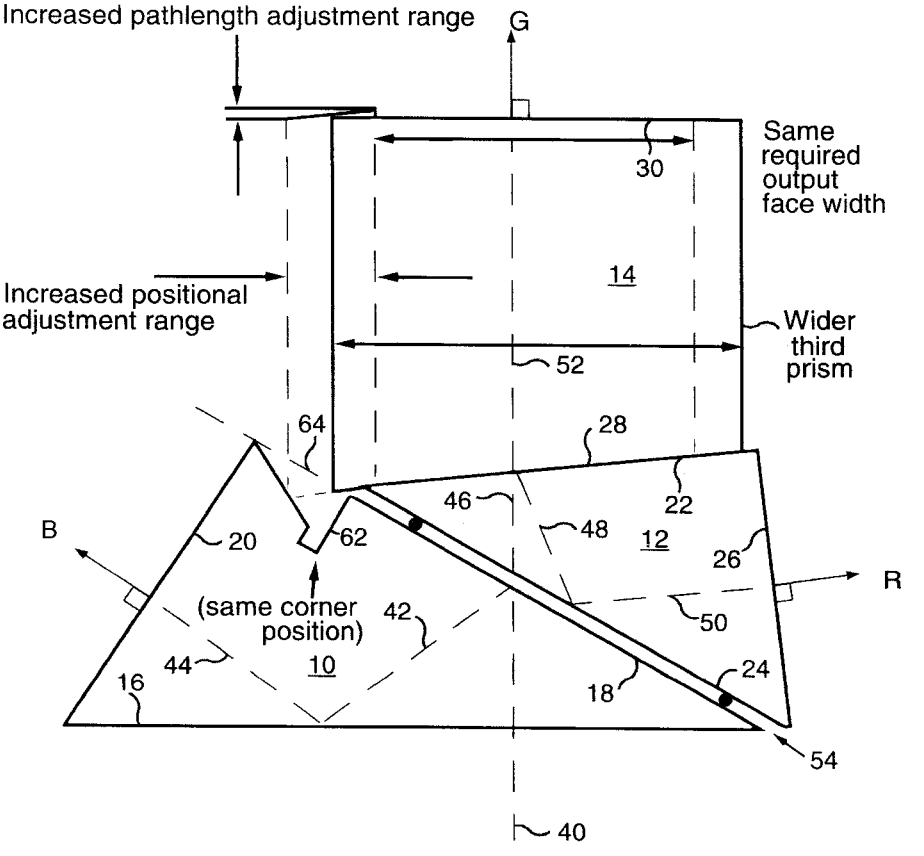
* cited by examiner

Primary Examiner—Ricky Mack
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A color-separation prism assembly comprises first, second and third prisms. The first and second prisms have entrance surfaces, exit surfaces, and partially-reflecting surfaces, wherein the entrance surface of the second prism is separated by an air gap from the partially-reflecting surface of the first prism. The third prism has an entrance surface and an exit surface, wherein the entrance surface of the third prism is adjacent to the partially-reflecting surface of the second prism. The first prism has a cut-out serving as a flare-stop stop, and providing relief so as to allow the entrance surface of the third prism to slide across a plane disposed over the cut-out into a volume defined by the cut-out. The plane is formed as an extension of the partially-reflecting surface of the first prism. An optical axis passes through the first, second and third prisms. The optical axis passes at normal angles through the entrance surface of the first prism, and the exit surfaces of the first, second and third prisms. The partially reflecting surfaces each have angles-of-incidence of less than **30°** relative to the optical axis.

2 Claims, 2 Drawing Sheets



US006369853B1

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

(10) **Patent No.: US 6,369,853 B1**
(45) **Date of Patent: Apr. 9, 2002**

(54) **INTRA-PIXEL FRAME STORAGE ELEMENT, ARRAY, AND ELECTRONIC SHUTTER METHOD SUITABLE FOR ELECTRONIC STILL CAMERA APPLICATIONS**

(75) Inventors: **Richard B. Merrill**, Woodside; **Richard M. Turner**, Menlo Park; **Carver A. Mead**, Cupertino; **Richard F. Lyon**, Los Altos, all of CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **08/969,383**

(22) Filed: **Nov. 13, 1997**

(51) **Int. Cl.**[7] **H04N 3/14**

(52) **U.S. Cl.** **348/302**; 348/308; 348/310; 250/208.1; 257/223; 257/291; 257/258; 257/445

(58) **Field of Search** 250/208.1; 257/223, 257/229, 230–233, 257, 258, 290, 291, 444, 445; 348/302–304, 307–310; H04N 3/14

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,934,161 A		1/1976	Caywood	307/311
3,988,619 A		10/1976	Malaviya et al.	307/311
4,330,796 A	*	5/1982	Anagnostopoulos	348/322

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

EP	0777379	6/1997	H04N/3/15
JP	54-108628	8/1979	G03B/7/20
JP	58-83824	5/1983	G03B/7/20
JP	59-42527	3/1984	G03B/17/14
JP	59-152424	8/1984	G03B/7/20
JP	60-23841	2/1985	G03B/17/14
JP	60-53912	3/1985	G02B/7/11

OTHER PUBLICATIONS

S. Decker et, al. "A 256x256 CMOS Imaging Array with Wide Dynamic Range Pixels and Column–Parallel Digital Output" IEEE International Solid–State Circuits Conference pp. 176–177 1998.

R.M. Guidash, et al. "A 0.6 um CMOS Pinned Photodiode Color Imager Technology" IEDM pp. 927–929 1997.

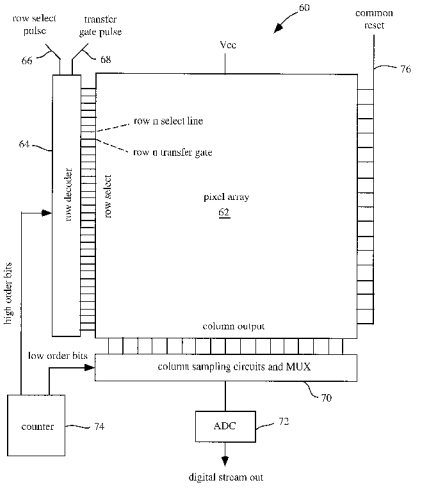
(List continued on next page.)

Primary Examiner—Wendy R. Garber
Assistant Examiner—Ngoc-Yen Vu
(74) *Attorney, Agent, or Firm*—Sierra Patent Group Ltd

(57) **ABSTRACT**

A storage pixel sensor disposed on a semiconductor substrate comprises a capacitive storage element having a first terminal connected to a fixed potential and a second terminal. A photodiode has an anode connected to a first potential and a cathode. A semiconductor reset switch has a first terminal connected to the cathode and a second terminal connected to a reset potential. A semiconductor transfer switch has a first terminal connected to the cathode and a second terminal connected to the second terminal of the capacitive storage element. A semiconductor amplifier has an input connected to the capacitive storage element and an output. The semiconductor reset switch and the semiconductor transfer switch each have a control element connected to a control circuit for selectively activating the semiconductor reset switch and the semiconductor transfer switch. A light shield is disposed over portions of the semiconductor substrate comprising a circuit node including the second terminal of the semiconductor transfer switch, the second terminal of the capacitive storage element and the input of the semiconductor amplifier and to prevent substantially all photons from entering the circuit node. Structures are present for preventing substantially all minority carriers generated in the semiconductor substrate from entering the circuit node. A plurality of storage pixel sensors are disposed in an array.

22 Claims, 11 Drawing Sheets



US006410899B1

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

(10) **Patent No.: US 6,410,899 B1**
(45) **Date of Patent: Jun. 25, 2002**

(54) **ACTIVE PIXEL SENSOR WITH BOOTSTRAP AMPLIFICATION AND REDUCED LEAKAGE DURING READOUT**

(75) Inventors: **Richard B. Merrill**, Woodside; **Richard M. Turner**, Menlo Park; **Milton B. Dong**, Saratoga; **Richard F. Lyon**, Los Altos, all of CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **09/492,103**

(22) Filed: **Feb. 14, 2000**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/099,116, filed on Jun. 17, 1998, now Pat. No. 6,097,022.

(51) **Int. Cl.**[7] **H04N 3/14**
(52) **U.S. Cl.** **250/208.1**; 348/308
(58) **Field of Search** 250/208.1, 214.1; 257/291, 292, 443, 444; 348/300, 301, 302, 308, 311

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,866,067	A	2/1975	Amelio	307/311
3,934,161	A	1/1976	Caywood	307/311
3,971,065	A	7/1976	Bayer	358/41
3,988,619	A	10/1976	Malaviya et al.	307/311
4,011,016	A	3/1977	Layne et al.	356/195
4,236,760	A	12/1980	Haar et al.	303/6 C
4,238,760	A	12/1980	Carr	357/30
4,309,604	A	1/1982	Yoshikawa et al.	250/226
4,363,963	A	12/1982	Ando	250/211
4,395,736	A	7/1983	Fraleux	358/213
4,473,836	A	9/1984	Chamberlain	357/30
4,499,529	A	2/1985	Figueroa	362/283
4,499,590	A	2/1985	Bluzer	377/60

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

DE	43 04 506 A1	8/1994	H04N/5/225
DE	WO 98/19455	5/1998	H04N/3/15
DE	19836356 A1	8/1998	H01L/27/146

(List continued on next page.)

OTHER PUBLICATIONS

Abbas El Gamal, et al. "Modeling and Estimation of FPN Components in CMOS Image Sensors", Information Systems Laboratory, Stanford University, and Fudan University, Shanghai, China, pp. 1–10,(sometime after 1/98).

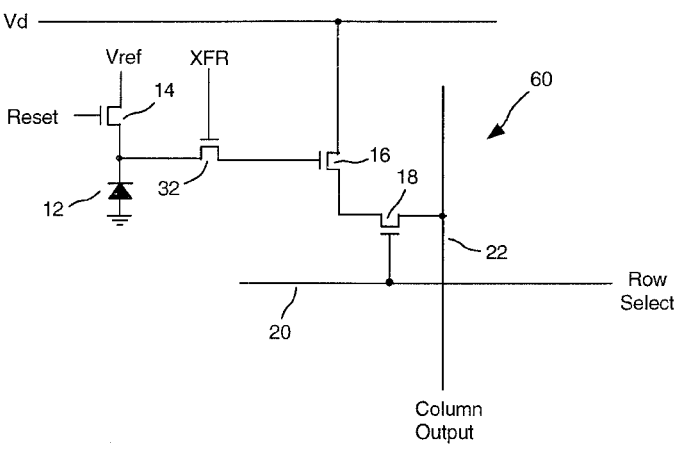
(List continued on next page.)

Primary Examiner—Stephone B Allen
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

An integrated active pixel sensor array comprises a plurality of row select lines, each of said row select lines coupled to a source of a row-select signal; a plurality of source-follower drain row lines, each of said source-follower drain row lines coupled to a source of a source-follower drain row signal; a plurality of column output lines; a reset line coupled to a source of a reset signal; a source of reset potential; and a plurality of active pixel sensors, each pixel sensor associated with one row and one column of the array and including a photodiode having a first terminal coupled to a first reference potential and a second terminal, a Reset transistor having a gate coupled to the reset line, a drain coupled to the reset potential to reverse bias the photodiode, and a source coupled to the second terminal of the photodiode, a Source-Follower transistor having a gate coupled to the second terminal of the photodiode, a drain connected to the one of the plurality of source-follower drain row lines with which its active pixel sensor is associated, and a source, a Row-select transistor having a gate coupled to the one of the plurality of row-select lines with which its active pixel sensor is associated, a drain coupled to the source of the Source-follower transistor, and a source coupled to the one of the plurality of column output lines with which its active pixel sensor is associated.

6 Claims, 7 Drawing Sheets



US006452633B1

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

(10) **Patent No.: US 6,452,633 B1**
(45) **Date of Patent: Sep. 17, 2002**

(54) **EXPOSURE CONTROL IN ELECTRONIC CAMERAS BY DETECTING OVERFLOW FROM ACTIVE PIXELS**

(75) Inventors: **Richard B. Merrill**, Woodside; **Carver A. Mead**, Cupertino; **Richard F. Lyon**, Los Altos, all of CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **09/031,333**

(22) Filed: **Feb. 26, 1998**

(51) **Int. Cl.**[7] **H01L 27/148**; H04N 3/14
(52) **U.S. Cl.** **348/302**; 348/294; 257/223
(58) **Field of Search** 348/302, 308, 348/294, 296, 297, 298, 299, 241, 243, 221, 250, 362; 250/208.1; 257/223, 290–294, 229, 230

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,866,067 A		2/1975	Amelio	307/311
3,934,161 A		1/1976	Caywood	307/311
4,363,963 A		12/1982	Ando	250/211
4,499,529 A		2/1985	Figueroa	362/283
4,573,077 A		2/1986	Imai	358/212
4,626,915 A		12/1986	Takatsu	358/213
4,742,238 A		5/1988	Sato	250/578
4,839,735 A		6/1989	Kyomasu et al.	358/213.31
4,843,474 A		6/1989	Suzuki	358/213.19
4,901,129 A		2/1990	Hynecek	357/30
4,908,651 A		3/1990	Fujino et al.	354/434
5,038,214 A		8/1991	Miida	358/213.11
5,117,292 A		5/1992	Matsunaga	358/213.19
5,227,887 A		7/1993	Dohi et al.	358/213.27
5,276,520 A	*	1/1994	Hawkins et al.	257/223
5,276,521 A		1/1994	Mori	358/213.31
5,335,015 A		8/1994	Cooper et al.	348/302
5,434,620 A		7/1995	Higuchi et al.	348/308

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

EP	0 466 929 A1	1/1992	
EP	0777379	6/1997	..... H04N/3/15
JP	54-108628	8/1979	..... G03B/7/20
JP	58-83824	5/1983	..... G03B/7/20
JP	59-42527	3/1984	..... G03B/17/14
JP	59-152424	8/1984	..... G03B/7/20
JP	60-23841	2/1985	..... G03B/17/14
JP	60-53912	3/1985	..... G02B/7/11
JP	62143571	6/1987	
JP	01103378	4/1989	

OTHER PUBLICATIONS

"Color sensitive photodetectors in standard CMOS and BiCMOS technologies" Mohamed Ben Chouikha, et al. pp 108–120, including cover sheet, SPIE vol. 2950, 0–8194–2354 8/96.

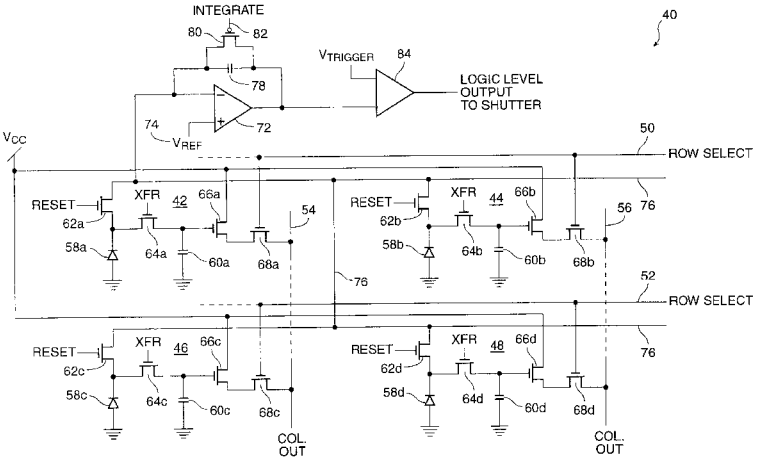
(List continued on next page.)

Primary Examiner—Wendy R. Garber
Assistant Examiner—Rashawn N. Tillery
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A method for controlling the exposure of an active pixel array electronic still camera includes the steps of: integrating photocurrent in each pixel during an integration time period; collecting overflow charge from all pixels in the array during the integration time period; developing an overflow signal as a function of the overflow charge; and terminating the integration time period when the overflow signal exceeds a preset threshold level selected to represent a desired reference exposure level. Apparatus for performing the method of the present invention includes circuitry for integrating photocurrent in each pixel during a integration time period; circuitry for diverting and detecting overflow charge from all pixels in the array during the integration time period; circuitry for developing an overflow signal as a function of the overflow charge; and circuitry for terminating said integration time period when the overflow signal exceeds a preset threshold level selected to represent a desired reference exposure level.

20 Claims, 10 Drawing Sheets



US006480621B1

(12) **United States Patent**
Lyon

(10) **Patent No.: US 6,480,621 B1**
(45) **Date of Patent: Nov. 12, 2002**

(54) **STATISTICAL CLASSIFIER WITH REDUCED WEIGHT MEMORY REQUIREMENTS**

(75) Inventor: **Richard F. Lyon**, Los Altos, CA (US)

(73) Assignee: **Apple Computer, Inc.**, Cupertino, CA (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.: **08/512,297**

(22) Filed: **Aug. 8, 1995**

(51) **Int. Cl.**[7] **G06K 9/62**
(52) **U.S. Cl.** **382/157**; 382/161; 382/224; 706/20
(58) **Field of Search** 382/156, 157, 382/159, 161, 224, 228, 229; 395/22, 23, 24, 27; 706/15, 20, 34, 38

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,972,187 A	*	11/1990	Wecker	395/22
5,040,230 A	*	8/1991	Takatori et al.	382/159
5,140,531 A	*	8/1992	Engeler	395/24

OTHER PUBLICATIONS

Holt et al, "Finite Precision Error Analysis of Neural Network Electronic Hardware Implementations" Jan. 1991 pp. 519–525 Jan. 91.*

Hoehfeld et al, "Learning with Limited Numerical Precision Using the Cascade–Correlation Algorithm" Jul. 1992 pp. 602–611.*

Asanovic, Krste, et al; *"Experimental Determination of Precision Requirements for Back–Propagation Training of Artificial Neural Networks"*, TR–91–036; Oct. 1991; pp. 1–6.

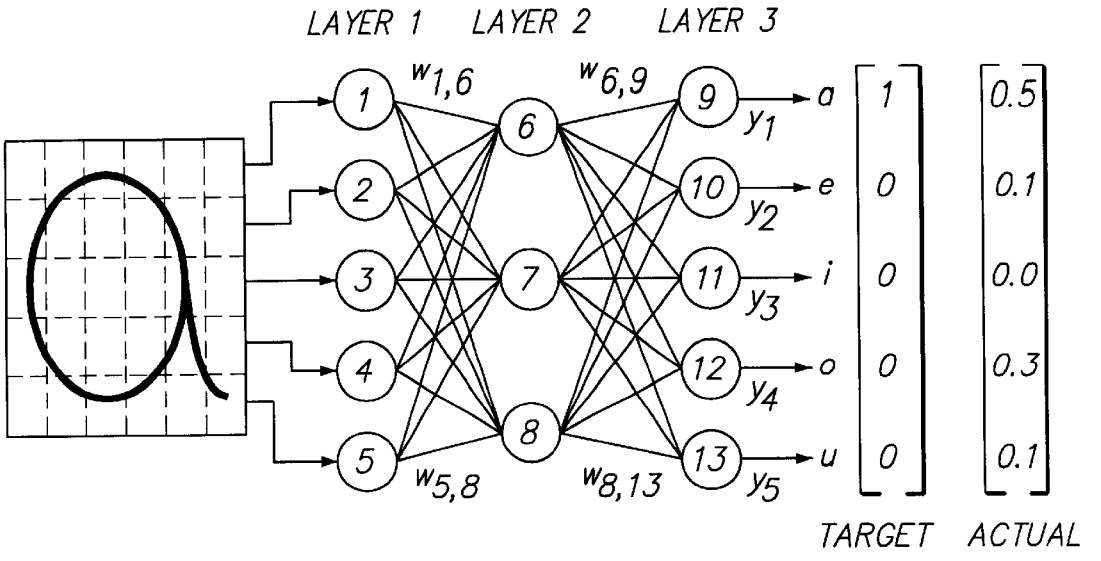
* cited by examiner

Primary Examiner—Bhavesh Mehta
(74) *Attorney, Agent, or Firm*—Burns, Doane, Swecker & Mathis, L.L.P.

(57) **ABSTRACT**

A neural network has reduced requirements for storing intermodal weight values, as a result of a dual-precision training process. In the forward propagation of training samples, low-resolution weight values are employed. During back-propagation of errors to train the network, higher-resolution values are used. After training, only the lower resolution values need to be stored for further run-time operation, thereby reducing memory requirements.

13 Claims, 2 Drawing Sheets



US006512544B1

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

(10) **Patent No.: US 6,512,544 B1**
(45) **Date of Patent: Jan. 28, 2003**

(54) **STORAGE PIXEL SENSOR AND ARRAY WITH COMPRESSION**

(75) Inventors: **Richard B. Merrill**, Woodside, CA (US); **Richard F. Lyon**, Los Altos, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **09/098,688**

(22) Filed: **Jun. 17, 1998**

(51) **Int. Cl.**[7] **H04N 3/14**; H04N 5/335; H01L 27/10; H01L 31/062; H01L 27/00

(52) **U.S. Cl.** **348/302**; 348/297; 348/298; 348/299; 348/304; 348/314; 257/291; 257/292; 250/208.1

(58) **Field of Search** 348/299, 297, 348/298, 304, 302, 314, 294; 257/204, 277, 291, 292; 250/208.1

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,866,067 A	*	2/1975	Amelio	327/514
3,934,161 A		1/1976	Caywood	307/311
3,988,619 A		10/1976	Malaviya et al.	307/311
4,363,963 A		12/1982	Ando	250/211
4,473,836 A		9/1984	Chamberlain	357/30
4,626,915 A		12/1986	Takatsu	358/213
4,654,714 A		3/1987	Hurst, Jr. et al.	358/213
4,680,489 A	*	7/1987	Stetson	327/543
4,734,776 A		3/1988	Wang et al.	358/213.31
4,742,238 A		5/1988	Sato	250/578
4,809,075 A		2/1989	Akimoto et al.	358/213.18
4,839,735 A		6/1989	Kyomasu et al.	358/213.31
4,845,553 A		7/1989	Konomura et al.	358/98
4,875,091 A		10/1989	Yamada et al.	358/42

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

EP	0777379	6/1997	H04N/3/15
EP	0 854 516 A2	1/1998	H01L/27/146
EP	0 854 516 A3	1/1998	H01L/27/146
JP	06/133320	5/1994	H04N/9/09
WO	WO 99/66560	12/1999	H01L/27/144

OTHER PUBLICATIONS

S. M. Sze, *Physics of Semiconductor Devices*, pp. 526–533, Wiley–Interscience, 1969.

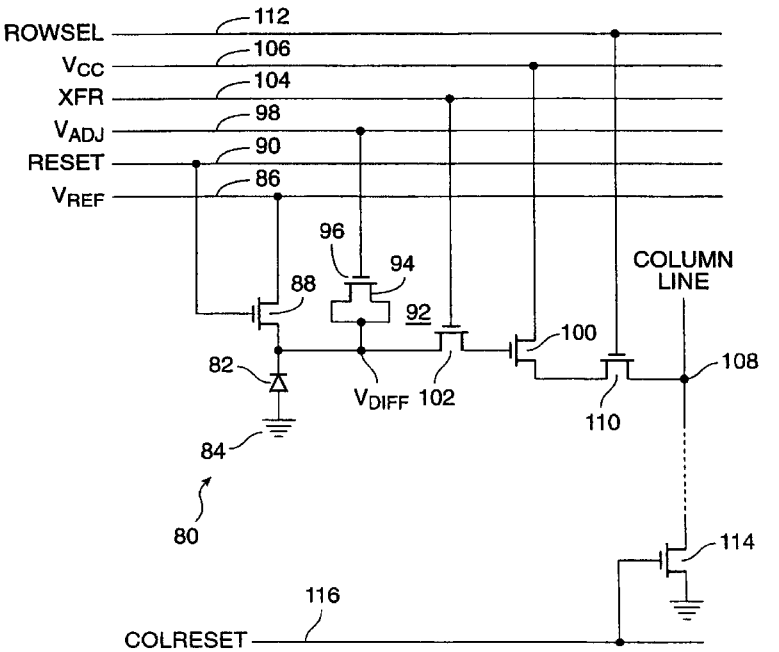
(List continued on next page.)

Primary Examiner—Wendy R. Garber
Assistant Examiner—John M. Villecco
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A storage pixel sensor disposed on a semiconductor substrate comprises a photosensor. At least one nonlinear capacitive element is coupled to the photosensor. At least one nonlinear capacitive element is arranged to have a compressive photocharge-to-voltage gain function. An amplifier has an input coupled to the nonlinear capacitor and an output. Other, non-capacitive elements may be employed to produce a compressive photo-charge-to-voltage gain having at least one breakpoint.

18 Claims, 9 Drawing Sheets



US006512858B2

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

(10) **Patent No.: US 6,512,858 B2**
(45) **Date of Patent: *Jan. 28, 2003**

(54) **IMAGE SCANNING CIRCUITRY WITH ROW AND COLUMN ADDRESSING FOR USE IN ELECTRONIC CAMERAS**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Richard M. Turner**, Menlo Park, CA (US); **Richard B. Merrill**, Woodside, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

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.: **09/120,491**

(22) Filed: **Jul. 21, 1998**

(65) **Prior Publication Data**

US 2002/0018600 A1 Feb. 14, 2002

(51) **Int. Cl.**[7] **G06K 9/60**; H01L 31/14

(52) **U.S. Cl.** **382/305**; 382/312; 250/553

(58) **Field of Search** 382/305, 232, 382/254, 312; 369/13; 348/96, 155, 302, 308, 321, 333.01; 711/2; 257/291; 358/213; 250/553, 208.1; 365/208, 230.1

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,988,619	A		10/1976	Malaviya et al. 307/311
4,002,824	A		1/1977	Petrocelli et al. 358/108
4,072,405	A		2/1978	Ozeki 350/173
4,084,180	A		4/1978	Stoffels et al. 358/55
4,129,859	A	*	12/1978	Iwamura et al. ..... 340/324 AD
4,539,598	A	*	9/1985	Dietrich et al. 358/213
4,654,714	A		3/1987	Hurst, Jr. et al. 358/213
4,809,075	A		2/1989	Akimoto et al. 358/213
4,839,735	A		6/1989	Kyomasu et al. 358/213.31
4,942,473	A		7/1990	Zeevi et al. 358/213.26
5,262,871	A		11/1993	Wilder et al. 358/213.11
5,291,463	A	*	3/1994	Ichikawa et al. 369/13
5,412,422	A	*	5/1995	Yamada et al. 348/218
5,428,390	A		6/1995	Cooper et al. 348/240
5,471,245	A		11/1995	Cooper et al. 348/302

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

EP	0777379	6/1997	..... H04N/3/15

OTHER PUBLICATIONS

C. Mead, *Analog VLSI and Neural Systems*, pp. 263–267, Addison Wesley Pub. Co. 1989.

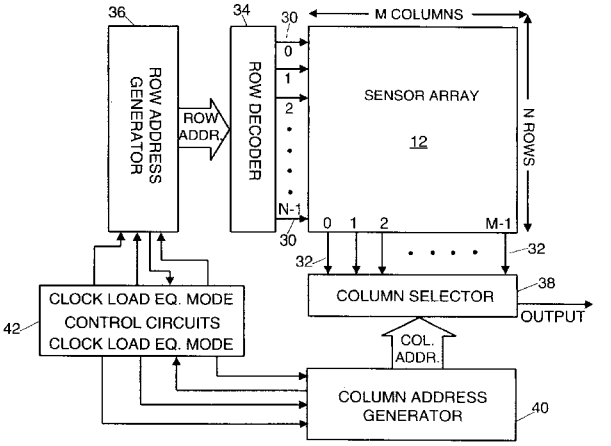
(List continued on next page.)

Primary Examiner—Jose L. Couso
Assistant Examiner—Kanji Patel
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A scanning circuit for use with an active pixel sensor array comprises a row-address generator configured to start at a selected row-start address, stop at a selected row-stop address, and increment row addresses by a factor K. A column-address generator is configured to start at a selected column-start address, stop at a selected column stop address, and increment column addresses by a factor K. Circuitry is coupled to the row address generator and the column address generator, for storing the row-start address, the row-stop address, the column-start address, the column-stop address and the factor K. A row decoder is coupled to the row-address generator and a column selector is coupled to the column-address generator. A plurality of row select lines are coupled to the row decoder, each one of the row select lines associated with a different row in the active pixel sensor array. A plurality of column output lines are coupled to the column selector, each one of the column output lines associated with a different column in the active pixel sensor array.

15 Claims, 8 Drawing Sheets



US006525304B1

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

(10) **Patent No.: US 6,525,304 B1**
(45) **Date of Patent: Feb. 25, 2003**

(54) **CIRCUITRY FOR CONVERTING ANALOG SIGNALS FROM PIXEL SENSOR TO A DIGITAL AND FOR STORING THE DIGITAL SIGNAL**

(75) Inventors: **Richard B. Merrill**, Woodside, CA (US); **Richard F. Lyon**, Los Altos, CA (US); **Richard M. Turner**, Mountain View, CA (US); **Milton B. Dong**, Saratoga, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 61 days.

(21) Appl. No.: **09/724,258**

(22) Filed: **Nov. 28, 2000**

(51) **Int. Cl.**[7] **H01L 27/00**

(52) **U.S. Cl.** **250/208.1**; 348/308

(58) **Field of Search** ..... 250/208.1, 214 A, 250/214 R; 348/294, 297, 308, 296, 301; 341/155, 161; 257/272; 356/218

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,227,887	A	7/1993	Dohi et al.	358/213.27
5,276,521	A	1/1994	Mori	358/213.31
5,461,425	A	10/1995	Fowler et al.	348/294
5,742,047	A *	4/1998	Buhler et al.	250/208.1
5,801,657	A	9/1998	Fowler et al.	341/155
6,330,030	B1 *	12/2001	O'Connor	348/297
6,377,303	B2 *	4/2002	O'Connor	341/155

FOREIGN PATENT DOCUMENTS

EP	0 605 898 A1	7/1994	H01L/27/146
EP	0 707 416 A2	4/1996	H04N/3/15
EP	0 954 167 A2	3/1999	
WO	WO 99/27708 A1	6/1999	H04N/3/14

OTHER PUBLICATIONS

Fowler et al., Techniques for Pixel Level Analog to Digital Conversion.

Yang et al., A 128×128 Pixel CMOS Area Image Sensor with Multiplexed Pixel Level A/D Conversion.

Fowler et al., A CMOS Area Image Sensor with Pixel Level A/D Conversion.

Yang et al., A Nyquist–Rate Pixel–Level ADC for CMOS Image Senors.

Yang et al., A 640×512 CMOS Image Sensor with Ultrawide Dynamic Range Floating–Point Pixel–Level ADC.

Nitayama et al., Future Directions for DRAM Memory Cell Technology.

Chye Huat Aw, et al. "*A 128×128–Pixel Standard–CMOS Image Sensor With Electronic Shutter*", IEEE International Solid–State Circuits Conference, 1996, pp. 4–39 to 4–40.

Guang Yang, et al. "*A Snap–Shot CMOS Active Pixel Imager For Low–Noise, High–Speed Imaging*", IEEE, 1998, pp. 45–48.

Hon–Sum Philip Wong, "*CMOS Image Sensors–Recent Advances and Device Scaling Considerations*", IEDM, 1997 IEEE, pp. 201–204.

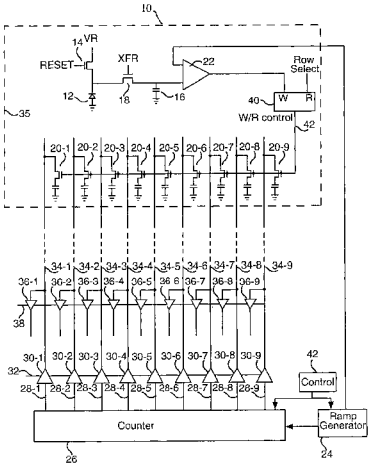
(List continued on next page.)

Primary Examiner—Stephone B. Allen
Assistant Examiner—Bradford Hill
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A digital pixel sensor is formed on a semiconductor substrate and comprises a phototransducer responsive to light for providing an analog output signal that is a function of an incident amount of light. A comparator is configured to compare the analog output signal and a ramp reference signal. A plurality of n DRAM cells are configured to store an at least n-bit digital signal in response to the output of the comparator. An array of digital pixel sensors is also disclosed.

24 Claims, 3 Drawing Sheets



US006606120B1

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

(10) **Patent No.: US 6,606,120 B1**
(45) **Date of Patent: Aug. 12, 2003**

(54) **MULTIPLE STORAGE NODE FULL COLOR ACTIVE PIXEL SENSORS**

(75) Inventors: **Ricahrd B. Merrill**, Woodside, CA (US); **Richard F. Lyon**, Los Altos, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **09/290,361**

(22) Filed: **Apr. 12, 1999**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/121,175, filed on Jul. 22, 1998, and a continuation-in-part of application No. 09/065,939, filed on Apr. 24, 1998, now Pat. No. 5,965,875.

(51) **Int. Cl.**[7] **H04N 3/14**; G01J 3/50

(52) **U.S. Cl.** **348/273**; 348/301; 348/308; 348/311; 250/226

(58) **Field of Search** 348/272, 273, 348/274, 277, 300, 301, 302, 308, 311; 250/208.1, 226, 214.1; 257/440, 458, 463, 291, 292

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,971,065	A		7/1976	Bayer 358/41
4,011,016	A		3/1977	Layne et al. 356/195
4,238,760	A		12/1980	Carr 357/30
4,309,604	A		1/1982	Yoshikawa et al. 250/226
4,613,895	A		9/1986	Burkey et al. 358/41
4,651,001	A		3/1987	Harada et al. 250/330
4,677,289	A	*	6/1987	Nozaki et al. 250/226
5,397,734	A		3/1995	Iguchi et al. 437/70
5,471,515	A	*	11/1995	Fossum et al. 257/292
5,502,299	A		3/1996	Standley 250/208.2
5,668,596	A		9/1997	Vogel 348/222
5,739,562	A	*	4/1998	Ackland et al. 257/291
5,883,421	A		3/1999	Ben Chouikha et al. 257/461
5,965,875	A	*	10/1999	Merrill 250/226
5,981,932	A	*	11/1999	Guerrieri et al. 250/208.1
6,078,037	A		6/2000	Booth, Jr. 250/208.1
6,150,683	A	*	11/2000	Merrill et al. 257/292
2002/0180875	A1	*	12/2002	Guidash 348/308

FOREIGN PATENT DOCUMENTS

DE	WO98/19455	10/1996	..... H04N/3/15
EP	0605898	7/1994	..... H01L/27/146

OTHER PUBLICATIONS

Albert J.P. Theuwissen, "Solid–State Imaging with Charge–Coupled Devices", Kluwer Academic Publishers, pp. 131–141.

Savvas G. Chamberlain, "Photosensitivity and Scanning of Silicon Image Detector Arrays", IEEE Journal of Solid–State Circuits, vol. SC–4, No. 6, Dec. 1969, pp. 333–342.

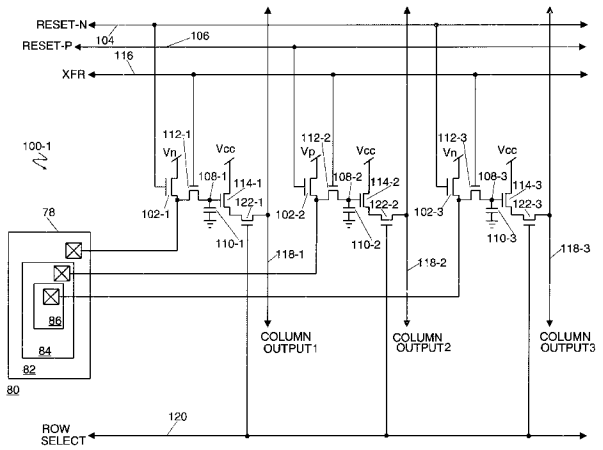
(List continued on next page.)

Primary Examiner—Wendy R. Garber
Assistant Examiner—Luong Nguyen
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

An active pixel sensor is disposed on a semiconductor substrate of a first conductivity type, and comprises a plurality of semiconductor regions disposed in the substrate, each successive one of the semiconductor regions being enclosed entirely within another enclosing one of the semiconductor regions. The plurality of semiconductor regions alternates between the first conductivity type and a second conductivity type opposite to that of the first conductivity type. A first enclosing one of the semiconductor regions containing all other ones of the semiconductor regions is of the second conductivity type, such that a plurality of series-connected photodiodes is formed between the substrate and an innermost enclosed one of the semiconductor regions. A plurality of reset switches each has a first terminal coupled to a different one of the alternating semiconductor regions, and a second terminal switchably coupled to a reset potential. Each one of a plurality of storage nodes is coupled to a separate one of the plurality of alternating semiconductor regions.

18 Claims, 13 Drawing Sheets



US006636261B1

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

(10) **Patent No.: US 6,636,261 B1**
(45) **Date of Patent: *Oct. 21, 2003**

(54) **DRIVEN CAPACITOR STORAGE PIXEL SENSOR AND ARRAY**

(75) Inventors: **J. Orion Pritchard**, San Francisco, CA (US); **Richard B. Merrill**, Woodside, CA (US); **Richard F. Lyon**, Los Altos, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/493,855**

(22) Filed: **Jan. 28, 2000**

Related U.S. Application Data

(63) Continuation of application No. 09/108,110, filed on Jun. 30, 1998, now Pat. No. 6,054,704.

(51) **Int. Cl.**[7] **H04N 5/335**
(52) **U.S. Cl.** **348/308**; 348/301; 250/208.1
(58) **Field of Search** ..... 348/207, 294, 348/302, 300, 301, 303, 304, 307, 308, 309, 207.99; 250/208.1, 214 R; 377/60–62; H04N 5/335

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,988,619	A		10/1976	Malaviya et al.
4,002,824	A		1/1977	Petrocelli et al.
4,626,915	A		12/1986	Takatsu
4,654,714	A		3/1987	Hurst, Jr. et al.
4,809,075	A		2/1989	Akimoto et al.
4,839,735	A		6/1989	Kyomasu et al.
4,942,473	A		7/1990	Zeevi et al.
5,161,024	A		11/1992	Oishi
5,262,871	A		11/1993	Wilder et al.
5,428,390	A		6/1995	Cooper et al.
5,471,245	A		11/1995	Cooper et al.
5,541,402	A		7/1996	Ackland et al.
5,576,763	A		11/1996	Ackland et al.
5,631,704	A		5/1997	Dickinson et al.
5,739,562	A		4/1998	Ackland et al.
6,046,444	A	*	4/2000	Afghahi 348/308
6,054,704	A	*	4/2000	Pritchard et al. 348/302
6,078,037	A		6/2000	Booth, Jr.
6,093,924	A	*	7/2000	Afghahi 348/308
6,115,066	A	*	9/2000	Gowda et al. 348/308
6,130,713	A	*	10/2000	Merrill 348/308
6,204,879	B1		3/2001	Koseki et al.

FOREIGN PATENT DOCUMENTS

EP	0 777 379 A1	6/1997	..... H04N/3/15
WO	WO99/66560	12/1999	..... H01L/27/144

OTHER PUBLICATIONS

C. Mead et al. "Scanners for Visualizing Activity of Analog VLSi Circuitry", *California Institute of Technology Computation and Neural Systems Programs, CNS Memo 11*, pp. 1–29, Jul. 1991.

O. Yadid–Pecht et al., "A Random Access Photodiode Array for Intelligent Image Capture, IEEE Transactions on Electron Devices", pp. 1772–1780, Aug. 1991.

E. Fossum "Active Pixel Sensors: are CCD's Dinosaurs?", *SPIE*, vol. 1900, 2–14, Jul. 1993.

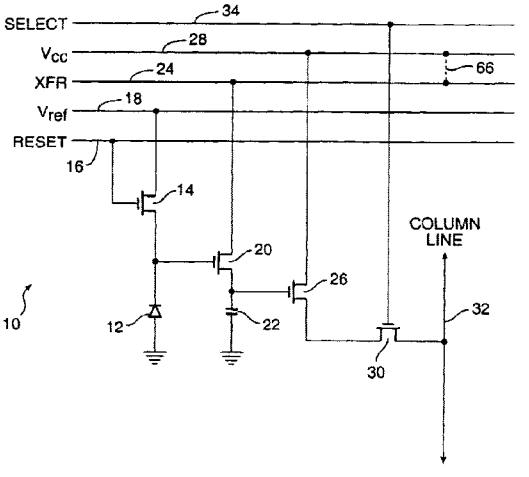
(List continued on next page.)

Primary Examiner—Tuan Ho
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A storage pixel sensor comprises a photosensor selectively connectable to a reset potential; a switched buffer amplifier having a control terminal coupled to said photosensor, a first terminal connected to a source of a transfer signal, and a second terminal; a storage capacitor coupled to said second terminal of said switched buffer amplifier; and an amplifier coupled to said storage capacitor.

29 Claims, 7 Drawing Sheets



US006646680B1

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

(10) **Patent No.: US 6,646,680 B1**
(45) **Date of Patent: Nov. 11, 2003**

(54) **FOCUSING METHOD AND APPARATUS FOR HIGH RESOLUTION DIGITAL CAMERAS**

(75) Inventors: **Carver A. Mead**, Cupertino, CA (US); **Richard A. Lyon**, Los Altos, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **09/164,190**

(22) Filed: **Sep. 30, 1998**

(51) **Int. Cl.**[7] **H04N 5/235**
(52) **U.S. Cl.** **348/230.1**; 348/320; 348/333.11; 348/345
(58) **Field of Search** 348/333.11, 333.12, 348/333.01, 345, 302, 296, 297, 230.1, 320; 250/301; 358/451; 382/205, 220, 264

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,002,824 A 1/1977 Petrocelli et al.
5,428,390 A 6/1995 Cooper et al.
6,204,879 B1 * 3/2001 Koseki et al. 348/333.11

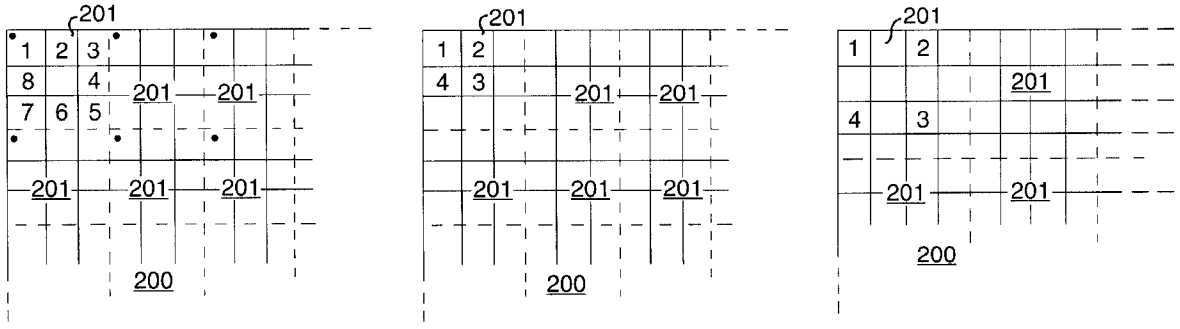
* cited by examiner

Primary Examiner—Wendy R. Garber
Assistant Examiner—Lin Ye
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A focusing method and apparatus, for use with digital cameras having an electronic viewfinder with less display resolution than in the image generated by the camera's photocell array, uses a uniformly subsampled representation of the entire image for focusing, rather than displaying a selected portion of the higher resolution image. The focusing is assisted by the exaggerated discontinuities produced by subsampling. Introducing flicker enhances focusing sensitivity by repetitively displaying, on the electronic viewfinder, a prescribed set of different reduced-resolution images obtained by subsampling the same high-resolution image at different sampling locations. Each subsampled image of the set of reduced resolution images uses a different set of substantially uniformly distributed pixels.

15 Claims, 8 Drawing Sheets



US006731397B1

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

(10) **Patent No.: US 6,731,397 B1**
(45) **Date of Patent: May 4, 2004**

(54) **METHOD FOR STORING AND RETRIEVING DIGITAL IMAGE DATA FROM AN IMAGING ARRAY**

(75) Inventors: **Richard B. Merrill**, Santa Clara, CA (US); **Richard F. Lyon**, Santa Clara, CA (US); **Carver A. Mead**, Santa Clara, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **09/316,731**

(22) Filed: **May 21, 1999**

(51) **Int. Cl.**[7] **G06K 1/00**; H01L 31/00; H01L 27/00; G01J 3/50

(52) **U.S. Cl.** **358/1.16**; 257/440; 250/208.1; 250/226

(58) **Field of Search** 358/1.16; 257/440; 250/226, 208.1

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,971,065 A		7/1976	Bayer	358/41
4,011,016 A		3/1977	Layne et al.	356/195
4,309,604 A		1/1982	Yoshikawa et al.	250/226
4,613,895 A		9/1986	Burkey et al.	358/41
4,651,001 A		3/1987	Harada et al.	250/330
4,677,289 A		6/1987	Nozaki et al.	250/226
4,845,553 A		7/1989	Konomura et al.	358/98
5,397,734 A		3/1995	Iguchi et al.	437/70
5,414,465 A		5/1995	Kodama et al.	348/236
5,502,299 A		3/1996	Standley	250/208.2
5,557,688 A	*	9/1996	Nakamura	382/164
5,600,373 A	*	2/1997	Chui et al.	375/240.1
5,668,596 A		9/1997	Vogel	348/222
5,739,562 A		4/1998	Ackland et al.	257/291
5,965,875 A	*	10/1999	Merrill	250/226
6,097,471 A	*	8/2000	Buhr et al.	355/38
6,281,561 B1	*	8/2001	Stiebig et al.	257/440
6,304,895 B1	*	10/2001	Schneider	709/203

FOREIGN PATENT DOCUMENTS

JP	04278930	10/1990	H04N/9/09
JP	06133320	5/1994	H04N/9/09
JP	06141488	6/1994	H04N/9/04
JP	08009391	12/1996	H04N/9/04

OTHER PUBLICATIONS

Don Sutherland, "The Latest in Digital SLRs", Neaveau Niche, Shutterbug, Nov. 1997, pp. 194–195, 202, 208, 210.

Bob Weibel, "High–end digital cameras can make professional indoor photography a snap", Buyer's Guide, Studio Audience, Published Apr. 1997, pp. 71–78.

Ken Parulski, et al., "Enabling technologies for a family of digital cameras", Invited Paper, SPIE vol. 2654, pp. 156–163.

Hon–Sum Wong, "Technology and Device Scaling Considerations for CMOS Imagers", Senior Member, IEEE, Transactions on Electron Devices, vol. 43, No. 12, Dec. 1996, pp. 2131–2142.

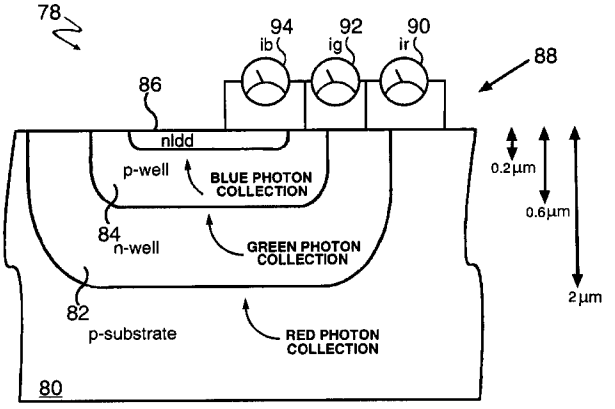
(List continued on next page.)

Primary Examiner—Edward Coles
Assistant Examiner—Houshang Safaipour
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A method for storing digital information from an image sensor comprises the steps of providing an image sensor producing three-color output data at each of a plurality of pixel locations; providing a digital storage device coupled to the image sensor; sensing three-color digital output data from the image sensor; and storing said three-color output data as digital data in the digital storage device without performing any interpolation on the three-color output data. The data may be compressed prior to storage and expanded after retrieval from storage. In a preferred embodiment, the image sensor comprises a triple-junction active pixel sensor array.

28 Claims, 16 Drawing Sheets



US006741283B1

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

(10) **Patent No.: US 6,741,283 B1**
(45) **Date of Patent: *May 25, 2004**

(54) **INTRA-PIXEL FRAME STORAGE ELEMENT, ARRAY, AND ELECTRONIC SHUTTER METHOD SUITABLE FOR ELECTRONIC STILL CAMERA APPLICATIONS**

(75) Inventors: **Richard B. Merrill**, Woodside, CA (US); **Richard M. Turner**, Menlo Park, CA (US); **Carver A. Mead**, Cupertino, CA (US); **Richard F. Lyon**, Los Altos, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

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

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/724,393**

(22) Filed: **Nov. 28, 2000**

Related U.S. Application Data

(63) Continuation of application No. 08/969,383, filed on Nov. 13, 1997, now Pat. No. 6,369,853.

(51) **Int. Cl.**[7] **H04N 3/14**

(52) **U.S. Cl.** **348/308**; 348/297; 250/208.1; 257/292

(58) **Field of Search** 250/208.1; 257/231, 257/232, 233, 291, 292, 293, 294; 348/294, 296, 297, 298, 300–304, 307–312

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,369,853 B1 * 4/2002 Merrill 348/302

* cited by examiner

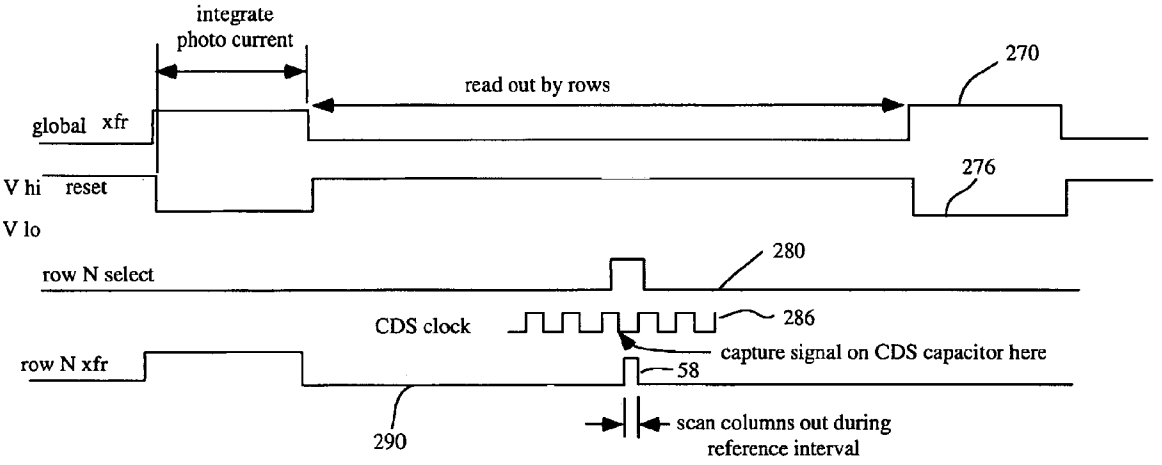
Primary Examiner—Ngoc-Yen Vu

(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A storage pixel sensor disposed on a semiconductor substrate comprises a capacitive storage element having a first terminal connected to a fixed potential and a second terminal. A photodiode has an anode connected to a first potential and a cathode. A semiconductor reset switch has a first terminal connected to the cathode and a second terminal connected to a reset potential. A semiconductor transfer switch has a first terminal connected to the cathode and a second terminal connected to the second terminal of the capacitive storage element. A semiconductor amplifier has an input connected to the capacitive storage element and an output. The semiconductor reset switch and the semiconductor transfer switch each have a control element connected to a control circuit for selectively activating the semiconductor reset switch and the semiconductor transfer switch. A light shield is disposed over portions of the semiconductor substrate comprising a circuit node including the second terminal of the semiconductor transfer switch, the second terminal of the capacitive storage element and the input of the semiconductor amplifier and to prevent substantially all photons from entering the circuit node. Structures are present for preventing substantially all minority carriers generated in the semiconductor substrate from entering the circuit node. A plurality of storage pixel sensors are disposed in an array.

8 Claims, 11 Drawing Sheets



US006760070B1

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

(10) **Patent No.: US 6,760,070 B1**
(45) **Date of Patent: Jul. 6, 2004**

(54) **HIGH-SENSITIVITY STORAGE PIXEL SENSOR ARRAY HAVING AUTO-EXPOSURE DETECTION**

(75) Inventors: **Richard B. Merrill**, Woodside, CA (US); **Richard M. Turner**, Menlo Park, CA (US); **Milton B. Dong**, Saratoga, CA (US); **Richard F. Lyon**, Los Altos, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **09/527,107**

(22) Filed: **Mar. 16, 2000**

Related U.S. Application Data

(62) Division of application No. 09/515,807, filed on Feb. 29, 2000.

(51) **Int. Cl.**[7] **H04N 5/335**; H01L 27/00

(52) **U.S. Cl.** **348/294**; 348/300; 348/302; 348/308; 250/208.1

(58) **Field of Search** 348/294, 300, 348/301, 302, 308; 257/291, 292, 293; 250/208.1

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,866,067 A	2/1975	Amelio	307/311
3,934,161 A	1/1976	Caywood	307/311
3,971,065 A	7/1976	Bayer	358/41

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

DE	43 04 506 A1	8/1994	H04N/5/225
DE	WO 96/15626	5/1996	H04N/5/335
DE	WO 97/17800	5/1997	H04N/3/143
DE	WO 98/19455	5/1998	H04N/3/15
DE	198 36 356 A1	5/1999	H01L/27/146
DE	WO 99/66560	12/1999	H01L/27/144
DE	WO 99/66712	12/1999	H04N/3/15
DE	WO 00/72604 A1	11/2000	H04N/9/04

(List continued on next page.)

OTHER PUBLICATIONS

Electrically Erasable and Reprogrammable Read–Only Memory Using the n–Channel SIMOS One–Transistor Cell; IEEE Transactions on Electron Devices, vol. ED–24, No. 5, May 1977, Bernward Rossler.

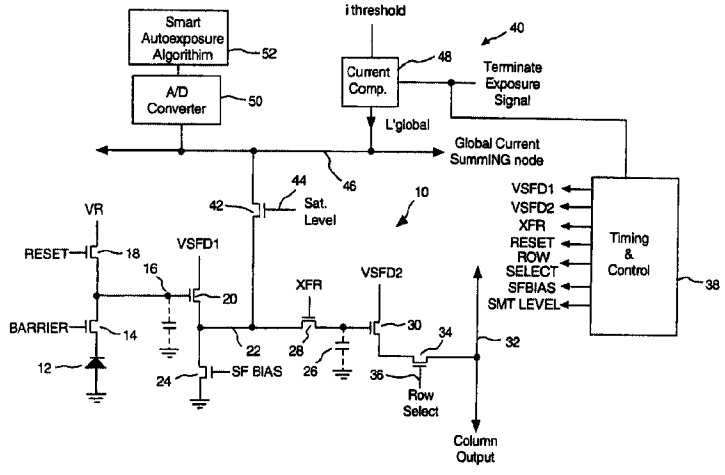
(List continued on next page.)

Primary Examiner—Wendy R. Garber
Assistant Examiner—Luong Nguyen
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

An integrated active pixel sensor array arranged in a plurality of rows and columns comprises a saturation level line coupled to a source of saturation level control voltage, a global current-summing node. A plurality of active pixel sensors is disposed in the array, each pixel sensor associated with one row and one column of the array and including a photodiode having a first terminal coupled to a first potential and a second terminal, a reset transistor having a first terminal coupled to the second terminal of the photodiode, a second terminal coupled to a reset reference potential that reverse biases the photodiode, and a control gate coupled to the reset line, a photocharge integration node coupled to the second terminal of the photodiode, the photocharge integration node comprising the gate of a first source-follower transistor, the first source-follower transistor having a drain, coupled to a first source-follower drain line, and a source, a circuit for generating a bias current at the source of the first source follower transistor, and an exposure transistor having a source coupled to the source of the first source-follower transistor, a drain coupled to the global current-summing node and a control gate coupled to the saturation level line.

27 Claims, 4 Drawing Sheets



US006794627B2

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

(10) **Patent No.: US 6,794,627 B2**
(45) **Date of Patent: Sep. 21, 2004**

(54) **AGGREGATION OF ACTIVE PIXEL SENSOR SIGNALS**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Robert S. Hannebauer**, Sunnyvale, CA (US); **Richard M. Turner**, Mountain View, CA (US); **Carver A. Mead**, Santa Clara, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **10/001,438**

(22) Filed: **Oct. 24, 2001**

(65) **Prior Publication Data**

US 2003/0164441 A1 Sep. 4, 2003

(51) **Int. Cl.**[7] **H04N 3/14**
(52) **U.S. Cl.** ..... **250/208.1**; 348/308; 250/214 A
(58) **Field of Search** ..... 250/208.1, 214 A, 250/214 LA, 214 LS, 214.1, 214 DC; 348/317, 318, 319, 302, 303, 304, 308; 257/443

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,262,871 A		11/1993	Wilder et al.	
5,304,790 A		4/1994	Arnold	
5,402,169 A		3/1995	Takase et al.	
5,452,004 A		9/1995	Roberts	
5,500,674 A		3/1996	Takase et al.	
5,733,382 A		3/1998	Hanoka	
5,773,832 A		6/1998	Sayed et al.	
5,848,123 A		12/1998	Strömmer	
5,909,026 A		6/1999	Zhou et al.	
5,949,483 A	*	9/1999	Fossum et al.	348/303
5,965,875 A		10/1999	Merrill	
5,970,115 A		10/1999	Colbeth et al.	
5,973,311 A		10/1999	Sauer et al.	
6,057,539 A		5/2000	Zhou et al.	
6,084,229 A		7/2000	Pace et al.	
6,255,638 B1		7/2001	Eräluoto et al.	
6,255,680 B1		7/2001	Nakashiba	
6,480,227 B1	*	11/2002	Yoneyama	348/308

FOREIGN PATENT DOCUMENTS

WO	WO 99/48281	9/1999
WO	WO 00/51345	8/2000

OTHER PUBLICATIONS

Mead, C. (1989). "Aggregating Signals" Chapter 7 *In Analog VLSI and Neural Systems*. C. Koch ed., Addison–Wesley Publishing Company, Inc., pp. 101–124.

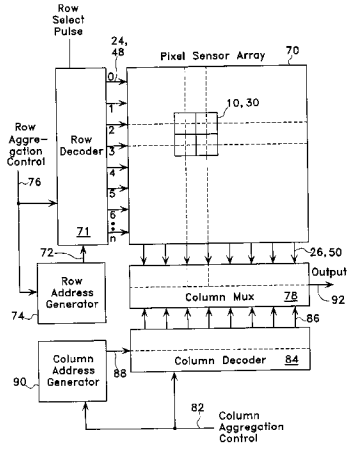
* cited by examiner

Primary Examiner—David V. Bruce
Assistant Examiner—Hoon Song
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

An image sensor includes a plurality of active pixel sensors arranged in an array. Each active pixel sensor includes a photosensor that generates a sensor signal nominally indicative of an intensity of light incident on the photosensor and a follower-type amplifier that couples the sensor signal to an output of the active pixel sensor to provide a buffered sensor signal. A column line is provided for each column in the array, and each column line is coupled to the output of the active pixel sensors associated with that column. Row select signal generating circuitry is configured to substantially simultaneously select a set of plural particular rows of the array such that each of the active pixel sensors in the selected set of plural particular rows substantially simultaneously provides the buffered sensor signal for that pixel sensor to the column line for the column to which that pixel sensor belongs such that an output node of the column line indicates a collective output signal for the active pixel sensors in the selected set of plural particular rows, belonging to that column. Column select signal generating circuitry configured to substantially simultaneously select a set of plural particular columns of the array such that the output nodes for the selected plural particular columns are substantially simultaneously coupled to an output node of the image sensor.

35 Claims, 12 Drawing Sheets



US006798586B1

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

(10) **Patent No.: US 6,798,586 B1**
(45) **Date of Patent: Sep. 28, 2004**

(54) **CORRECTOR OPTIC COMPENSATING SPHERICAL AND COMA ABERRATIONS GENERATED BY A PRISM**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Mark E. McDonald**, Milpitas, CA (US); **Timothy F. Slagle**, Menlo Park, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 17 days.

(21) Appl. No.: **10/001,354**

(22) Filed: **Oct. 30, 2001**

(51) **Int. Cl.**[7] **G02B 2/04**; H04N 9/07; G03B 17/00

(52) **U.S. Cl.** **359/793**; 359/795; 348/337; 396/71

(58) **Field of Search** 359/366, 637, 359/618, 672, 692, 793, 795; 348/335, 337; 396/71

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,009,942	A *	3/1977	Hirose	359/629
4,444,472	A	4/1984	Tanaka	350/423
5,140,462	A *	8/1992	Kitagishi	359/554
5,602,682	A *	2/1997	Ito et al.	359/672
5,721,994	A *	2/1998	Ogata et al.	396/317
5,726,809	A *	3/1998	Griffith	359/675
6,043,938	A	3/2000	Ogasawara	359/652
6,058,269	A *	5/2000	Tsutsumi	396/71
6,078,429	A	6/2000	Lyon	359/634
6,137,638	A	10/2000	Yamagishi et al.	359/682
6,157,781	A *	12/2000	Konno et al.	396/71

FOREIGN PATENT DOCUMENTS

JP	361027516 A *	2/1986		G02B/7/11

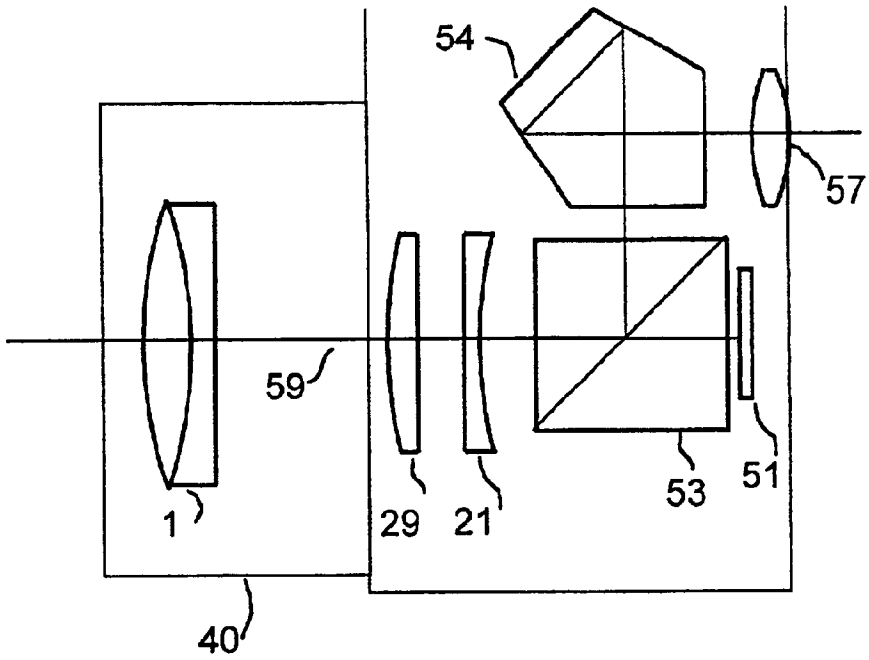
* cited by examiner

Primary Examiner—Georgia Epps
Assistant Examiner—Alicia M. Harrington
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A corrector optic is provided, for use in a camera system that includes a thick prism in front of the focal plane. The corrector optic includes preferably two lenses to be aligned on the optical axis of the camera system. When coupled within the camera system, the corrector optic is disposed between the objective lens and the prism. A preferred corrector optic includes a positive lens having a convex surface facing the objective lens and a negative lens having a concave surface facing the prism, such that the lenses together reduce spherical and coma aberrations caused by imaging through the prism. Chromatic aberration is also reduced by choosing the negative lens material to have a higher index of refraction and higher dispersion than those of the positive lens material.

21 Claims, 7 Drawing Sheets



US006833871B1

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

(10) **Patent No.: US 6,833,871 B1**
(45) **Date of Patent: Dec. 21, 2004**

(54) **EXPOSURE CONTROL IN ELECTRONIC CAMERAS BY DETECTING OVERFLOW FROM ACTIVE PIXELS**

(75) Inventors: **Richard B. Merrill**, Woodside, CA (US); **Carver A. Mead**, Santa Clara, CA (US); **Richard F. Lyon**, Los Altos, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 654 days.

(21) Appl. No.: **09/872,070**

(22) Filed: **Jul. 16, 2001**

Related U.S. Application Data

(62) Division of application No. 09/031,333, filed on Feb. 26, 1998, now Pat. No. 6,452,633.

(51) **Int. Cl.**[7] **H04N 3/14**; H04N 5/335
(52) **U.S. Cl.** **348/302**; 257/223; 348/299
(58) **Field of Search** 348/302, 294, 348/308, 296, 297, 288, 299, 241, 243; 257/223; 250/208.1

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,866,067 A	2/1975	Amelio	307/311
3,934,161 A	1/1976	Caywood	307/311

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

EP	0466929	1/1992	
EP	0 466 929	1/1992	H04N/5/238
EP	0777379	6/1997	H04N/3/15
JP	54-108628	8/1979	
JP	58-83824	5/1983	G03B/7/20
JP	59-42527	3/1984	G03B/7/20
JP	59-152424	8/1984	G03B/7/20
JP	60-23841	2/1985	G03B/7/14
JP	60-53912	3/1985	G02B/7/11
JP	62-143571	6/1987	G02B/7/11
JP	01103378	4/1989	G02B/7/11
WO	WO 97/28558	8/1997	
WO	WO 99/26408	5/1999	H04N/3/15

OTHER PUBLICATIONS

Tatsuo Nomoto et al. "FA 11.4: A 4M–Pixel Image Sensor with Block and Step Access Capability" IEEE pp. 186–187 1997.

Hon–Sum Philip Wong et al. "CMOS Active Pixel Image Sensors Fabricated Using a 1.8–V, 0.25μm CMOS Technology" pp. 889–894 IEEE Transactions on Electron Devices vol. 45, No. 4, Apr. 1998.

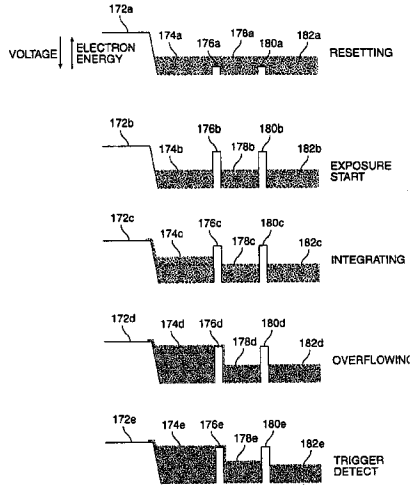
(List continued on next page.)

Primary Examiner—Ngoc-Yen Vu
Assistant Examiner—Gary L Solomon
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A method for controlling the exposure of an active pixel array electronic still camera includes the steps of: integrating photocurrent in each pixel during an integration time period; collecting overflow charge from all pixels in the array during the integration time period; developing an overflow signal as a function of the overflow charge; and terminating the integration time period when the overflow signal exceeds a preset threshold level selected to represent a desired reference exposure level. Apparatus for performing the method of the present invention includes circuitry for integrating photocurrent in each pixel during a integration time period; circuitry for diverting and detecting overflow charge from all pixels in the array during the integration time period; circuitry for developing an overflow signal as a function of the overflow charge; and circuitry for terminating said integration time period when the overflow signal exceeds a preset threshold level selected to represent a desired reference exposure level.

3 Claims, 10 Drawing Sheets



US006841816B2

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

(10) **Patent No.: US 6,841,816 B2**
(45) **Date of Patent: Jan. 11, 2005**

(54) **VERTICAL COLOR FILTER SENSOR GROUP WITH NON-SENSOR FILTER AND METHOD FOR FABRICATING SUCH A SENSOR GROUP**

(75) Inventors: **Richard B. Merrill**, Woodside, CA (US); **Richard F. Lyon**, Los Altos, CA (US); **Richard M. Turner**, Mountain View, CA (US); **Robert S. Hannebauer**, Sunnyvale, CA (US); **Russel A. Martin**, Menlo Park, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **10/355,940**

(22) Filed: **Jan. 31, 2003**

(65) **Prior Publication Data**

US 2004/0178465 A1 Sep. 16, 2004

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/103,304, filed on Mar. 20, 2002.

(51) **Int. Cl.**[7] **H01L 31/113**

(52) **U.S. Cl.** **257/294**; 257/432; 257/440; 257/443

(58) **Field of Search** 257/294, 432, 257/440, 443, 461

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,617,753	A	11/1971	Kato et al.	250/211 J
4,238,760	A	12/1980	Carr	357/30
4,581,625	A	4/1986	Gay et al.	357/30
4,677,289	A	6/1987	Nozaki et al.	250/226
5,883,421	A	3/1999	Ben Chouikha et al.	257/461
5,889,315	A	3/1999	Farrenkopf et al.	257/552
5,899,714	A	5/1999	Farrenkopf et al.	438/202
5,965,875	A	10/1999	Merrill	250/226
6,111,300	A	8/2000	Cao et al.	257/440
6,455,833	B1	9/2002	Berezin	250/208.1
6,593,558	B1	7/2003	Edgar	250/208.1
2002/0101895	A1 *	8/2002	Augusto	372/44

FOREIGN PATENT DOCUMENTS

JP	61-187282	8/1986	H01L/31/10
JP	01134966	5/1989	H01L/27/14

OTHER PUBLICATIONS

U.S. patent application Publication No. U.S. 2002/0130957 A1, Published Sep. 19, 2002 (filed Jan. 24, 2001) by Andrew C. Gallagher, et al.

U.S. patent application Publication No. U.S. 2002/0058353 A1, Published May 16, 2002, "*Vertical Color Filter Detector Group and Array*", by Richard B. Merrill.

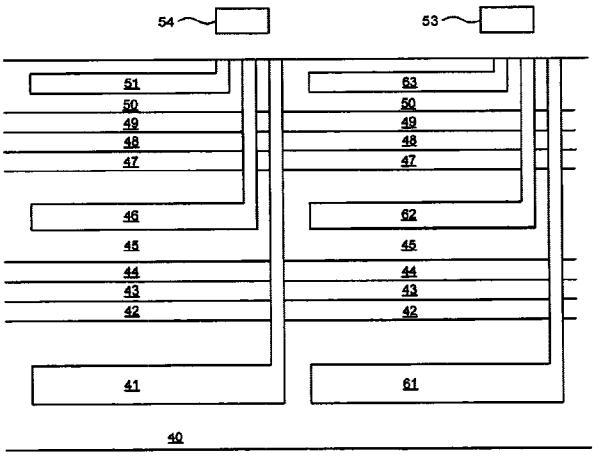
(List continued on next page.)

Primary Examiner—Minh-Loan Tran
(74) *Attorney, Agent, or Firm*—Girard & Equitz LLP

(57) **ABSTRACT**

A vertical color filter sensor group formed on a substrate (preferably a semiconductor substrate) and including at least two vertically stacked, photosensitive sensors. In preferred embodiments, the sensor group includes at least one filter positioned relative to the sensors such that radiation that has propagated through or reflected from the filter will propagate into at least one sensor. Preferably, the filter is or includes a layer that has been integrated with the sensors by a semiconductor integrated circuit fabrication process. In other embodiments, the sensor group includes a micro-lens. Other aspects of the invention are arrays of vertical color filter sensor groups, some or all of which include at least one filter or micro-lens, and methods for fabricating vertical color filter sensor groups and arrays thereof.

99 Claims, 29 Drawing Sheets



US006853404B1

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

(10) **Patent No.: US 6,853,404 B1**
(45) **Date of Patent: Feb. 8, 2005**

(54) **ELECTRONIC VIEW CAMERA FOR TRIPOD MOUNTING**

(75) Inventors: **Carver A. Mead**, Cupertino, CA (US); **Jeffrey O. Pritchard**, San Francisco, CA (US); **Richard F. Lyon**, Los Altos, CA (US); **Peter O. Schmidt**, Campbell, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 716 days.

(21) Appl. No.: **09/075,777**

(22) Filed: **May 11, 1998**

(51) **Int. Cl.**[7] **H04N 5/225**
(52) **U.S. Cl.** **348/373**; 348/207.1
(58) **Field of Search** 248/639; 361/683, 361/679, 680, 681, 682; 348/552, 373, 375, 376, 14.01; 708/105, 109; 312/223.1

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,940,777 A		2/1976	Komine	354/197
4,104,649 A		8/1978	Tanaka et al.	354/289
4,258,387 A	*	3/1981	Lemelson et al.	348/14.01
4,448,509 A		5/1984	Katsuma et al.	354/286
4,457,609 A		7/1984	Tomino et al.	354/286
4,464,034 A		8/1984	Tomino	354/286
4,527,879 A		7/1985	Hosoe et al.	354/400
4,536,071 A		8/1985	Maekawa et al.	354/400
4,596,454 A		6/1986	Kawai et al.	354/286
4,603,955 A		8/1986	Haneishi	354/286
4,642,700 A	*	2/1987	Ohta et al.	358/285
4,731,665 A	*	3/1988	Hashimoto et al.	358/213
4,830,328 A	*	5/1989	Takach, Jr. et al.	361/683
5,041,858 A		8/1991	Yamamichi et al.	354/286
5,212,628 A	*	5/1993	Bradbury	361/683
5,392,067 A	*	2/1995	Konno et al.	348/72
5,402,170 A	*	3/1995	Parulski et al.	348/376
5,475,441 A		12/1995	Parulski et al.	348/358
5,627,616 A	*	5/1997	Sergeant et al.	354/81
5,675,358 A	*	10/1997	Bullock et al.	348/552
5,877,811 A	*	3/1999	Iljama et al.	348/375
5,880,783 A	*	3/1999	Ma	348/373
5,883,820 A	*	3/1999	Ota et al.	364/708.1

FOREIGN PATENT DOCUMENTS

DE	4304506 A1	2/1993	H04N/5/225
EP	0683596 A2	11/1995	H04N/1/21
GB	2 078 384 A	1/1982	G03B/17/14

(List continued on next page.)

OTHER PUBLICATIONS

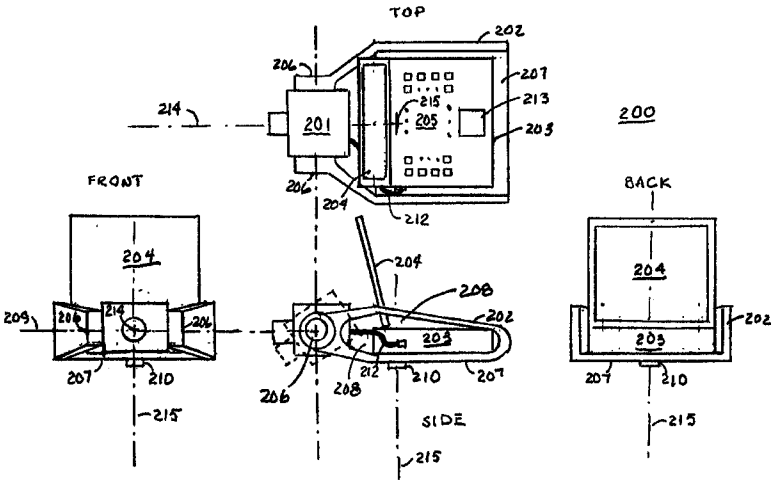
Author Unknown "Phot Argus" pp. 13,14,15,19,20,24,25, 31,32 Nov. 1977.
Compact Ability "Camcorders" pp. 65–66.
Daniel Grotta, et al. "Digital Cameras" PC Magazine pp. 132–173 Feb. 10, 1998.
Photographic Industries "Title Unknown" pp. 56–60 No. 2 Feb. 1977.
Photographic Industries "Title Unknown" vol unknown No. 10 1982.
The PC Zone "The A–to–Z of Digital Imaging" pp. 53–56.

Primary Examiner—Ngoc-Yen Vu
Assistant Examiner—Rashawn N. Tillery
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

An electronic view camera integrates a camera head assembly and laptop computer into a tripod mountable unified structure. The rigid frame, that unifies the camera head and computer, accommodates a choice of laptop type computers from a variety of different manufacturers. The open front, back and side design of the rigid frame permits ready access for electrical connections and for access to removable storage devices, keyboard, and pointing device. The computer LCD acts as a large screen viewfinder for the camera and has the "feel" of a professional type view camera rather than the "feel" of a computer system with a photographic peripheral.

44 Claims, 3 Drawing Sheets



US006864557B2

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

(10) **Patent No.: US 6,864,557 B2**
(45) **Date of Patent: Mar. 8, 2005**

(54) **VERTICAL COLOR FILTER DETECTOR GROUP AND ARRAY**

(75) Inventors: **Richard M. Turner**, Mountain View, CA (US); **Richard F. Lyon**, Los Altos, CA (US); **Rudolph J. Guttosch**, Los Gatos, CA (US); **Richard B. Merrill**, Woodside, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 148 days.

(21) Appl. No.: **10/103,304**

(22) Filed: **Mar. 20, 2002**

(65) **Prior Publication Data**

US 2002/0190254 A1 Dec. 19, 2002

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/884,863, filed on Jun. 18, 2001, now Pat. No. 6,727,521.

(51) **Int. Cl.**[7] **H01L 31/00**

(52) **U.S. Cl.** **257/440**; 257/432; 257/443; 257/444

(58) **Field of Search** 257/432, 440, 257/443, 444, 461, 294

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,971,065	A	7/1976	Bayer	358/41
4,011,016	A	3/1977	Layne et al.	356/195
4,238,760	A	12/1980	Carr	357/30
4,309,604	A	1/1982	Yoshikawa et al.	250/226
4,613,895	A	9/1986	Burkey et al.	358/41
4,651,001	A	3/1987	Harada et al.	250/330
4,677,289	A	6/1987	Nozaki et al.	250/226
4,772,335	A	9/1988	Huang	136/258
5,397,734	A	3/1995	Iguchi et al.	437/70
5,502,299	A	3/1996	Standley	250/208.2
5,668,596	A	9/1997	Vogel	348/222
5,739,562	A	4/1998	Ackland et al.	257/291
5,872,371	A	2/1999	Guidash et al.	257/230
5,883,421	A	3/1999	Chouikha et al.	257/461
5,889,315	A	3/1999	Farrenkopf et al.	257/552
5,899,714	A	5/1999	Farrenkopf et al.	438/202
5,965,875	A	10/1999	Merrill	250/226
6,078,037	A	6/2000	Booth, Jr.	250/208.1

FOREIGN PATENT DOCUMENTS

DE	WO 98/19455	5/1998	H04N/3/15
JP	61 187282	8/1986	H01L/31/10
JP	01 134966	5/1989	H01L/27/14
JP	0605898	7/1994	H01L/27/146

OTHER PUBLICATIONS

S. Chamberlain, "Photosensitivity and Scanning of Silicon Image Detector Arrays", *IEEE Journal of Solid–State Circuits*, vol. SC–4, No. 6, pp. 333–342, Dec. 1969.

R. Wolffenbuttel et al., "A Novel Approach to Solid–state Colour Sensing", *Sensors and Actuators*, vol. 9, pp. 199–211, 1986 (no month).

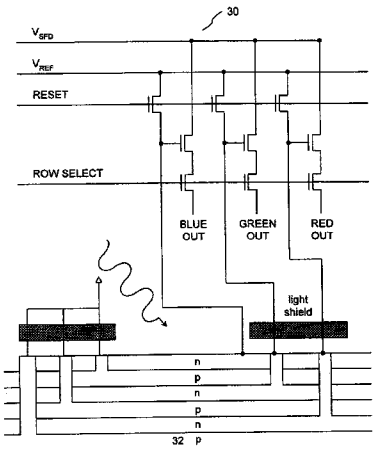
(List continued on next page.)

Primary Examiner—Minh-Loan Tran
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A vertical color detector group according to the present invention is formed on a semiconductor substrate and includes layers for collecting photons of different wavelength bands. The color detector group can be programmed to perform dynamic switching between sub-sampled color data and full measured color readout. The color detector group can also be configured in a portion of an array to emulate color filter array patterns, and programmed to dynamically alter the degree to which color information is sub-sampled. The programmable color detector groups can allow for switching between different levels of quality and resolution, allowing for selection of an optimal pattern based on image content or lighting conditions. By combining the color detector group of the present invention with conventional color filters, color filter arrays of more than three colors can be constructed.

16 Claims, 19 Drawing Sheets



US006882367B1

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

(10) **Patent No.: US 6,882,367 B1**
(45) **Date of Patent: Apr. 19, 2005**

(54) **HIGH-SENSITIVITY STORAGE PIXEL SENSOR HAVING AUTO-EXPOSURE DETECTION**

(75) Inventors: **Richard B. Merrill**, Woodside, CA (US); **Richard M. Turner**, Menlo Park, CA (US); **Milton B. Dong**, Saratoga, CA (US); **Richard F. Lyon**, Los Altos, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (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.: **09/515,807**

(22) Filed: **Feb. 29, 2000**

(51) **Int. Cl.**[7] **H04N 5/335**; H01L 27/00

(52) **U.S. Cl.** **348/308**; 348/294; 348/302; 250/208.1

(58) **Field of Search** 348/301, 302, 348/308, 312, 313, 296; 257/291, 293, 494; 250/208.1

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,866,067	A	2/1975	Amelio
3,934,161	A	1/1976	Caywood
3,971,065	A	7/1976	Bayer
3,988,619	A	10/1976	Malaviya
4,011,016	A	3/1977	Layne et al.
4,236,760	A	12/1980	Haar et al.
4,238,760	A	12/1980	Carr
4,309,604	A	1/1982	Yoshikawa et al.
4,363,963	A	12/1982	Ando
4,473,836	A	9/1984	Chamberlain

(Continued)

FOREIGN PATENT DOCUMENTS

DE	43 04 506 A1	8/1994	..... H04N/5/225
DE	198 36 356 A1	5/1999	..... H01L/27/146
EP	62143571	6/1987	..... H04N/5/335
EP	0 300 365 A2	1/1989	..... H04N/3/15
EP	0 300365 A3	1/1989	..... H04N/3/15

(Continued)

OTHER PUBLICATIONS

Orly Yadid–Pecht, et al. "A Random Access Photodiode Array for Intelligent Image Capture", IEEE Transactions on Electron Devices, vol. 38, No. 8. Aug. 1991, pp. 1772–1780.

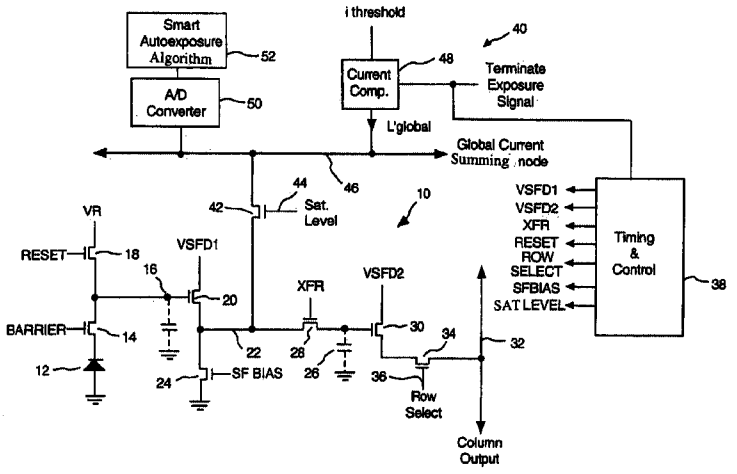
(Continued)

Primary Examiner—Andrew Christensen
Assistant Examiner—Lin Ye
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A storage pixel sensor disposed on a semiconductor substrate comprises a photodiode having a first terminal coupled to a first potential and a second terminal. A barrier transistor has a first terminal coupled to the second terminal of the photodiode, a second terminal and a control gate coupled to a barrier set voltage. A reset transistor has a first terminal coupled to the second terminal of the barrier transistor, a second terminal coupled to a reset reference potential that reverse biases the photodiode, and a control gate coupled to a source of a RESET signal. A photocharge integration node is coupled to said second terminal of said barrier transistor. The photocharge integration node comprises the control gate of a first source-follower transistor. The first source-follower transistor is coupled to a source of bias current and has an output. A capacitive storage node is coupled to the output of the first source-follower transistor and comprises the control gate of a second source-follower transistor having an output. An exposure transistor is coupled between the output of the first source-follower transistor and a global current-summing node and has a control gate coupled to a saturation level voltage.

30 Claims, 4 Drawing Sheets



US006934050B2

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

(10) **Patent No.: US 6,934,050 B2**
(45) **Date of Patent: Aug. 23, 2005**

(54) **METHOD FOR STORING AND RETRIEVING DATA FROM AN IMAGING ARRAY OF VERTICAL-COLOR-FILTER DETECTOR GROUPS**

(75) Inventors: **Richard B. Merrill**, Woodside, CA (US); **Richard F. Lyon**, Los Altos, CA (US); **Carver A. Mead**, Santa Clara, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 626 days.

(21) Appl. No.: **10/091,361**

(22) Filed: **Mar. 4, 2002**

(65) **Prior Publication Data**

US 2002/0171881 A1 Nov. 21, 2002

Related U.S. Application Data

(63) Continuation of application No. 09/884,863, filed on Jun. 18, 2001, now Pat. No. 6,727,521, which is a continuation of application No. 09/316,731, filed on May 21, 1999, now Pat. No. 6,731,397.

(51) **Int. Cl.**[7] **G06K 1/00**; H01L 31/00; H01L 27/00; G01S 3/50

(52) **U.S. Cl.** **358/1.16**; 257/98; 257/440; 250/226; 250/208.1

(58) **Field of Search** 358/1.16; 257/98, 257/440; 250/226, 208.1

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,677,289 A		6/1987	Nozaki et al.	250/226
4,845,553 A		7/1989	Konomura et al.	358/98
5,414,465 A		5/1995	Kodama et al.	348/236
5,557,688 A	*	9/1996	Nakamura	382/164
5,965,875 A	*	10/1999	Merrill	250/226
6,281,561 B1	*	8/2001	Stiebig et al.	257/440

FOREIGN PATENT DOCUMENTS

JP	06 133 320	5/1994	H04N/9/09
JP	08 009 391	1/1996	H04N/9/04

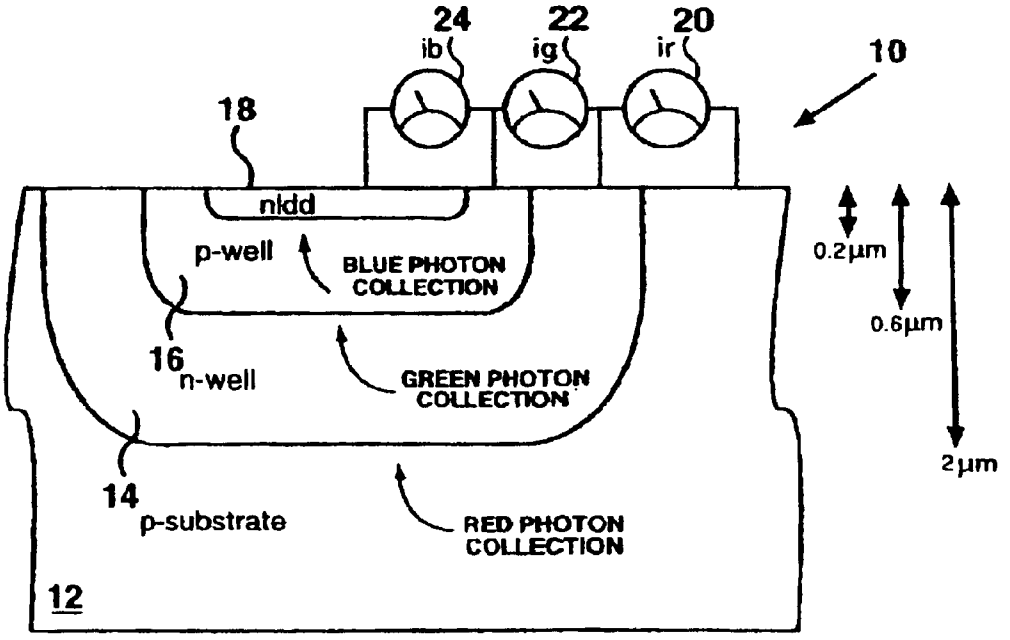
* cited by examiner

Primary Examiner—Edward Coles
Assistant Examiner—Houshang Safaipour
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A method for storing a full Red, Green, Blue (RGB) data set. A full RGB data set is three-color image data captured with an imager array formed on a semiconductor substrate and comprising a plurality of vertical-color-filter detector groups. Each of the vertical color detector groups comprises three detector layers each configured to collect photo-generated carriers of a first polarity, separated by intervening reference layers configured to collect and conduct away photo-generated carriers of opposite polarity, the three detector layers being disposed substantially in vertical alignment with respect to one another and having different spectral sensitivities. The three-color image data is then stored as digital data in a digital storage device without performing interpolation on the three-color image data.

36 Claims, 21 Drawing Sheets



US006998660B2

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

(10) **Patent No.: US 6,998,660 B2**
(45) **Date of Patent: Feb. 14, 2006**

(54) **VERTICAL COLOR FILTER SENSOR GROUP ARRAY THAT EMULATES A PATTERN OF SINGLE-LAYER SENSORS WITH EFFICIENT USE OF EACH SENSOR GROUP'S SENSORS**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Richard B. Merrill**, Woodside, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 133 days.

(21) Appl. No.: **10/738,484**

(22) Filed: **Dec. 17, 2003**

(65) **Prior Publication Data**

US 2004/0178467 A1 Sep. 16, 2004

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/355,723, filed on Jan. 31, 2003, which is a continuation-in-part of application No. 10/103,304, filed on Mar. 20, 2002, now Pat. No. 6,864,557.

(51) **Int. Cl.**
H01L 31/00 (2006.01)

(52) **U.S. Cl.** **257/294**; 257/440; 257/443

(58) **Field of Classification Search** 348/272–274, 348/280, 281; 257/290–294, 443, 432, 440, 257/444

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,617,753	A	11/1971	Kato et al.	250/211 J
3,971,065	A	7/1976	Bayer	358/41
4,011,016	A	3/1977	Layne et al.	356/195
4,238,760	A	12/1980	Carr	357/30
4,309,604	A	1/1982	Yoshikawa et al.	250/226
4,581,625	A	4/1986	Gay et al.	357/30
4,613,895	A	9/1986	Burkey et al.	358/41
4,651,001	A	3/1987	Harada et al.	250/330
4,677,289	A	6/1987	Nozaki et al.	250/226
4,772,957	A	9/1988	Nakagawa et al.	358/280
5,397,734	A	3/1995	Iguchi et al.	437/70
5,502,299	A	3/1996	Standley	250/208.2
5,668,596	A	9/1997	Vogel	348/222
5,739,562	A	4/1998	Ackland et al.	257/291
5,872,371	A	2/1999	Guidash et al.	257/230

(Continued)

FOREIGN PATENT DOCUMENTS

EP 0 605 898 A1 12/1993

(Continued)

OTHER PUBLICATIONS

I. Takayanagi, et al., *"A Low Dark Current Stacked CMOS-APS for Charged Particle Imaging", IEDM Technical Digest,* Washington, D.C., Dec. 2-5, 2001, pp. 551-554.

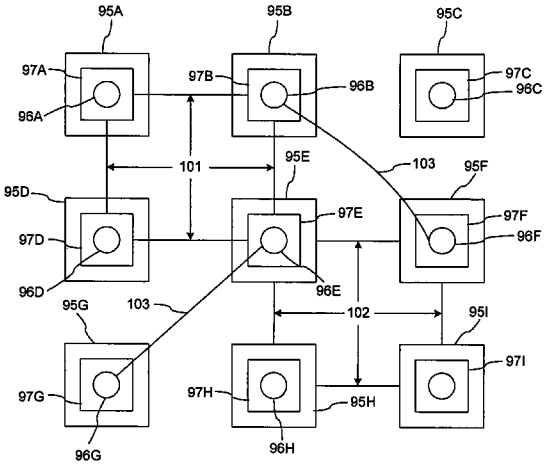
(Continued)

Primary Examiner—Minh-Loan Tran
(74) *Attorney, Agent, or Firm*—Girard & Equitz LLP

(57) **ABSTRACT**

An array of vertical color filter (VCF) sensor groups, each VCF sensor group including at least two vertically stacked, photosensitive sensors. Preferably, the array is fabricated, or the readout circuitry is configured (or has a state in which it is configured), to combine the outputs of sensors of multiple sensor groups such that the array emulates a conventional array of single-layer sensors arranged in a Bayer pattern or other single-layer sensor pattern, and such that the outputs of at least substantially all of the sensors of each of the VCF sensor groups are utilized to emulate the array of single-layer sensors.

43 Claims, 28 Drawing Sheets



US007166880B2

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

(10) **Patent No.: US 7,166,880 B2**
(45) **Date of Patent: Jan. 23, 2007**

(54) **VERTICAL COLOR FILTER SENSOR GROUP WITH CARRIER-COLLECTION ELEMENTS OF DIFFERENT SIZE AND METHOD FOR FABRICATING SUCH A SENSOR GROUP**

(75) Inventors: **Richard B. Merrill**, Woodside, CA (US); **Richard F. Lyon**, Los Altos, CA (US); **Richard M. Turner**, Mountain View, CA (US); **Paul M. Hubel**, Mountain View, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 315 days.

(21) Appl. No.: **10/975,093**

(22) Filed: **Oct. 27, 2004**

(65) **Prior Publication Data**

US 2005/0087829 A1 Apr. 28, 2005

Related U.S. Application Data

(63) Continuation of application No. 10/355,723, filed on Jan. 31, 2003, now abandoned, and a continuation-in-part of application No. 10/103,304, filed on Mar. 20, 2002, now Pat. No. 6,864,557.

(51) **Int. Cl.**
H01L 31/06 (2006.01)

(52) **U.S. Cl.** **257/294**; 257/440; 257/443; 257/465; 257/E31.121

(58) **Field of Classification Search** 257/222, 257/233, 291, 292, 294, 440, 443, 444, 446, 257/461, 465, E31.121
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,617,753 A 11/1971 Kato et al. ..... 250/211 J

(Continued)

FOREIGN PATENT DOCUMENTS

JP 61-187282 8/1986

(Continued)

OTHER PUBLICATIONS

K.M. Findlater, et al., "A CMOS Image Sensor Employing a Doulbe Junction Photodiode", *2001 IEEE Workshop on Charge-Coupled Devices and Advanced Image Sensors, IEEE Electron Devices Society (2001)*, pp. 60-63.

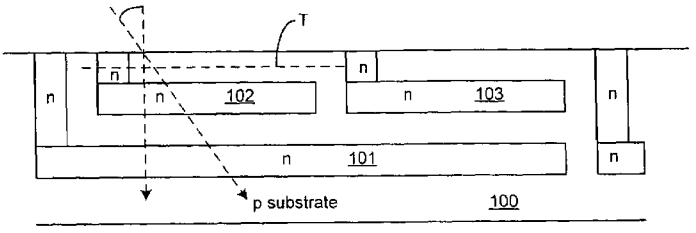
(Continued)

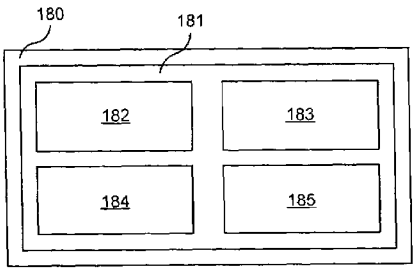
Primary Examiner—Minh-Loan Tran
(74) *Attorney, Agent, or Firm*—Girard & Equitz LLP

(57) **ABSTRACT**

A vertical color filter sensor group formed on a substrate (preferably a semiconductor substrate) and including at least two vertically stacked, photosensitive sensors, and an array of such sensor groups. In some embodiments, a carrier-collection element of at least one sensor of the group has substantially larger area, projected in a plane perpendicular to a normal axis defined by a top surface of a top sensor of the group, than does each minimum-sized carrier-collection element of the group. In some embodiments, the array includes at least two sensor groups that share at least one carrier-collection element. Optionally, the sensor group includes at least one filter positioned relative to the sensors such that radiation that has propagated through or reflected from the filter will propagate into at least one sensor of the group.

14 Claims, 29 Drawing Sheets





US007339216B1

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

(10) **Patent No.: US 7,339,216 B1**
(45) **Date of Patent: Mar. 4, 2008**

(54) **VERTICAL COLOR FILTER SENSOR GROUP ARRAY WITH FULL-RESOLUTION TOP LAYER AND LOWER-RESOLUTION LOWER LAYER**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Paul M. Hubel**, Mountain View, CA (US); **Mark O. Bagula**, Morgan Hill, CA (US); **Richard B. Merrill**, Woodside, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 96 days.

(21) Appl. No.: **11/285,470**

(22) Filed: **Nov. 22, 2005**

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/738,484, filed on Dec. 17, 2003, now Pat. No. 6,998,660, and a continuation-in-part of application No. 10/355,723, filed on Jan. 31, 2003, now abandoned.

(51) **Int. Cl.**
H01L 31/00 (2006.01)

(52) **U.S. Cl.** **257/291**; 257/440; 257/443; 257/E27.134

(58) **Field of Classification Search** 257/222, 257/291, 443, 440, E31.121, E27.134, E27.135
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,617,753 A 11/1971 Kato et al. ..... 250/211 J
3,971,065 A 7/1976 Bayer 358/41
4,011,016 A 3/1977 Layne et al. 356/195
4,238,760 A 12/1980 Carr 357/30

(Continued)

FOREIGN PATENT DOCUMENTS

EP 0 605 898 A1 12/1993

(Continued)

OTHER PUBLICATIONS

K.M. Findlater, et al., "A CMOS Image Sensor Employing a Double Junction Photodiode", *2001 IEEE Workshop on Charge-Coupled Devices and Advanced Image Sensors, IEEE Electron Devices Society (2001)*, pp. 60-63.

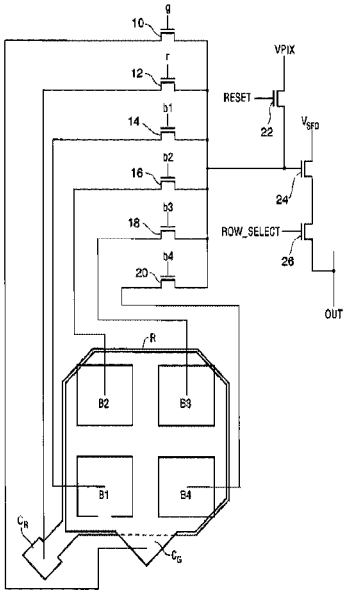
(Continued)

Primary Examiner—Minh-Loan T Tran
(74) *Attorney, Agent, or Firm*—Girard & Equitz LLP

(57) **ABSTRACT**

An array of vertical color filter (VCF) sensor groups, optionally including or coupled to circuitry for converting photo-generated carriers produced in the sensors to electrical signals, and methods for reading out any embodiment of the array. The array has a top layer (including the top sensors of the sensor group) and at least one low layer including other ones of the sensors. Only the top layer can be read out with full resolution. Each low layer can only be read out with less than full resolution to generate fewer sensor output values than the total number of pixel sensor locations. Typically, the sensor groups are arranged in cells, each cell including a S sensor groups (e.g., S=4), with S sensors in the top layer and fewer than S sensors in each low layer of the cell. Typically, each cell includes at least one shared sensor (a sensor shared by two or more VCF sensor groups) in each low layer, and each cell includes sensor selection switches (e.g., transistors) between the cell's sensors and a sense node.

17 Claims, 10 Drawing Sheets



US007372595B1

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

(10) **Patent No.: US 7,372,595 B1**
(45) **Date of Patent: May 13, 2008**

(54) **FLEXIBLE IMAGE RENDERING SYSTEM UTILIZING INTERMEDIATE DEVICE-INDEPENDENT UNRENDERED IMAGE DATA**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Allen H. Rush**, Danville, CA (US)

(73) Assignee: **Foveon, Inc.**, San Jose, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1282 days.

(21) Appl. No.: **10/100,250**

(22) Filed: **Mar. 14, 2002**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/933,545, filed on Aug. 20, 2001, now abandoned.

(51) **Int. Cl.**
H04N 1/40 (2006.01)

(52) **U.S. Cl.** **358/1.9**; 358/2.1; 358/3.24

(58) **Field of Classification Search** 358/1.9, 358/2.1, 3.24, 3.27, 1.13, 1.15, 1.18, 518, 358/527; 348/207.2, 222.1, 333.12; 709/246
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,606,365	A	2/1997	Maurinus et al.	
5,806,420	A	9/1998	Erhard et al.	101/37
5,867,214	A	2/1999	Anderson et al.	348/231
5,883,380	A	3/1999	Sinor	250/214 VT
5,949,551	A	9/1999	Miller et al.	
5,965,875	A	10/1999	Merrill	
6,128,097	A	10/2000	Parker et al.	358/1.2
6,426,801	B1 *	7/2002	Reed	358/1.16
6,515,758	B2	2/2003	Uda et al.	358/1.15
6,573,927	B2 *	6/2003	Parulski et al.	348/231.7
6,704,024	B2	3/2004	Robotham et al.	345/581
6,721,802	B1 *	4/2004	Wright et al.	709/246
6,785,019	B2	8/2004	Anderson et al.	358/1.9
6,937,370	B1 *	8/2005	Nitta et al.	358/518
7,027,172	B1 *	4/2006	Parulski et al.	358/1.15
2002/0049852	A1	4/2002	Lee et al.	709/231
2002/0122198	A1 *	9/2002	Tsue et al.	358/1.13
2002/0191206	A1	12/2002	Anderson et al.	358/1.13
2004/0196381	A1 *	10/2004	Matsuzaka	348/222.1

(Continued)

OTHER PUBLICATIONS

About Bibble at <<http://www.bibblelabs.com/about.html>> visited on Jan. 3, 2002, pp. 1-4.

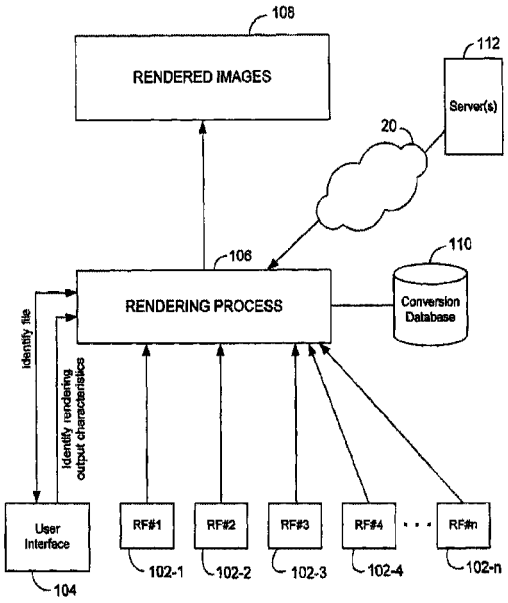
(Continued)

Primary Examiner—Scott A. Rogers
(74) *Attorney, Agent, or Firm*—Sierra Patent Group, Ltd.

(57) **ABSTRACT**

A flexible, user-friendly computer-implemented image processing system is provided. The system includes a process to receive an image rendering request. The image rendering request includes an indication of raw image data and an indication of desired rendering output characteristics. A rendering process is configured to process the raw image data to generate at least one rendered image, based on an indication of a particular image acquisition device employed to generate the raw image data. In accordance with some embodiments, the rendering process includes a plurality of rendering sub-processes. Each sub-process corresponds to a separate image acquisition device, and the rendering process is configured to process the raw image data based on the sub-process corresponding to the indication of the particular image acquisition device employed to generate the raw image data.

32 Claims, 5 Drawing Sheets



US007683958B1

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

(10) **Patent No.: US 7,683,958 B1**
(45) **Date of Patent: Mar. 23, 2010**

(54) **CAMERA EXPOSURE INDICATION INTERFACE**

(75) Inventors: **Michael Chen**, Mountain View, CA (US); **Richard F. Lyon**, Los Altos, CA (US); **Richard M. Turner**, Mountain View, CA (US)

(73) Assignee: **Foveon, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 2095 days.

(21) Appl. No.: **10/355,750**

(22) Filed: **Jan. 31, 2003**

(51) **Int. Cl.**
H04N 5/222 (2006.01)

(52) **U.S. Cl.** **348/333.01**; 348/333.02; 348/333.12

(58) **Field of Classification Search** ..... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,286,857	A *	9/1981	Mita	396/296
5,041,911	A	8/1991	Moorman	
5,164,836	A	11/1992	Jackson et al.	
5,228,450	A *	7/1993	Sellers	600/524
6,347,192	B1 *	2/2002	Malloy Desormeaux et al.	396/287
7,098,946	B1 *	8/2006	Koseki et al.	348/229.1
7,154,544	B2 *	12/2006	Kowno et al.	348/240.99
7,158,183	B1 *	1/2007	Ohta	348/364
2004/0012689	A1 *	1/2004	Tinnerino et al.	348/218.1
2006/0092151	A1 *	5/2006	Allen	345/204

OTHER PUBLICATIONS

Phil Askey, Nikon D1 Review, Nov. 2000, http://www.dpreview.com/reviews/nikond1/page9.asp (This document has been faxed to Applicant on Jun. 17, 2009).*

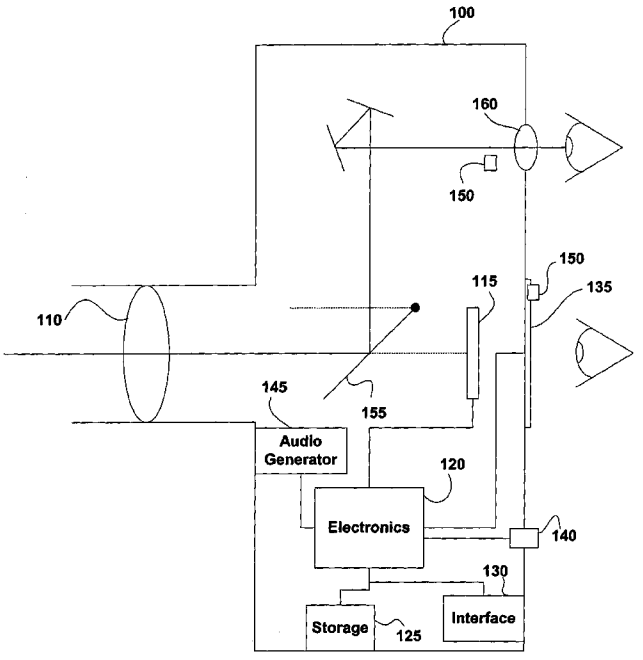
(Continued)

Primary Examiner—Luong T Nguyen
(74) *Attorney, Agent, or Firm*—Lewis and Roca LLP

(57) **ABSTRACT**

Systems and methods of providing spatially dependent image exposure information to a user of a digital camera. The described approach is applicable to determination of image exposure quality in a digital camera system. In these applications an image is displayed in a first display mode wherein the exposure information is overlaid on the image or in a second display mode wherein the exposure information is eliminated or reduced and thus is less obstructive of the image. In the second display mode, a separate exposure warning optionally conveys a subset of the information displayed in the first display mode. The invention includes a user input operable to temporarily specify a change in the display of the image between the first mode and the second mode while an image is displayed, thus providing the user with direct control of the presence and duration of spatially dependent image exposure information.

58 Claims, 2 Drawing Sheets



US008158870B2

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

(10) **Patent No.: US 8,158,870 B2**
(45) **Date of Patent: Apr. 17, 2012**

(54) **INTERVALGRAM REPRESENTATION OF AUDIO FOR MELODY RECOGNITION**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Thomas C. Walters**, San Francisco, CA (US); **David Ross**, San Jose, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 122 days.

(21) Appl. No.: **12/826,623**

(22) Filed: **Jun. 29, 2010**

(65) **Prior Publication Data**

US 2011/0314995 A1 Dec. 29, 2011

(51) **Int. Cl.**
A63H 5/00 (2006.01)

(52) **U.S. Cl.** **84/609**; 379/88.01

(58) **Field of Classification Search** 84/609, 84/610; 379/88.1

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,043,473	B1	5/2006	Rassool et al.	
7,518,052	B2 *	4/2009	Kourbatov	84/609
2003/0233930	A1 *	12/2003	Ozick	84/610
2004/0190687	A1 *	9/2004	Baker	379/88.01

OTHER PUBLICATIONS

"Pitch detection algorithm," Wikipedia, last modified on Aug. 3, 2010, 3 pages, [online][retrieved on Dec. 15, 2010] Retrieved from the internet <URL:http://en.wikipedia.org/wiki/Pitch_detection_algorithm>.

Ellis, D., et al., "The 2007 Labrosa Cover Song Detection System," Music Information Retrieval Evaluation eXchange (MIREX), Australian Computer Society, 2007, 4 Pages

Jensen, J., et al., "A Tempo-Insensitive Distance Measure for Cover Song Identification Based on Chroma Features," Proc. IEEE Int. Conf. Acoust., Speech, Signal Processing, 2008, pp. 2209-2212.

Katsiamia, A.G., et. al., "Practical Gammatone-Like Filters for Auditory Processing," EURASIP Journal on Audio, Speech, and Music Processing, v. 2007, Article ID 63685, 15 pages.

Lyon, R., "A Computational Model of Filtering, Detection, and Compression in the Cochlea", Proceedings IEEE International Conference on Acoustics, Speech, and Signal Processing, Paris, May 1982, pp. 1282-1285.

Patterson, R., "Auditory Images: How Complex Sounds are Represented in the Auditory System," Acoustical Science and Technology, Jpn , 2000, pp. 183-190,(E) 21, 4.

Serra, J., et al., "Audio Cover Song Identification and Similarity: Background, Approaches, Evaluation, and Beyond," Advances in Music Information Retrieval, SCI 274, 2010, pp. 307-332.

Weintraub, M., "The GRASP Sound Separation System", Proceedings IEEE International Conference on Acoustics, Speech, and Signal Processing, San Diego, Mar. 1984, pp. 18A.6.1-18A.6.4.

Egorov, A., et al., "Cover Song Identification with IF-F0 Pitch Class Profiles," MIREX extended abstract, Sep. 2008, 4 pages.

(Continued)

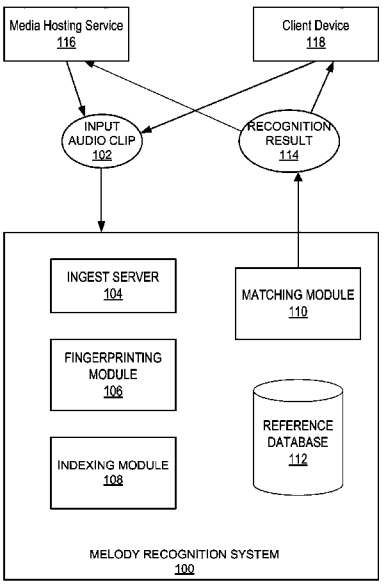
Primary Examiner — Jianchun Qin

(74) *Attorney, Agent, or Firm* — Fenwick & West LLP

(57) **ABSTRACT**

A system, method, and computer readable storage medium generates an audio fingerprint for an input audio clip that is robust to differences in key, instrumentation, and other performance variations. The audio fingerprint includes a sequence of intervalgrams that represent a melody in an audio clip according pitch intervals between different time points in the audio clip. The fingerprint for an input audio clip can be compared to a set of reference fingerprints in a reference database to determine a matching reference audio clip.

18 Claims, 7 Drawing Sheets



US008440900B2

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

(10) **Patent No.: US 8,440,900 B2**
(45) **Date of Patent: *May 14, 2013**

(54) **INTERVALGRAM REPRESENTATION OF AUDIO FOR MELODY RECOGNITION**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Thomas C. Walters**, San Francisco, CA (US); **David Ross**, San Jose, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (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.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/615,061**

(22) Filed: **Sep. 13, 2012**

(65) **Prior Publication Data**

US 2013/0000467 A1 Jan. 3, 2013

Related U.S. Application Data

(60) Division of application No. 13/416,096, filed on Mar. 9, 2012, which is a continuation of application No. 12/826,623, filed on Jun. 29, 2010, now Pat. No. 8,158,870.

(51) **Int. Cl.**
A63H 5/00 (2006.01)

(52) **U.S. Cl.**
USPC **84/609**

(58) **Field of Classification Search** 84/609, 84/610; 379/88.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,115,089	B2 *	2/2012	Saino et al.	84/622
8,116,746	B2	2/2012	Lu et al.	
2007/0131094	A1 *	6/2007	Kemp	84/609
2008/0223200	A1 *	9/2008	Kwak	84/610
2009/0025540	A1 *	1/2009	Hillborg	84/609

OTHER PUBLICATIONS

Office Action for U.S. Appl. No. 13/416,096, Oct. 4, 2012, 10 pages.

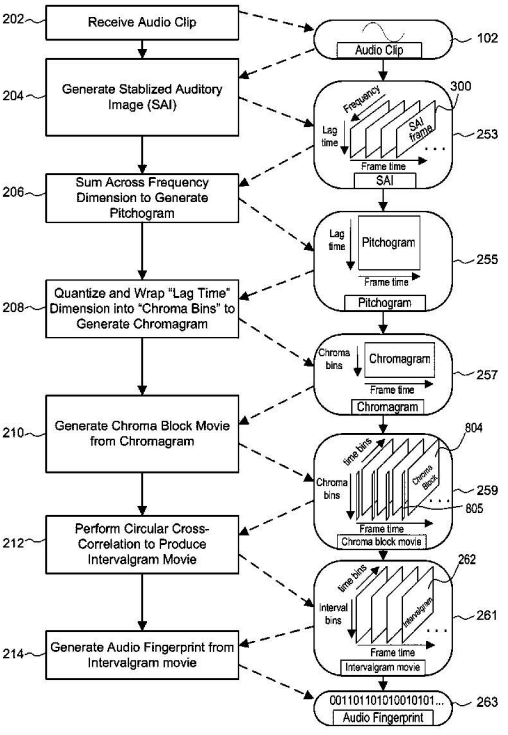
* cited by examiner

Primary Examiner — Jianchun Qin
(74) *Attorney, Agent, or Firm* — Fenwick & West LLP

(57) **ABSTRACT**

A system, method, and computer readable storage medium generates an audio fingerprint for an input audio clip that is robust to differences in key, instrumentation, and other performance variations. The audio fingerprint includes a sequence of intervalgrams that represent a melody in an audio clip according pitch intervals between different time points in the audio clip. The fingerprint for an input audio clip can be compared to a set of reference fingerprints in a reference database to determine a matching reference audio clip.

20 Claims, 7 Drawing Sheets



US008463719B2

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

(10) **Patent No.: US 8,463,719 B2**
(45) **Date of Patent: Jun. 11, 2013**

(54) **AUDIO CLASSIFICATION FOR INFORMATION RETRIEVAL USING SPARSE FEATURES**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Martin Rehn**, Stockholm (SE); **Thomas Walters**, Cambridge (GB); **Samy Bengio**, Mountain View, CA (US); **Gal Chechik**, Los Altos, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 615 days.

(21) Appl. No.: **12/722,437**

(22) Filed: **Mar. 11, 2010**

(65) **Prior Publication Data**

US 2010/0257129 A1 Oct. 7, 2010

Related U.S. Application Data

(60) Provisional application No. 61/159,398, filed on Mar. 11, 2009.

(51) **Int. Cl.**
G06F 15/18 (2006.01)

(52) **U.S. Cl.**
USPC **706/12**

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,536,844	A	8/1985	Lyon
5,422,977	A	6/1995	Patterson et al.
5,473,759	A	12/1995	Slaney et al.
5,918,223	A	6/1999	Blum et al.
6,434,520	B1	8/2002	Kanevsky et al.

OTHER PUBLICATIONS

Chechik et al., "Large-Scale Content Based Audio Retrieval from Text Queries", Proceeding of the 1st ACM International Conference on Multimedia Information Retrieval; Oct. 30, 2008; pp. 105-112.*

Daniel P. W. Ellis, "Prediction-driven Computational Auditory Scene Analysis", Massachusetts Institute of Technology, Jun. 1996, pp. 1-180.*

Turnbull et al., "Semantic Annotation and Retrieval of Music and Sound Effects," IEEE Transactions on Audio, Speech and Language Processing, Dec. 15, 2006, 10 pages.

Chechik et al., "Large-scale content based audio retrieval from text queries," Proceeding of the 1st ACM International Conference on Multimedia Information Retrieval; Oct. 30, 2008; 8 pages.

International Search Report and Written Opinion mailed Jul. 12, 2010 from related International Application No. PCT/US2010/027031; 10 pages.

Rehn et al., "Sound Ranking Using Auditory Sparse-Code Representations," ICML 2009 Workshop Sparse Methods for Music Audio, Jun. 18, 2009; 3 pages.

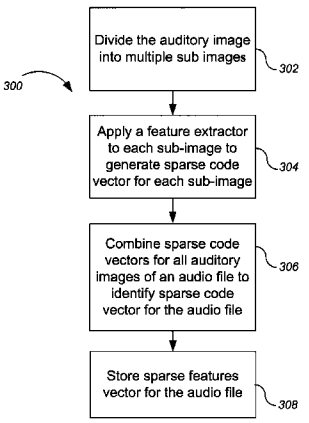
(Continued)

Primary Examiner — Jeffrey A Gaffin
Assistant Examiner — Paulinho E Smith
(74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

(57) **ABSTRACT**

Methods, systems, and apparatus, including computer programs encoded on computer storage media, are provided for using audio features to classify audio for information retrieval. In general, one aspect of the subject matter described in this specification can be embodied in methods that include the actions of generating a collection of auditory images, each auditory image being generated from respective audio files according to an auditory model; extracting sparse features from each auditory image in the collection to generate a sparse feature vector representing the corresponding audio file; and ranking the audio files in response to a query including one or more words using the sparse feature vectors and a matching function relating sparse feature vectors to words in the query.

30 Claims, 8 Drawing Sheets



US008493436B2

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

(10) **Patent No.: US 8,493,436 B2**
(45) **Date of Patent: Jul. 23, 2013**

(54) **PANORAMIC CAMERA WITH MULTIPLE IMAGE SENSORS USING TIMED SHUTTERS**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Gary Embler**, Redwood City, CA (US); **Iain Richard Tyrone McClatchie**, Los Altos, CA (US); **Jason Holt**, Mountain View, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1073 days.

(21) Appl. No.: **12/368,014**

(22) Filed: **Feb. 9, 2009**

(65) **Prior Publication Data**

US 2009/0201361 A1 Aug. 13, 2009

Related U.S. Application Data

(60) Provisional application No. 61/027,237, filed on Feb. 8, 2008.

(51) **Int. Cl.**
H04N 13/02 (2006.01)

(52) **U.S. Cl.**
USPC **348/47**

(58) **Field of Classification Search**
USPC 348/36, 47
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,473,364	A *	12/1995	Burt	348/47
5,801,760	A *	9/1998	Uomori	348/47
6,118,475	A *	9/2000	Iijima et al.	348/42
6,141,034	A *	10/2000	McCutchen	348/36
6,535,114	B1 *	3/2003	Suzuki et al.	340/435
6,593,960	B1 *	7/2003	Sugimoto et al.	348/148
6,993,159	B1 *	1/2006	Ishii et al.	382/104
7,277,118	B2 *	10/2007	Foote	348/36
7,307,655	B1 *	12/2007	Okamoto et al.	348/222.1
7,388,598	B2 *	6/2008	Lee et al.	348/42
7,436,429	B2 *	10/2008	Tillotson	348/36

(Continued)

FOREIGN PATENT DOCUMENTS

JP	2006-350713	12/2006
JP	2007-214620	8/2007
WO	WO 2007/045714 A	4/2007

OTHER PUBLICATIONS

Niclass, et al., "Design and Characterization of a CMOS 3-D Image Sensor Based on Single Photon Avalanche Diodes," *IEEE Journal of Solid-State Circuits*, vol. 40, No. 9, Sep. 2005; pp. 1847-1854.

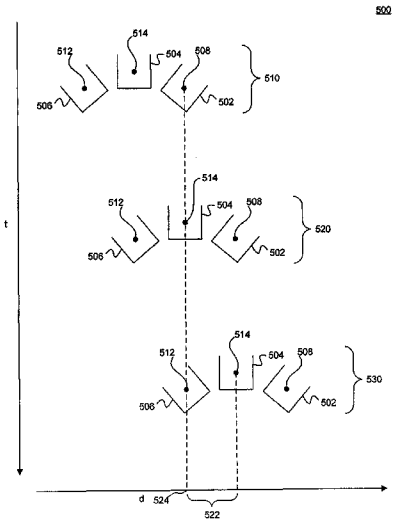
(Continued)

Primary Examiner — Douglas Blair
(74) *Attorney, Agent, or Firm* — Sterne, Kessler, Goldstein & Fox PLLC

(57) **ABSTRACT**

The present invention relates to the field of panoramic still and motion photography. In a first embodiment, a camera apparatus for panoramic photography includes a first image sensor positioned to capture a first image. The first image sensor has a rolling-shutter readout arranged in portrait orientation. The camera apparatus also includes second image sensor positioned to capture a second image. The second image sensor has a rolling-shutter readout arranged in portrait orientation. Finally, the camera apparatus includes a controller configured to signal the second image sensor to start capturing the second image before the first image sensor finishes capturing the first image. At least a portion of the first image is in front of the second image relative to a forward direction of the camera apparatus.

10 Claims, 6 Drawing Sheets



US008497417B2

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

(10) **Patent No.: US 8,497,417 B2**
(45) **Date of Patent: *Jul. 30, 2013**

(54) **INTERVALGRAM REPRESENTATION OF AUDIO FOR MELODY RECOGNITION**

(75) Inventors: **Richard F. Lyon**, Los Altos, CA (US); **Thomas C. Walters**, San Francisco, CA (US); **David Ross**, San Jose, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (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.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/416,096**

(22) Filed: **Mar. 9, 2012**

(65) **Prior Publication Data**

US 2012/0160078 A1 Jun. 28, 2012

Related U.S. Application Data

(63) Continuation of application No. 12/826,623, filed on Jun. 29, 2010, now Pat. No. 8,158,870.

(51) **Int. Cl.**
A63H 5/00 (2006.01)

(52) **U.S. Cl.**
USPC **84/609**

(58) **Field of Classification Search**
USPC 84/609
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,115,089 B2 2/2012 Saino et al.
8,116,746 B2 * 2/2012 Lu et al. 455/414.1
2002/0069073 A1 6/2002 Fasciano
2005/0281410 A1 12/2005 Grosvenor
2007/0038446 A1 2/2007 Shen et al.
2007/0131094 A1 6/2007 Kemp
2008/0221881 A1 9/2008 Carraux et al.
2008/0223200 A1 9/2008 Kwak
2009/0025540 A1 1/2009 Hillborg

OTHER PUBLICATIONS

PCT International Search Report and Written Opinion, PCT/US2011/041681, Feb. 9, 2012, 6 pages.

Baluja, S., et al., "Waveprint: Efficient wavelet-based audio fingerprinting," Pattern recognition, 2008, pp. 3467-3480, vol. 41, No. 11.

Bertin-Mahieux, T., et al., "Large-scale cover song recognition using hashed chroma landmarks," In Proceedings of the International Symposium on Music Information Retrieval (ISMIR), Oct. 16-19, 2011, 4 pages.

Casey, M., et al., "Analysis of minimum distances in high-dimensional musical spaces," IEEE Transactions on Audio, Speech, and Language Processing, Jul. 2008, pp. 1015-1028, vol. 16, No. 5.

Ellis, D., et al., "The 2007 LabROSA cover song detection system," MIREX2007 Audio Cover Song Evaluation system description, 2007, 5 Pages.

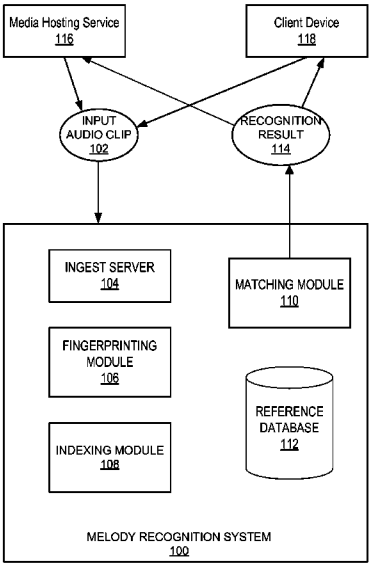
(Continued)

Primary Examiner — Jianchun Qin
(74) *Attorney, Agent, or Firm* — Fenwick & West LLP

(57) **ABSTRACT**

A system, method, and computer readable storage medium generates an audio fingerprint for an input audio clip that is robust to differences in key, instrumentation, and other performance variations. The audio fingerprint comprises a sequence of intervalgrams that represent a melody in an audio clip according pitch intervals between different time points in the audio clip. The fingerprint for an input audio clip can be compared to a set of reference fingerprints in a reference database to determine a matching reference audio clip.

16 Claims, 7 Drawing Sheets



US008705320B1

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

(10) **Patent No.: US 8,705,320 B1**
(45) **Date of Patent: Apr. 22, 2014**

(54) **AUDIO LOCALIZATION USING MULTILATERATION**

(75) Inventors: **Jason Holt**, Mountain View, CA (US); **Richard Francis Lyon**, Los Altos, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (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.: **13/615,212**

(22) Filed: **Sep. 13, 2012**

(51) **Int. Cl.**
G01S 3/80 (2006.01)
G01S 3/808 (2006.01)

(52) **U.S. Cl.**
CPC ***G01S 3/8083*** (2013.01)
USPC **367/125**; 367/124; 367/127

(58) **Field of Classification Search**
USPC 367/124, 125, 127
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,445,118	A *	4/1984	Taylor et al.	342/357.395
8,203,910	B2 *	6/2012	Zhao et al.	367/127
2005/0249038	A1 *	11/2005	Rui et al.	367/124
2008/0232192	A1 *	9/2008	Williams	367/8
2009/0190441	A1 *	7/2009	Zhao et al.	367/128
2009/0207694	A1 *	8/2009	Guigne et al.	367/127
2009/0310444	A1 *	12/2009	Hiroe	367/125
2011/0038230	A1 *	2/2011	Napolitano et al.	367/127
2012/0044786	A1 *	2/2012	Booij et al.	367/127
2012/0214544	A1 *	8/2012	Shivappa et al.	455/556.1

OTHER PUBLICATIONS

Walworth, M.; Mahajan, A.; "3D Position sensing using the difference in the time of flights from a wave source to various receivers". , ICAR '97. Proceeding of 8th Int. Conf. on Advanced Robotics, 1997. p. 611-616.*

Farrokhi, et al., "The designing of an indoor acoustic ranging system using the audible spread spectrum LFM (chirp) signal", Canadian Conference on Electrical and Computer Engineering, May 1-4, 2005, pp. 2131-2134.

Girod, et al., "Robust range estimation using acoustic and multimodal sensing", IEEE/RSJ International Conference on Intelligent Robots and Systems, 2001, pp. 1312-1320, vol. 3.

Girod, et al., "Locating tiny sensors in time and space: a case study", IEEE International Conference on Computer Design: VLSI in Computers and Processors, 2002, pp. 214-219.

Hazas, et al., "Broadband Ultrasonic Location Systems for Improved Indoor Positioning", IEEE Transactions on Mobile Computing, May 2006, pp. 536-547. vol. 5, No. 5.

Lienhart, et al., "Providing Common Time and Space in Distributed AV-Sensor Networks by Self-Calibration", Intelligent Multimedia Processing with Soft Computing Studies in Fuzziness and Soft Computing, 2005, pp. 453-473, vol. 168.

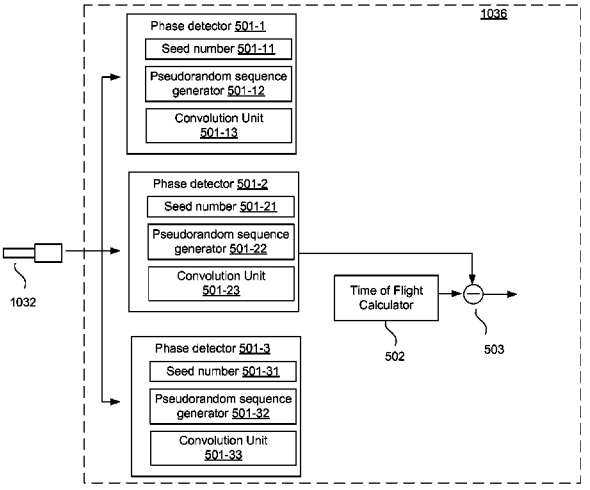
(Continued)

Primary Examiner — Isam Alsomiri
Assistant Examiner — James Hulka
(74) *Attorney, Agent, or Firm* — McDermott Will & Emery LLP

(57) **ABSTRACT**

Systems and methods for providing audio localization are provided. In some aspects, a method includes receiving phase offsets of a plurality of fixed transmitters from a source other than the plurality of fixed transmitters, detecting an audio localization signal from each of the plurality of fixed transmitters, determining a received phase of the audio localization signal from each of the plurality of fixed transmitters, determining time differences of flight from the mobile receiver to the plurality of fixed transmitters using the received phases, determining distance differences from the mobile receiver to the plurality of fixed transmitters using the time differences of flight, and determining the location of the mobile receiver by performing multilateration using the distance differences.

12 Claims, 11 Drawing Sheets



US008736706B1

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

(10) **Patent No.: US 8,736,706 B1**
(45) **Date of Patent: May 27, 2014**

(54) **METHOD AND SYSTEM FOR GENERATING HIGH RESOLUTION COMPOSITE IMAGES**

(75) Inventors: **Matthew Thomas Valente**, Mountain View, CA (US); **Richard Francis Lyon**, Los Altos, CA (US); **Peter Gregory Brueckner**, Santa Cruz, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 144 days.

(21) Appl. No.: **13/418,598**

(22) Filed: **Mar. 13, 2012**

(51) **Int. Cl.**
H04N 5/228 (2006.01)

(52) **U.S. Cl.**
USPC **348/222.1**; 348/218.1; 382/284; 382/299

(58) **Field of Classification Search**
CPC G06T 3/4053; H04N 5/23238; H04N 5/23232
USPC 348/222.1, 218.1, 219.1; 382/299, 284
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,015,954 B1 * 3/2006 Foote et al. 348/218.1
7,646,932 B1 1/2010 Peterson
7,860,343 B2 12/2010 Tico et al.
2005/0237631 A1 * 10/2005 Shioya et al. 359/770
2010/0172549 A1 7/2010 Weiss

OTHER PUBLICATIONS

Kovacs et al., "Focus Area Extraction by Blind Deconvolution for Defining Regions of Interest", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 29, No. 6, Jun. 2007, pp. 1080-1085.
Shaked et al., "Sharpness Measure: Towards Automatic Image Enhancement", In Proceedings of ICIP (1). 2005, 937-940.

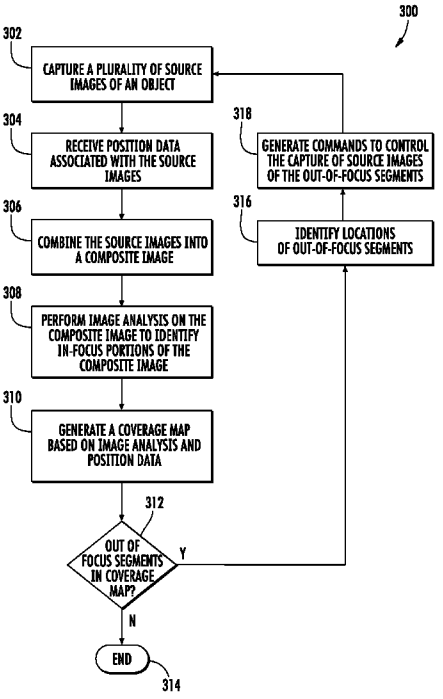
* cited by examiner

Primary Examiner — Paul Berardesca
(74) *Attorney, Agent, or Firm* — Dority & Manning, P.A.

(57) **ABSTRACT**

Methods and systems for generating high resolution composite imagery are provided. The methods and systems can create a fully-in-focus high resolution composite image by combining a number of source images in which only a part of the source image is in-focus. The composite image can be analyzed to identify portions of the composite image that satisfy an image quality metric. The capture of additional source images can be controlled based at least in part on the image analysis of the composite image. In addition, a control routine for capturing the plurality of source images can be dynamically adjusted based on the image quality of the individual source images.

13 Claims, 10 Drawing Sheets



US009042912B1

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

(10) **Patent No.: US 9,042,912 B1**
(45) **Date of Patent: May 26, 2015**

(54) **TWO-PASS COPRESENCE**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventors: **Andrew Ames Bunner**, Belmont, CA (US); **Alan Lee Gardner, III**, San Mateo, CA (US); **Mohammed Waleed Kadous**, Santa Clara, CA (US); **Brian Patrick Williams**, Mountain View, CA (US); **Marc Stogaitis**, San Mateo, CA (US); **Nadav Aharony**, Sunnyvale, CA (US); **Brian Duff**, Santa Clara, CA (US); **Pascal Tom Getreuer**, San Francisco, CA (US); **Zhentao Sun**, Sunnyvale, CA (US); **Daniel Estrada Alva**, Mountain View, CA (US); **Ami Patel**, Mountain View, CA (US); **Benjamin Razon**, Mountain View, CA (US); **Richard Daniel Webb**, Redwood City, CA (US); **Tony Weber**, San Jose, CA (US); **Thomas Yuchin Chao**, Burlingame, CA (US); **Ryan Michael Rifkin**, San Francisco, CA (US); **Richard Francis Lyon**, Los Altos, CA (US); **Liem Tran**, Milpitas, CA (US); **Joseph A. Farfel**, San Fracisco, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (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.: **14/313,949**

(22) Filed: **Jun. 24, 2014**

Related U.S. Application Data

(60) Provisional application No. 61/941,467, filed on Feb. 18, 2014.

(51) **Int. Cl.**
H04W 24/00 (2009.01)
H04L 29/08 (2006.01)

(52) **U.S. Cl.**
CPC ***H04L 67/18*** (2013.01)

(58) **Field of Classification Search**
CPC H04W 4/02; H04W 4/023; H04W 64/00
USPC 455/456.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,213,617	B1	7/2012	Appleton	
2008/0147798	A1*	6/2008	Paalasmaa et al.	709/204
2011/0238755	A1*	9/2011	Khan et al.	709/204
2012/0258665	A1	10/2012	Sip	
2013/0217332	A1	8/2013	Altaman et al.	
2013/0260693	A1	10/2013	Un et al.	

FOREIGN PATENT DOCUMENTS

WO WO2014033351 3/2014

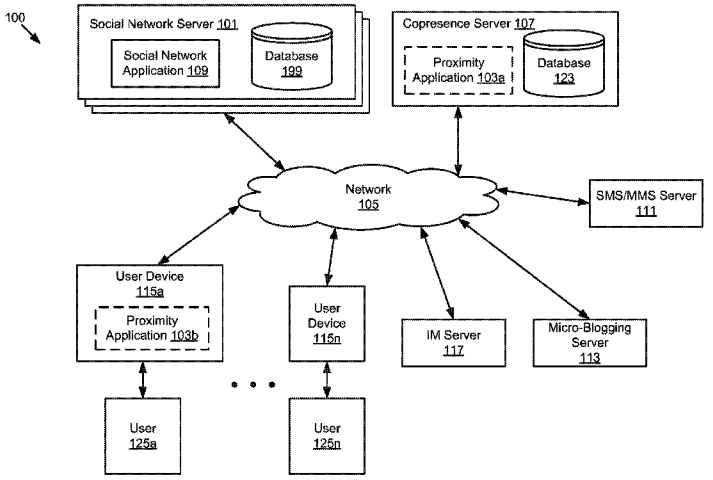
* cited by examiner

Primary Examiner — Omoniyi Obayanju
(74) *Attorney, Agent, or Firm* — Patent Law Works LLP

(57) **ABSTRACT**

The disclosure includes a system and method for detecting fine grain copresence between users. The system includes a processor and a memory storing instructions that when executed cause the system to: process one or more signals to determine coarse grain location information of a first device and a second device; determine whether the first device and the second device are copresent based on the coarse grain location information; in response to determining that the first device and the second device are copresent based on the coarse grain location information, transmit a signal to the second device to alert the second device to listen for a fine grain copresence token from the first device; and refine copresence based on receiving an indication that the second device has received the fine grain copresence token.

18 Claims, 7 Drawing Sheets



US009158842B1

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

(10) **Patent No.: US 9,158,842 B1**
(45) **Date of Patent: Oct. 13, 2015**

(54) **SOUND REPRESENTATION VIA WINNER-TAKE-ALL CODING OF AUDITORY SPECTRA**

(75) Inventors: **Jay Yagnik**, Santa Clara, CA (US); **Richard Francis Lyon**, Los Altos, CA (US); **Thomas Chadwick Walters**, San Francisco, CA (US); **Douglas Eck**, Palo Alto, CA (US)

(73) Assignee: **GOOGLE INC.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 361 days.

(21) Appl. No.: **13/616,938**

(22) Filed: **Sep. 14, 2012**

(51) **Int. Cl.**
G06F 17/30 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/30743*** (2013.01); ***G06F 17/3074*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 17/30743; G06F 17/3074
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,990,453	B2 *	1/2006	Wang et al.	704/270
8,290,918	B1 *	10/2012	Ioffe	707/698
8,549,022	B1 *	10/2013	Kaminski, Jr.	707/758
2003/0021441	A1 *	1/2003	Levy et al.	382/100
2003/0086341	A1 *	5/2003	Wells et al.	369/13.56
2004/0028281	A1 *	2/2004	Cheng et al.	382/232
2007/0112565	A1 *	5/2007	Kim et al.	704/229
2007/0124756	A1 *	5/2007	Covell et al.	725/18
2010/0257129	A1 *	10/2010	Lyon et al.	706/12
2011/0113037	A1 *	5/2011	Wessling et al.	707/747
2011/0173185	A1 *	7/2011	Vogel	707/722
2011/0173208	A1 *	7/2011	Vogel	707/746
2011/0307085	A1 *	12/2011	Selby et al.	700/94
2011/0314995	A1 *	12/2011	Lyon et al.	84/609
2012/0123831	A1 *	5/2012	King et al.	705/14.7
2012/0124638	A1 *	5/2012	King et al.	726/1
2012/0209612	A1 *	8/2012	Bilobrov	704/270

OTHER PUBLICATIONS

Foote et al., "Content-Based Retrieval of Music and Audio", Multimedia Storage and Archiving Systems II, Proc. of SPIE, 1997.*
Yagnik et al., "The Power of Comparative Reasoning", Proceeding ICCV '11 Proceedings of the 2011 International Conference on Computer Vision, 2011.*

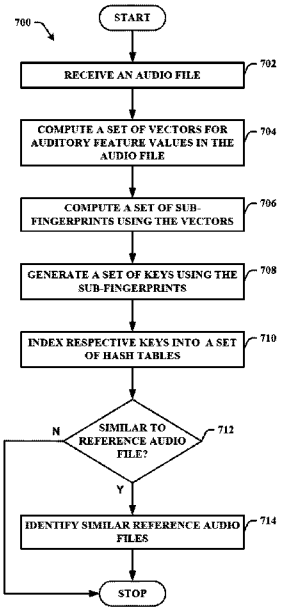
* cited by examiner

Primary Examiner — Samuel G Neway
(74) *Attorney, Agent, or Firm* — Morris & Kamlay LLP

(57) **ABSTRACT**

Sound representations and winner-take-all codes of auditory spectra are used in the identification of audio content. A transformation component converts a set of sound frames from audio content into a set of spectral slices. A spectral encoder component encodes the spectral slices of auditory spectra into winner-take-all codes with a winner-take-all hash function. An identification component identifies which spectral dimension of a subset of spectral dimensions within a spectral slice has highest spectral value according to the winner-take-all codes. Reference audio content is determined to be similar or matching to the audio content based on the winner-take-all codes.

16 Claims, 11 Drawing Sheets



US009195431B2

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

(10) **Patent No.: US 9,195,431 B2**
(45) **Date of Patent: Nov. 24, 2015**

(54) **SYSTEM AND METHOD FOR SELECTIVE REMOVAL OF AUDIO CONTENT FROM A MIXED AUDIO RECORDING**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventors: **Christopher Russell LaRosa**, San Francisco, CA (US); **Sam Kvaalen**, San Francisco, CA (US); **Thomas Chadwick Walters**, San Francisco, CA (US); **Richard Francis Lyon**, Los Altos, CA (US); **Robert Steven Glickstein**, San Rafael, CA (US); **Rushabh Ashok Doshi**, Menlo Park, CA (US); **Molly Castle Nix**, San Francisco, CA (US); **Jason Matthew Toff**, San Francisco, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 340 days.

(21) Appl. No.: **13/730,076**

(22) Filed: **Dec. 28, 2012**

(65) **Prior Publication Data**

US 2013/0338806 A1 Dec. 19, 2013

Related U.S. Application Data

(60) Provisional application No. 61/661,225, filed on Jun. 18, 2012.

(51) **Int. Cl.**
G06F 17/00 (2006.01)
G06F 3/16 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G06F 3/16*** (2013.01); ***G10H 1/0008*** (2013.01); ***G10L 21/0272*** (2013.01); ***G11B 27/034*** (2013.01); ***G11B 27/28*** (2013.01); *G10H 2210/125* (2013.01); *H04H 60/04* (2013.01)

(58) **Field of Classification Search**
CPC .. G06F 3/16; G10H 1/0008; G10H 2210/125; G10L 21/0272; G11B 27/034; G11B 27/28
USPC 700/94
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,148,484 A 9/1992 Kane et al.
8,121,714 B2 * 2/2012 Yamashita et al. 700/94
(Continued)

FOREIGN PATENT DOCUMENTS

KR 101123865 3/2012
WO 9908380 2/1999
WO 2008140238 11/2008

OTHER PUBLICATIONS

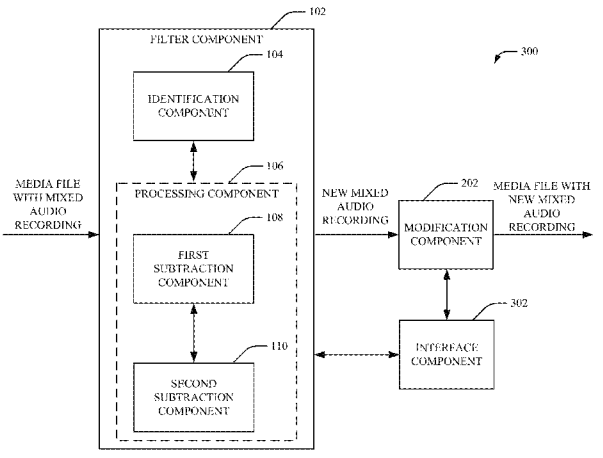
Adobe Audition Manual: Copyright 2003.*
(Continued)

Primary Examiner — Paul McCord
(74) *Attorney, Agent, or Firm* — Fenwick & West LLP

(57) **ABSTRACT**

Systems and techniques for removing a sound recording from an audio recording (e.g., an audio recording embedded in a media file) are presented. The system can include an identification component, a first subtraction component and a second subtraction component. The identification component identifies a sound recording in a mixed audio recording. The first subtraction component determines a local linear transformation of the sound recording and subtracts the local linear transformation of the sound recording from the mixed audio recording to generate a new mixed audio recording. The second subtraction component compares one or more segments of the sound recording with one or more corresponding segments of the new mixed audio recording and reduces a power level of the new mixed audio recording based at least in part on correlation of the one or more corresponding segments with the one or more segments.

23 Claims, 12 Drawing Sheets



US009319096B1

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

(10) **Patent No.: US 9,319,096 B1**
(45) **Date of Patent: Apr. 19, 2016**

(54) **ULTRASONIC COMMUNICATION BETWEEN DEVICES**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventors: **Ryan Michael Rifkin**, San Francisco, CA (US); **Richard Francis Lyon**, Los Altos, CA (US); **Pascal Tom Getreuer**, San Francisco, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (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.: **14/288,137**

(22) Filed: **May 27, 2014**

(51) **Int. Cl.**

H04B 1/69	(2011.01)
H04B 1/707	(2011.01)
H04B 1/713	(2011.01)
H04B 1/7075	(2011.01)
H04B 1/709	(2011.01)

(52) **U.S. Cl.**
CPC ***H04B 1/70752*** (2013.01); ***H04B 1/709*** (2013.01); *H04B 2201/70718* (2013.01)

(58) **Field of Classification Search**
CPC H04B 1/7052; H04B 1/709; H04B 2201/70718
USPC 375/147, 149, 150, 152, 142, 143, 145; 370/320, 335, 342; 367/137, 178
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,505,823 B1 * 3/2009 Bartlett et al. 700/94
7,796,978 B2 * 9/2010 Jones et al. 455/414.3

OTHER PUBLICATIONS

Mohammed Alloula and Mike Hazas. An efficient CDMA core for indoor acoustic position sensing. In Indoor Positioning and Indoor Navigation (IPIN), 2010 International Conference on, pp. 1-5, Sep. 2010.

Robert J. Baxley, Chunming Zhao, and G. Tong Zhou. Constrained clipping for crest factor reduction in OFDM. IEEE Transactions on Broadcasting, 52, 2006.

Kiho Cho, Jae Choi, Hwan Sik Yun, and Nam Soo Kim. Spectral magnitude adjusted data hiding in mclt domain of audio signal for robust acoustic data transmission. AP-SIPA ASC 2011 Xi'an, 2011.

Aditya Dhananjay, Ashlesh Sharma, Michael Paik, Jay Chen, Trishank Karthik Kup-pusamy, Jinyang Li, and Lakshminarayanan Subramanian. Hermes: data transmission over unknown voice channels. MOBICOM, pp. 113-124, 2010.

Robert C. Dixon. Spread Spectrum Techniques. IEEE Press Selected Reprint Series, 1976.

Poulami Dutta, Debnath Bhattacharyya, and Tai Hoon Kim. Data hiding in audio signal: A review. International Journal of Database Theory and Application, 2, 2009; 8 Pages.

Laura Galluccio, Tommaso Melodia, Sergio Palazzo, and Giuseppe Enrico Santagati. Challenges and implications of using ultrasonic communications in intra-body area networks. In Wireless On-demand Network Systems and Services (WONS), 2012 9th Annual Conference on, pp. 182-189, Jan. 2012.

Robert Gold. Optimal binary sequences for spread spectrum multiplexing. 13:619-621, 1967.

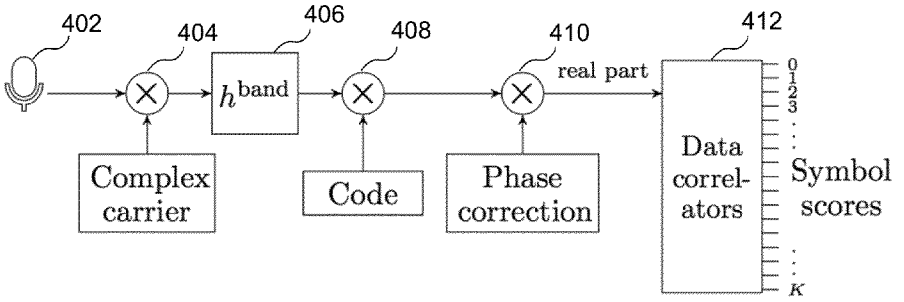
(Continued)

Primary Examiner — Phuong Phu

(57) **ABSTRACT**

Implementations generally relate to ultrasonic communication between devices. In some implementations, a method includes receiving a data signal, where the data signal is transmitted and received in an indoor environment. The method further includes demodulating the data signal based on direct sequence spread spectrum.

15 Claims, 14 Drawing Sheets



US009373320B1

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

(10) **Patent No.: US 9,373,320 B1**
(45) **Date of Patent: Jun. 21, 2016**

(54) **SYSTEMS AND METHODS FACILITATING SELECTIVE REMOVAL OF CONTENT FROM A MIXED AUDIO RECORDING**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventors: **Richard Francis Lyon**, Los Altos, CA (US); **Ron Weiss**, New York, NY (US); **Thomas Chadwick Walters**, Bromely (GB)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 490 days.

(21) Appl. No.: **13/972,262**

(22) Filed: **Aug. 21, 2013**

(51) **Int. Cl.**

G10L 21/028	(2013.01)
G10L 13/033	(2013.01)
G10L 21/02	(2013.01)
G10L 21/0272	(2013.01)
G10L 21/0308	(2013.01)

(52) **U.S. Cl.**
CPC ***G10L 13/033*** (2013.01); ***G10L 21/02*** (2013.01); ***G10L 21/028*** (2013.01); ***G10L 21/0272*** (2013.01); ***G10L 21/0308*** (2013.01)

(58) **Field of Classification Search**
CPC G10L 21/0272; G10L 21/028; G10L 21/0308
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,140,637	A *	8/1992	McCarthy	H04S 1/00 381/1
6,690,799	B1 *	2/2004	Iwase	H04S 1/00 381/1
7,672,466	B2	3/2010	Yamada et al.	
8,370,164	B2	2/2013	Beack et al.	
2002/0083060	A1 *	6/2002	Wang	G06F 17/30743
2006/0008092	A1 *	1/2006	Baril	G09B 15/00 381/77
2006/0204019	A1 *	9/2006	Suzuki	G10L 21/0272 381/92
2007/0021959	A1	1/2007	Goto	
2007/0076902	A1 *	4/2007	Master	H04S 7/00 381/94.3
2008/0075292	A1 *	3/2008	Wong	G10H 1/20 381/61

(Continued)

FOREIGN PATENT DOCUMENTS

WO	2010003346	1/2010

OTHER PUBLICATIONS

Hrebień, Maciej, and Józef Korbicz. "Hough transform in music tunes recognition systems." Artificial Intelligence and Soft Computing—ICAISC 2008. Springer Berlin Heidelberg, 2008. 588-596.*

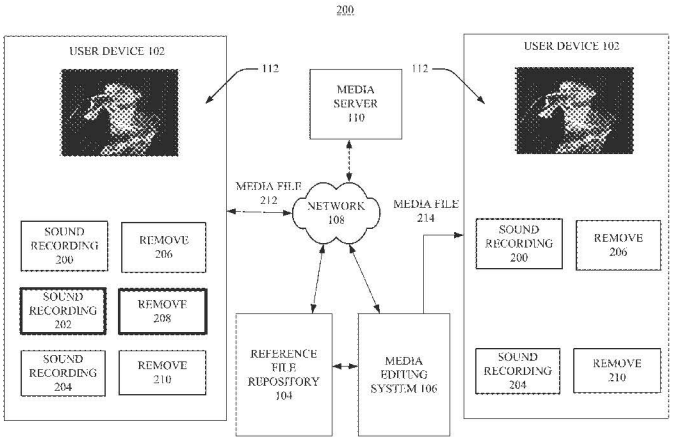
(Continued)

Primary Examiner — Brian Albertalli
(74) *Attorney, Agent, or Firm* — Byrne Poh LLP

(57) **ABSTRACT**

Systems and methods facilitating removal of content from audio files are described. A method includes identifying a sound recording in a first audio file, identifying a reference file having at least a defined level of similarity to the sound recording, and processing the first audio file to remove the sound recording and generate a second audio file. In some embodiments, winner-take-all coding and Hough transforms are employed for determining alignment and rate adjustment of the reference file in the first audio file. After alignment, the reference file is filtered in the frequency domain to increase similarity between the reference file and the sound recording. The frequency domain representation (FR) of the filtered version is subtracted from the FR first audio and the result converted to a time representation of the second audio file. In some embodiments, spectral subtraction is also performed to generate a further improved second audio file.

30 Claims, 14 Drawing Sheets



US009386417B1

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

(10) **Patent No.: US 9,386,417 B1**
(45) **Date of Patent: *Jul. 5, 2016**

(54) **TWO-PASS COPRESENCE**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventors: **Andrew Ames Bunner**, Belmont, CA (US); **Alan Lee Gardner, III**, San Mateo, CA (US); **Mohammed Waleed Kadous**, Santa Clara, CA (US); **Brian Patrick Williams**, Mountain View, CA (US); **Marc Stogaitis**, San Mateo, CA (US); **Nadav Aharony**, Sunnyvale, CA (US); **Brian Duff**, Santa Clara, CA (US); **Pascal Tom Getreuer**, San Francisco, CA (US); **Zhentao Sun**, Sunnyvale, CA (US); **Daniel Estrada Alva**, Mountain View, CA (US); **Ami Patel**, Mountain View, CA (US); **Benjamin Razon**, Mountain View, CA (US); **Richard Daniel Webb**, Redwood City, CA (US); **Tony Weber**, San Jose, CA (US); **Thomas Yuchin Chao**, Burlingame, CA (US); **Ryan Michael Rifkin**, San Francisco, CA (US); **Richard Francis Lyon**, Los Altos, CA (US); **Liem Tran**, Milpitas, CA (US); **Joseph A. Farfel**, San Francisco, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (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.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/720,825**

(22) Filed: **May 24, 2015**

Related U.S. Application Data

(63) Continuation of application No. 14/313,949, filed on Jun. 24, 2014, now Pat. No. 9,042,912.

(60) Provisional application No. 61/941,467, filed on Feb. 18, 2014.

(51) **Int. Cl.**

H04W 24/00	(2009.01)
H04W 4/02	(2009.01)
H04L 29/08	(2006.01)

(52) **U.S. Cl.**
CPC ***H04W 4/021*** (2013.01); ***H04L 67/18*** (2013.01)

(58) **Field of Classification Search**
CPC H04W 4/02; H04W 64/00
USPC 455/456.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,213,617 B1	7/2010	Appleton
2008/0147798 A1	6/2008	Paalasmaa et al.

(Continued)

FOREIGN PATENT DOCUMENTS

WO	WO2014033351	3/2014

OTHER PUBLICATIONS

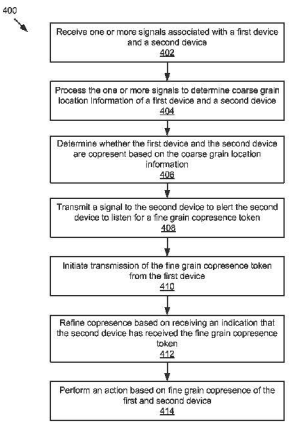
Kovach, Steve, "How to: Link Foursquare and GroupMe for Texting Nearby Friends", Business Insider, dated Feb. 18, 2011, 2 pages, http://www.businessinsider.com/how-to-send-a-text-to-your-four-square-friends-using-groupme-2011-2.

Primary Examiner — Omoniyi Obayanju
(74) *Attorney, Agent, or Firm* — Patent Law Works LLP

(57) **ABSTRACT**

The disclosure includes a system and method for detecting fine grain copresence between users. The system includes a processor and a memory storing instructions that when executed cause the system to: process one or more signals to determine coarse grain location information of a first device and a second device; determine whether the first device and the second device are copresent based on the coarse grain location information; in response to determining that the first device and the second device are copresent based on the coarse grain location information, transmit a signal to the second device to alert the second device to listen for a fine grain copresence token from the first device; and refine copresence based on receiving an indication that the second device has received the fine grain copresence token.

20 Claims, 7 Drawing Sheets



US009471673B1

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

(10) **Patent No.: US 9,471,673 B1**
(45) **Date of Patent: Oct. 18, 2016**

(54) **AUDIO MATCHING USING TIME-FREQUENCY ONSETS**

(75) Inventors: **Matthew Sharifi**, Zurich (CH); **Richard Francis Lyon**, Los Altos, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1013 days.

(21) Appl. No.: **13/418,334**

(22) Filed: **Mar. 12, 2012**

(51) **Int. Cl.**

G10L 15/00	(2013.01)
G06F 17/30	(2006.01)
G10L 15/02	(2006.01)

(52) **U.S. Cl.**
CPC ... ***G06F 17/30743*** (2013.01); *G10H 2210/051* (2013.01); *G10H 2210/061* (2013.01); *G10H 2240/141* (2013.01); *G10L 15/02* (2013.01)

(58) **Field of Classification Search**
CPC .. G06F 17/00; G06F 17/18; G06F 17/30017; G06F 17/3002; G06F 17/30023; G06F 17/30029; G06F 17/3033; G06F 17/30743; G06F 17/30761; G06F 17/30784; G06F 17/30799; G06F 21/10; G06K 9/00; G06K 9/00744; G06K 9/00758; G06K 9/62; G06T 9/002; G06T 9/005; G10H 2210/061; G10L 19/00; G10L 19/018; G10L 25/18; G10L 25/48; G10L 25/51; G10L 25/54; G11B 27/034; G11B 27/28; H04H 20/14; H04H 60/37; H04H 60/372; H04H 60/375; H04H 60/58; H04H 60/59; H04H 60/64; H04H 2201/90; H04L 2209/60; H04N 21/26603; H04N 21/4394; Y10S 707/99933; Y10S 707/99936
USPC 382/100, 181, 190, 224; 700/94; 704/231, 243, 245, 256, 270, 273, 704/E11.001, E11.002; 705/57; 707/737, 707/741, 747, 749, 752, 758, 769, 999.003, 707/999.006, E17.014, E17.101; 713/176, 713/180; 725/18, 19; 726/26
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,393,450	B1 *	5/2002	Whikehart	708/316
6,453,252	B1	9/2002	Laroche	
6,721,488	B1	4/2004	Dimitrova et al.	
7,516,074	B2	4/2009	Bilobrov	
7,809,580	B2	10/2010	Hotho et al.	
8,488,800	B2 *	7/2013	Crockett	381/56
2002/0023020	A1	2/2002	Kenyon et al.	
2002/0037083	A1 *	3/2002	Weare et al.	381/58
2005/0104654	A1 *	5/2005	Muhammad et al.	327/552
2005/0273319	A1 *	12/2005	Dittmar et al.	704/203

(Continued)

OTHER PUBLICATIONS

Project Report: Onset Detection, Mikkel Gravgaard Nielsen Aarhus University, Feb. 4, 2010 http://cs.au.dk/~grav/onset/.*

Media Hedge, "Digital Fingerprinting," White Paper, Civolution and Gracenote, 2010, http://www.civolution.com/fileadmin/bestanden/white%20papers/Fingerprinting%20-%20by%20Civolution%20and%20Gracenote%20-%202010.pdf, Last accessed Jul. 11, 2012.

Milano, Dominic, "Content Control: Digital Watermarking and Fingerprinting," White Paper, Rhozet, a business unit of Harmonic Inc., http://www.rhozet.com/whitepapers/Fingerprinting_Watermarking.pdf, Last accessed Jul. 11, 2012.

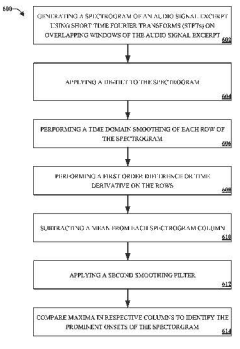
(Continued)

Primary Examiner — Paul McCord
Assistant Examiner — Alexander Eljaiek
(74) *Attorney, Agent, or Firm* — Fenwick & West LLP

(57) **ABSTRACT**

Systems and methods are provided herein relating to audio matching. Interest points that are onsets are generally very efficient in audio matching in that they are robust to multiple types of distortion. Prominent onsets can be detected within an audio signal excerpt as interest points and combined as a function of a set of interest points to form a descriptor. Descriptors associated with an audio signal excerpt that contain a set of prominent onsets as interest points can be used in matching the audio signal excerpt to an audio reference. The benefits in generating and using prominent onsets within descriptors improve the accuracy of an audio matching system.

23 Claims, 11 Drawing Sheets



US009596419B1

(12) **United States Patent**
Lyon

(10) **Patent No.: US 9,596,419 B1**
(45) **Date of Patent: Mar. 14, 2017**

(54) **IMAGE CAPTURE SYSTEM WITH MOTION COMPENSATION**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventor: **Richard Francis Lyon**, Los Altos, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 20 days.

(21) Appl. No.: **14/832,335**

(22) Filed: **Aug. 21, 2015**

(51) **Int. Cl.**

H04N 5/228	(2006.01)
H04N 5/353	(2011.01)
H04N 5/374	(2011.01)

(52) **U.S. Cl.**
CPC ***H04N 5/3532*** (2013.01); ***H04N 5/3743*** (2013.01)

(58) **Field of Classification Search**
CPC H04N 5/3532; H04N 5/3743
USPC 348/208.7
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,953,304	A	4/1934	Lutz
2,899,882	A	8/1959	Wylie et al.
6,304,284	B1	10/2001	Dunton et al.
6,351,288	B1	2/2002	Johnson et al.

OTHER PUBLICATIONS

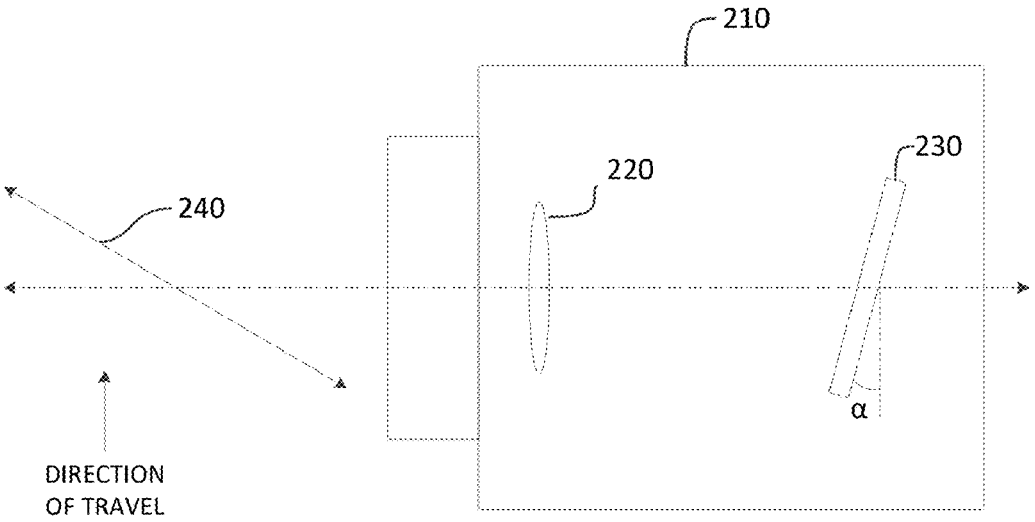
Andrew Wilson, "Shift/tilt lenses bring new perspectives", Vision Systems Design, May 1, 2006, Accessed on Jul. 8, 2015, <http://www.vision-systems.com/articles/print/volume-11/issue-5/features/product-focus/shift-tilt-lenses-bring-new-perspectives.html>.

Primary Examiner — Usman Khan
(74) *Attorney, Agent, or Firm* — Lerner, David, Littenberg, Krumholz & Mentlik, LLP

(57) **ABSTRACT**

An example image system may include a lens that produces an image, an image sensor, an image stabilizer, and a controller. This image sensor has a first edge and an opposite second edge. The first edge is placed closer to lens such that it focuses on more distant objects. The image stabilizer provides a time-varying compensation of image motion at the image sensor. The controller operates the image capture system in a repeating cycle where the sensor exposes and reads out an image progressively from one edge to the opposite edge. The controller operates the image stabilizer to provide an image motion compensation that varies in time such that the image motion compensation is greater when exposing and reading the second edge of the sensor than when exposing and reading the first edge of the sensor.

20 Claims, 9 Drawing Sheets



US009618604B1

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

(10) **Patent No.: US 9,618,604 B1**
(45) **Date of Patent: Apr. 11, 2017**

(54) **AUDIO LOCALIZATION USING MULTILATERATION**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventors: **Jason Holt**, Mountain View, CA (US); **Richard Francis Lyon**, Los Altos, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 626 days.

(21) Appl. No.: **14/133,423**

(22) Filed: **Dec. 18, 2013**

Related U.S. Application Data

(62) Division of application No. 13/615,212, filed on Sep. 13, 2012.

(51) **Int. Cl.**
G01S 5/00 (2006.01)
G01S 5/26 (2006.01)

(52) **U.S. Cl.**
CPC ***G01S 5/26*** (2013.01)

(58) **Field of Classification Search**
USPC 367/117, 124, 127
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,445,118	A	4/1984	Taylor et al.	
8,203,910	B2	6/2012	Zhao et al.	
8,447,330	B2 *	5/2013	Chakravarty et al.	455/456.1
8,705,320	B1 *	4/2014	Holt	G01S 5/10 367/124
2005/0249038	A1	11/2005	Rui et al.	
2007/0001867	A1 *	1/2007	Rowe et al.	340/825.49
2008/0157970	A1 *	7/2008	Single	G01S 5/0263 340/572.1
2008/0232192	A1	9/2008	Williams	
2009/0190441	A1	7/2009	Zhao et al.	
2009/0207694	A1	8/2009	Guigne et al.	
2009/0310444	A1	12/2009	Hiroe	

(Continued)

FOREIGN PATENT DOCUMENTS

JP WO 2011013418 A1 * 2/2011 ..... G01S 11/16

OTHER PUBLICATIONS

Farrokhi, et al., "The designing of an indoor acoustic ranging system using the audible spread spectrum LFM (chirp) signal", Canadian Conference on Electrical and Computer Engineering, May 1-4, 2005, pp. 2131-2134.

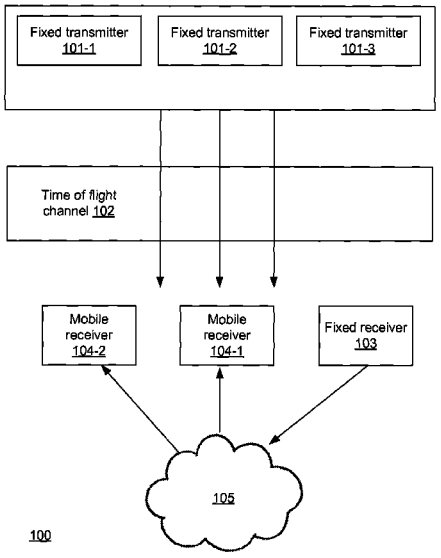
(Continued)

Primary Examiner — James Hulka
(74) *Attorney, Agent, or Firm* — Dority & Manning, P.A.

(57) **ABSTRACT**

Systems and methods for providing audio localization are provided. In some aspects, a method includes receiving phase offsets of a plurality of fixed transmitters from a source other than the plurality of fixed transmitters, detecting an audio localization signal from each of the plurality of fixed transmitters, determining a received phase of the audio localization signal from each of the plurality of fixed transmitters, determining time differences of flight from the mobile receiver to the plurality of fixed transmitters using the received phases, determining distance differences from the mobile receiver to the plurality of fixed transmitters using the time differences of flight, and determining the location of the mobile receiver by performing multilateration using the distance differences.

6 Claims, 11 Drawing Sheets



US009679579B1

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

(10) **Patent No.: US 9,679,579 B1**
(45) **Date of Patent: Jun. 13, 2017**

(54) **SYSTEMS AND METHODS FACILITATING SELECTIVE REMOVAL OF CONTENT FROM A MIXED AUDIO RECORDING**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventors: **Richard Francis Lyon**, Los Altos, CA (US); **Ron Weiss**, New York, NY (US); **Thomas Chadwick Walters**, Bromely (GB)

(73) Assignee: **Google Inc.**, Mountain View, CA (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.: **15/186,993**

(22) Filed: **Jun. 20, 2016**

Related U.S. Application Data

(63) Continuation of application No. 13/972,262, filed on Aug. 21, 2013, now Pat. No. 9,373,320.

(51) **Int. Cl.**

G10L 21/028	(2013.01)
G10L 21/0356	(2013.01)
G10L 25/51	(2013.01)
G10L 21/0308	(2013.01)
G10L 21/0388	(2013.01)

(52) **U.S. Cl.**
CPC ***G10L 21/0356*** (2013.01); ***G10L 21/0308*** (2013.01); ***G10L 21/0388*** (2013.01); ***G10L 25/51*** (2013.01)

(58) **Field of Classification Search**
CPC G10L 21/0272; G10L 21/028; G10L 21/0308
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,140,637	A	8/1992	McCarthy
6,690,799	B1	2/2004	Iwase et al.
7,672,466	B2	3/2010	Yamada et al.
8,370,164	B2	2/2013	Beack et al.
9,449,611	B2 *	9/2016	Leveau G10L 21/0272
2002/0083060	A1	6/2002	Wang et al.
2006/0008092	A1	1/2006	Baril et al.
2006/0204019	A1	9/2006	Suzuki et al.
2007/0021959	A1	1/2007	Goto

(Continued)

FOREIGN PATENT DOCUMENTS

WO	WO/2010/003346	1/2010

OTHER PUBLICATIONS

"Google's Winner Takes All Hashing Implemmentation", pp. 1-2, available at: https://gist.github.com/erogol/6391423/.

(Continued)

Primary Examiner — Brian Albertalli
(74) *Attorney, Agent, or Firm* — Byrne Poh LLP

(57) **ABSTRACT**

Systems and methods facilitating removal of content from audio files are described. A method includes identifying a sound recording in a first audio file, identifying a reference file having at least a defined level of similarity to the sound recording, and processing the first audio file to remove the sound recording and generate a second audio file. In some embodiments, winner-take-all coding and Hough transforms are employed for determining alignment and rate adjustment of the reference file in the first audio file. After alignment, the reference file is filtered in the frequency domain to increase similarity between the reference file and the sound recording. The frequency domain representation (FR) of the filtered version is subtracted from the FR first audio and the result converted to a time representation of the second audio file. In some embodiments, spectral subtraction is also performed to generate a further improved second audio file.

21 Claims, 14 Drawing Sheets