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(54) **VOLTAGE-PROGRAMMING SCHEME FOR CURRENT-DRIVEN AMOLED DISPLAYS**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,354,162	A	10/1982	Wright
5,589,847	A	12/1996	Lewis
5,670,973	A	9/1997	Bassetti et al.
5,748,160	A	5/1998	Shieh et al.
5,815,303	A	9/1998	Berlin
6,097,360	A	8/2000	Holloman
6,259,424	B1	7/2001	Kurogane
6,288,696	B1	9/2001	Holloman
6,320,325	B1	11/2001	Cok et al.
6,414,661	B1	7/2002	Shen et al.
6,580,657	B2	6/2003	Sanford et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CA 1294034 1/1992

(Continued)

OTHER PUBLICATIONS

Alexander et al.: "Pixel circuits and drive schemes for glass and elastic AMOLED displays"; dated Jul. 2005 (9 pages).

(Continued)

*Primary Examiner* — Amare Mengistu

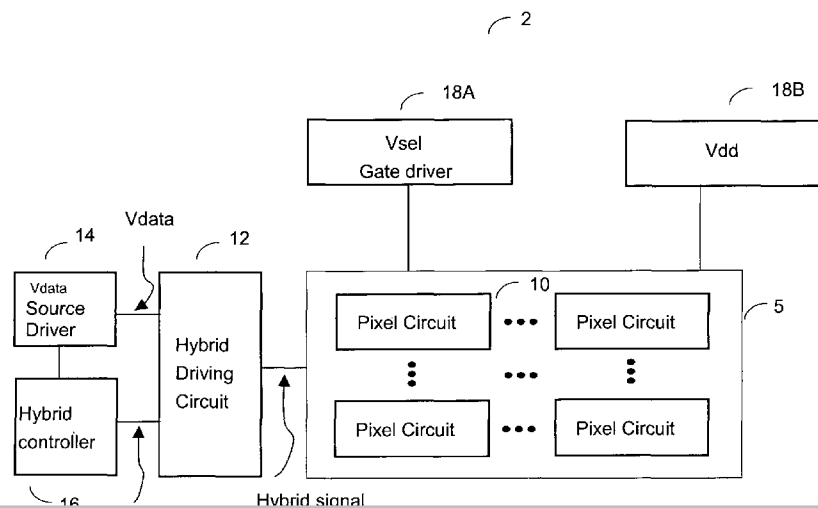
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(57) **ABSTRACT**

A system and method for driving an AMOLED display is provided. The AMOLED display includes a plurality of pixel circuits. A voltage-programming scheme, a current-programming scheme or a combination thereof is applied to drive the display. Threshold shift information, and/or voltage necessary to obtain hybrid driving circuit may be acquired. A data sampling may be implemented to acquire a current/voltage relationship. A feedback operation may be implemented to correct the brightness of the pixel.

**37 Claims, 23 Drawing Sheets**



U.S. PATENT DOCUMENTS

6,594,606	B2	7/2003	Everitt	
6,618,030	B2*	9/2003	Kane et al.	345/82
6,677,713	B1	1/2004	Sung	
6,687,266	B1	2/2004	Ma et al.	
6,690,344	B1	2/2004	Takeuchi et al.	
6,693,388	B2	2/2004	Oomura	
6,720,942	B2	4/2004	Lee et al.	
6,738,035	B1	5/2004	Fan	
6,771,028	B1	8/2004	Winters	
6,777,712	B2	8/2004	Sanford et al.	
6,806,638	B2	10/2004	Lin et al.	
6,809,706	B2	10/2004	Shimoda	
6,873,117	B2*	3/2005	Ishizuka	315/169.1
6,909,419	B2	6/2005	Zavracky et al.	
6,937,215	B2	8/2005	Lo	
6,943,500	B2	9/2005	LeChevalier	
6,956,547	B2*	10/2005	Bae et al.	345/77
6,995,510	B2	2/2006	Murakami et al.	
6,995,519	B2	2/2006	Arnold et al.	
7,023,408	B2	4/2006	Chen et al.	
7,027,015	B2	4/2006	Booth, Jr. et al.	
7,034,793	B2	4/2006	Sekiya et al.	
7,088,051	B1*	8/2006	Cok	315/169.1
7,106,285	B2	9/2006	Naugler	
7,116,058	B2	10/2006	Lo et al.	
7,245,277	B2*	7/2007	Ishizuka	345/78
7,274,363	B2	9/2007	Ishizuka et al.	
7,321,348	B2	1/2008	Cok et al.	
7,355,574	B1	4/2008	Leon et al.	
7,358,941	B2*	4/2008	Ono et al.	345/82
7,502,000	B2	3/2009	Yuki et al.	
7,535,449	B2	5/2009	Miyazawa	
7,554,512	B2	6/2009	Steer	
7,619,594	B2	11/2009	Hu	
7,619,597	B2*	11/2009	Nathan et al.	345/82
7,859,492	B2*	12/2010	Kohno	345/77
2002/0084463	A1	7/2002	Sanford et al.	
2002/0101172	A1	8/2002	Bu	
2002/0122308	A1*	9/2002	Ikeda	362/259
2002/0158823	A1	10/2002	Zavracky et al.	
2002/0186214	A1	12/2002	Siwinski	
2002/0190971	A1	12/2002	Nakamura et al.	
2002/0195967	A1	12/2002	Kim et al.	
2003/0020413	A1	1/2003	Oomura	
2003/0030603	A1	2/2003	Shimoda	
2003/0063081	A1*	4/2003	Kimura et al.	345/211
2003/0076048	A1	4/2003	Rutherford	
2003/0122745	A1	7/2003	Miyazawa	
2003/0151569	A1	8/2003	Lee et al.	
2003/0179626	A1	9/2003	Sanford et al.	
2004/0066357	A1	4/2004	Kawasaki	
2004/0070557	A1	4/2004	Asano et al.	
2004/0090400	A1*	5/2004	Yoo	345/76
2004/0135749	A1	7/2004	Kondakov et al.	
2004/0150592	A1*	8/2004	Mizukoshi et al.	345/76
2004/0174347	A1*	9/2004	Sun et al.	345/204
2004/0183759	A1	9/2004	Stevenson et al.	
2004/0189627	A1	9/2004	Shirasaki et al.	
2004/0239596	A1*	12/2004	Ono et al.	345/76
2004/0257355	A1	12/2004	Naugler	
2005/0067970	A1	3/2005	Libsch et al.	
2005/0068270	A1*	3/2005	Awakura et al.	345/76
2005/0088103	A1*	4/2005	Kageyama et al.	315/169.3
2005/0110420	A1	5/2005	Arnold et al.	
2005/0140598	A1*	6/2005	Kim et al.	345/76
2005/0140610	A1	6/2005	Smith et al.	
2005/0145891	A1	7/2005	Abe	
2005/0156831	A1	7/2005	Yamazaki et al.	
2005/0168416	A1*	8/2005	Hashimoto et al.	345/76
2005/0206590	A1	9/2005	Sasaki et al.	
2005/0269959	A1	12/2005	Uchino et al.	
2005/0269960	A1*	12/2005	Ono et al.	315/169.3
2006/0030084	A1*	2/2006	Young	438/149
2006/0038758	A1	2/2006	Routley et al.	
2006/0232522	A1	10/2006	Roy et al.	
2006/0273997	A1	12/2006	Nathan et al.	

2007/0008268	A1	1/2007	Park et al.	
2007/0080905	A1*	4/2007	Takahara	345/76
2007/0080908	A1	4/2007	Nathan et al.	
2007/0103419	A1	5/2007	Uchino et al.	
2007/0182671	A1	8/2007	Nathan et al.	
2007/0285359	A1	12/2007	Ono	
2007/0296672	A1	12/2007	Kim et al.	
2008/0042948	A1	2/2008	Yamashita et al.	
2008/0074413	A1	3/2008	Ogura	
2009/0213046	A1*	8/2009	Nam	345/76

FOREIGN PATENT DOCUMENTS

CA	2109951	11/1992
CA	2368386	9/1999
CA	2498136	3/2004
CA	2522396	11/2004
CA	2443206	3/2005
CA	2472671	12/2005
CA	2567076	1/2006
CA	2526782	4/2006
EP	1 194 013	3/2002
EP	1 335 430	A1 8/2003
EP	1 381 019	1/2004
EP	1 521 203	A2 4/2005
JP	10-254410	9/1998
JP	2002-278513	9/2002
JP	2003-076331	3/2003
JP	2003177709	6/2003
JP	2003/308046	10/2003
WO	9948079	9/1999
WO	01/27910	A1 4/2001
WO	03/063124	3/2002
WO	03/034389	4/2003
WO	2004/003877	1/2004
WO	2004/034364	4/2004
WO	2005/022498	3/2005
WO	2005/055185	6/2005
WO	2006/063448	6/2006

OTHER PUBLICATIONS

Ashtiani et al.: "AMOLED Pixel Circuit With Electronic Compensation of Luminance Degradation"; dated Mar. 2007 (4 pages).

Chahi et al.: "An Enhanced and Simplified Optical Feedback Pixel Circuit for AMOLED Displays"; dated Oct. 2006.

Chaji et al.: "A Low-Cost Stable Amorphous Silicon AMOLED Display with Full V~T- and V~O~L~E~D Shift Compensation"; dated May 2007 (4 pages).

Chaji et al.: "A low-power driving scheme for a-Si:H active-matrix organic light-emitting diode displays"; dated Jun. 2005 (4 pages).

Chaji et al.: "A low-power high-performance digital circuit for deep submicron technologies"; dated Jun. 2005 (4 pages).

Chaji et al.: "A novel a-Si:H AMOLED pixel circuit based on short-term stress stability of a-Si:H TFTs"; dated Oct. 2005 (3 pages).

Chaji et al.: "A Novel Driving Scheme and Pixel Circuit for AMOLED Displays"; dated Jun. 2006 (4 pages).

Chaji et al.: "A novel driving scheme for high-resolution large-area a-Si:H AMOLED displays"; dated Aug. 2005 (4 pages).

Chaji et al.: "A Stable Voltage-Programmed Pixel Circuit for a-Si:H AMOLED Displays"; dated Dec. 2006 (12 pages).

Chaji et al.: "A Sub-μA fast-settling current-programmed pixel circuit for AMOLED displays"; dated Sep. 2007.

Chaji et al.: "Driving scheme for stable operation of 2-TFT a-Si AMOLED pixel"; dated Apr. 2005 (2 pages).

Chaji et al.: "Dynamic-effect compensating technique for stable a-Si:H AMOLED displays"; dated Aug. 2005 (4 pages).

Chaji et al.: "Electrical Compensation of OLED Luminance Degradation"; dated Dec. 2007 (3 pages).

Chaji et al.: "eUTDSP: a design study of a new VLIW-based DSP architecture"; dated May 2003 (4 pages).

Chaji et al.: "High Speed Low Power Adder Design With a New Logic Style: Pseudo Dynamic Logic (SDL)"; dated Oct. 2001 (4 pages).

- Chaji et al.: "Low-Cost Stable a-Si:H AMOLED Display for Portable Applications"; dated Jun. 2006 (4 pages).
- Chaji et al.: "Parallel Addressing Scheme for Voltage-Programmed Active-Matrix OLED Displays"; dated May 2007 (6 pages).
- Chaji et al.: "Pseudo dynamic logic (SDL): a high-speed and low-power dynamic logic family"; dated 2002 (4 pages).
- Chaji et al.: "Stable a-Si:H circuits based on short-term stress stability of amorphous silicon thin film transistors"; dated May 2006 (4 pages).
- Chaji et al.: "Stable Pixel Circuit for Small-Area High-Resolution a-Si:H AMOLED Displays"; dated 2008 (7 pages).
- Chaji et al.: "Thin-Film Transistor Integration for Biomedical Imaging and AMOLED Displays"; dated 2008 (177 pages).
- European Search Report for European Application No. EP 05 75 9141 dated Oct. 30, 2009.
- He et al., "Current-Source a-Si:H Thin Film Transistor Circuit for Active-Matrix Organic Light-Emitting Displays", IEEE Electron Device Letters, vol. 21, No. 12, Dec. 2000, pp. 590-592.
- International Search Report for International Application No. PCT/CA2005/001007 dated Oct. 18, 2005.
- Goh et al., "A New a-Si:H Thin Film Transistor Pixel Circuit for Active-Matrix Organic Light-Emitting Diodes", IEEE Electron Device Letters, vol. 24, No. 9, Sep. 2003, 4 pages.
- Jafarabadiashtiani et al.: "A New Driving Method for a-Si AMOLED Displays Based on Voltage Feedback"; May 27, 2005 (4 pages).
- Lee et al.: "Ambipolar Thin-Film Transistors Fabricated by PECVD Nanocrystalline Silicon"; dated 2006 (6 pages).
- Matsueda y et al.: "35.1: 2.5-in. AMOLED with Integrated 6-bit Gamma Compensated Digital Data Driver"; dated May 2004 (4 pages).
- Nathan et al., "Amorphous Silicon Thin Film Transistor Circuit Integration for Organic LED Displays on Glass and Plastic", IEEE Journal of Solid-State Circuits, vol. 39, No. 9, Sep. 2004, 12 pages.
- Nathan et al.: "Backplane Requirements for Active Matrix Organic Light Emitting Diode Displays"; dated 2006 (16 pages).
- Nathan et al.: "Driving schemes for a-Si and LTPS AMOLED displays"; dated Dec. 2005 (11 pages).
- Nathan et al.: "Invited Paper: a-Si for AMOLED—Meeting the Performance and Cost Demands of Display Applications (Cell Phone to HDTV)"; dated 2006 (4 pages).
- Philipp: "Charge transfer sensing" Sensor Review, vol. 19, No. 2, Dec. 31, 1999, 10 pages.
- Rafati et al.: "Comparison of a 17 b multiplier in Dual-rail domino and in Dual-rail D L (D L) logic styles"; dated 2002 (4 pages).
- Safavian et al.: "Three-TFT image sensor for real-time digital X-ray imaging"; dated Feb. 2, 2006 (2 pages).
- Safavian et al.: "3-TFT active pixel sensor with correlated double sampling readout circuit for real-time medical x-ray imaging"; dated Jun. 2006 (4 pages).
- Safavian et al.: "A novel current scaling active pixel sensor with correlated double sampling readout circuit for real time medical x-ray imaging", dated May 2007 (7 pages).
- Safavian et al.: "Self-compensated a-Si:H detector with current-mode readout circuit for digital X-ray fluoroscopy"; dated Aug. 2005 (4 pages).
- Safavian et al.: "TFT active image sensor with current-mode readout circuit for digital x-ray fluoroscopy [5969D-82]"; dated Sep. 2005 (9 pages).
- International Preliminary Report on Patentability for International Application No. PCT/CA2005/001007 dated Oct. 16, 2006, 4 pages.

\* cited by examiner

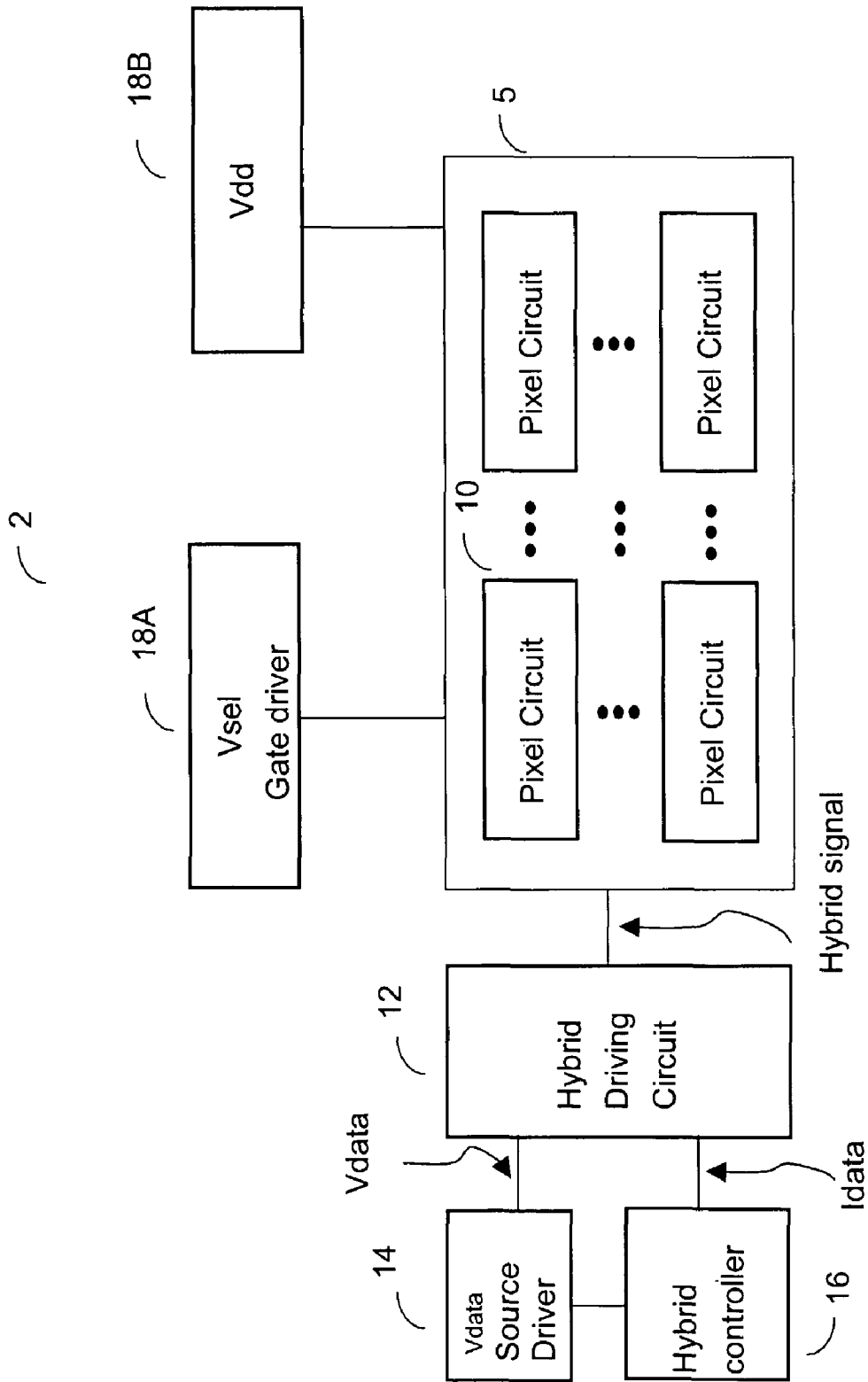


FIG. 1

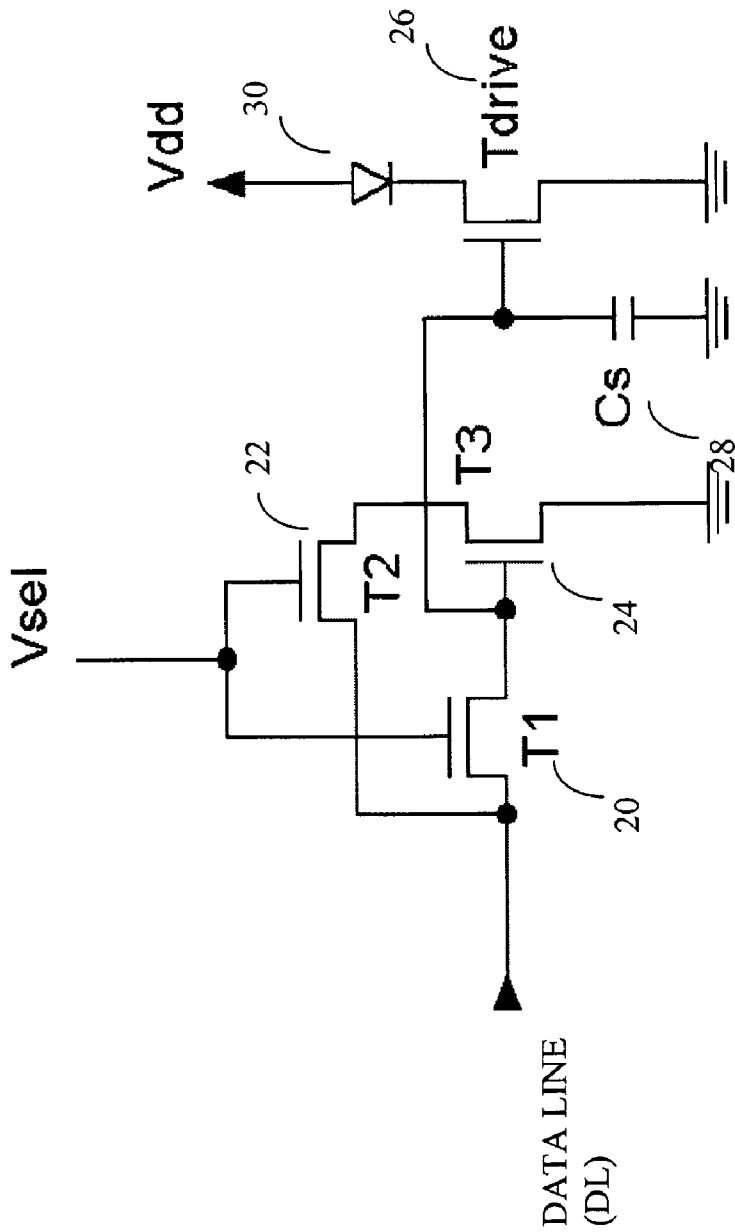


FIG. 2

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