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(54) **INTEGRATED TOUCH SCREENS**

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3,974,332 A	8/1976	Abe et al.
4,194,083 A	3/1980	Abe et al.
4,233,522 A	11/1980	Grummer et al.
4,246,452 A	1/1981	Chandler
4,250,495 A	2/1981	Beckerman et al.
4,266,144 A	5/1981	Bristol
4,268,815 A	5/1981	Eventoff et al.
4,277,517 A	7/1981	Smith, Jr.
4,290,052 A	9/1981	Eichelberger et al.

(Continued)

FOREIGN PATENT DOCUMENTS

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AU	2005246219 A1	12/2005
CA	1243096 A	10/1988

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OTHER PUBLICATIONS

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(56) **References Cited**

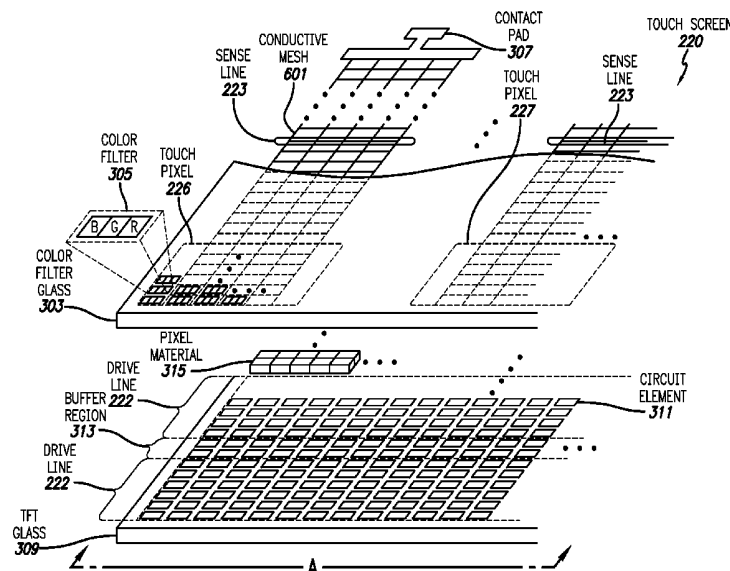
U.S. PATENT DOCUMENTS

2,751,555 A	6/1956	Kirkpatrick
3,333,160 A	7/1967	Gorski
3,541,541 A	11/1970	Englebart
3,644,835 A	2/1972	Thompson
3,662,105 A	5/1972	Hurst et al.
3,798,370 A	3/1974	Hurst

(57) **ABSTRACT**

Integrated touch screens are provided including drive lines formed of grouped-together circuit elements of a thin film transistor layer and sense lines formed between a color filter layer and a material layer that modifies or generates light. The common electrodes (Vcom) in the TFT layer can be grouped together during a touch sensing operation to form drive lines. Sense lines can be formed on an underside of a color filter glass, and a liquid crystal region can be disposed between the color filter glass and the TFT layer. Placing the sense lines on the underside of the color filter glass, i.e., within the display pixel cell, can provide a benefit of allowing the color filter glass to be thinned after the pixel cells have been assembled, for example.

22 Claims, 16 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

4,307,383	A	12/1981	Brienza	5,543,589	A	8/1996	Buchana et al.
4,313,108	A	1/1982	Yoshida	5,543,590	A	8/1996	Gillespie et al.
4,345,000	A	8/1982	Kawazoe et al.	5,543,591	A	8/1996	Gillespie et al.
4,363,027	A	12/1982	Brienza	5,550,659	A	8/1996	Fujieda et al.
4,394,643	A	7/1983	Williams	5,552,787	A	9/1996	Schuler et al.
4,526,043	A	7/1985	Boie	5,563,632	A	10/1996	Roberts
4,550,221	A	10/1985	Mabusth	5,563,727	A	10/1996	Larson et al.
4,587,378	A	5/1986	Moore	5,563,996	A	10/1996	Tchao
4,618,989	A	10/1986	Tsukune et al.	5,565,658	A	10/1996	Gerpheide et al.
4,623,757	A	11/1986	Marino	5,572,205	A	11/1996	Caldwell et al.
4,639,720	A	1/1987	Rympalski et al.	5,576,070	A	11/1996	Yaniv
4,672,364	A	6/1987	Lucas	5,579,036	A	11/1996	Yates, IV
4,672,558	A	6/1987	Beckes et al.	5,581,681	A	12/1996	Tchao et al.
4,686,332	A	8/1987	Greanias et al.	5,583,946	A	12/1996	Gourdol
4,692,809	A	9/1987	Beining et al.	5,589,856	A	12/1996	Stein et al.
4,695,827	A	9/1987	Beining et al.	5,590,219	A	12/1996	Gourdol
4,707,845	A	11/1987	Krein et al.	5,592,566	A	1/1997	Pagallo et al.
4,723,056	A	2/1988	Tamaru et al.	5,594,806	A	1/1997	Colbert
4,733,222	A	3/1988	Evans	5,594,810	A	1/1997	Gourdol
4,734,685	A	3/1988	Watanabe	5,596,694	A	1/1997	Capps
4,740,781	A	4/1988	Brown	5,612,719	A	3/1997	Beernink et al.
4,746,770	A	5/1988	McAvinney	5,623,280	A	4/1997	Akins et al.
4,771,276	A	9/1988	Parks	5,631,805	A	5/1997	Bonsall
4,772,885	A	9/1988	Uehara et al.	5,633,955	A	5/1997	Bozinovic et al.
4,788,384	A	11/1988	Bruere-Dawson et al.	5,634,102	A	5/1997	Capps
4,806,709	A	2/1989	Evans	5,636,101	A	6/1997	Bonsall et al.
4,806,846	A	2/1989	Kerber	5,638,093	A	6/1997	Takahashi et al.
4,853,493	A	8/1989	Schlosser et al.	5,642,108	A	6/1997	Gopher et al.
4,898,555	A	2/1990	Sampson	5,644,657	A	7/1997	Capps et al.
4,910,504	A	3/1990	Eriksson	5,648,642	A	7/1997	Miller et al.
4,914,624	A	4/1990	Dunthorn	5,650,597	A	7/1997	Redmayne
4,916,308	A	4/1990	Meadows	5,666,113	A	9/1997	Logan
4,954,823	A	9/1990	Binstead	5,666,502	A	9/1997	Capps
4,968,877	A	11/1990	McAvinney et al.	5,666,552	A	9/1997	Greyson et al.
5,003,519	A	3/1991	Noirjean	5,675,361	A	10/1997	Santilli
5,017,030	A	5/1991	Crews	5,677,710	A	10/1997	Thompson-Rohrlich
5,062,198	A	11/1991	Sun	5,677,744	A	10/1997	Yoneda et al.
5,073,950	A	12/1991	Colbert et al.	5,686,973	A	11/1997	Lee
5,105,186	A	4/1992	May	5,689,253	A	11/1997	Hargreaves et al.
5,105,288	A	4/1992	Senda et al.	5,710,844	A	1/1998	Capps et al.
5,113,041	A	5/1992	Blonder et al.	5,729,250	A	3/1998	Bishop et al.
5,117,071	A	5/1992	Greanias et al.	5,730,165	A	3/1998	Philipp
5,178,477	A	1/1993	Gambaro	5,734,742	A	3/1998	Asaeda et al.
5,189,403	A	2/1993	Franz et al.	5,734,751	A	3/1998	Saito
5,194,862	A	3/1993	Edwards	5,736,976	A	4/1998	Cheung
5,224,861	A	7/1993	Glass et al.	5,741,990	A	4/1998	Davies
5,239,152	A	8/1993	Caldwell et al.	5,745,116	A	4/1998	Pisutha-Armond
5,241,308	A	8/1993	Young	5,745,716	A	4/1998	Tchao et al.
5,252,951	A	10/1993	Tannenbaum et al.	5,748,269	A	5/1998	Harris et al.
5,281,966	A	1/1994	Walsh	5,764,218	A	6/1998	Bona et al.
5,293,430	A	3/1994	Shiau et al.	5,764,818	A	6/1998	Capps et al.
5,305,017	A	4/1994	Gerpheide	5,767,457	A	6/1998	Gerpheide et al.
5,345,543	A	9/1994	Capps et al.	5,767,842	A	6/1998	Korth
5,353,135	A	10/1994	Edwards	5,777,596	A	7/1998	Herbert
5,374,787	A	12/1994	Miller et al.	5,790,104	A	8/1998	Shieh
5,376,948	A	12/1994	Roberts	5,790,106	A	8/1998	Hirano et al.
5,381,160	A	1/1995	Landmeier	5,790,107	A	8/1998	Kasser et al.
5,386,219	A	1/1995	Greanias et al.	5,802,516	A	9/1998	Shwartz et al.
5,392,058	A	2/1995	Tagawa	5,805,144	A	9/1998	Scholder et al.
5,398,310	A	3/1995	Tchao et al.	5,808,567	A	9/1998	McCloud
5,432,671	A	7/1995	Allavena	5,809,166	A	9/1998	Huang et al.
5,442,742	A	8/1995	Greyson et al.	5,809,267	A	9/1998	Moran et al.
5,457,289	A	10/1995	Huang et al.	5,815,141	A	9/1998	Phares
5,459,463	A	10/1995	Gruaz et al.	5,821,690	A	10/1998	Martens et al.
5,463,388	A	10/1995	Boie et al.	5,821,930	A	10/1998	Hansen
5,463,696	A	10/1995	Beernink et al.	5,823,782	A	10/1998	Marcus et al.
5,483,261	A	1/1996	Yasutake	5,825,351	A	10/1998	Tam
5,488,204	A	1/1996	Mead et al.	5,825,352	A	10/1998	Bisset et al.
5,495,077	A	2/1996	Miller et al.	5,835,079	A	11/1998	Shieh
5,499,026	A	3/1996	Liao et al.	5,838,308	A	11/1998	Knapp et al.
5,513,309	A	4/1996	Meier et al.	5,841,078	A	11/1998	Miller et al.
5,523,775	A	6/1996	Capps	5,841,415	A	11/1998	Kwon et al.
5,530,455	A	6/1996	Gillick et al.	5,844,506	A	12/1998	Binstead
5,534,892	A	7/1996	Tagawa	5,847,690	A	12/1998	Boie et al.
5,543,588	A	8/1996	Bisset et al.	5,852,487	A	12/1998	Fujimori et al.
				5,854,450	A	12/1998	Kent
				5,854,625	A	12/1998	Frisch et al.
				5,856,822	A	1/1999	Du et al.
				5,861,583	A	1/1999	Schediwy et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

5,861,875	A	1/1999	Gerpheide		
5,867,151	A	2/1999	Nakai		
5,869,790	A	2/1999	Shigetaka et al.		
5,869,791	A	2/1999	Young		
5,880,411	A	3/1999	Gillespie et al.		
5,898,434	A	4/1999	Small et al.		
5,914,465	A	6/1999	Allen et al.		
5,917,165	A	6/1999	Platt et al.		
5,920,298	A	7/1999	McKnight		
5,920,309	A	7/1999	Bisset et al.		
5,923,319	A	7/1999	Bishop et al.		
5,929,834	A	7/1999	Inoue et al.		
5,933,134	A	8/1999	Shieh		
5,940,055	A	8/1999	Lee		
5,940,064	A	8/1999	Kai et al.		
5,942,733	A	8/1999	Allen et al.		
5,943,043	A	8/1999	Furuhata et al.		
5,943,044	A	8/1999	Martinelli et al.		
5,945,980	A	8/1999	Moissev et al.		
5,952,998	A	9/1999	Clancy et al.		
5,955,198	A	9/1999	Hashimoto et al.		
5,982,352	A	11/1999	Pryor		
5,986,723	A *	11/1999	Nakamura et al.	349/39	
6,002,389	A	12/1999	Kasser		
6,002,808	A	12/1999	Freeman		
6,008,800	A	12/1999	Pryor		
6,020,881	A	2/2000	Naughton et al.		
6,020,945	A	2/2000	Sawai et al.		
6,023,265	A	2/2000	Lee		
6,028,581	A	2/2000	Umeya		
6,029,214	A	2/2000	Dorfman et al.		
6,031,524	A	2/2000	Kunert		
6,037,882	A	3/2000	Levy		
6,050,825	A	4/2000	Nichol et al.		
6,052,339	A	4/2000	Frenkel et al.		
6,057,903	A	5/2000	Colgan et al.		
6,061,177	A	5/2000	Fujimoto		
6,072,494	A	6/2000	Nguyen		
6,081,259	A	6/2000	Teterwak		
6,084,576	A	7/2000	Leu et al.		
6,107,654	A	8/2000	Yamazaki		
6,107,997	A	8/2000	Ure		
6,124,848	A	9/2000	Ballare et al.		
6,128,003	A	10/2000	Smith et al.		
6,131,299	A	10/2000	Raab et al.		
6,135,958	A	10/2000	Mikula-Curtis et al.		
6,137,427	A	10/2000	Binstead		
6,144,380	A	11/2000	Shwartz et al.		
6,163,313	A	12/2000	Aroyan et al.		
6,172,667	B1	1/2001	Sayag		
6,177,918	B1	1/2001	Colgan et al.		
6,188,391	B1	2/2001	Seely et al.		
6,191,828	B1	2/2001	Kim et al.		
6,198,515	B1	3/2001	Cole		
6,204,897	B1	3/2001	Colgan et al.		
6,208,329	B1	3/2001	Ballare		
6,211,585	B1	4/2001	Sato et al.		
6,222,465	B1	4/2001	Kumar et al.		
6,239,389	B1	5/2001	Allen et al.		
6,239,788	B1	5/2001	Nohno et al.		
6,239,790	B1	5/2001	Martinelli et al.		
6,243,071	B1	6/2001	Shwartz et al.		
6,246,862	B1	6/2001	Grivas et al.		
6,249,606	B1	6/2001	Kiraly et al.		
6,259,490	B1	7/2001	Colgan et al.		
6,271,835	B1	8/2001	Hoeksma		
6,285,428	B1	9/2001	Kim et al.		
6,288,707	B1	9/2001	Philipp		
6,289,326	B1	9/2001	LaFleur		
6,292,178	B1	9/2001	Bernstein et al.		
6,297,811	B1	10/2001	Kent		
6,310,610	B1	10/2001	Beaton et al.		
6,323,846	B1	11/2001	Westerman et al.		
6,323,849	B1	11/2001	He et al.		
6,337,678	B1	1/2002	Fish		
6,342,938	B1	1/2002	Song et al.		
6,347,290	B1	2/2002	Bartlett		
6,377,009	B1	4/2002	Philipp		
6,380,931	B1	4/2002	Gillespie et al.		
6,411,287	B1	6/2002	Scharff et al.		
6,414,671	B1	7/2002	Gillespie et al.		
6,417,846	B1	7/2002	Lee		
6,421,039	B1	7/2002	Moon et al.		
6,421,234	B1	7/2002	Ricks et al.		
6,425,289	B1	7/2002	Igel et al.		
6,452,514	B1	9/2002	Philipp		
6,457,355	B1	10/2002	Philipp		
6,459,424	B1	10/2002	Resman		
6,466,036	B1	10/2002	Philipp		
6,483,498	B1	11/2002	Colgan et al.		
6,501,528	B1	12/2002	Hamada		
6,501,529	B1	12/2002	Kurihara et al.		
6,504,530	B1	1/2003	Wilson et al.		
6,504,713	B1	1/2003	Pandolfi et al.		
6,515,669	B1	2/2003	Mohri		
6,522,772	B1	2/2003	Morrison et al.		
6,525,547	B2	2/2003	Hayes		
6,525,749	B1	2/2003	Moran et al.		
6,535,200	B2	3/2003	Philipp		
6,543,684	B1	4/2003	White et al.		
6,543,947	B2	4/2003	Lee		
6,549,193	B1	4/2003	Huang et al.		
6,570,557	B1	5/2003	Westerman et al.		
6,593,916	B1	7/2003	Aroyan		
6,602,790	B2	8/2003	Kian et al.		
6,610,936	B2	8/2003	Gillespie et al.		
6,624,833	B1	9/2003	Kumar et al.		
6,624,835	B2	9/2003	Willig		
6,628,268	B1	9/2003	Harada et al.		
6,639,577	B2	10/2003	Eberhard		
D482,368	S	11/2003	DenToonder et al.		
6,650,319	B1	11/2003	Hurst et al.		
6,658,994	B1	12/2003	McMillan		
6,670,894	B2	12/2003	Mehring		
6,677,932	B1	1/2004	Westerman		
6,677,934	B1	1/2004	Blanchard		
6,680,448	B2	1/2004	Kawashima et al.		
6,690,387	B2	2/2004	Zimmerman et al.		
6,721,375	B1	4/2004	Hammel		
6,723,929	B2	4/2004	Kent		
6,724,366	B2	4/2004	Crawford		
6,757,002	B1	6/2004	Oross et al.		
6,762,752	B2	7/2004	Perski et al.		
6,784,948	B2	8/2004	Kawashima et al.		
6,785,578	B2	8/2004	Johnson et al.		
6,803,906	B1	10/2004	Morrison et al.		
6,825,833	B2	11/2004	Mulligan et al.		
6,842,672	B1	1/2005	Straub et al.		
6,846,579	B2	1/2005	Anderson et al.		
6,856,259	B1	2/2005	Sharp		
6,876,355	B1	4/2005	Ahn et al.		
6,888,536	B2	5/2005	Westerman et al.		
6,900,795	B1	5/2005	Knight, III et al.		
6,906,692	B2	6/2005	Ishiyama		
6,924,789	B2	8/2005	Bick		
6,927,761	B2	8/2005	Badaye et al.		
6,927,763	B2	8/2005	LaMonica		
6,942,571	B1	9/2005	McAllister et al.		
6,943,779	B2	9/2005	Satoh		
6,961,049	B2	11/2005	Mulligan et al.		
6,965,375	B1	11/2005	Gettemy et al.		
6,970,160	B2	11/2005	Mulligan et al.		
6,972,401	B2	12/2005	Akitt et al.		
6,977,666	B1	12/2005	Hedrick		
6,982,432	B2	1/2006	Umemoto et al.		
6,985,801	B1	1/2006	Straub et al.		
6,992,659	B2	1/2006	Gettemy		
6,995,752	B2	2/2006	Lu		
7,015,894	B2	3/2006	Morohoshi		
7,023,427	B2	4/2006	Kraus et al.		
7,030,860	B1	4/2006	Hsu et al.		
7,031,228	B2	4/2006	Born et al.		
7,038,659	B2	5/2006	Rajkowski		
7,042,444	B2	5/2006	Cok		

(56)

References Cited

U.S. PATENT DOCUMENTS

7,046,235	B2	5/2006	Katoh	2003/0035479	A1	2/2003	Kan et al.
7,088,342	B2	8/2006	Rekimoto	2003/0067451	A1	4/2003	Tagg et al.
7,088,343	B2	8/2006	Smith	2003/0069653	A1	4/2003	Johnson et al.
7,098,127	B2	8/2006	Ito	2003/0076301	A1	4/2003	Tsuk et al.
7,098,897	B2	8/2006	Vakil et al.	2003/0076303	A1	4/2003	Huppi
7,109,978	B2	9/2006	Gillespie et al.	2003/0076306	A1	4/2003	Zadesky et al.
7,129,935	B2	10/2006	Mackey	2003/0085882	A1	5/2003	Lu
7,133,032	B2	11/2006	Cok	2003/0095095	A1	5/2003	Pihlaja
7,138,984	B1	11/2006	Miles	2003/0095096	A1	5/2003	Robbin et al.
7,151,528	B2	12/2006	Taylor et al.	2003/0098858	A1	5/2003	Perski et al.
7,154,481	B2	12/2006	Cross et al.	2003/0151600	A1	8/2003	Takeuchi et al.
7,177,001	B2	2/2007	Lee	2003/0174128	A1	9/2003	Matsufusa
7,184,064	B2	2/2007	Zimmerman et al.	2003/0179323	A1	9/2003	Abileah et al.
7,190,416	B2	3/2007	Paukshto et al.	2003/0201984	A1	10/2003	Falvo
7,202,856	B2	4/2007	Cok	2003/0206162	A1	11/2003	Roberts
7,230,608	B2	6/2007	Cok	2003/0206202	A1	11/2003	Moriya
7,254,775	B2	8/2007	Geaghan et al.	2003/0222857	A1	12/2003	Abileah
7,268,770	B1	9/2007	Takahata et al.	2003/0234768	A1	12/2003	Rekimoto et al.
7,274,353	B2	9/2007	Chiu et al.	2003/0234769	A1	12/2003	Cross et al.
7,280,167	B2	10/2007	Choi et al.	2003/0234770	A1	12/2003	MacKey
7,292,229	B2	11/2007	Morag et al.	2004/0022010	A1	2/2004	Shigetaka
7,307,231	B2	12/2007	Matsumoto et al.	2004/0056839	A1	3/2004	Yoshihara
RE40,153	E	3/2008	Westerman et al.	2004/0080501	A1	4/2004	Koyama
7,339,579	B2	3/2008	Richter et al.	2004/0090429	A1	5/2004	Geaghan et al.
7,355,592	B2	4/2008	Jong et al.	2004/0095335	A1	5/2004	Oh et al.
7,362,313	B2	4/2008	Geaghan et al.	2004/0109097	A1	6/2004	Mai
7,372,455	B2	5/2008	Perski et al.	2004/0119701	A1	6/2004	Mulligan et al.
7,379,054	B2	5/2008	Lee	2004/0141096	A1	7/2004	Mai
7,453,444	B2	11/2008	Geaghan	2004/0150629	A1	8/2004	Lee
7,463,246	B2	12/2008	Mackey	2004/0155871	A1	8/2004	Perski et al.
7,483,016	B1	1/2009	Gettemy et al.	2004/0155991	A1	8/2004	Lowles et al.
7,554,624	B2	6/2009	Kusuda et al.	2004/0165005	A1	8/2004	Yoshikawa et al.
7,633,484	B2	12/2009	Ito	2004/0183076	A1	9/2004	Yamazaki et al.
7,663,607	B2	2/2010	Hotelling et al.	2004/0188150	A1	9/2004	Richard et al.
7,688,315	B1	3/2010	Gettemy et al.	2004/0189587	A1	9/2004	Jung et al.
7,705,834	B2	4/2010	Swedin	2004/0189612	A1	9/2004	Bottari et al.
7,730,401	B2	6/2010	Gillespie et al.	2004/0217945	A1	11/2004	Miyamoto et al.
7,746,326	B2	6/2010	Sato	2004/0227736	A1	11/2004	Kamrath et al.
7,755,683	B2	7/2010	Sergio et al.	2004/0239650	A1	12/2004	Mackey
7,800,589	B2	9/2010	Hurst et al.	2004/0243747	A1	12/2004	Rekimoto
7,812,828	B2	10/2010	Westerman et al.	2004/0263484	A1	12/2004	Mantysalo et al.
7,843,439	B2	11/2010	Perski et al.	2005/0007349	A1	1/2005	Vakil et al.
7,920,129	B2	4/2011	Hotelling et al.	2005/0012723	A1	1/2005	Pallakoff
8,125,463	B2	2/2012	Hotelling et al.	2005/0017737	A1	1/2005	Yakabe et al.
8,243,027	B2	8/2012	Hotelling et al.	2005/0046621	A1	3/2005	Kaikuranta
8,259,078	B2	9/2012	Hotelling et al.	2005/0052425	A1	3/2005	Zadesky et al.
8,416,209	B2	4/2013	Hotelling et al.	2005/0052427	A1	3/2005	Wu et al.
8,432,371	B2	4/2013	Hotelling et al.	2005/0052582	A1	3/2005	Mai
8,479,122	B2	7/2013	Hotelling et al.	2005/0062620	A1	3/2005	Schaefer
8,493,330	B2	7/2013	Krah	2005/0073507	A1	4/2005	Richter et al.
8,552,989	B2	10/2013	Hotelling et al.	2005/0083307	A1	4/2005	Aufderheide et al.
8,605,051	B2	12/2013	Hotelling et al.	2005/0099402	A1	5/2005	Nakanishi et al.
8,654,083	B2	2/2014	Hotelling et al.	2005/0104867	A1	5/2005	Westerman et al.
2001/0000961	A1	5/2001	Hikida et al.	2005/0110768	A1	5/2005	Marriott et al.
2001/0020578	A1	9/2001	Baier	2005/0146511	A1	7/2005	Hill et al.
2001/0020986	A1	9/2001	Ikeda et al.	2005/0162402	A1	7/2005	Watanachote
2001/0020987	A1	9/2001	Ahn et al.	2005/0170668	A1	8/2005	Park et al.
2002/0015024	A1	2/2002	Westerman et al.	2005/0231487	A1	10/2005	Ming
2002/0041356	A1	4/2002	Tanada et al.	2005/0237439	A1	10/2005	Mai
2002/0049070	A1	4/2002	Bick	2005/0243023	A1	11/2005	Reddy et al.
2002/0084922	A1	7/2002	Yagi	2006/0007087	A1	1/2006	Choi et al.
2002/0089496	A1	7/2002	Numao	2006/0007165	A1	1/2006	Yang et al.
2002/0101410	A1	8/2002	Sakata et al.	2006/0012575	A1	1/2006	Knapp et al.
2002/0118848	A1	8/2002	Karpenstein	2006/0017710	A1	1/2006	Lee et al.
2002/0140649	A1	10/2002	Aoyama et al.	2006/0022955	A1	2/2006	Kennedy
2002/0159015	A1	10/2002	Seo et al.	2006/0022956	A1	2/2006	Lengeling et al.
2002/0167489	A1	11/2002	Davis	2006/0026521	A1	2/2006	Hotelling et al.
2002/0185981	A1	12/2002	Dietz et al.	2006/0026535	A1	2/2006	Hotelling et al.
2002/0185999	A1	12/2002	Tajima et al.	2006/0026536	A1	2/2006	Hotelling et al.
2002/0186210	A1	12/2002	Itoh	2006/0032680	A1	2/2006	Elias et al.
2002/0190964	A1	12/2002	Van Berkel	2006/0033724	A1	2/2006	Chaudhri et al.
2002/0191029	A1	12/2002	Gillespie et al.	2006/0044259	A1	3/2006	Hotelling et al.
2002/0192445	A1	12/2002	Ezzell et al.	2006/0053387	A1	3/2006	Ording
2002/0196237	A1	12/2002	Fernando et al.	2006/0066582	A1	3/2006	Lyon et al.
2003/0006974	A1	1/2003	Clough et al.	2006/0085757	A1	4/2006	Andre et al.
				2006/0109222	A1	5/2006	Lee et al.
				2006/0132462	A1	6/2006	Geaghan
				2006/0145365	A1	7/2006	Halls et al.
				2006/0145983	A1	7/2006	Lee et al.

(56)

References Cited

FOREIGN PATENT DOCUMENTS

U.S. PATENT DOCUMENTS					
2006/0146033	A1	7/2006	Chen et al.	CN	1867882 A
2006/0146034	A1	7/2006	Chen et al.	DE	197 06 168 A1
2006/0197753	A1	9/2006	Hotelling	DE	102 51 296 A1
2006/0227114	A1	10/2006	Geaghan et al.	EP	0 156 593 A2
2006/0232564	A1	10/2006	Nishimura et al.	EP	0 156 593 A3
2006/0232567	A1	10/2006	Westerman et al.	EP	0 250 931 A2
2006/0238517	A1	10/2006	King et al.	EP	0 250 931 A3
2006/0238518	A1	10/2006	Westerman et al.	EP	0 250 931 B1
2006/0238519	A1	10/2006	Westerman et al.	EP	0 464 908 A2
2006/0238520	A1	10/2006	Westerman et al.	EP	0 464 908 A3
2006/0238521	A1	10/2006	Westerman et al.	EP	0 464 908 B1
2006/0238522	A1	10/2006	Westerman et al.	EP	0 288 692 A2
2006/0244736	A1	11/2006	Tseng	EP	0 288 692 A3
2006/0278444	A1	12/2006	Binstead	EP	0 288 692 B1
2006/0279679	A1	12/2006	Fujisawa et al.	EP	0 664 504 A2
2006/0290863	A1	12/2006	HoeSup	EP	0 786 745 A2
2007/0013678	A1	1/2007	Nakajima et al.	EP	0 786 745 A3
2007/0018969	A1	1/2007	Chen et al.	EP	0 786 745 B1
2007/0027932	A1	2/2007	Thibeault	EP	0 932 117 A2
2007/0062739	A1	3/2007	Philipp et al.	EP	0 932 117 A3
2007/0075977	A1	4/2007	Chen et al.	EP	0 932 117 B1
2007/0085838	A1	4/2007	Ricks et al.	EP	0 973 123 A1
2007/0109274	A1	5/2007	Reynolds	EP	1 014 295 A2
2007/0152976	A1	7/2007	Townsend et al.	EP	1 014 295 A3
2007/0159561	A1	7/2007	Chien	EP	1 211 633 A1
2007/0176905	A1	8/2007	Shih et al.	EP	1 211 633 B1
2007/0182706	A1	8/2007	Cassidy et al.	EP	1 322 104 A1
2007/0216657	A1	9/2007	Konicek	EP	1 391 807 A1
2007/0229464	A1	10/2007	Hotelling et al.	EP	1 396 812 A2
2007/0236466	A1	10/2007	Hotelling	EP	1 396 812 A3
2007/0247429	A1	10/2007	Westerman	EP	1 418 491 A2
2007/0257890	A1	11/2007	Hotelling et al.	EP	1 418 491 A3
2007/0262967	A1	11/2007	Rho	EP	1 422 601 A1
2008/0048994	A1	2/2008	Lee et al.	EP	1 455 264 A2
2008/0055221	A1	3/2008	Yabuta et al.	EP	1 455 264 A3
2008/0055268	A1	3/2008	Yoo et al.	EP	2 214 084 A
2008/0055270	A1	3/2008	Cho et al.	GB	1 486 988 A
2008/0062139	A1	3/2008	Hotelling et al.	GB	2 168 816 A
2008/0062140	A1	3/2008	Hotelling et al.	GB	2 368 483 A
2008/0062147	A1	3/2008	Hotelling et al.	JP	53-147626 A
2008/0062148	A1	3/2008	Hotelling et al.	JP	58-166430 A
2008/0067528	A1	3/2008	Choi et al.	JP	59-214941 A
2008/0074401	A1	3/2008	Chung et al.	JP	60-123927 A
2008/0079697	A1	4/2008	Lee et al.	JP	60-211529 A
2008/0129317	A1	6/2008	Oba	JP	61-131314 A
2008/0129898	A1	6/2008	Moon	JP	63-279316 A
2008/0131624	A1	6/2008	Egami et al.	JP	02-030024 A
2008/0136980	A1	6/2008	Rho et al.	JP	03-180922 A
2008/0150901	A1	6/2008	Lowles et al.	JP	03-294918 A
2008/0157867	A1	7/2008	Krah	JP	04-127314 A
2008/0158167	A1	7/2008	Hotelling et al.	JP	05-080923 A
2008/0158181	A1	7/2008	Hamblin et al.	JP	05-224818 A
2008/0165158	A1	7/2008	Hotelling et al.	JP	06-161661 A
2008/0186288	A1*	8/2008	Chang	JP	07-036017 A
2008/0297476	A1	12/2008	Hotelling et al.	JP	07-044305 A
2009/0066670	A1	3/2009	Hotelling et al.	JP	07-110741 A
2009/0090694	A1	4/2009	Hotelling et al.	JP	07-141086 A
2009/0096757	A1	4/2009	Hotelling et al.	JP	08-016307 A
2009/0096758	A1	4/2009	Hotelling et al.	JP	08-147092 A
2009/0115743	A1	5/2009	Oowaki	JP	08-242458 A
2009/0160816	A1	6/2009	Westerman et al.	JP	08-297267 A
2009/0273581	A1	11/2009	Kim et al.	JP	09-054650 A
2009/0303193	A1	12/2009	Lim et al.	JP	09-096792 A
2010/0066650	A1	3/2010	Lee et al.	JP	09-212302 A
2010/0103121	A1	4/2010	Kim et al.	JP	09-292950 A
2010/0182273	A1	7/2010	Noguchi et al.	JP	10-003349 A
2010/0188347	A1	7/2010	Mizuhashi et al.	JP	11-505641 A
2010/0194698	A1	8/2010	Hotelling et al.	JP	2000-105670 A
2010/0238134	A1	9/2010	Day et al.	JP	2000-112642 A
2010/0289770	A1	11/2010	Lee et al.	JP	2000-163031 A
2011/0187677	A1	8/2011	Hotelling	JP	2000-172437 A
2012/0105371	A1	5/2012	Hotelling et al.	JP	2000-172447 A
2012/0162584	A1	6/2012	Chang	JP	2000-221932 A
2012/0268423	A1	10/2012	Hotelling et al.	JP	2001-283228 A
2013/0106780	A1	5/2013	Hotelling et al.	JP	2002-501271 A
				JP	2002-116017 A
				JP	2002-259052 A

(56)

References Cited

FOREIGN PATENT DOCUMENTS

JP	2002-287660	A	10/2002
JP	2002-342014	A	11/2002
JP	2002-342033	A	11/2002
JP	2002-366304	A	12/2002
JP	2003-029899	A	1/2003
JP	2003-099192	A	4/2003
JP	2003-173237	A	6/2003
JP	2003-185688	A	7/2003
JP	2003-196023	A	7/2003
JP	2003-249738	A	9/2003
JP	2003-255855	A	9/2003
JP	2004-038919	A	2/2004
JP	2004-102985	A	4/2004
JP	2004-186333	A	7/2004
JP	2005-346047	A	12/2005
JP	2007-533044	T	11/2007
JP	2008-032756	A	2/2008
JP	2009-244958	A	10/2009
KR	10-0226812	B1	7/1999
TW	200302778	A	8/2003
TW	200529441	A	9/2005
WO	WO-87/04553	A1	7/1987
WO	WO-92/13328	A1	8/1992
WO	WO-96/15464	A1	5/1996
WO	WO-96/18179	A1	6/1996
WO	WO-97/18547	A1	5/1997
WO	WO-97/23738	A1	7/1997
WO	WO-98/14863	A1	4/1998
WO	WO-99/38149	A1	7/1999
WO	WO-01/27868	A1	4/2001
WO	WO-03/079176	A1	9/2003
WO	WO-03/088176	A1	10/2003
WO	WO-2004/013833	A2	2/2004
WO	WO-2004/013833	A3	2/2004
WO	WO-2004/023376	A2	3/2004
WO	WO-2004/023376	A3	3/2004
WO	WO-2004/053576	A1	6/2004
WO	WO-2004/061808	A2	7/2004
WO	WO-2004/061808	A3	7/2004
WO	WO-2004/114265	A2	12/2004
WO	WO-2005/064451	A1	7/2005
WO	WO-2005/114369	A2	12/2005
WO	WO-2006/023569	A1	3/2006
WO	WO-2006/054585	A1	5/2006
WO	WO-2007/115032	A2	10/2007
WO	WO-2007/115032	A3	10/2007
WO	WO-2007/146779	A2	12/2007
WO	WO-2007/146779	A3	12/2007
WO	WO-2007/146780	A2	12/2007
WO	WO-2007/146780	A3	12/2007
WO	WO-2007/146783	A2	12/2007
WO	WO-2007/146783	A3	12/2007
WO	WO-2007/146785	A2	12/2007
WO	WO-2007/146785	A3	12/2007
WO	WO-2008/085457	A2	7/2008
WO	WO-2008/085457	A3	7/2008
WO	WO-2009/035471	A1	3/2009
WO	WO-2010/137727	A1	2/2010

OTHER PUBLICATIONS

Lee, S.K. et al. (Apr. 1985). "A Multi-Touch Three Dimensional Touch-Sensitive Tablet," *Proceedings of CHI: ACM Conference on Human Factors in Computing Systems*, pp. 21-25.

Rubine, D.H. (Dec. 1991). "The Automatic Recognition of Gestures," CMU-CS-91-202, Submitted in Partial Fulfillment of the Requirements of the Degree of Doctor of Philosophy in Computer Science at Carnegie Mellon University, 285 pages.

Rubine, D.H. (May 1992). "Combining Gestures and Direct Manipulation," CHI '92, pp. 659-660.

Westerman, W. (Spring 1999). "Hand Tracking, Finger Identification, and Chordic Manipulation on a Multi-Touch Surface," A Dissertation Submitted to the Faculty of the University of Delaware in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Electrical Engineering, 364 pages.

"Gesture Recognition," (2006). Located at <http://www.fingerworks.com/gesture_recognition.html>, last visited Jul. 25, 2006, two pages.

3M (2002). MicroTouch Capacitive Touch Screens Datasheets, 3M Innovation, six pages.

Agrawal, R. et al. (Jul. 1986). "An Overview of Tactile Sensing," Center For Research on Integrated Manufacturing: Robot Systems Division, The University of Michigan, 47 pages.

Anonymous. (May 8, 1992). "The Sensor Frame Graphic Manipulator," *NASA Phase II Final Report*, 28 pages.

Anonymous. (Oct. 30, 2001). "Radiotelephone with Rotating Symbol Keypad and Multi-Directional Symbol Input," located at www.vitgn.com/mobile_terminal.com, 12 pages.

Anonymous. "4-Wire Resistive Touchscreens" obtained from <http://www.touchscreens.com/intro-touchtypes-4resistive.html> generated Aug. 5, 2005.

Anonymous. "5-Wire Resistive Touchscreens" obtained from <http://www.touchscreens.com/intro-touchtypes-resistive.html> generated Aug. 5, 2005.

Anonymous. "A Brief Overview of Gesture Recognition" obtained from http://www.Dai.Ed.Ac.uk/Cvonline/LOCA_COPIES/COHEN/gesture_overview.html, generated Apr. 20, 2004.

Anonymous. "Capacitive Position Sensing" obtained from <http://www.synaptics.com/technology/cps.cfm> generated Aug. 5, 2005.

Anonymous. "Capacitive Touchscreens" obtained from <http://www.touchscreens.com/intro-touchtypes-capacitive.html> generated Aug. 5, 2005.

Anonymous. "Comparing Touch Technologies" obtained from <http://www.touchscreens.com/intro-touchtypes.html> generated Oct. 10, 2004.

Anonymous. "FingerWorks—Gesture Guide—Application Switching," obtained from http://www.fingerworks.com/gesture_guide_apps.html generated on Aug. 27, 2004, 1-pg.

Anonymous. "FingerWorks—Gesture Guide—Editing," obtained from http://www.fingerworks.com/gesture_guide_editing.html, generated on Aug. 27, 2004, 1-pg.

Anonymous. "FingerWorks—Gesture Guide—File Operations," obtained from http://www.fingerworks.com/gesture_guide_files.html, generated on Aug. 27, 2004, 1-pg.

Anonymous. "FingerWorks—Gesture Guide—Text Manipulation," obtained from http://www.fingerworks.com/gesture_guide_text_manip.html, generated on Aug. 27, 2004, 2-pg.

Anonymous. "FingerWorks—Gesture Guide—Tips and Tricks," obtained from http://www.fingerworks.com/gesture_guide_tips.html, generated Aug. 27, 2004, 2-pgs.

Anonymous. "FingerWorks—Gesture Guide—Web," obtained from http://www.fingerworks.com/gesture_guide_web.html, generated on Aug. 27, 2004, 1-pg.

Anonymous. "FingerWorks—Guide to Hand Gestures for USB Touchpads," obtained from http://www.fingerworks.com/igesture_userguide.html, generated Aug. 27, 2004, 1-pg.

Anonymous. "FingerWorks—iGesture—Technical Details," obtained from http://www.fingerworks.com/igesture_tech.html, generated Aug. 27, 2004, 1-pg.

Anonymous. "FingerWorks—The Only Touchpads with Ergonomic Full-Hand Resting and Relaxation!" obtained from <http://www.fingerworks.com/resting.html>, Copyright 2001, 1-pg.

Anonymous. "FingerWorks—Tips for Typing on the Mini," obtained from http://www.fingerworks.com/mini_typing.html, generated on Aug. 27, 2004, 2-pgs.

Anonymous. "GlidePoint®" obtained from http://www.cirque.com/technology/technology_gp.html generated Aug. 5, 2005.

Anonymous. "How do touchscreen monitors know where you're touching?" obtained from <http://www.electronics.howstuffworks.com/question716.html> generated Aug. 5, 2005.

Anonymous. "How does a touchscreen work?" obtained from <http://www.touchscreens.com/intro-anatomy.html> generated Aug. 5, 2005.

Anonymous. "iGesture Pad—the MultiFinger USB TouchPad with Whole-Hand Gestures," obtained from <http://www.fingerworks.com/igesture.html>, generated Aug. 27, 2004, 2-pgs.

Anonymous. "iGesture Products for Everyone (learn in minutes) Product Overview" FingerWorks.com downloaded Aug. 30, 2005.

(56)

References Cited

OTHER PUBLICATIONS

- Anonymous. "Infrared Touchscreens" obtained from <http://www.touchscreens.com/intro-touchtypes-infrared.html> generated Aug. 5, 2005.
- Anonymous. "Mouse Emulation" FingerWorks obtained from http://www.fingerworks.com/gesture_guide_mouse.html generated Aug. 30, 2005.
- Anonymous. "Mouse Gestures in Opera" obtained from <http://www.opera.com/products/desktop/mouse/index.dml> generated Aug. 30, 2005.
- Anonymous. "Mouse Gestures," Optim oz, May 21, 2004.
- Anonymous. "MultiTouch Overview" FingerWorks obtained from <http://www.fingerworks.com/multoverview.html> generated Aug. 30, 2005.
- Anonymous. "Near Field Imaging Touchscreens" obtained from <http://www.touchscreens.com/intro-touchtypes-nfi.html> generated Aug. 5, 2005.
- Anonymous. "PenTouch Capacitive Touchscreens" obtained from <http://www.touchscreens.com/intro-touchtypes-pentouch.html> generated Aug. 5, 2005.
- Anonymous. "Surface Acoustic Wave Touchscreens" obtained from <http://www.touchscreens.com/intro-touchtypes-saw.html> generated Aug. 5, 2005.
- Anonymous. "Symbol Commander" obtained from <http://www.sensiva.com/symbolcommander/>, generated Aug. 30, 2005.
- Anonymous. "Touch Technologies Overview" 2001, 3M Touch Systems, Massachusetts.
- Anonymous. "Touchscreen Technology Choices," <<http://www.elotouch.com/products/detech2.asp>>, downloaded Aug. 5, 2005.
- Anonymous. "Wacom Components—Technology" obtained from <http://www.wacom-components.com/english/tech.asp> generated on Oct. 10, 2004.
- Anonymous. "Watershed Algorithm" <http://rsb.info.nih.gov/ij/plugins/watershed.html> generated Aug. 5, 2005.
- Baxter, L.K. (1996). *Capacitive Sensors: Design and Applications*, vol. 1 of IEEE Press Series on Electronics Technology, John Wiley & Sons: New York, NY, (Table of Contents Only) three pages.
- Bennion, S.I. et al. (Dec. 1981). "Touch Sensitive Graphics Terminal Applied to Process Control," *Computer Graphics* 15(4):342-350.
- Bier et al., "Toolglass and Magic Lenses: The see-through interface" In James Kijiya, editor, *Computer Graphics (SIGGRAPH '93 Proceedings)*, vol. 27, pp. 73-80, Aug. 1993.
- Boie, R.A. (Mar. 1984). "Capacitive Impedance Readout Tactile Image Sensor," *Proceedings of 1984 IEEE International Conference on Robotics and Automation*, pp. 370-378.
- Buxton, W.A.S. (Mar./Apr. 1994). "Combined Keyboard/Touch Tablet Input Device," *XEROX Disclosure Journal* 19(2):109-111.
- Chun, K. et al. (Jul. 1985). "A High-Performance Silicon Tactile Imager Based on a Capacitive Cell," *IEEE Transactions on Electron Devices* 32(7):1196-1201.
- Cliff (Jul. 24, 2002). "Building a Pressure-Sensitive, Multi-Point TouchScreen?" Posted from the D-I-Y-Baby Department, one page.
- Collberg, C. et al. (2002). "TetraTetris: A Study of Multi-User Touch-Based Interaction Using DiamondTouch," located at cs.arizona.edu, eight pages.
- Dannenberg, R.B. et al. (1989). "A Gesture Based User Interface Prototyping System," *ACM*, pp. 127-132.
- Davies, E.R. (Aug. 1987). "Lateral Histograms for Efficient Object Location: Speed versus Ambiguity," *Pattern Recognition Letters* 6(3):189-198.
- Davies, E.R. (1990). *Machine Vision: Theory, Algorithms, Practicalities*, Academic Press, Inc.: San Diego CA, pp. xi-xxi (Table of Contents Only).
- Davies, E.R. (1997). "Boundary Pattern Analysis," Chapter 7 in *Machine Vision: Theory, Algorithms, Practicalities*, 2nd Edition, Academic Press, Inc.: San Diego, CA, pp. 171-191.
- Davies, E.R. (1997). "Ellipse Detection," Chapter 11 in *Machine Vision: Theory, Algorithms, Practicalities*, 2nd Edition, Academic Press, Inc.: San Diego, CA, pp. 271-290.
- Davies, E.R. (1997). "Image Acquisition," in *Machine Vision: Theory, Algorithms, Practicalities*, 2nd Edition, Academic Press, Inc.: San Diego, CA, pp. 583-601.
- Diaz-Marino, R.A. et al. (2003). "Programming for Multiple Touches and Multiple Users: A Toolkit for the DiamondTouch Hardware," *Proceedings of ACM UIST'03 User Interface Software and Technology*, two pages.
- Dietz, P. et al. (2001). "DiamondTouch: A Multi-User Touch Technology," *Proceedings of the 14th Annual ACM Symposium on User Interface Software and Technology*, Nov. 11-14, 2001, Orlando, FL, pp. 219-226.
- Douglas et al., *The Ergonomics of Computer Pointing Devices* (1997).
- Esenher, A. et al. (Nov. 2002). "DiamondTouch SDK: Support for Multi-User, Multi-Touch Applications," *Mitsubishi Electric Research Laboratories, Inc.*, five pages.
- European Search Report mailed Feb. 16, 2012, for EP Application No. 11183531.0, 11 pages.
- European Search Report mailed Mar. 27, 2012, for EP Application No. 10178558.2, nine pages.
- European Search Report received in EP 1 621 989 (@ Beyer Weaver & Thomas, LLP) dated Mar. 27, 2006.
- EVN Elektronik "TSOP6238 IR Receiver Modules for Infrared Remote Control Systems" dated Jan. 2004 1-pg.
- Fearing, R.S. (Jun. 1990). "Tactile Sensing Mechanisms," *The International Journal of Robotics Research* 9(3):3-23.
- Final Office Action mailed Sep. 1, 2011, for U.S. Appl. No. 11/650,203, filed Jan. 3, 2007, nine pages.
- Final Office Action mailed Oct. 17, 2011, for U.S. Appl. No. 11/818,395, filed Jun. 13, 2007, 16 pages.
- Fisher et al., "Repetitive Motion Disorders: The Design of Optimal Rate-Rest Profiles," *Human Factors*, 35(2):283-304 (Jun. 1993).
- Fukumoto and Yoshinobu Tonomura, "Body Coupled Fingering: Wireless Wearable Keyboard," *CHI97*, pp. 147-154 (Mar. 1997).
- Fukumoto et al., "ActiveClick: Tactile Feedback for Touch Panels," In *CHI 2001 Summary*, pp. 121-122, 2001.
- Hardy, "Fingerworks" Mar. 7, 2002; BBC World On Line.
- Hillier and Gerald J. Lieberman, *Introduction to Operations Research* (1986).
- Hinckley et al., "Touch-Sensing Input Devices," in *CHI '99 Proceedings*, pp. 223-230, 1999.
- Hinckley, K. et al. (1998). "Interaction and Modeling Techniques for Desktop Two-Handed Input," *Proceedings of ACM UIST'98 Symposium on User Interface Software and Technology*, pp. 49-58.
- Hinckley, K. et al. (May 1999). "Touch-Sensing Input Devices," *CHI 99* pp. 223-230.
- Hinckley, K. et al. (2000). "Sensing Techniques for Mobile Interaction," *CHI Letters* 2(2):91-100.
- Hlady, A.M. (1969). "A Touch Sensitive X-Y Position Encoder for Computer Input," *Fall Joint Computer Conference*, pp. 545-551.
- Hotelling et al., Office action for U.S. Appl. No. 10/840,862 mailed May 14, 2008.
- International Search Report dated Mar. 3, 2006 (PCT/US 05/03325; 119-0052W0).
- International search report for International Application No. PCT/US2005/014364 mailed Jan. 12, 2005.
- International Search Report mailed Jun. 24, 2008, for PCT Application No. PCT/US2007/026298, filed Dec. 21, 2007, two pages.
- International Search Report mailed Oct. 16, 2008, for PCT Application No. PCT/US2007/088749, filed Dec. 21, 2007, four pages.
- International Search Report received in corresponding PCT application No. PCT/US2006/008349 dated Oct. 6, 2006.
- Jacob et al., "Integrality and Separability of Input Devices," *ACM Transactions on Computer-Human Interaction*, 1:3-26 (Mar. 1994).
- Kionx "KXP84 Series Summary Data Sheet" copyright 2005, dated Oct. 21, 2005, 4-pgs.
- Kirk, D.E. (1970). "Numerical Determination of Optimal Trajectories," Chapter 6 in *Optimal Control Theory: An Introduction*, Prentice Hall, Inc.: Englewood Cliffs, NY, pp. 329-413, with Table of Contents, pp. vii-ix, (90 pages total).

(56)

References Cited

OTHER PUBLICATIONS

- Kling, M. et al. (Sep. 2003). "Interface Design: LCD Touch Interface for ETRAX 100LX," Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science, UMEA University, Umea, Sweden, 79 pages.
- Ko, H. (Jul. 2000). "Open Systems Advanced Workstation Transition Report," Technical Report 1822, U.S. Navy, SSC San Diego, CA, 82 pages.
- Krein, P. et al. (May/Jun. 1990). "The Electroquasistatics of the Capacitive Touch Panel," *IEEE Transactions on Industry Applications* 26(3):529-534.
- Krueger, M. et al. (Jun. 10, 1988). "Videoplace, Responsive Environment, 1972-1990," located at <http://www.youtube.com/watch?v=dmmxVA5xhuo>, last visited Aug. 5, 2011, two pages.
- Lee, "A Fast Multiple-Touch-Sensitive Input Device," Master's Thesis, University of Toronto. (1984).
- Leigh, J. et al. (2002). "Amplified Collaboration Environments," *VizGrid Symposium*, Nov. 2002, Tokyo, Japan, nine pages.
- Ljungstrand, P. et al. eds. (2002). UBICOMP2002, Adjunct Proceedings, 4th International Conference on Ubiquitous Computing, Sep. 29-Oct. 1, 2002, Goteborg, Sweden, 90 pages.
- Magerkurth, C. et al. (2004). "Towards the Next Generation of Tabletop Gaming Experiences," *Graphics Interface 2004 (GI'04)*, May 17-19, 2004, Ontario, Canada, pp. 1-8.
- Malik, S. et al. (2004). "Visual Touchpad: A Two-Handed Gestural Input Device," *ICMI'04 Proceedings of the 6th International Conference on Multimodal Intercases*, ACM, 8 pages.
- Matsushita et al., "HoloWall: Designing a Finger, Hand, Body and Object Sensitive Wall," In Proceedings of UIST '97, Oct. 1997.
- Matsushita, N. et al. (2000). "Dual Touch: A Two-Handed Interface for Pen-Based PDAs," *CHI Letters* 2(2):211-212.
- McMillan, G.R. (Oct. 1998). "The Technology and Applications of Gesture-Based Control," presented at the *RTO Lecture Series on Alternative Control Technologies: Human Factor Issues*, Oct. 14-15, 1998, Ohio, USA, pp. 4-14-11.
- Mehta, N. et al. (May 1982). "Feature Extraction as a Tool for Computer Input," *Proceedings of ICASSP '82*, May 3-5, 1982, Paris, France, pp. 818-820.
- Mitchell, G. D. (Oct. 2003). "Orientation on Tabletop Displays," Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science, Simon Fraser University, 119 pages.
- Noda, K. et al. (2001). "Production of Transparent Conductive Films with Inserted SiO₂ Anchor Layer, and Application to a Resistive Touch Panel," *Electronics and Communications in Japan Part 2* 84(7):39-45.
- Non-Final Office Action mailed May 14, 2008, for U.S. Appl. No. 10/840,862, filed May 6, 2004, six pages.
- Non-Final Office Action mailed Dec. 24, 2008, for U.S. Appl. No. 10/840,862, filed May 6, 2004, nine pages.
- Non-Final Office Action mailed Jun. 2, 2009, for U.S. Appl. No. 10/840,862, filed May 6, 2004, seven pages.
- Non-Final Office Action mailed Nov. 12, 2009, for U.S. Appl. No. 10/840,862, filed May 6, 2004, eight pages.
- Non-Final Office Action mailed Jun. 21, 2010, for U.S. Appl. No. 11/650,203, filed Jan. 3, 2007, eight pages.
- Non-Final Office Action mailed Jan. 25, 2011, for U.S. Appl. No. 11/818,395, filed Jun. 13, 2007, 31 pages.
- Non-Final Office Action mailed Mar. 14, 2011, for U.S. Appl. No. 11/650,203, filed Jan. 3, 2007, nine pages.
- Non-Final Office Action mailed May 13, 2011, for U.S. Appl. No. 12/267,540, filed Nov. 7, 2008, seven pages.
- Non-Final Office Action mailed Jul. 8, 2011, for U.S. Appl. No. 12/267,532, filed Nov. 7, 2008, five pages.
- Non-Final Office Action mailed Jul. 14, 2011, for U.S. Appl. No. 12/267,522, filed Nov. 7, 2008, six pages.
- Non-Final Office Action mailed Jun. 20, 2012, for U.S. Appl. No. 13/345,347, filed Jan. 6, 2012, five pages.
- Non-Final Office Action mailed Sep. 12, 2012, for U.S. Appl. No. 11/650,203, filed Jan. 3, 2007, nine pages.
- Notice of Allowance mailed Oct. 25, 2011, for U.S. Appl. No. 12/267,540, filed Nov. 7, 2008, seven pages.
- Notice of Allowance mailed Sep. 19, 2012, for U.S. Appl. No. 13/345,347, filed Jan. 6, 2012, seven pages.
- Ogawa, H. et al. (1979). "Preprocessing for Chinese Character Recognition and Global Classification of Handwritten Chinese Characters," *Pattern Recognition* 11:1-7.
- Phipps, C.A. (Spring 2003). "A Metric to Measure Whole Keyboard Index of Difficulty Based on Fitts' Law," A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Ph.D., 103 pages.
- Quantum Research Group Ltd. (1997). QT9701B2 Datasheet, 30 pages.
- Quantum Research Group Ltd. (1999). QProx™ QT60320 32-Key Qmatrix™ Charge-Transfer IC Datasheet, pp. 1-14.
- Quantum Research Group Ltd. (2001). QT60325, QT60485, QT60645 32, 48, 64 Key QMatrix™ Keypad Sensor Ics Datasheet, 42 pages.
- Quantum Research Group Ltd. (2002). QMatrix™ QT60040 4-Key Charge-Transfer IC Datasheet, pp. 1-9.
- Quantum Research Group Ltd. (Oct. 10, 2002). Quantum Research Application Note AN-KD01: Qmatrix™ Panel Design Guidelines, four pages.
- Quantum Research Group "QT510 / Qwheel™ Touch Slider IC" copyright 2004-2005, 14-pgs.
- Quek, "Unencumbered Gestural Interaction," *IEEE Multimedia*, 3:36-47 (Winter 1996).
- Rabuffetti, M. (2002). "Touch-screen System for Assessing Visuomotor Exploratory Skills in Neuropsychological Disorders of Spatial Cognition," *Medical & Biological Engineering & Computing* 40:675-686.
- Radwin, "Activation Force and Travel Effects on Overexertion in Repetitive Key Tapping," *Human Factors*, 39(1):130-140 (Mar. 1997).
- Raisamo, R. (Dec. 7, 1999). "Multimodal Human-Computer Interaction: A Constructive and Empirical Study," Dissertation, University of Tampere, Finland, 86 pages.
- Rekimoto et al., "ToolStone: Effective Use of the Physical Manipulation Vocabularies of Input Devices," In Proc. Of UIST 2000, 2000.
- Rekimoto, J. (2002). "SmartSkin: An Infrastructure for Freehand Manipulation on Interactive Surfaces," *CHI 2002*, Apr. 20-25, 2002. [(Apr. 25, 2002). 4(1):113-120.].
- Rekimoto, J. et al. (2003). "Pre-Sense: Interaction Techniques for Finger Sensing Input Devices," *CHI Letters* 5(2):203-212.
- Rong, J. et al. (2002). "AIAA 2002-4553: Hierarchical Agent Based System for General Aviation CD&R Under Free Flight," *AIAA Guidance, Navigation, and Control Conference and Exhibit*, Aug. 5-8, 2002, Monterey, CA, pp. 1-11.
- Rubine et al., "Programmable Finger-Tracking Instrument Controllers," *Computer Music Journal*, vol. 14, No. 1 (Spring 1990).
- Rubine, D. (Jul. 1991). "Specifying Gestures by Example," *Computer Graphics* 25(4):329-337.
- Rubine, D. et al. (1988). "The VideoHarp," *Proceedings of the 14th International Computer Music Conference*, Cologne, W. Germany, Sep. 20-25, 1988, pp. 49-55.
- Rubine, D. et al. (1991). "The Videoharp: An Optical Scanning MIDI Controller," *Contemporary Music Review* 6(1):31-46.
- Russell, D.M. et al. (2004). "The Use Patterns of Large, Interactive Display Surfaces: Case Studies of Media Design and use for BlueBoard and MERBoard," *Proceedings of the 37th Hawaii International Conference on System Sciences* 2004, IEEE, pp. 1-10.
- Rutledge et al., "Force-To-Motion Functions for Pointing," *Human-Computer Interaction—INTERACT* (1990).
- Sears, A. (Mar. 11, 1991). "Improving Touchscreen Keyboards: Design Issues and a Comparison with Other Devices," *Human-Computer Interaction Laboratory*, pp. 1-19.
- Sears, A. et al. (Jun. 1990). "A New Era for High-Precision Touchscreens," *Advances in Human-Computer Interaction*, vol. 3, Tech Report HCIL-90-01, one page only.
- Segen, J. et al. (1998). "Human-Computer Interaction Using Gesture Recognition and 3D Hand Tracking," *IEEE*, pp. 188-192.

(56)

References Cited

OTHER PUBLICATIONS

- Shen, C. et al. (Jan. 2004). "DiamondSpin: An Extensible Toolkit for Around-the-Table Interaction," *CHI 2004*, Apr. 24-29, 2004, Vienna, Austria, 10 pgs.
- Siegel, D.M. et al. (1987). "Performance Analysis of a Tactile Sensor," *IEEE*, pp. 1493-1499.
- Singapore Examination Report mailed Jan. 11, 2010, for SG Patent Application No. 0607116-1, five pages.
- Son, J.S. et al. (1996). "Comparison of Contact Sensor Localization Abilities During Manipulation," *Robotics and Autonomous System* 17 pp. 217-233.
- Stansfield, S.A. (Mar. 1990). "Haptic Perception With an Articulated, Sensate Robot Hand," *SANDIA Report SAND90-0085-UC-406*, 37 pages.
- Stauffer, R.N. ed. (Jun. 1983). "Progress in Tactile Sensor Development," *Robotics Today* pp. 43-49.
- Stumpe, B. (Mar. 16, 1977). "A New Principle for an X-Y Touch Screen," *CERN*, 19 pages.
- Stumpe, B. (Feb. 6, 1978). "Experiments to Find a Manufacturing Process for an X-Y Touch Screen: Report on a Visit to Polymer-Physik GmbH," *CERN*, five pages.
- Subatai Ahmad, "A Usable Real-Time 3D Hand Tracker," *Proceedings of the 28th Asilomar Conference on Signals, Systems and Computers—Part 2 (of 2)*, vol. 2 (Oct. 1994).
- Sugiyama, S. et al. (Mar. 1990). "Tactile Image Detection Using a 1k-element Silicon Pressure Sensor Array," *Sensors and Actuators A21-A23* (1-3):397-400.
- Suzuki, K. et al. (Aug. 1990). "A 1024-Element High-Performance Silicon Tactile Imager," *IEEE Transactions on Electron Devices* 37(8):1852-1860.
- Texas Instruments "TSC2003 / 12C Touch Screen Controller" Data Sheet SBAS 162, dated Oct. 2001, 20-pgs.
- TW Search Report mailed Jun. 27, 2011, for TW Patent Application No. 097100481, one page.
- U.S. Appl. No. 10/789,676, filed on Feb. 27, 2004 entitled "Shape Detecting Input Device."
- U.S. Appl. No. 11/015,978, filed Dec. 17, 2004.
- U.S. Appl. No. 60/072,509, filed Jan. 26, 1998, by Westerman et al.
- U.S. Appl. No. 60/333,770, filed Nov. 29, 2001, by Perski et al.
- U.S. Appl. No. 60/501,484, filed Sep. 5, 2003, by Perski et al.
- Van Kleek, M. (Feb. 2003). "Intelligent Environments for Informal Public Spaces: The Ki/o Kiosk Platform," Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Engineering, MIT, 108 pages.
- Van Oversteegen, B.G.F.A.W. (Apr. 10, 1998). "Touch Screen Based Measuring Equipment: Design and Implementation," Master's Thesis, Submitted to Technische Universiteit, Eindhoven, The Netherlands, 103 pages.
- Vazquez, A.A. (Sep. 1990). "Touch Screen Use on Flight Simulator Instructor/Operator Stations," Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Information Systems, 78 pages.
- Vernier, F. et al. (2002). "Multi-User, Multi-Finger Drag & Drop of Multiple Documents," located at http://www.edgelab.ca/CSCW/Workshop2002/fred_vernier, three pages.
- Wacom Company Limited. (Nov. 12, 2003). *Wacom intuose®2 User's Manual for Windows®, English V4.1*, 165 pages.
- Wallergard, M. (2003). "Designing Virtual Environments for Brain Injury Rehabilitation," Thesis, Lund University, Sweden, 98 pages.
- Wellner, "The Digital Desk Calculators: Tangible Manipulation on a Desk Top Display" IN *ACM UIST '91 Proceedings*, pp. 27-34, Nov. 1991.
- Westerman, W. et al. (2001). "Multi-Touch: A New Tactile 2-D Gesture Interface for Human-Computer Interaction," *Proceedings of the Human Factors and Ergonomics Society 4th Annual Meeting*, pp. 632-636.
- Williams, "Applications for a Switched-Capacitor Instrumentation Building Block" Linear Technology Application Note 3, Jul. 1985, pp. 1-16.
- Wu, M. et al. (2003). "Multi-Finger and Whole Hand Gestural Interaction Techniques for Multi-User Tabletop Displays," *ACM* pp. 193-202.
- Yamada et al., "A Switched-Capacitor Interface for Capacitive Pressure Sensors" *IEEE Transactions on Instrumentation and Measurement*, vol. 41, No. 1, Feb. 1992, pp. 81-86.
- Yee, K-P. (2004). "Two-Handed Interaction on a Tablet Display," *CHI'04*, pp. 1493-1496.
- Yeh et al., "Switched Capacitor Interface Circuit for Capacitive Transducers" 1985 *IEEE*.
- Zhai et al., "Dual Stream Input for Pointing and Scrolling," *Proceedings of CHI '97 Extended Abstracts* (1997).
- Zimmerman et al., "Applying Electric Field Sensing to Human-Computer Interfaces," In *CHI '85 Proceedings*, pp. 280-287, 1995.
- Notice of Allowance mailed Oct. 10, 2013 for U.S. Appl. No. 11/760,080, filed Jun. 8, 2007, ten pages.
- Non-Final Office Action mailed Mar. 29, 2013, for U.S. Appl. No. 13/717,573, filed Dec. 17, 2012, five pages.
- Notice of Allowance mailed Oct. 29, 2012, for U.S. Appl. No. 13/345,347, filed Jan. 6, 2012, eight pages.
- Notice of Allowance mailed Feb. 6, 2013, for U.S. Appl. No. 13/084,402, filed Apr. 11, 2011, 13 pages.
- Notice of Allowance mailed Feb. 19, 2013, for U.S. Appl. No. 13/538,498, filed Jun. 29, 2012, 16 pages.
- Non-Final Office Action mailed Oct. 5, 2012, for U.S. Appl. No. 12/976,997, filed Dec. 22, 2010, 6 pages.
- Non-Final Office Action mailed Oct. 11, 2012, for U.S. Appl. No. 13/538,498, filed Jun. 29, 2012, 17 pages.
- European Search Report mailed Jul. 28, 2011, for EP Application No. 11159164.0, filed Jun. 8, 2007, eight pages.
- European Search Report mailed Oct. 21, 2011, for EP Application No. 11159166.5, filed Jun. 8, 2007, seven pages.
- Final Office Action mailed Jul. 6, 2010, for U.S. Appl. No. 11/760,036, filed Jun. 8, 2007, 51 pages.
- Final Office Action mailed Jul. 6, 2010, for U.S. Appl. No. 11/760,080, filed Jun. 8, 2007, 66 pages.
- Final Office Action mailed Jul. 22, 2010, for U.S. Appl. No. 11/760,049, filed Jun. 8, 2007, 52 pages.
- Final Office Action mailed Aug. 2, 2010, for U.S. Appl. No. 11/760,060, filed Jun. 8, 2007, 78 pages.
- Final Office Action mailed Dec. 16, 2011, for U.S. Appl. No. 11/760,036, filed Jun. 8, 2007, 53 pages.
- Final Office Action mailed Jan. 30, 2012, for U.S. Appl. No. 11/760,049, filed Jun. 8, 2007, 64 pages.
- Final Office Action mailed Feb. 27, 2012, for U.S. Appl. No. 11/760,080, filed Jun. 8, 2007, 62 pages.
- Hector, J. et al. (May 2002). "Low Power Driving Options for an AMLCD Mobile Display Chipset," Chapter 16.3 in *SID 02 Digest* (2002 SID International Symposium, Digest of Technical Papers), XXXIII(II):694-697.
- International Search Report mailed Mar. 6, 2008, for PCT Application No. PCT/2007/70733, filed Jun. 8, 2007, five pages.
- International Search Report mailed Mar. 7, 2008, for PCT Application No. PCT/2007/70722, filed Jun. 8, 2007, three pages.
- International Search Report mailed Jul. 18, 2008, for PCT Application No. PCT/2007/70725, filed Jun. 8, 2007, six pages.
- International Search Report mailed Jul. 18, 2008, for PCT Application No. PCT/2007/70729, filed Jun. 8, 2007, five pages (98.42).
- Kanda, E. et al. (2008). "55.2: Integrated Active Matrix Capacitive Sensors for Touch Panel LTPS-TFT LCDs," *SID 08 Digest*, pp. 834-837.
- Non-Final Office Action mailed Mar. 12, 2010, for U.S. Appl. No. 11/760,080, filed Jun. 8, 2007, 31 pages.
- Non-Final Office Action mailed Apr. 22, 2010, for U.S. Appl. No. 11/760,036, filed Jun. 8, 2007, 37 pages.
- Non-Final Office Action mailed Apr. 23, 2010, for U.S. Appl. No. 11/760,060, filed Jun. 8, 2007, 66 pages.
- Non-Final Office Action mailed May 5, 2010, for U.S. Appl. No. 11/760,049, filed Jun. 8, 2007, 65 pages.
- Non-Final Office Action mailed Aug. 4, 2011, for U.S. Appl. No. 11/760,036, filed Jun. 8, 2007, 45 pages.
- Non-Final Office Action mailed Aug. 11, 2011, for U.S. Appl. No. 11/760,049, filed Jun. 8, 2007, 60 pages.

(56)

References Cited

OTHER PUBLICATIONS

Non-Final Office Action mailed Sep. 1, 2011, for U.S. Appl. No. 11/760,060, filed Jun. 8, 2007, 76 pages.

Non-Final Office Action mailed Nov. 14, 2011, for U.S. Appl. No. 11/760,080, filed Jun. 8, 2007, 60 pages.

Notice of Allowance mailed Mar. 27, 2012, for U.S. Appl. No. 11/760,060, filed Jun. 8, 2007, 17 pages.

Notice of Allowance mailed Apr. 27, 2012, for U.S. Appl. No. 11/760,036, filed Jun. 8, 2007, eight pages.

Partial European Search Report mailed Mar. 15, 2011, for EP Application No. 10178661.4, filed Jun. 8, 2007, six pages.

Partial European Search Report mailed Oct. 21, 2011, for EP Application No. 11159165.7 filed Jun. 8, 2007, seven pages.

Partial European Search Report mailed Oct. 24, 2011, for EP Application No. 11159167.3 filed Jun. 8, 2007, eight pages.

Non-Final Office Action mailed Dec. 30, 2013, for U.S. Appl. No. 12/976,997, filed Dec. 22, 2010, six pages.

Final Office Action mailed May 9, 2013, for U.S. Appl. No. 12/976,997, filed Dec. 22, 2010, 7 pages.

Netherlands Search Report dated Jul. 2, 2013, for Dutch Patent Application No. 2008003, eight pages.

Non-Final Office Action mailed Jun. 27, 2013, for U.S. Appl. No. 11/760,080, filed Jun. 8, 2007, 48 pages.

Notice of Allowance mailed Apr. 26, 2013, for U.S. Appl. No. 11/650,203, filed Jan. 3, 2007, 8 pages.

Notice of Allowance mailed May 28, 2013, for U.S. Appl. No. 11/760,049, filed Jun. 8, 2007, 10 pages.

Notice of Allowance mailed Jul. 19, 2013, for U.S. Appl. No. 13/717,573, filed Dec. 17, 2012, 8 pages.

* cited by examiner

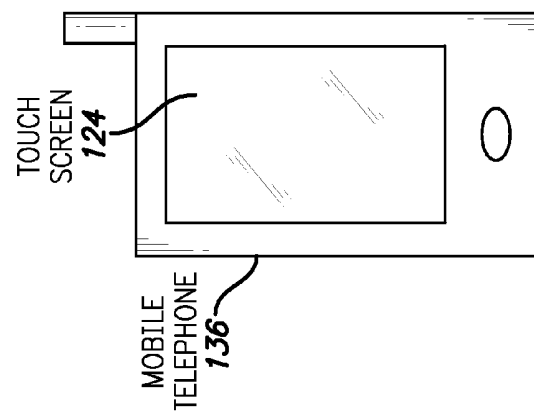


FIG. 1A

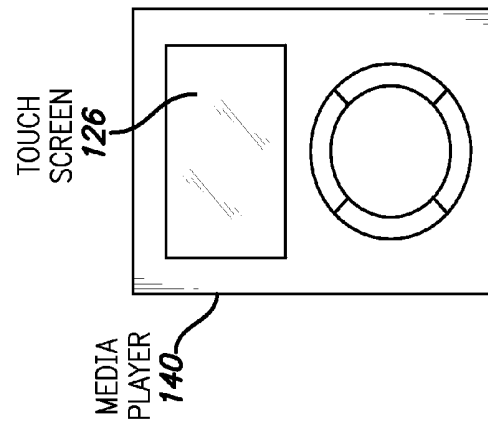


FIG. 1B

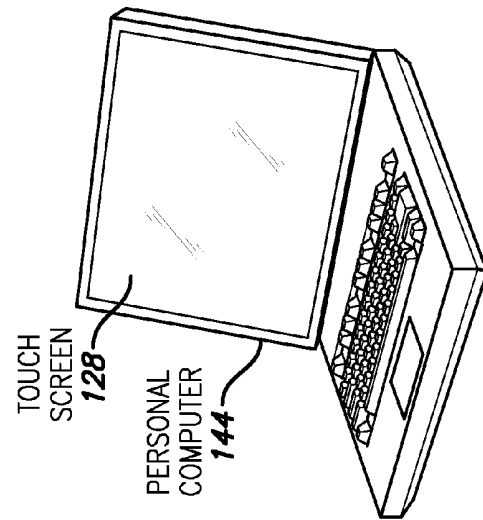


FIG. 1C

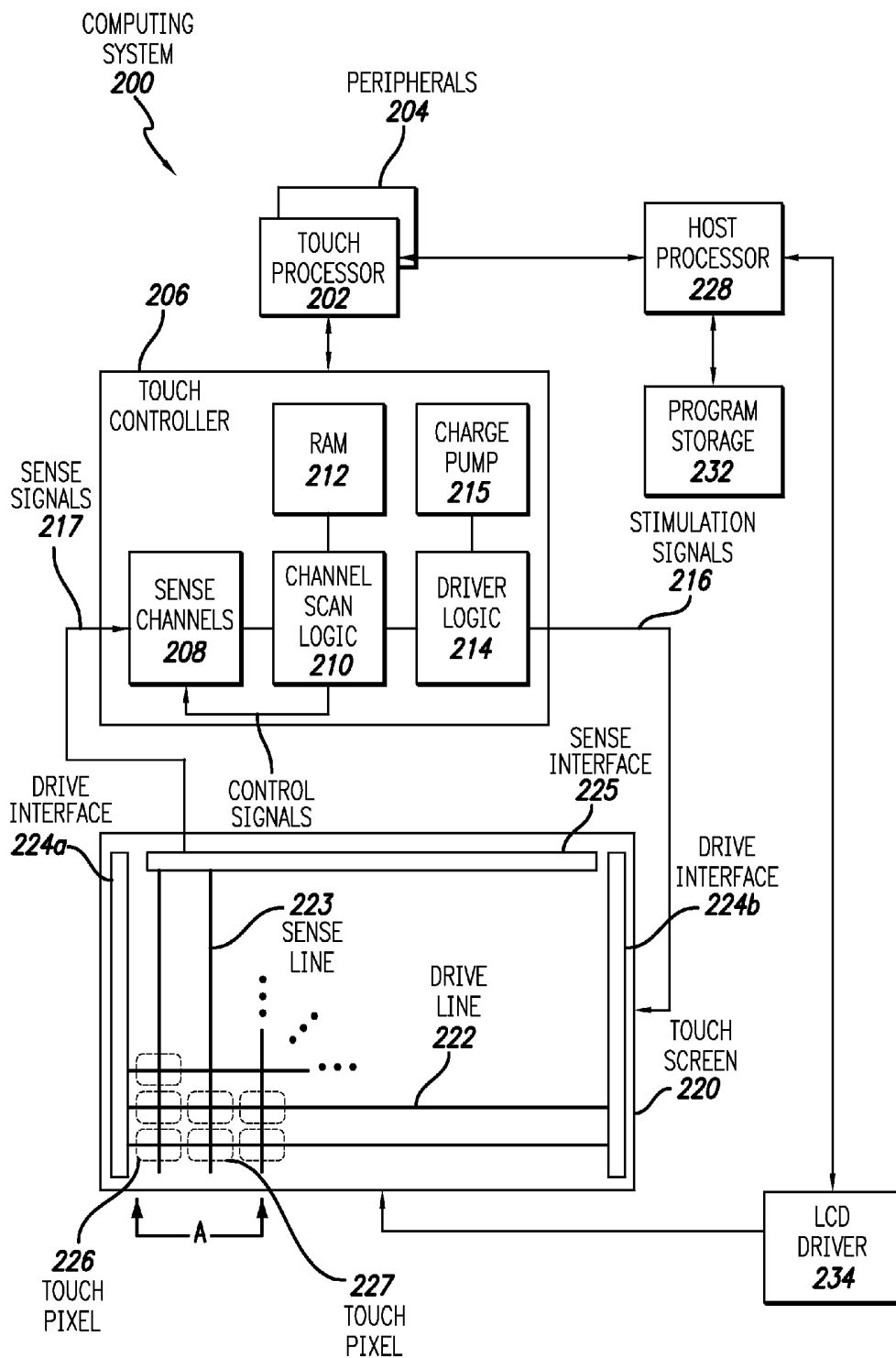


FIG. 2

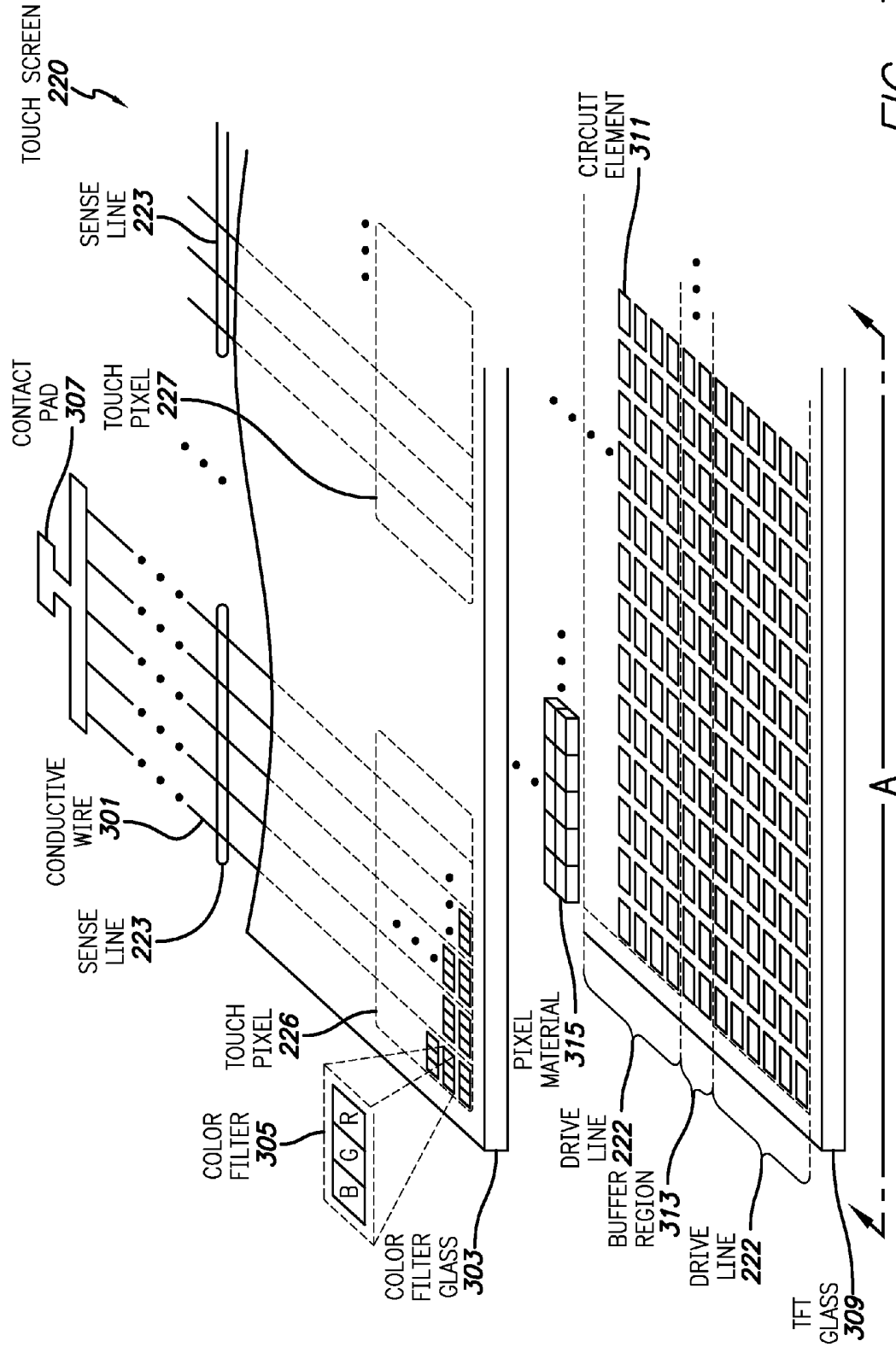


FIG. 3

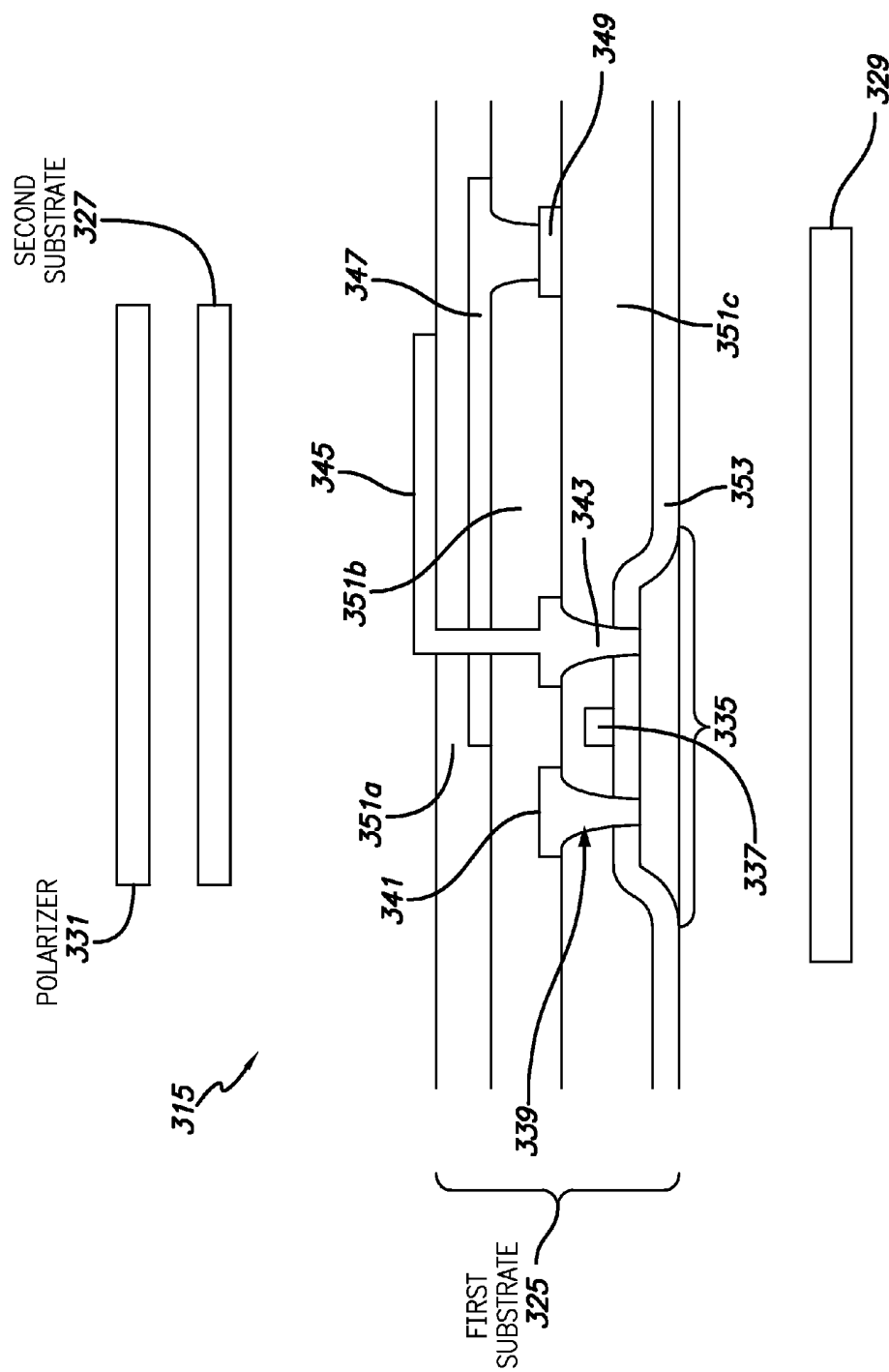
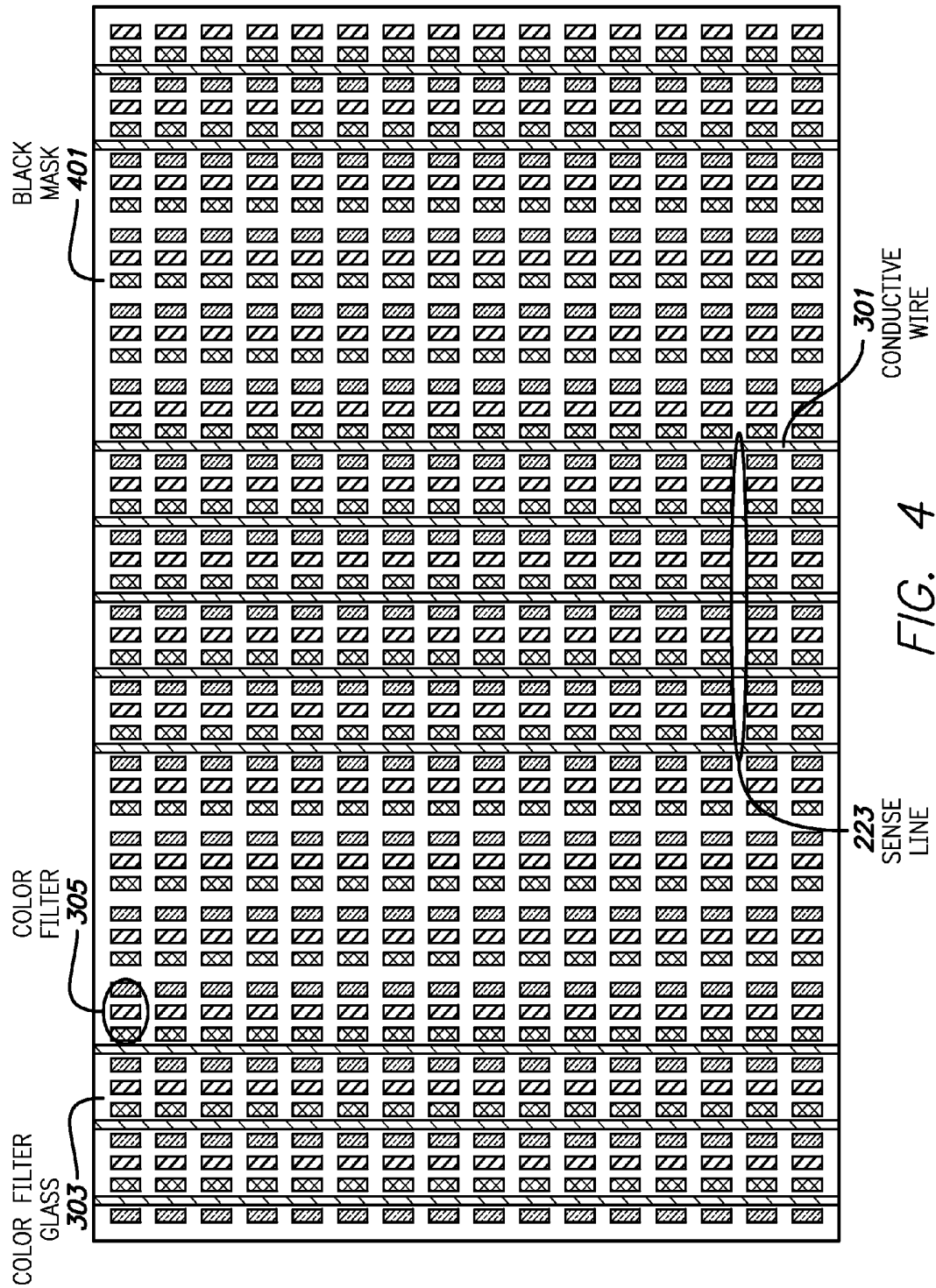
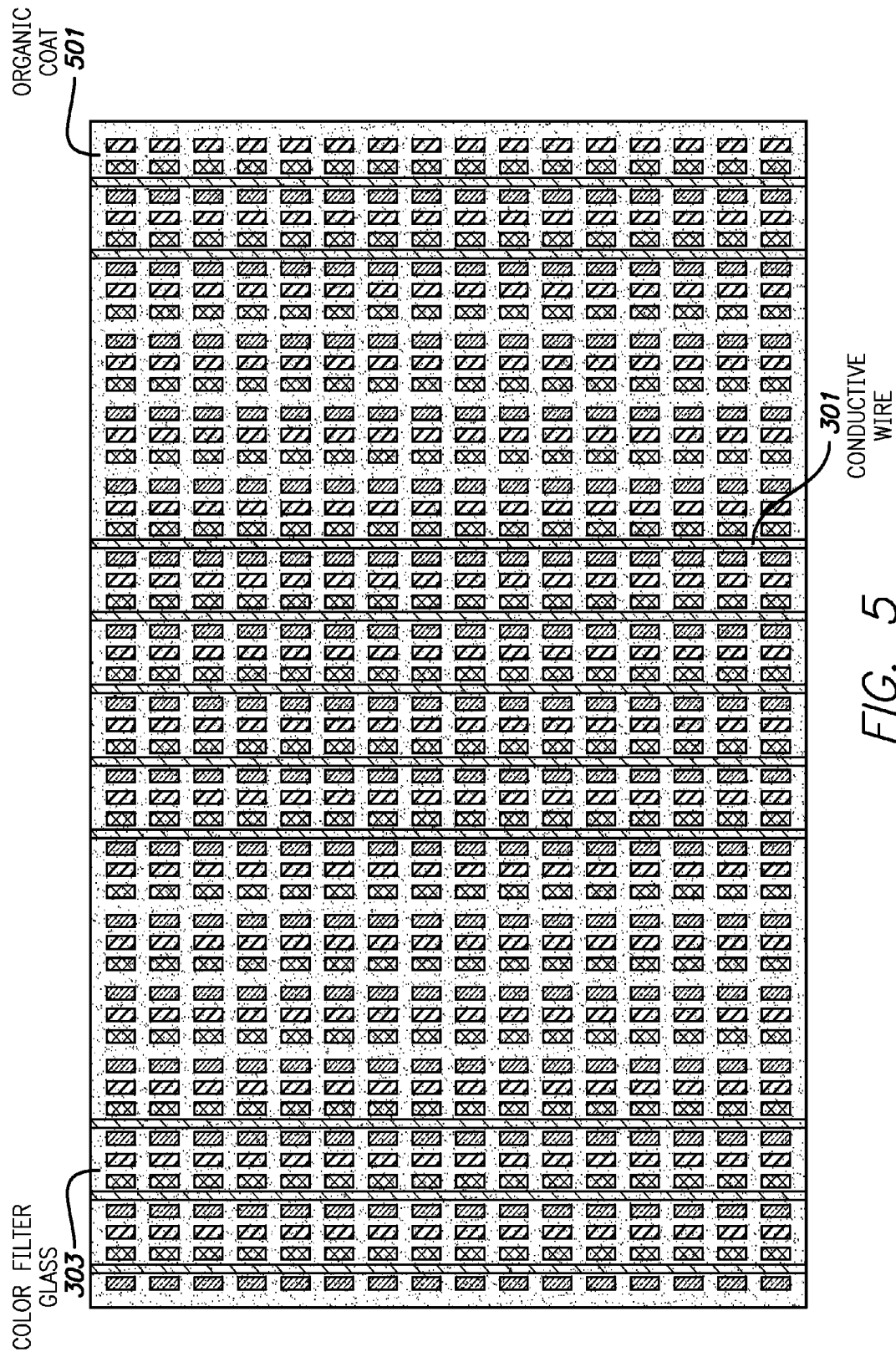


FIG. 3A





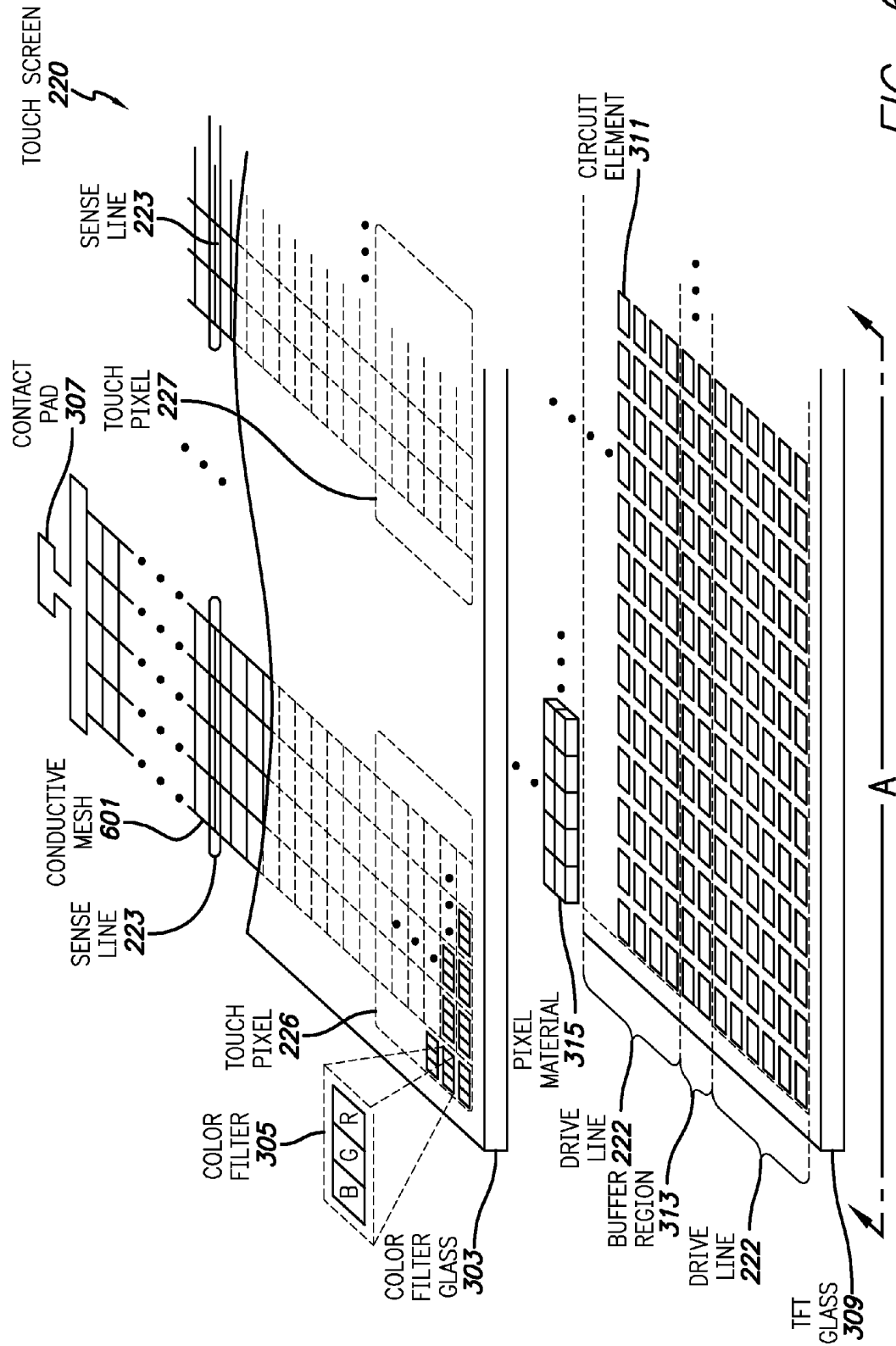
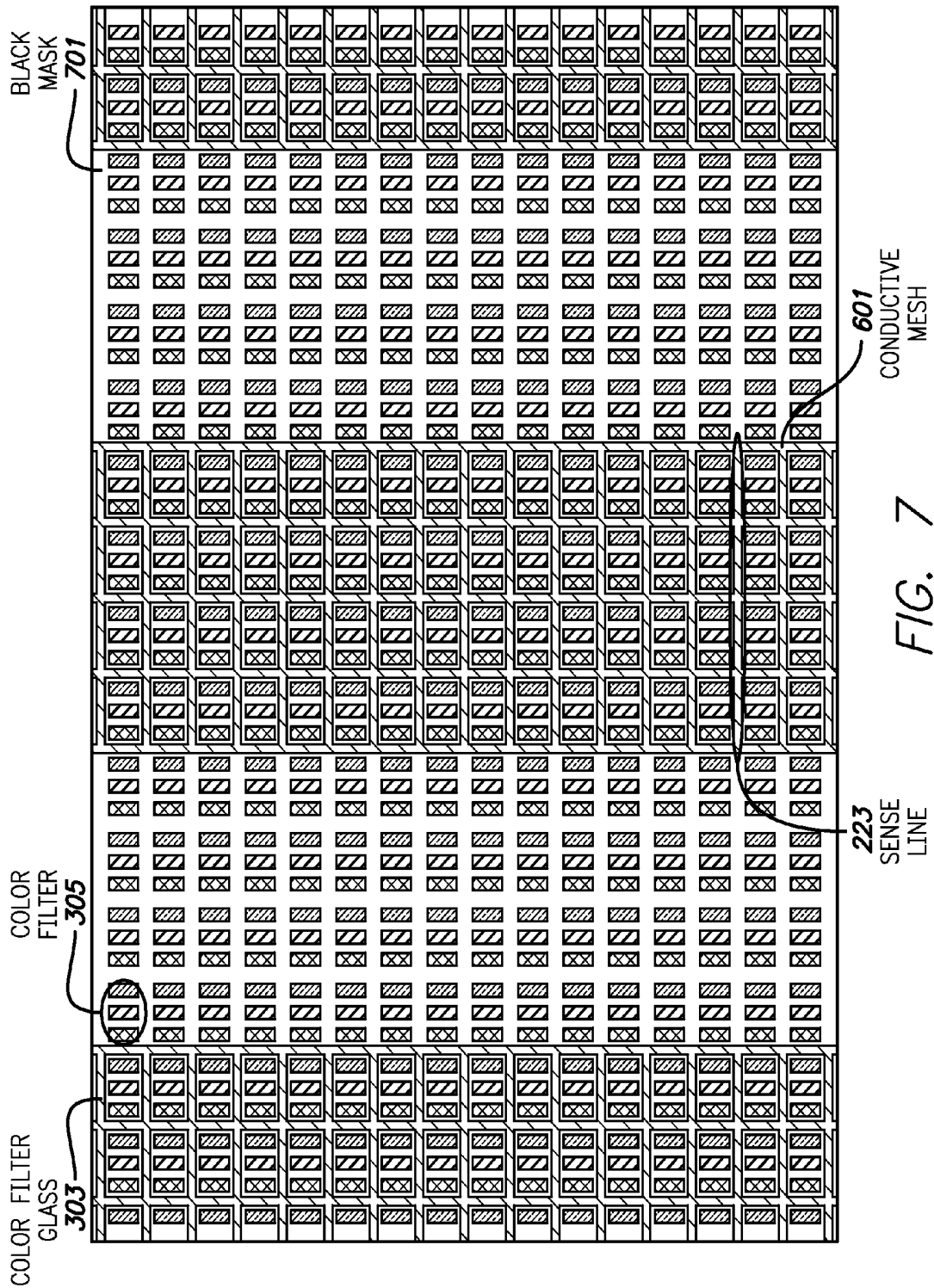


FIG. 6



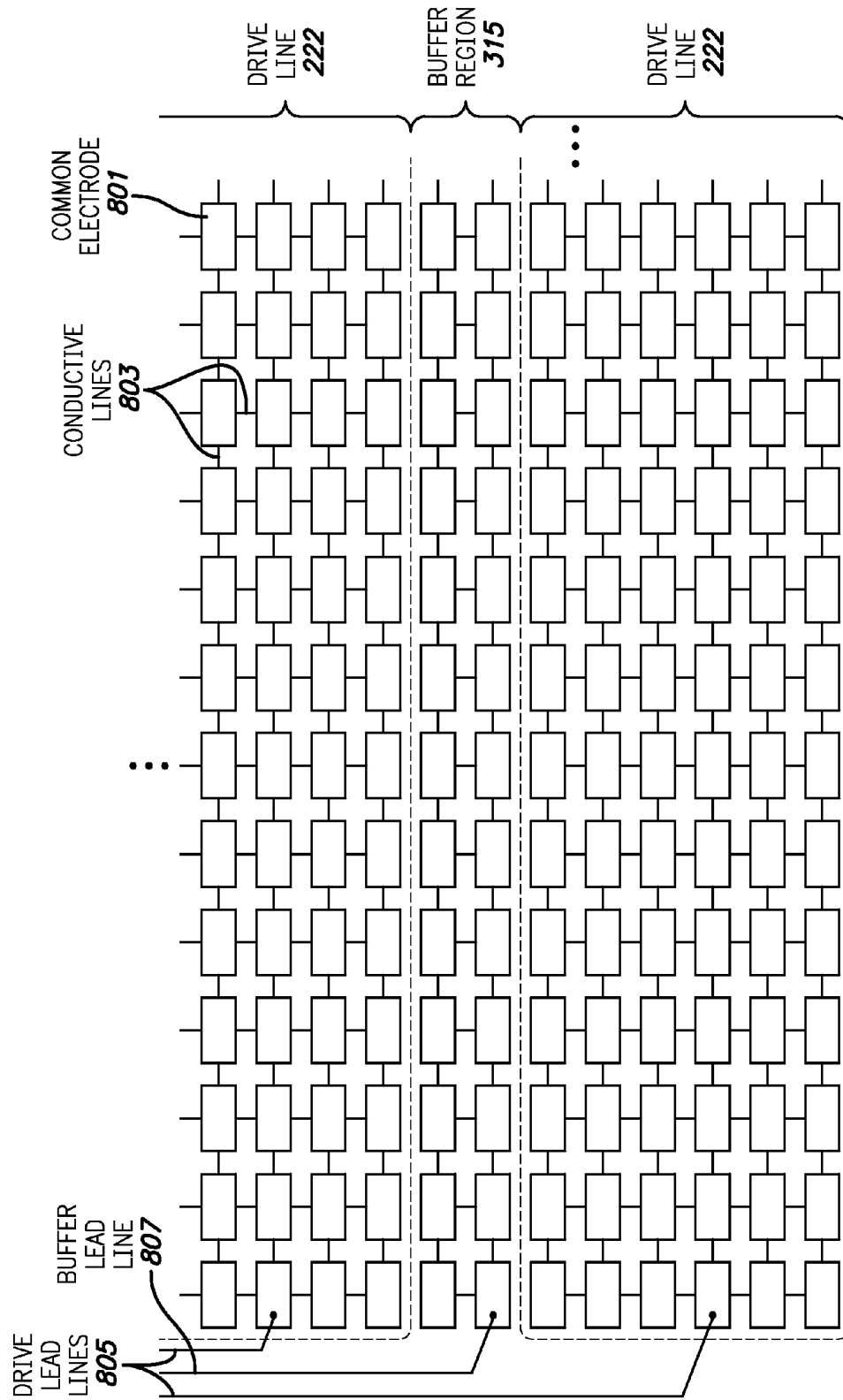


FIG. 8

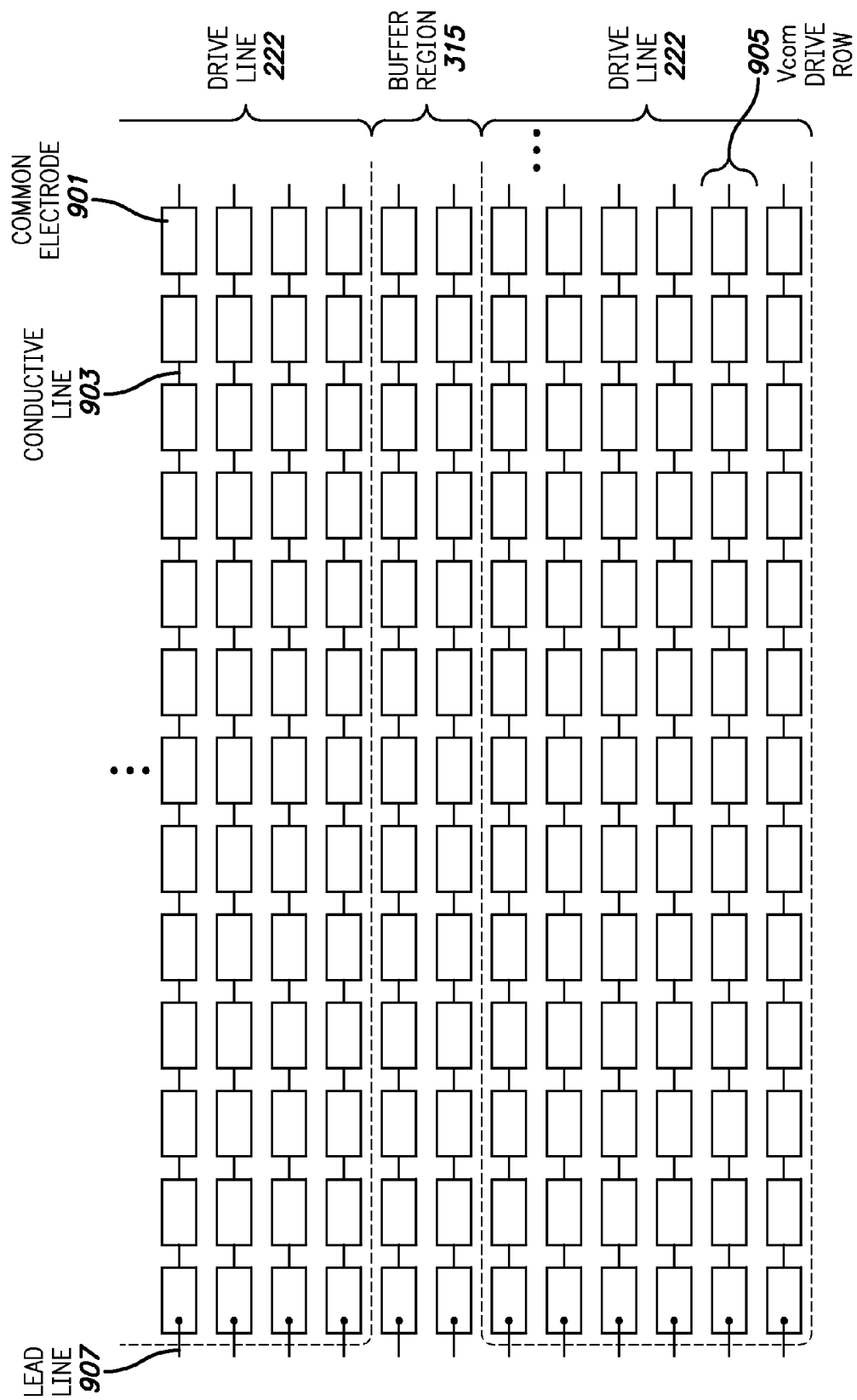


FIG. 9

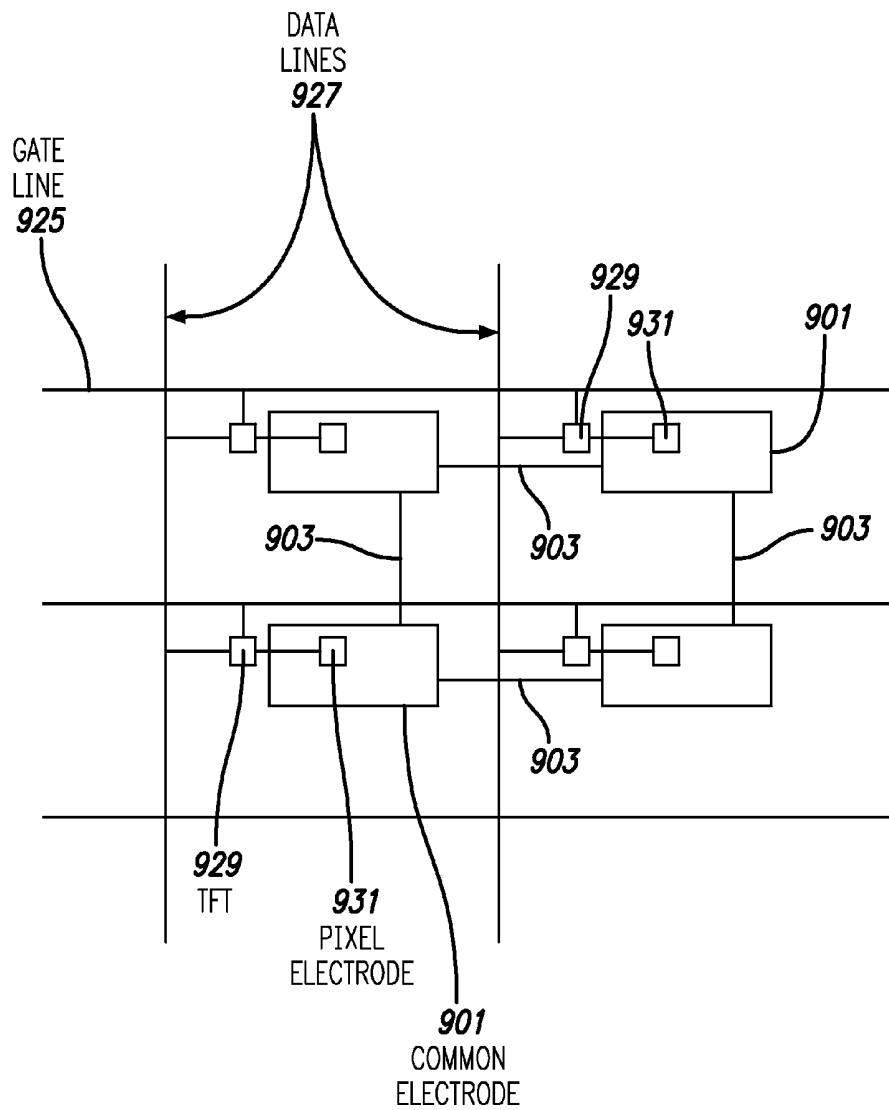
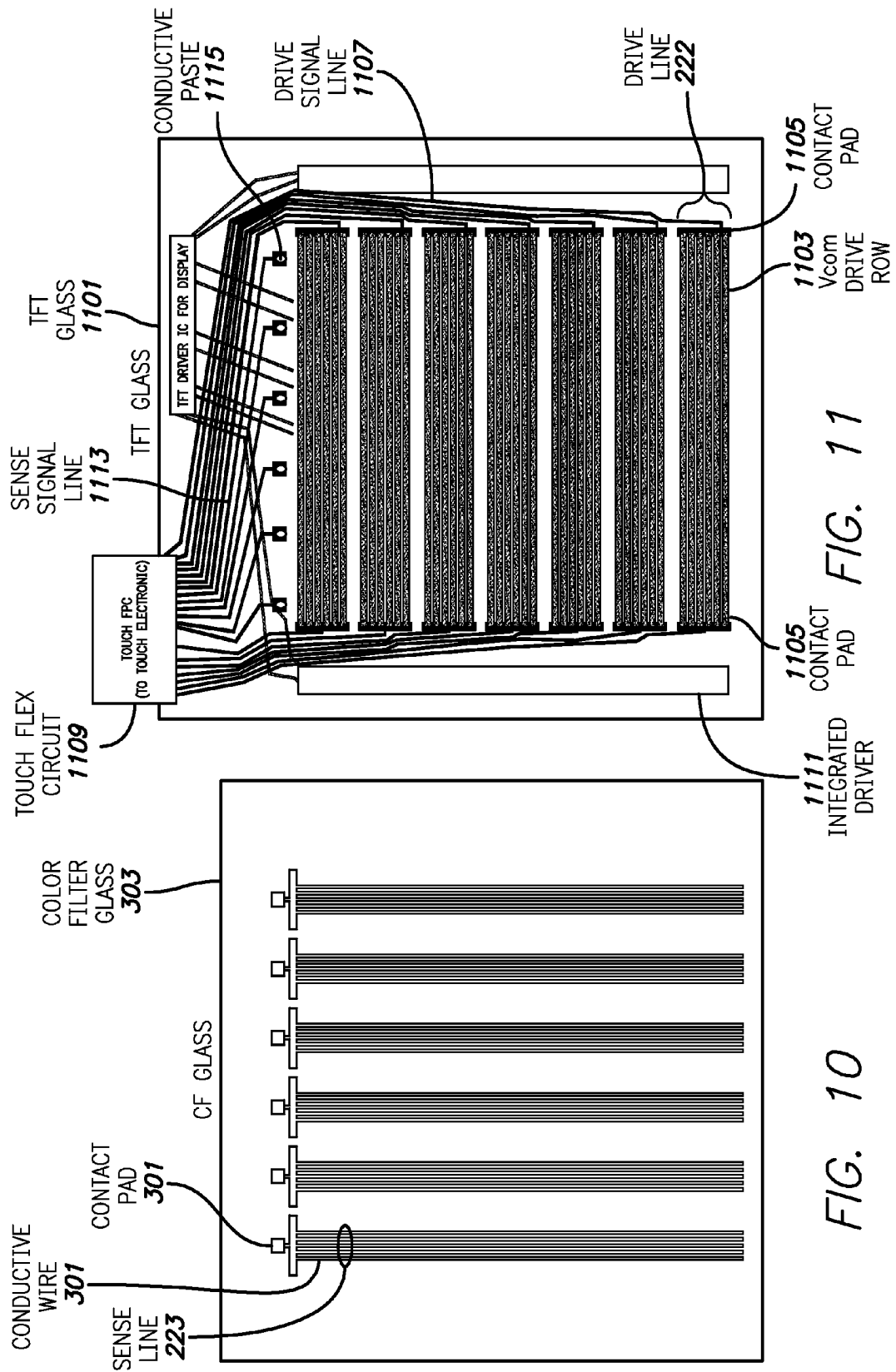


FIG. 9A



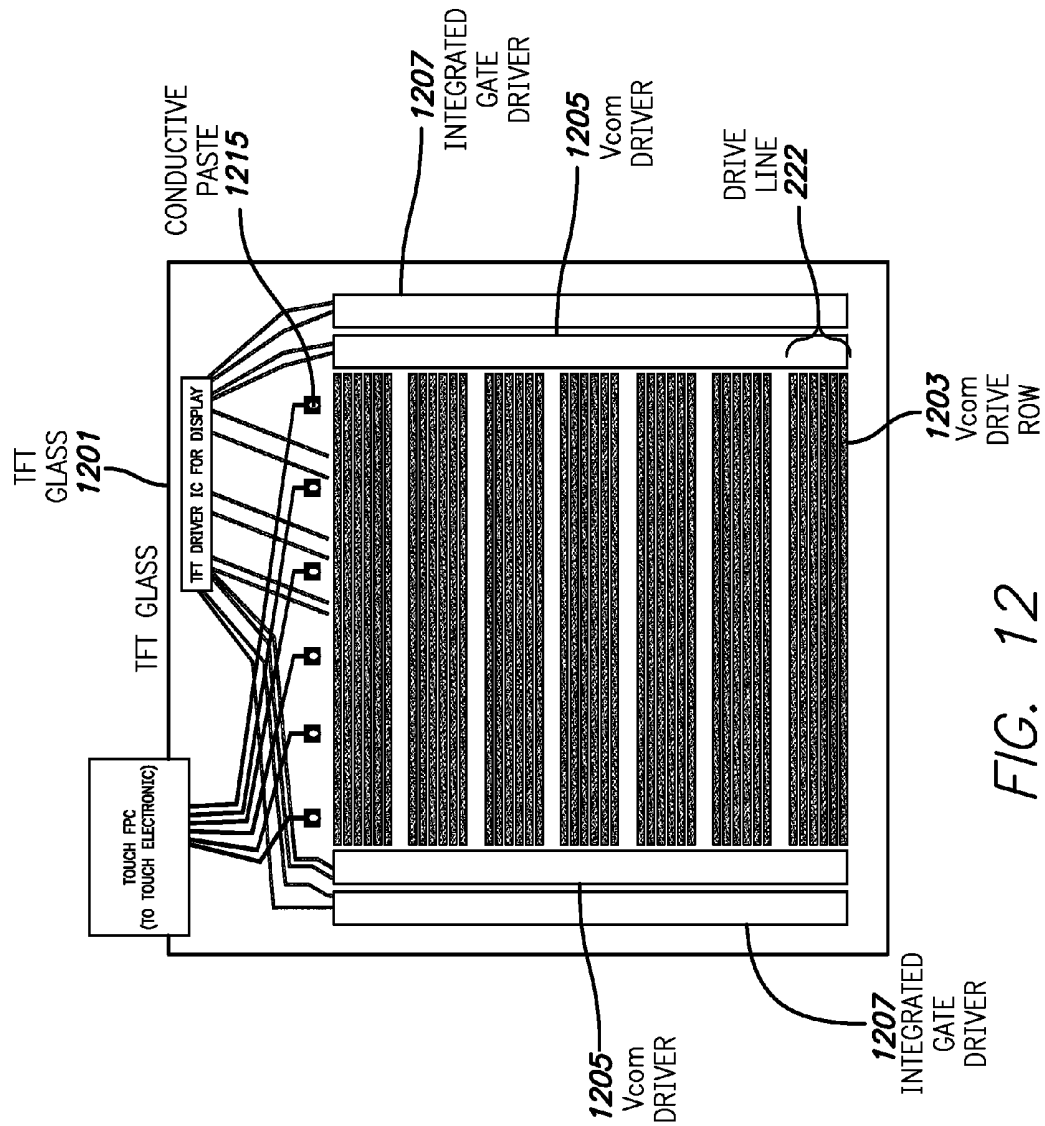


FIG. 12

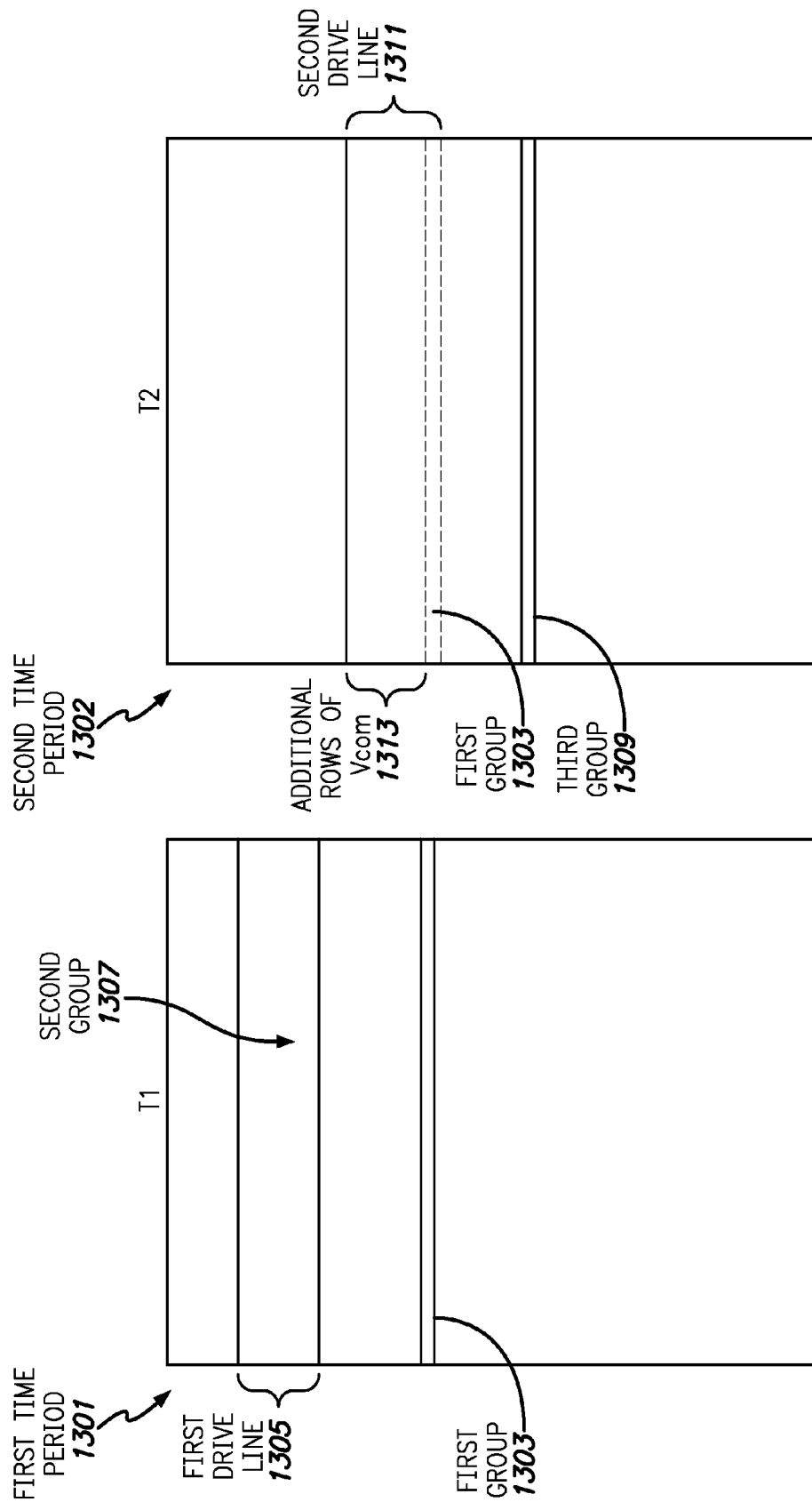
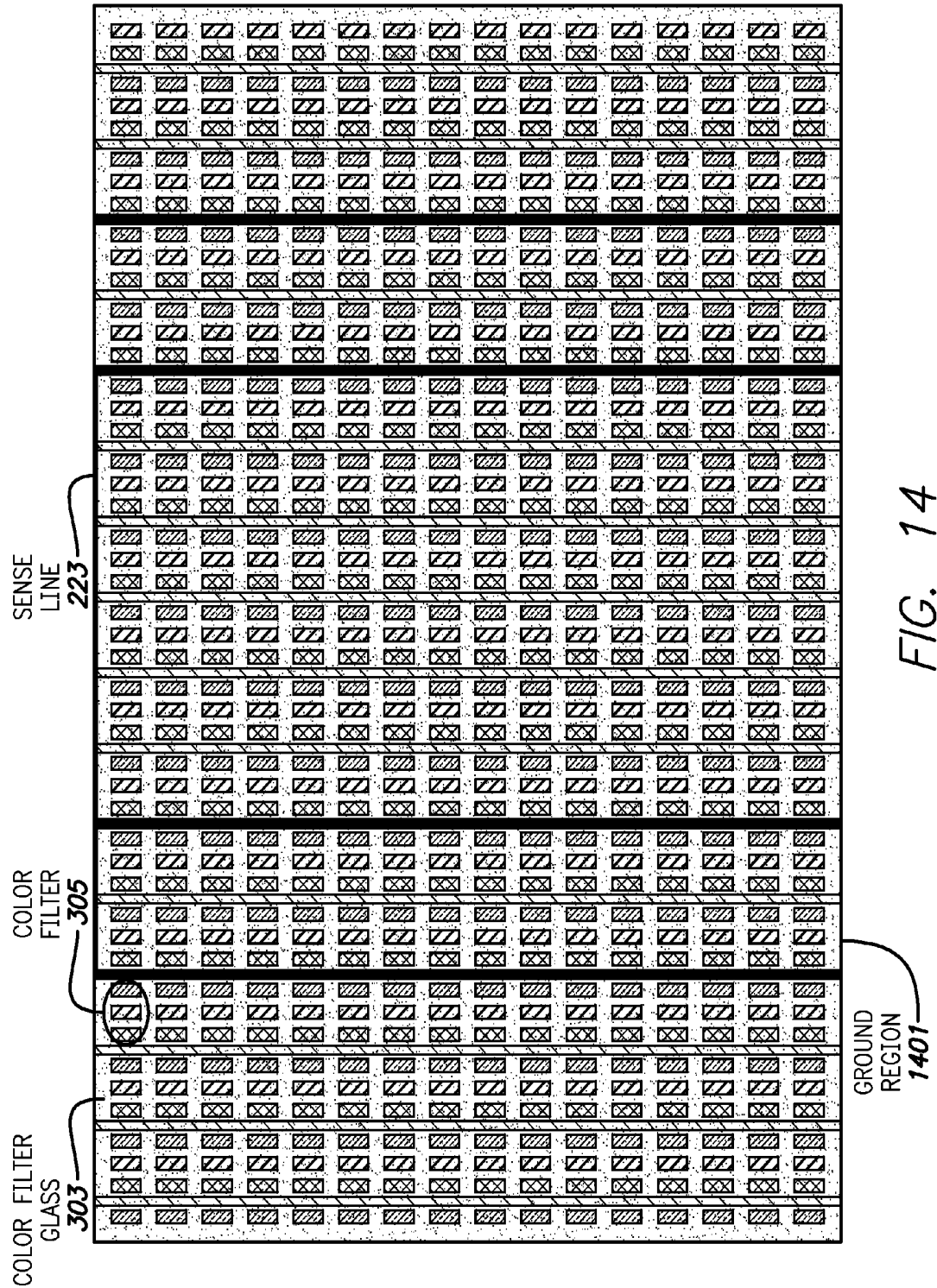
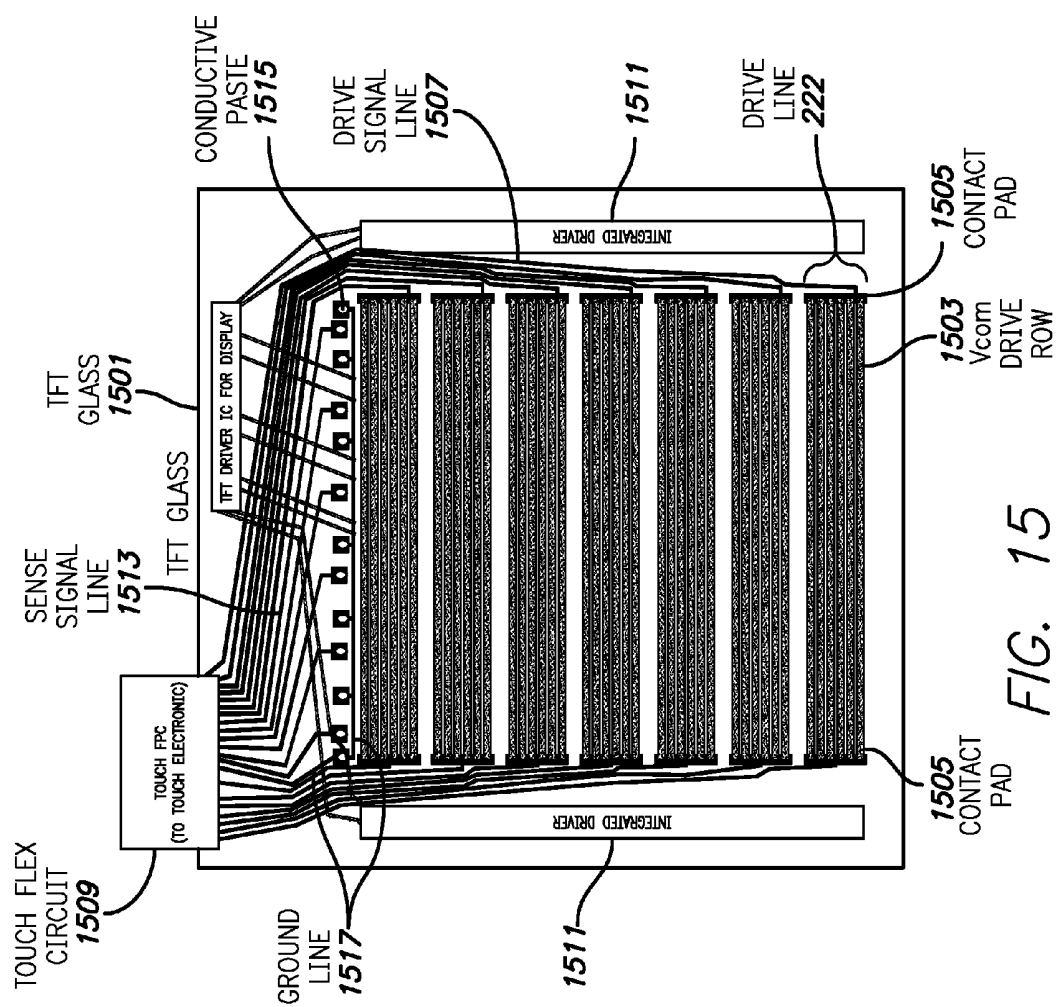


FIG. 13





1

INTEGRATED TOUCH SCREENS**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application is a continuation of U.S. patent application Ser. No. 12/976,997, filed Dec. 22, 2010, the entire disclosure of which is incorporated herein by reference for all purposes.

FIELD OF THE DISCLOSURE

This relates generally to integrated touch screens, and more particularly, to integrated touch screens including drive lines formed of grouped-together circuit elements of a thin film transistor layer and sense lines formed between a color filter layer and a material layer that modifies or generates light.

BACKGROUND OF THE DISCLOSURE

Many types of input devices are presently available for performing operations in a computing system, such as buttons or keys, mice, trackballs, joysticks, touch sensor panels, touch screens and the like. Touch screens, in particular, are becoming increasingly popular because of their ease and versatility of operation as well as their declining price. Touch screens can include a touch sensor panel, which can be a clear panel with a touch-sensitive surface, and a display device such as a liquid crystal display (LCD) that can be positioned partially or fully behind the panel so that the touch-sensitive surface can cover at least a portion of the viewable area of the display device. Touch screens can allow a user to perform various functions by touching the touch sensor panel using a finger, stylus or other object at a location often dictated by a user interface (UI) being displayed by the display device. In general, touch screens can recognize a touch and the position of the touch on the touch sensor panel, and the computing system can then interpret the touch in accordance with the display appearing at the time of the touch, and thereafter can perform one or more actions based on the touch. In the case of some touch sensing systems, a physical touch on the display is not needed to detect a touch. For example, in some capacitive-type touch sensing systems, fringing electrical fields used to detect touch can extend beyond the surface of the display, and objects approaching near the surface may be detected near the surface without actually touching the surface.

Capacitive touch sensor panels can be formed from a matrix of drive and sense lines of a substantially transparent conductive material, such as Indium Tin Oxide (ITO), often arranged in rows and columns in horizontal and vertical directions on a substantially transparent substrate. It is due in part to their substantial transparency that capacitive touch sensor panels can be overlaid on a display to form a touch screen, as described above. Some touch screens can be formed by integrating touch sensing circuitry into a display pixel stackup (i.e., the stacked material layers forming the display pixels).

SUMMARY

The following description includes examples of integrated touch screens including drive lines formed of grouped-together circuit elements of a thin film transistor layer and sense lines formed between a color filter layer and a material layer that modifies or generates light. In some examples, the touch screen can be an in-plane switching (IPS) liquid crystal display (LCD), fringe field switching (FFS), advanced fringe

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field switching (AFFS), etc. The common electrodes (Vcom) in the TFT layer can be grouped together during a touch sensing operation to form drive lines. Sense lines can be formed on an underside of a color filter glass, and a liquid crystal region can be disposed between the color filter glass and the TFT layer. Placing the sense lines on the underside of the color filter glass, i.e., within the display pixel cell, can provide a benefit of allowing the color filter glass to be thinned after the pixel cells have been assembled, for example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A-1C illustrate an example mobile telephone, an example media player, and an example personal computer that each include an example touch screen according to embodiments of the disclosure.

FIG. 2 is a block diagram of an example computing system that illustrates one implementation of an example touch screen according to embodiments of the disclosure.

FIG. 3 illustrates example configurations of sense lines, drive lines, and other example structures of a touch screen according to embodiments of the disclosure.

FIG. 3A illustrates an example display pixel stackup according to embodiments of the disclosure.

FIG. 4 illustrates a more detailed view of an example color filter glass including sense lines disposed on an underside of the color filter glass according to embodiments of the disclosure.

FIG. 5 illustrates an example color filter glass that includes an organic coat formed over conductive wires according to embodiments of the disclosure.

FIG. 6 illustrates other example configurations of sense lines, drive lines, and other example structures of a touch screen according to embodiments of the disclosure.

FIG. 7 illustrates a more detailed view of another example color filter glass including sense lines disposed on an underside of the color filter glass according to embodiments of the disclosure.

FIG. 8 illustrates an example configuration of drive lines including circuit elements of a TFT layer of a touch screen according to embodiments of the disclosure.

FIG. 9 illustrates another example configuration of drive lines including circuit elements of a TFT layer of a touch screen according to embodiments of the disclosure.

FIG. 9A illustrates an example circuit of a TFT substrate according to embodiments of the disclosure.

FIG. 10 includes an example configuration of a color filter glass including contact pads connected to sense lines according to embodiments of the disclosure.

FIG. 11 illustrates an example configuration of a TFT glass according to embodiments of the disclosure.

FIG. 12 illustrates another example configuration of a TFT glass according to embodiments of the disclosure.

FIG. 13 illustrates an example method of driving circuit elements of a touch screen in a display operation and in a touch sensing operation according to embodiments of the disclosure.

FIG. 14 illustrates another example configuration of a color filter glass according to embodiments of the disclosure.

FIG. 15 illustrates another example configuration of a TFT glass according to embodiments of the disclosure.

DETAILED DESCRIPTION

In the following description of example embodiments, reference is made to the accompanying drawings which form a

part hereof, and in which it is shown by way of illustration specific embodiments in which embodiments of the disclosure can be practiced. It is to be understood that other embodiments can be used and structural changes can be made without departing from the scope of the embodiments of this disclosure.

The following description includes examples of integrated touch screens including drive lines formed of grouped-together circuit elements of a thin film transistor layer and sense lines formed between a color filter layer and a material layer that modifies or generates light. In some examples, the touch screen can be an in-plane switching (IPS) liquid crystal display (LCD), fringe field switching (FFS), advanced fringe field switching (AFFS), etc. The common electrodes (Vcom) in the TFT layer can be grouped together during a touch sensing operation to form drive lines. Sense lines can be formed on an underside of a color filter glass, and a liquid crystal region can be disposed between the color filter glass and the TFT layer. Placing the sense lines on the underside of the color filter glass, i.e., within the display pixel cell, can provide a benefit of allowing the color filter glass to be thinned after the pixel cells have been assembled, for example.

During a display operation, in which an image is displayed on the touch screen, the Vcom can serve as part of the display circuitry, for example, by carrying a common voltage to create, in conjunction with a pixel voltage on a pixel electrode, an electric field across the liquid crystal. During a touch sensing operation, the a stimulation signal can be applied to a group of Vcom that form a drive line. A sense signal based on the stimulation signal can be received by the sense lines on the underside of the color filter glass and processed by a touch processor to determine an amount and location of touch on the touch screen.

FIGS. 1A-1C show example systems in which a touch screen according to embodiments of the disclosure may be implemented. FIG. 1A illustrates an example mobile telephone 136 that includes a touch screen 124. FIG. 1B illustrates an example digital media player 140 that includes a touch screen 126. FIG. 1C illustrates an example personal computer 144 that includes a touch screen 128. Touch screens 124, 126, and 128 can be based on mutual capacitance. A mutual capacitance based touch system can include, for example, drive regions and sense regions, such as drive lines and sense lines. For example, drive lines can be formed in rows while sense lines can be formed in columns (e.g., orthogonal). Touch pixels can be formed at the intersections of the rows and columns. During operation, the rows can be stimulated with an AC waveform and a mutual capacitance can be formed between the row and the column of the touch pixel. As an object approaches the touch pixel, some of the charge being coupled between the row and column of the touch pixel can instead be coupled onto the object. This reduction in charge coupling across the touch pixel can result in a net decrease in the mutual capacitance between the row and the column and a reduction in the AC waveform being coupled across the touch pixel. This reduction in the charge-coupled AC waveform can be detected and measured by the touch sensing system to determine the positions of multiple objects when they touch the touch screen. In some embodiments, a touch screen can be multi-touch, single touch, projection scan, full-imaging multi-touch, capacitive touch, etc.

FIG. 2 is a block diagram of an example computing system 200 that illustrates one implementation of an example touch screen 220 according to embodiments of the disclosure. Computing system 200 could be included in, for example, mobile telephone 136, digital media player 140, personal computer

144, or any mobile or non-mobile computing device that includes a touch screen. Computing system 200 can include a touch sensing system including one or more touch processors 202, peripherals 204, a touch controller 206, and touch sensing circuitry (described in more detail below). Peripherals 204 can include, but are not limited to, random access memory (RAM) or other types of memory or storage, watchdog timers and the like. Touch controller 206 can include, but is not limited to, one or more sense channels 208, channel scan logic 210 and driver logic 214. Channel scan logic 210 can access RAM 212, autonomously read data from the sense channels and provide control for the sense channels. In addition, channel scan logic 210 can control driver logic 214 to generate stimulation signals 216 at various frequencies and phases that can be selectively applied to drive lines of the touch sensing circuitry of touch screen 220, as described in more detail below. In some embodiments, touch controller 206, touch processor 202 and peripherals 204 can be integrated into a single application specific integrated circuit (ASIC).

Computing system 200 can also include a host processor 228 for receiving outputs from touch processor 202 and performing actions based on the outputs. For example, host processor 228 can be connected to program storage 232 and a display controller, such as an LCD driver 234. The LCD driver 234 can provide voltages on select (gate) lines to each pixel transistor and can provide data signals along data lines to these same transistors to control the pixel display image as described in more detail below. Host processor 228 can use LCD driver 234 to generate an image on touch screen 220, such as an image of a user interface (UI), and can use touch processor 202 and touch controller 206 to detect a touch on or near touch screen 220, such a touch input to the displayed UI. The touch input can be used by computer programs stored in program storage 232 to perform actions that can include, but are not limited to, moving an object such as a cursor or pointer, scrolling or panning, adjusting control settings, opening a file or document, viewing a menu, making a selection, executing instructions, operating a peripheral device connected to the host device, answering a telephone call, placing a telephone call, terminating a telephone call, changing the volume or audio settings, storing information related to telephone communications such as addresses, frequently dialed numbers, received calls, missed calls, logging onto a computer or a computer network, permitting authorized individuals access to restricted areas of the computer or computer network, loading a user profile associated with a user's preferred arrangement of the computer desktop, permitting access to web content, launching a particular program, encrypting or decoding a message, and/or the like. Host processor 228 can also perform additional functions that may not be related to touch processing.

Touch screen 220 can include touch sensing circuitry that can include a capacitive sensing medium having a plurality of drive lines 222 and a plurality of sense lines 223. It should be noted that the term "lines" is a sometimes used herein to mean simply conductive pathways, as one skilled in the art will readily understand, and is not limited to elements that are strictly linear, but includes pathways that change direction, and includes pathways of different size, shape, materials, etc, and multiple electrically conductive circuit elements that can be electrically connected to form a single electrically conductive pathway. Drive lines 222 can be driven by stimulation signals 216 from driver logic 214 through drive interfaces 224a and 224b, and resulting sense signals 217 generated in sense lines 223 can be transmitted through a sense interface 225 to sense channels 208 (also referred to as an event detec-

tion and demodulation circuit) in touch controller **206**. The stimulation signal may be an alternating current (AC) waveform. In this way, drive lines and sense lines can be part of the touch sensing circuitry that can interact to form capacitive sensing nodes, which can be thought of as touch picture elements (touch pixels), such as touch pixels **226** and **227**. This way of understanding can be particularly useful when touch screen **220** is viewed as capturing an "image" of touch. In other words, after touch controller **206** has determined an amount of touch detected at each touch pixel in the touch screen, the pattern of touch pixels in the touch screen at which a touch occurred can be thought of as an "image" of touch (e.g. a pattern of fingers touching the touch screen).

Structures and operations of various example embodiments of integrated touch screens will now be described with reference to FIGS. **3-15**.

FIG. **3** illustrates example embodiments of sense lines, drive lines, and other example structures of touch screen. FIG. **3** shows a more detailed view of a lower left hand portion of touch screen **220** along line "A" shown in FIG. **2**. In the example embodiment shown in FIG. **3**, each sense line **223** includes multiple conductive wires **301**, e.g., five conductive wires in this example embodiment. Conductive wires **301** are disposed on the underside of a color filter glass **303**, between the color filter glass and the TFT glass. The color filter glass **303** can include a plurality of color filters **305**. In this example embodiment, color filters **305** each include three colors, blue (B), green (G), and red (R), such as in an RGB display. Each conductive wire **301** is positioned between two columns of color filters **305**. In this example, the space between the columns of the color filters can be widened to accommodate the conductive wire. In the example shown, five conductive wires **301** of each sense line **223** can be connected to a contact pad **307** that conductively connects the conductive wires of the sense line and allows each group of five conductive wires to operate as a single sense line. Contact pads **307** can be electrically connected to, for example, sense channels **208** of touch controller **206** shown in FIG. **2**, so that sense signals **217** received by each sense line **223** can be processed by the touch controller.

FIG. **3** also shows a TFT glass **309**, on which can be formed circuit elements **311**. Circuit elements **311** can be, for example, multi-function circuit elements that operate as part of the display circuitry of the touch screen and also as part of the touch sensing circuitry of the touch screen. In some embodiments, circuit elements **311** can be single-function circuit elements that operate only as part of the touch sensing system. In addition to circuit elements **311**, other circuit elements (not shown) can be formed on TFT glass **309**, such as transistors, capacitors, conductive vias, data lines, gate lines, etc. Circuit elements **311** and the other circuit elements formed on TFT glass **309** can operate together to perform various display functionality required for the type of display technology used by touch screen **220**, as one skilled in the art would understand. The circuit elements can include, for example, elements that can exist in conventional LCD displays. It is noted that circuit elements are not limited to whole circuit components, such a whole capacitor, a whole transistor, etc., but can include portions of circuitry, such as only one of the two plates of a parallel plate capacitor.

Some of the circuit elements **311** can be electrically connected together such that the circuit elements **311** and their interconnections together form drive lines **222**. Various example methods of connecting together circuit elements **311** to form drive lines **222** will be discussed in more detail in reference to FIGS. **8-9**. Some of the circuit elements **311** that lie between drive lines **222** can serve as a buffer region **313**.

One purpose of the buffer region **313** can be to separate drive lines **222** from one another to reduce or to prevent cross talk and stray capacitance effects. Circuit elements **311** in buffer region **313** can, for example, be unconnected from drive lines **222**. In various embodiments, some or all of the circuit elements **311** in buffer region **313** can be, for example, electrically connected to each other, electrically unconnected from each other, maintained at a fixed voltage during a touch sensing operation, maintained at a floating potential during a touch sensing operation, etc. The example configurations of sense lines **223** and drive lines **222** shown in FIG. **3** can be laid out as shown in FIG. **2** as an overlapping orthogonal grid to form touch pixels **226** and **227**, for example. Although not illustrated in FIG. **3**, it is understood that first and second polarizers can be provided, the first polarizer can be adjacent the TFT glass and the second polarizer can be adjacent the color filter glass such that the TFT glass and the color filter glass are disposed between the first and second polarizers.

FIG. **3** also shows a pixel material **315** disposed between TFT glass **309** and color filtered glass **303**. Pixel material **315** is shown in FIG. **3** as separate column regions or cells above the circuit elements **311**. For example, when the pixel material is a liquid crystal, these column regions or cells are meant to illustrate regions of the liquid crystal controlled by the electric field produced by the pixel electrode and common electrode of the volume region or cell under consideration. Pixel material **315** can be a material that, when operated on by the display circuitry of touch screen **220**, can generate or control an amount, color, etc., of light produced by each display pixel. For example, in an LCD touch screen, pixel material **315** can be formed of liquid crystal, with each display pixel controlling a column region or cell of the liquid crystal. In this case, for example, various methods exist for operating liquid crystal in a display operation to control the amount of light emanating from each display pixel, e.g., applying an electric field in a particular direction depending on the type of LCD technology employed by the touch screen. In an in-plane switching (IPS), fringe field switching (FFS), and advanced fringe field switching (AFFS) LCD displays, for example, electrical fields between pixel electrodes and common electrodes (Vcom) disposed on the same side of the liquid crystal can operate on the liquid crystal material to control the amount of light from a backlight that passes through the display pixel. In an OLED (organic light emitting diode) display, for example, pixel material **315** can be, for example, an organic material in each pixel that generates light when a voltage is applied across the material. One skilled in the art would understand that various pixel materials can be used, depending on the type of display technology of the touch screen.

FIG. **3A** illustrates an enlarged view of a display pixel (as for example, a particular R, B, or G sub-pixel). As may be seen in FIG. **3A**, there can be provided a first substrate **325** (such as the TFT glass **309** of FIG. **3**), a second substrate **327** (such as the color filter glass **303** of FIG. **3**), a first polarizer **329** and a second polarizer **331**. The first polarizer **329** can be disposed adjacent the first substrate **325**, and the second polarizer **331** can be disposed adjacent the second substrate **327**. One display pixel of the first substrate **325** is shown greatly enlarged for purposes of illustration. A TFT **335** can have a gate **337**, a source **339** connected to a data line **341**, and a drain **343** connected to pixel electrode **345**. Common electrode **347** can be disposed adjacent the pixel electrode **345** and can be connected to a common electrode conductive line **349**. Layers of dielectric material **351a**, **351b** and **351c** can be disposed as shown in FIG. **3A** to separate electrodes from one another. FIG. **3A** also illustrates gate insulation layer **353**. An

electrical fringe field between the pixel electrode **345** and the common electrode **347** can control the pixel material disposed between the first and second substrates during the display operation in order to provide a display image.

FIG. **4** illustrates a more detailed view of color filter glass **303**. FIG. **4** includes color filters **305**, conductive wires **301**, which form sense lines **203**. Conductive wires **301** can be, for example, metal lines such as aluminum, etc. In this regard conductive wires **301** can be positioned behind a black mask **401** so that the conductive wires are not visible to a user. Therefore conductive wires **301** need not be transparent conductors. However, in some example embodiments, conductive wires **301** can be transparent metal. Although in the example embodiment shown in FIG. **4** the spacing between the columns of color filters **305** can be widened to accommodate conductive wires **301**, in some embodiments the spacing can be different, including equal spacing between the color filters.

FIG. **5** illustrates an example embodiment that includes an organic coat **501** that has been formed over conductive wires **301**. In other words, conductive wires **301** can be formed on the underside of color filter glass **303**, and then organic coat **501** can be formed on conductive wires **301**, such that the conductive wires are disposed between color filter glass **303** and organic coat **501**. Organic coat **501** can be formed of a material that can protect the conductive wires from exposure to chemicals, from physical abrasion, etc.

FIG. **6** illustrates another example embodiment showing another example configuration of sense lines **223**. As in the example shown in FIG. **3**, the example shown in FIG. **6** is a perspective view along line "A" shown in FIG. **2**. In the example embodiment shown in FIG. **6**, each of the sense lines **223** can include a conductive mesh **601**. Conductive mesh **601** can be formed of, for example, metal wires, metal strips, etc., that are formed on the underside of color filter glass **303**. Conductive mesh **601** can be, for example, a conductive orthogonal grid, the conductive lines of which are disposed between individual color filters **305**.

Sense line **223**, formed of conductive mesh **601**, can be conductively connected to contact pad **307** such that a sense signal received by the sense line can be transmitted to touch controller **206** for processing. Similar to the previous embodiment, the portion of touch screen **220** shown in example embodiment in FIG. **6** includes drive lines **222** and buffer regions **313**, each of which can be formed of circuit elements **311** that have been grouped together either operationally or physically to perform their respective functions. In a touch sensing operation, stimulation signals applied to drive lines **222** can allow touches to be sensed by sense lines **223** in the areas of various touch pixels, such as touch pixels **226** and **227**. The example embodiment shown in FIG. **6** also includes pixel material **315**, similar to the example embodiment shown in FIG. **3**.

FIG. **7** illustrates a more detailed view of color filter glass **303** shown in the example embodiment FIG. **6**. FIG. **7** includes color filters **305** and conductive mesh **601**, which form sense lines **203**. Conductive mesh **601** can be, for example, formed of non-transparent metal lines such as aluminum, etc. In this regard conductive mesh **601** can be positioned behind a black mask **701** so that the conductive mesh is not visible to a user. Therefore, in this embodiment, the conductive mesh **601** need not be made of transparent conductors. However, in some example embodiments, conductive mesh **601** can be transparent metal.

FIG. **8** illustrates a more detailed view of an example configuration of drive lines **222** and buffer regions **313** according to various embodiments. In this example embodi-

ment, circuit elements **311** can include common electrodes **801**. Common electrodes **801** can be operated as multi-function circuit elements that can operate as part of the display circuitry in a display operation and can operate as part of the touch sensing circuitry in a touch sensing operation of the touch screen. Common electrodes **801** can be electrically connected together with conductive lines **803**, to form the required regions such as regions that operate as drive lines **222** and regions that operate as buffer regions **313**. In this example embodiment, common electrodes functional region can be physically connected with fixed conductive lines. In other words, the common electrodes in each region can be permanently connected through the physical design of the touch screen. In other words, common electrodes **801** can be grouped together to form drive lines. Grouping multi-function circuit elements of display pixels can include operating the multi-function circuit elements of the display pixels together to perform a common function of the group. Grouping into functional regions may be accomplished through one or a combination of approaches, for example, the structural configuration of the system (e.g., physical breaks and bypasses, voltage line configurations), the operational configuration of the system (e.g., switching circuit elements on/off, changing voltage levels and/or signals on voltage lines), etc.

Stimulation signals can be applied to drive lines **222** through drive lead lines **805**. For example, drive lead lines can be electrically connected to driver logic **214**, which can provide the stimulation signals during the touch sensing operation. Buffer region **313** can be connected to a buffer lead line **807**, which can be connected to a buffer operator (not shown).

In the example shown in FIG. **8**, each common electrode (Vcom) **801** can serve as a multi-function circuit element that can operate as display circuitry of the display system of touch screen **220** and can also operate as touch sensing circuitry of the touch sensing system. In this example, each common electrode **801** can operate as a common electrode of the display circuitry of the touch screen, and can also operate together when grouped with other common electrodes as touch sensing circuitry of the touch screen. For example, a group of common electrodes **801** can operate together as a part of a drive line of the touch sensing circuitry during the touch sensing operation. Other circuit elements of touch screen **220** can form part of the touch sensing circuitry by, for example, electrically connecting together common electrodes **801** of a region, switching electrical connections, etc. Each display pixel can include a common electrode **801**, which can be a circuit element of the display system circuitry in the pixel stackup (i.e., the stacked material layers forming the display pixels) of the display pixels of some types of conventional LCD displays, e.g., fringe field switching (FFS) displays, that can operate as part of the display system to display an image.

In general, each of the touch sensing circuit elements may be either a multi-function circuit element that can form part of the touch sensing circuitry and can perform one or more other functions, such as forming part of the display circuitry, or may be a single-function circuit element that can operate as touch sensing circuitry only. Similarly, each of the display circuit elements may be either a multi-function circuit element that can operate as display circuitry and perform one or more other functions, such as operating as touch sensing circuitry, or may be a single-function circuit element that can operate as display circuitry only. Therefore, in some embodiments, some of the circuit elements in the display pixel stackups can be multi-function circuit elements and other circuit elements may be single-function circuit elements. In other embodi-

ments, all of the circuit elements of the display pixel stackups may be single-function circuit elements.

In the embodiment shown in FIG. 9, the circuit elements used to form drive lines, Vcom 901 in this example, can be physically connected together on the TFT glass through conductive lines 903 to form individual rows of connected together Vcom 901. The individual rows of Vcom, i.e., Vcom drive rows 905, can be connected together with other Vcom drive rows in the periphery using contact pads 907. In this example, each drive line 222 can be formed through fixed electrical connections.

FIG. 9A illustrates a more detailed view of the of the TFT glass substrate previously illustrated in FIGS. 3, 6, 8 and 9. It is understood that the pixel electrodes, gate lines, data lines, TFT elements, and common electrode conductive lines connecting together the common electrodes are also present in FIGS. 3, 6, 8 and 9, but have been omitted for simplicity of illustration. Thus, as seen in FIG. 9A, gate lines 925 extend in a row (horizontal) direction and data lines 927 extend in a column (vertical) direction. The gate lines can be connected to gates of transistors 929 (for example, thin film transistors, TFTs) and control (e.g., turn on) these transistors to permit data from the data lines 927 to be applied to pixel electrodes 931 during a display operation. During the display operation, common electrodes 901 can be held at a preset voltage. FIG. 9A also shows conductive lines 903 interconnecting common electrodes 901 along the row and column directions. An electrical field can be formed by the difference in voltage between pixel electrode 931 and its corresponding common electrode 901 and this electric field can control the pixel material disposed above the first substrate (disposed between the first and second substrates). A pixel can be formed at each crossing of gate line 925 and data line 927 and comprises the pixel electrode 931 and its corresponding common electrode 901.

FIGS. 10 and 11 illustrate an example color filter glass design and an example TFT design, respectively, according to various embodiments. FIG. 10 includes an example configuration of multiple sense lines 223, each including multiple conductive wires such as conductive wires 301, connected to multiple contact pads, such as contact pad 311. For the sake of clarity, individual color filters are not shown in FIG. 10. In this example embodiment, conductive wires 301 and contact pads 307 can be formed on color filter glass 303 by, for example, physical vapor deposition (PVD).

FIG. 11 illustrates an example TFT glass according to various example embodiments. TFT glass 1101 can include various touch sensing circuitry and display circuitry. Touch sensing circuitry can include, for example, drive lines 222. In this example embodiment, each drive line 222 can include multiple Vcom drive rows 1103. In this example embodiment, each Vcom drive row 1103 in a drive line 222 can be connected to a single conductive contact pad 1105 on the left side of the TFT glass, and connected to a single contact pad 1105 on the right side of TFT glass. Contact pads 1105 can be connected through drive signal lines 1107 to touch controller 206 (FIG. 2) through a touch flex circuit 1109. In this way, for example, multiple Vcom drive rows 1103 can be driven together as a single drive line 222 during a touch sensing operation. TFT glass 1101 can also include integrated drivers 1111 that can drive the display circuitry, for example, using various display circuit elements such as gate lines, data lines, etc. Touch flex circuit 1109 can also be connected to sense signal lines 1113, which can be connected to contact pads 307 on the color filter glass through conductive paste 1115.

FIG. 12 illustrates another example TFT glass design. FIG. 12 shows a TFT glass 1201 in which individual rows of Vcom are electrically connected together to form Vcom drive rows

1203. In other words, similar to the previous embodiment, each Vcom circuit element in Vcom drive row 1203 is permanently connected to the other Vcom in the drive row. However, in the example embodiment shown in FIG. 12, each individual Vcom drive row 1203 can be connected to a Vcom driver 1205 in the periphery of TFT glass 1201. Vcom driver 1205 can operate the Vcom drive rows 1203 in each drive line 222 to generate the same stimulation signals on each individual Vcom drive row 1203 of each drive line 222 during a touch sensing operation. In other words, a first stimulation signal can be applied to a first group of individual rows of Vcom, and a second stimulation signal can be applied to a second group of individual rows of Vcom. In this way, for example, a group of multiple Vcom drive rows 1203 can be operated together as a single drive line 222 even though the individual Vcom drive rows themselves are not connected to each other through fixed electrical connections.

Likewise, during a display operation of the touch screen, integrated gate drivers 1207 can operate the individual Vcom drive rows 1203 as part of the display circuitry to display an image on the touch screen. Therefore, in this example embodiment, the individual Vcom drive rows 1203 can be grouped together or operated individually as needed depending on the operation of the touch screen.

FIG. 13 illustrates an example method of driving the circuit elements of the touch screen in the display operation and in the touch sensing operation. This example method can apply to an operation of a touch screen including the design of TFT glass 1201 of FIG. 12, for example. In this example embodiment, the display operation in which an image is displayed and the touch sensing operation in which touch is sensed can occur concurrently by operating different portions of the touch screen differently, that is, one group of circuit elements can be operated as display circuitry to display an image while, at the same time, another group of the circuit elements can be operated as touch sensing circuitry to sense a touch.

In a first time period 1301, integrated gate driver 1207, along with other display circuitry, can update a first group 1303 of circuit elements, e.g., an individual row of display pixels, to display a line of an image on the touch screen. For example, integrated gate driver 1207 can apply a common voltage to the Vcom in the first row of display pixels. Concurrently, in first time period 1301, Vcom driver 1205 can apply a stimulation signal to a first drive line 1305 that includes a second group 1307 of the circuit elements. Applying the stimulation signal can include, for example, applying the same stimulation signal to each of the individual Vcom drive rows 1203 in the first drive line 222. Because the image scanning row currently being scanned by integrated gate driver 1207 is not located in first drive line 1305, the Vcom drive rows 1203 being used for updating the displayed image do not overlap with the Vcom drive rows 1203 used for touch sensing as a drive line.

A second time period 1302 shows a third group 1309 of circuit elements can be operated as display circuitry, e.g., integrated gate driver 1207 can apply a common voltage to the Vcom in a third row of display pixels. The common voltage applied to the Vcom in the third row can be, for example, of an opposite polarity to the common voltage applied to the Vcom in the first row of display pixels. Concurrently, in second time period 1302, Vcom driver 1205 can apply a stimulation signal to a second drive line 1311 that includes first group 1303 and additional rows of Vcom 1313. In this way, for example, display operation and touch sensing operation can occur concurrently in an integrated touch screen.

In the example driving method shown in FIG. 13, display updating can be done on a row by row basis for individual

Vcom drive rows **1203**. In some embodiments, integrated gate driver **1207** can change the Vcom polarity on a row by row basis as well. For example, for each row of display pixel integrated gate driver **1207** can operate to change the polarity of Vcom, switch the gates of the row of display pixels to an “on” state, write data into each display pixel, and switch the gates to an “off” state. When different rows of Vcom are operated to perform touch sensing concurrently with display updating, as in this example embodiment, it is noted that in the touch sensing groups of circuit elements no data is being written into the display pixels in the rows of pixels in the drive line because the gate lines of these rows of display pixels are in the “off” state.

FIG. **14** illustrates another example embodiment of sense lines **223**. FIG. **14** illustrates a color filter glass **303** that includes sense lines **223** formed of a transparent conductor, such as indium tin oxide (ITO), on the underside of color filter glass **303**. The ITO can be deposited on the underside of color filter glass **303** to cover a contiguous area including covering color filters **305**. FIG. **14** also illustrates ground regions **1401** between sense lines **223**. Ground regions **1401** can be formed of transparent conductor, such as ITO formed on the underside of color filter glass **303** and electrically separated from the sense lines on either side of each sense line. Ground regions **1401** can be connected to, for example, a ground or virtual ground in the periphery of the panel. Positioning ground regions between sense regions can help reduce interference in some embodiments.

FIG. **15** illustrates an example TFT glass design, TFT glass **1501**. In this example, TFT glass **1501** can include various touch sensing circuitry and display circuitry. Touch sensing circuitry can include, for example, drive lines **222**. In this example embodiment, each drive line **222** can include multiple Vcom drive rows **1503**. In this example embodiment, each Vcom drive row **1503** in a drive line **222** can be connected to a single conductive contact pad **1505** on the left side of the TFT glass, and connected to a single contact pad **1105** on the right side of TFT glass. Contact pads **1505** can be connected through drive signal lines **1507** to touch controller **206** through a touch flex circuit **1509**. In this way, for example, multiple Vcom drive rows **1503** can be driven together as a single drive line **222** during a touch sensing operation. TFT glass **1501** can also include integrated drivers **1511** that can drive the display circuitry, for example, using various display circuit elements such as gate lines, data lines, etc. Touch flex circuit **1509** can also be connected to sense signal lines **1513**, which can be connected to contact pads **307** on the color filter glass through conductive paste **1515**.

In FIGS. **3**, **6**, **8** and **9**, each row of display pixels is illustrated as having a separate common electrode for each display pixel. These common electrodes (for example, circuit elements **311** of FIGS. **3** and **6**, common electrode **801** of FIG. **8**, and common electrode **901** of FIG. **9**) may however, not be physically distinct and separate structures corresponding to each pixel electrode. In some embodiments the common electrodes that are electrically connected together across a particular row, as for example, Vcom drive row **905** of FIG. **9**, may be formed by a single, continuous layer of conductive material, e.g., ITO. Further, a single continuous layer of conductive material (ITO) may be used for an entire drive line **222** such as in FIG. **8** where the illustrated common electrodes within each drive line **222** are electrically connected together along both rows (first direction) and columns (second direction, perpendicular to the first direction).

In addition, although example embodiments herein may describe the display circuitry as operating during a display operation, and describe the touch sensing circuitry as operat-

ing during a touch sensing operation, it should be understood that a display operation and a touch sensing operation may be operated at the same time, e.g., partially or completely overlap, or the display operation and touch phase may operate at different times. Also, although example embodiments herein describe certain circuit elements as being multi-function and other circuit elements as being single-function, it should be understood that the circuit elements are not limited to the particular functionality in other embodiments. In other words, a circuit element that is described in one example embodiment herein as a single-function circuit element may be configured as a multi-function circuit element in other embodiments, and vice versa.

Although embodiments of this disclosure have been fully described with reference to the accompanying drawings, it is to be noted that various changes and modifications including, but not limited to, combining features of different embodiments, omitting a feature or features, etc., as will be apparent to those skilled in the art in light of the present description and figures.

For example, one or more of the functions of computing system **200** described above can be performed by firmware stored in memory (e.g. one of the peripherals **204** in FIG. **2**) and executed by touch processor **202**, or stored in program storage **232** and executed by host processor **228**. The firmware can also be stored and/or transported within any computer-readable medium for use by or in connection with an instruction execution system, apparatus, or device, such as a computer-based system, processor-containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions. In the context of this document, a “computer-readable medium” can be any medium that can contain or store the program for use by or in connection with the instruction execution system, apparatus, or device. The computer readable medium can include, but is not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus or device, a portable computer diskette (magnetic), a random access memory (RAM) (magnetic), a read-only memory (ROM) (magnetic), an erasable programmable read-only memory (EPROM) (magnetic), a portable optical disc such a CD, CD-R, CD-RW, DVD, DVD-R, or DVD-RW, or flash memory such as compact flash cards, secured digital cards, USB memory devices, memory sticks, and the like.

The firmware can also be propagated within any transport medium for use by or in connection with an instruction execution system, apparatus, or device, such as a computer-based system, processor-containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions. In the context of this document, a “transport medium” can be any medium that can communicate, propagate or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The transport readable medium can include, but is not limited to, an electronic, magnetic, optical, electromagnetic or infrared wired or wireless propagation medium.

Example embodiments may be described herein with reference to a Cartesian coordinate system in which the x-direction and the y-direction can be equated to the horizontal direction and the vertical direction, respectively. However, one skilled in the art will understand that reference to a particular coordinate system is simply for the purpose of clarity, and does not limit the direction of the elements to a particular direction or a particular coordinate system. Furthermore, although specific materials and types of materials

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may be included in the descriptions of example embodiments, one skilled in the art will understand that other materials that achieve the same function can be used. For example, it should be understood that a “metal layer” as described in the examples below can be a layer of any electrically conductive material.

In some embodiments, the drive lines and/or sense lines can be formed of other elements including, for example other elements already existing in typical LCD displays (e.g., other electrodes, conductive and/or semiconductive layers, metal lines that would also function as circuit elements in a typical LCD display, for example, carry signals, store voltages, etc.), other elements formed in an LCD stackup that are not typical LCD stackup elements (e.g., other metal lines, plates, whose function would be substantially for the touch sensing system of the touch screen), and elements formed outside of the LCD stackup (e.g., such as external substantially transparent conductive plates, wires, and other elements). For example, part of the touch sensing system can include elements similar to known touch panel overlays.

Although various embodiments are described with respect to display pixels, one skilled in the art would understand that the term display pixels can be used interchangeably with the term display sub-pixels in embodiments in which display pixels are divided into sub-pixels. For example, some embodiments directed to RGB displays can include display pixels divided into red, green, and blue sub-pixels. In other words, in some embodiments, each sub-pixel can be a red (R), green (G), or blue (B) sub-pixel, with the combination of all three R, G and B sub-pixels forming one color display pixel. One skilled in the art would understand that other types of touch screen could be used. For example, in some embodiments, a sub-pixel may be based on other colors of light or other wavelengths of electromagnetic radiation (e.g., infrared) or may be based on a monochromatic configuration, in which each structure shown in the figures as a sub-pixel can be a pixel of a single color.

What is claimed is:

1. A capacitive touch screen including a plurality of display pixels, the touch screen comprising:

a color filter layer;

a thin film transistor (TFT) layer including a plurality of drive lines, wherein the drive lines are configured to transmit a stimulation signal, the stimulation signal used to stimulate the capacitive touch screen for the purpose of detecting touch input events;

a liquid crystal layer disposed between the TFT layer and the color filter layer; and

a plurality of sense lines disposed between liquid crystal layer and the color filter layer, wherein the sense lines are configured to receive signal based on the stimulation signals transmitted by the drive lines and wherein the drive lines and the sense lines form a plurality of capacitive sensing nodes.

2. The touch screen of claim 1, wherein each display pixel includes a circuit element in the TFT layer, and each drive line includes a plurality of the circuit elements.

3. The touch screen of claim 2, wherein the circuit elements in each individual row of display pixels are electrically connected through fixed conductive connections, and during a touch sensing operation a first stimulation signal is applied to a first plurality of individual rows of the circuit elements and a second stimulation signal is applied to a second plurality of individual rows of the circuit elements.

4. The touch screen of claim 2, wherein the circuit elements are connected to display circuitry during a display operation of the touch screen.

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5. The touch screen of claim 4, wherein the circuit elements include common electrodes.

6. The touch screen of claim 4, wherein electric fields are applied to the liquid crystal layer during the display operation, the electric fields being based on voltages applied to the circuit elements.

7. The touch screen of claim 1, wherein each sense line includes a plurality of conductive lines disposed on the color filter layer.

8. The touch screen of claim 7, wherein each sense line includes a conductive mesh disposed on the color filter layer.

9. The touch screen of claim 1, wherein the color filter layer includes a black mask, and the sense lines are disposed on the black mask.

10. A capacitive touch screen including a plurality of display pixels, the touch screen comprising:

a color filter layer;

a plurality of drive lines that carry, during a touch sensing operation, stimulation signals that are used to stimulate the touch screen for the purpose of detecting touch and proximity events;

a pixel material disposed between the plurality of drive lines and the color filter layer, the pixel material;

display circuitry that controls, during a display operation, the pixel material of each display pixel such that a controlled amount of light from each display pixel passes through the color filter to form an image; and

a plurality of sense lines that receive sense signals based on the stimulation signals, the sense lines being disposed between the pixel material and the color filter layer.

11. The touch screen of claim 10, wherein the sense lines are disposed on the color filter layer.

12. The touch screen of claim 11, wherein the color filter layer includes a plurality of individual color filters, and the sense lines include conductive material disposed between individual color filters.

13. The touch screen of claim 12, wherein the sense lines include non-transparent conductive material.

14. The touch screen of claim 11, wherein the sense lines include transparent conductive material.

15. The touch screen of claim 11, further comprising an organic coat disposed on the sense lines.

16. A touch screen including a plurality of display pixels, the touch screen comprising:

a first substrate including a plurality display pixels disposed thereon, each display pixel including a pixel electrode and a switching element for connecting a data line to the pixel electrode to display an image on the touch screen during a display mode of operation, and for disconnecting the data line from the pixel electrode during a touch sensing mode of operation;

the display pixels including common electrodes for receiving a common voltage during the display mode of operation and a stimulation voltage during the touch sensing mode of operation;

a second substrate including a color filter;

a pixel material disposed between the first and second substrates; and

a plurality of sense lines disposed between the second substrate and the pixel material.

17. The touch screen of claim 16, wherein the stimulation voltage includes an alternating current waveform.

18. The touch screen of claim 17 wherein the display pixels are arranged along a first direction and along a second direction, perpendicular to the first direction, and wherein each

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drive line of a plurality of drive lines is formed by at least one group of common electrodes disposed in the first direction; and

the sense lines are disposed along the second direction, crossing the drive lines;

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wherein each intersection of one of the drive lines with one of the sense lines forms a capacitive sensing node.

19. The touch screen of claim **16**, wherein the pixel material includes a light modifying material.

20. The touch screen of claim **16**, wherein the pixel material includes a light generating material.

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21. The touch screen of claim **10**, wherein the pixel material includes a light modifying material.

22. The touch screen of claim **10**, wherein the pixel material includes a light generating material.

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专利名称(译)	集成触摸屏		
公开(公告)号	US8743300	公开(公告)日	2014-06-03
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[标]申请(专利权)人(译)	张世CHANG 钟约翰Z		
申请(专利权)人(译)	张世CHANG 钟JOHN Z.		
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发明人	CHANG, SHIH CHANG ZHONG, JOHN Z.		
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代理机构(译)	美富律师事务所		
其他公开文献	US20120162104A1		
外部链接	Espacenet USPTO		

摘要(译)

提供集成触摸屏，包括由薄膜晶体管层的分组在一起的电路元件形成的驱动线和在滤色器层和修改或产生光的材料层之间形成的感测线。TFT层中的公共电极（Vcom）可以在触摸感测操作期间被分组在一起以形成驱动线。感光线可以形成在滤色镜玻璃的下侧，并且液晶区域可以设置在滤色镜玻璃和TFT层之间。将感测线放置在滤色器玻璃的下侧上，即在显示像素单元内，可以提供例如在组装像素单元之后允许滤色器玻璃变薄的益处。

