



(12) **United States Patent  
Hall**

(10) **Patent No.: US 9,535,650 B2**  
(45) **Date of Patent: Jan. 3, 2017**

(54) **SYSTEM FOR MODULAR MULTI-PANEL  
DISPLAY WHEREIN EACH DISPLAY IS  
SEALED TO BE WATERPROOF AND  
INCLUDES ARRAY OF DISPLAY ELEMENTS  
ARRANGED TO FORM DISPLAY PANEL  
SURFACE**

(58) **Field of Classification Search**  
CPC .... G06F 3/1446; G06F 3/147; H05K 7/20954;  
H05K 1/181

(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

(71) Applicant: **Ultravision Technologies, LLC**, Dallas,  
TX (US)

1,816,254 A 7/1931 Heath  
3,150,455 A 9/1964 Indorf

(Continued)

(72) Inventor: **William Y. Hall**, Dallas, TX (US)

(73) Assignee: **Ultravision Technologies, LLC**, Dallas,  
TX (US)

FOREIGN PATENT DOCUMENTS

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

CN 201226214 Y 4/2009  
CN 201449702 U 5/2010

(Continued)

OTHER PUBLICATIONS

(21) Appl. No.: **14/948,939**

Final Office action dated Jul. 21, 2015 received in U.S. Appl. No.  
14/328,624, 42 pages.

(22) Filed: **Nov. 23, 2015**

(Continued)

(65) **Prior Publication Data**

US 2016/0086521 A1 Mar. 24, 2016

*Primary Examiner* — Tammara Peyton

(74) *Attorney, Agent, or Firm* — Slater Matsil, LLP

(57)

**ABSTRACT**

Embodiments of the present invention relate to integrated modular display systems. In one embodiment, a modular multi-panel display system includes a mechanical support structure, and a plurality of display panels detachably mounted to the mechanical support structure so as to form an integrated display panel. Each LED panel includes an LED array and an LED driver coupled to the LED array. Each panel further includes a power supply unit disposed outside the housing and electrically coupled to the receiver circuit. The mechanical structure is configured to provide mechanical support to the plurality of display panels without providing hermetic sealing. Each of the plurality of display panels is hermetically sealed.

**Related U.S. Application Data**

(63) Continuation of application No. 14/341,678, filed on  
Jul. 25, 2014, now Pat. No. 9,195,281.

(Continued)

(51) **Int. Cl.**

**G03F 3/00** (2006.01)

**G06F 3/14** (2006.01)

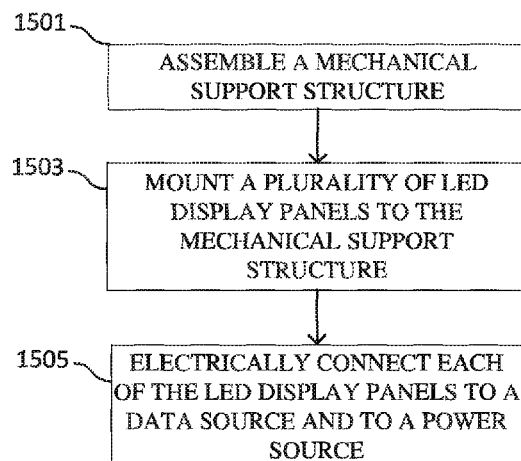
(Continued)

(52) **U.S. Cl.**

CPC ..... **G06F 3/1446** (2013.01); **F21K 9/20**  
(2016.08); **F21V 23/023** (2013.01);

(Continued)

**6 Claims, 50 Drawing Sheets**



## Related U.S. Application Data

- (60) Provisional application No. 62/025,463, filed on Jul. 16, 2014, provisional application No. 61/922,631, filed on Dec. 31, 2013.

## (51) Int. Cl.

**G06F 3/147** (2006.01)  
**H05K 7/20** (2006.01)  
**H05K 1/18** (2006.01)  
**H05K 5/03** (2006.01)  
**F21V 23/02** (2006.01)  
**F21V 31/00** (2006.01)  
**G06F 1/16** (2006.01)  
**G06F 1/18** (2006.01)  
**G09F 9/302** (2006.01)  
**G09F 13/22** (2006.01)  
**H01B 7/282** (2006.01)  
**H01B 9/00** (2006.01)  
**H01B 11/02** (2006.01)  
**H05K 5/00** (2006.01)  
**H05K 5/02** (2006.01)  
**H05K 7/14** (2006.01)  
**G06F 1/26** (2006.01)  
**H04N 7/00** (2011.01)  
**G09G 3/32** (2016.01)  
**F21Y 101/00** (2016.01)

## (52) U.S. Cl.

CPC ..... **F21V 31/005** (2013.01); **G06F 1/1601** (2013.01); **G06F 1/183** (2013.01); **G06F 1/188** (2013.01); **G06F 1/189** (2013.01); **G06F 1/26** (2013.01); **G06F 3/147** (2013.01); **G09F 9/3023** (2013.01); **G09F 13/22** (2013.01); **H01B 7/2825** (2013.01); **H01B 9/003** (2013.01); **H01B 11/02** (2013.01); **H05K 1/181** (2013.01); **H05K 5/0017** (2013.01); **H05K 5/0247** (2013.01); **H05K 5/03** (2013.01); **H05K 7/1427** (2013.01); **H05K 7/20** (2013.01); **H05K 7/2039** (2013.01); **H05K 7/20136** (2013.01); **H05K 7/20954** (2013.01); **F21Y 2101/00** (2013.01); **G09F 2013/222** (2013.01); **G09G 3/32** (2013.01); **G09G 2300/026** (2013.01); **G09G 2360/04** (2013.01); **H04N 7/00** (2013.01); **H05K 2201/10106** (2013.01)

## (58) Field of Classification Search

USPC ..... 710/8–10; 367/622  
 See application file for complete search history.

## (56) References Cited

## U.S. PATENT DOCUMENTS

4,457,090 A 7/1984 McDonough  
 4,497,125 A 2/1985 Hutchinson  
 4,782,336 A 11/1988 Bailey  
 4,964,231 A 10/1990 De Maat et al.  
 5,172,504 A 12/1992 De Maat et al.  
 5,341,088 A 8/1994 Davis  
 5,523,769 A 6/1996 Lauer et al.  
 5,600,910 A 2/1997 Blackburn  
 5,722,767 A 3/1998 Lin  
 5,796,376 A 8/1998 Banks  
 5,900,850 A 5/1999 Bailey et al.  
 5,949,581 A 9/1999 Kurtenbach et al.  
 5,990,802 A 11/1999 Maskeny  
 6,045,240 A 4/2000 Hochstein  
 6,065,854 A 5/2000 West et al.  
 6,114,632 A 9/2000 Planas, Sr. et al.

6,175,342 B1 1/2001 Nicholson et al.  
 6,237,290 B1 5/2001 Tokimoto et al.  
 6,314,669 B1 11/2001 Tucker  
 6,335,829 B1 1/2002 Van De Voorde  
 6,362,801 B1 3/2002 Yuhara  
 6,414,650 B1 7/2002 Nicholson et al.  
 6,550,521 B1 4/2003 McNabb  
 6,570,548 B2 5/2003 Smith  
 6,634,124 B1 10/2003 Bierschbach  
 6,657,605 B1 12/2003 Boldt, Jr. et al.  
 6,677,918 B2 1/2004 Yuhara et al.  
 6,737,983 B1 5/2004 Temple  
 6,741,222 B1 5/2004 Tucker  
 6,810,612 B2 11/2004 Huang  
 6,813,853 B1 11/2004 Tucker  
 6,819,303 B1 11/2004 Berger et al.  
 6,998,538 B1 2/2006 Fetterolf, Sr. et al.  
 7,055,271 B2 6/2006 Lutz et al.  
 7,072,407 B2 7/2006 Schurig  
 7,086,188 B2 8/2006 Tsao  
 7,091,933 B2 8/2006 McClintock et al.  
 7,161,558 B1 1/2007 Eidem et al.  
 7,170,480 B2 1/2007 Boldt, Jr. et al.  
 7,204,602 B2 4/2007 Archer  
 7,267,459 B2 9/2007 Matheson  
 7,319,408 B2 1/2008 Temple  
 7,334,361 B2 2/2008 Schrimpf et al.  
 7,355,562 B2 4/2008 Schubert et al.  
 7,450,085 B2 11/2008 Thielemans et al.  
 7,495,576 B2 2/2009 Maskeny et al.  
 7,502,950 B1 3/2009 Brands  
 7,557,781 B2 7/2009 Chuang et al.  
 7,605,772 B2 10/2009 Syrstad  
 7,674,000 B2 3/2010 Valerio, Jr. et al.  
 7,688,280 B2 3/2010 Callegari et al.  
 7,694,444 B2 4/2010 Miller et al.  
 7,703,941 B2 4/2010 Lee  
 7,774,968 B2 8/2010 Nearman et al.  
 7,779,568 B2 8/2010 Gettelfinger et al.  
 7,797,865 B2 9/2010 Patel et al.  
 7,868,903 B2 1/2011 Wendler et al.  
 7,869,198 B1 1/2011 Nearman et al.  
 7,907,133 B2 3/2011 Joffer et al.  
 7,926,213 B1 4/2011 Kludt et al.  
 7,950,174 B2 5/2011 Xu  
 7,971,378 B2 7/2011 Campoy Odena  
 8,007,121 B2 8/2011 Elliott et al.  
 8,016,452 B2 9/2011 Dunn  
 8,066,403 B2 11/2011 Sanfilippo et al.  
 8,074,387 B2 12/2011 Mancuso  
 8,081,145 B2 12/2011 Ronkholz et al.  
 8,104,204 B1 1/2012 Syrstad  
 8,111,208 B2 2/2012 Brown  
 8,115,229 B2 2/2012 Christy  
 8,122,627 B2 2/2012 Miller  
 8,130,175 B1 3/2012 Joffer et al.  
 8,136,279 B1 3/2012 Nearman et al.  
 8,154,864 B1 4/2012 Nearman et al.  
 8,156,672 B2 4/2012 Xu  
 8,168,990 B2 5/2012 Christy  
 8,172,097 B2 5/2012 Nearman et al.  
 8,184,114 B2 5/2012 Oh et al.  
 8,228,261 B2 7/2012 Callegari et al.  
 8,281,344 B1 10/2012 Mathias  
 8,301,939 B2 10/2012 Gloege et al.  
 8,314,433 B2 11/2012 Christy  
 8,344,410 B2 1/2013 Wendler et al.  
 8,350,788 B1 1/2013 Nearman et al.  
 8,362,696 B2 1/2013 Zheng  
 8,410,993 B2 4/2013 Jenks et al.  
 8,414,149 B2 4/2013 Nearman  
 8,434,898 B2 5/2013 Sanfilippo et al.  
 8,552,928 B2 10/2013 Wendler et al.  
 8,558,755 B2 10/2013 Kharrati et al.  
 8,599,108 B2 12/2013 Kline et al.  
 8,604,509 B2 12/2013 Wendler et al.  
 8,648,774 B2 2/2014 Kline et al.  
 8,702,048 B2 4/2014 Kludt et al.  
 8,714,665 B2 5/2014 Campagna et al.

(56)

**References Cited****U.S. PATENT DOCUMENTS**

8,766,880	B2	7/2014	Kharrati et al.
8,803,766	B2	8/2014	Kline et al.
8,824,124	B1	9/2014	Carlson et al.
8,824,125	B1	9/2014	Cox et al.
9,047,039	B2	6/2015	Perkins et al.
9,047,791	B2 *	6/2015	Cox ..... G09F 9/3026
9,131,600	B1 *	9/2015	Hall ..... G06F 3/1446
9,164,722	B2 *	10/2015	Hall ..... H01H 11/04
9,167,191	B2	10/2015	Kondo et al.
9,207,904	B2 *	12/2015	Hall ..... G06F 3/147
2001/0037591	A1	11/2001	Nicholson et al.
2002/0126086	A1	9/2002	Takeuchi et al.
2002/0176267	A1	11/2002	Tanaka et al.
2003/0146882	A1	8/2003	Ogino et al.
2003/0158886	A1	8/2003	Walls et al.
2004/0008155	A1	1/2004	Cok
2004/0090391	A1	5/2004	Kondo
2004/0104871	A1	6/2004	Boldt, Jr. et al.
2004/0186723	A1	9/2004	Mizutani et al.
2004/0196049	A1	10/2004	Yano et al.
2004/0222941	A1	11/2004	Wong et al.
2004/0240230	A1	12/2004	Kitajima et al.
2005/0052374	A1	3/2005	Devos et al.
2005/0052375	A1	3/2005	Devos et al.
2005/0078104	A1	4/2005	Matthies et al.
2005/0134525	A1	6/2005	Tanghe et al.
2005/0134526	A1	6/2005	Willem et al.
2005/0178034	A1	8/2005	Schubert et al.
2005/0189311	A1	9/2005	Colby et al.
2005/0190520	A1	9/2005	Schomaker et al.
2005/0264471	A1	12/2005	Yamazaki et al.
2006/0031720	A1	2/2006	Choi
2006/0039142	A1	2/2006	Temple
2006/0132048	A1	6/2006	Popovich
2006/0164587	A1	7/2006	Oh
2006/0170614	A1	8/2006	Tzong et al.
2006/0185612	A1	8/2006	Bonner et al.
2006/0241878	A1	10/2006	Jung et al.
2006/0242871	A1	11/2006	Kondo et al.
2006/0256033	A1	11/2006	Chan et al.
2007/0000849	A1	1/2007	Lutz et al.
2007/0279314	A1	12/2007	Brown
2008/0047184	A1	2/2008	Dean
2008/0078733	A1	4/2008	Nearman et al.
2008/0141571	A1	6/2008	Kottwitz
2008/0266206	A1	10/2008	Nelson et al.
2008/0285087	A1	11/2008	Perkins et al.
2008/0303747	A1	12/2008	Velicescu
2009/0021532	A1	1/2009	Gloege et al.
2009/0024929	A1	1/2009	Gloege et al.
2009/0073080	A1	3/2009	Meersman et al.
2009/0096711	A1	4/2009	Jang et al.
2009/0146910	A1	6/2009	Gardner
2009/0146919	A1	6/2009	Kline et al.
2009/0147028	A1	6/2009	Sefton et al.
2009/0251391	A1	10/2009	Ng et al.
2009/0289160	A1	11/2009	Kludt et al.
2009/0322251	A1	12/2009	Hilgers
2010/0026973	A1	2/2010	Hemphill et al.
2010/0123732	A1	5/2010	Jenks et al.

2010/0251583	A1	10/2010	Brown et al.
2010/0288895	A1	11/2010	Shamie
2010/0295424	A1	11/2010	Alexander
2010/0309185	A1	12/2010	Koester et al.
2011/0025696	A1	2/2011	Wyatt et al.
2011/0096568	A1	4/2011	Schattinger et al.
2011/0134640	A1	6/2011	Bertele
2011/0168653	A1	7/2011	Garrett et al.
2011/0205757	A1	8/2011	Whyte
2011/0267328	A1	11/2011	Venkatasubramanian et al.
2012/0005563	A1	1/2012	Gloege et al.
2012/0019490	A1	1/2012	Huang
2012/0021873	A1	1/2012	Brunner
2012/0062540	A1	3/2012	Quadri et al.
2012/0112235	A1	5/2012	Preuschl et al.
2012/0218753	A1	8/2012	Joffer et al.
2012/0218758	A1	8/2012	Wang et al.
2012/0236509	A1	9/2012	Cope et al.
2012/0248950	A1	10/2012	Niibori
2012/0299480	A1	11/2012	Peting et al.
2013/0002634	A1	1/2013	Wendler et al.
2013/0182440	A1	7/2013	Ferrie et al.
2013/0271973	A1	10/2013	Rycyna, III
2013/0279161	A1	10/2013	Pickard et al.
2013/0321387	A1	12/2013	Ohe
2014/0259645	A1	9/2014	Cox et al.
2014/0267784	A1	9/2014	Rykowski
2014/0267896	A1	9/2014	Cox et al.
2015/0145851	A1	5/2015	Takeda et al.
2015/0205565	A1	7/2015	Koguchi

**FOREIGN PATENT DOCUMENTS**

CN	201540699	U	8/2010
CN	202383944	U	8/2012
CN	103280164	A	9/2013
CN	203250491	U	10/2013
CN	203607050	U	5/2014
WO	2005083660		9/2005
WO	2014005600		1/2014

**OTHER PUBLICATIONS**

International Search Report and Written Opinion received in International Application No. PCT/US2014/072373 mailed May 27, 2015, 19 pages.

Daktronics, "Daktronics LED Billboard Technology," [www.daktronics.com](http://www.daktronics.com) Nov. 14, 2013, 3 pages.

Daktronics, "The Smarter Approach to Digital Outdoor," Daktronics Digital Billboard Products, 2013, 16 pages.

Ekta, "WOWStrip," [www.ekta-led.com](http://www.ekta-led.com), Jun. 19, 2014, 5 pages.

"What is IP? Explained: Ingress Protection rating (IP Rating, IP65-IP68) system," Waterproof TVs Direct; Apr. 11, 2012; <http://waterproof-tvs-direct.co.uk/blog/waterproof-tv/what-is-ip-ip-explained-ingress-protection-rating-ip-rating-ip65-ip68-system>.

WOWstrip Semi-Transparent LED Displays product page, <http://www.ekta-led.com/prod/68/17/190/>, retrieved Jun. 19, 2014, 3 pages.

UK Intellectual Property Office, Search Report in Application No. GB1518912.9, Mar. 2, 2016, pp. 1-6.

\* cited by examiner

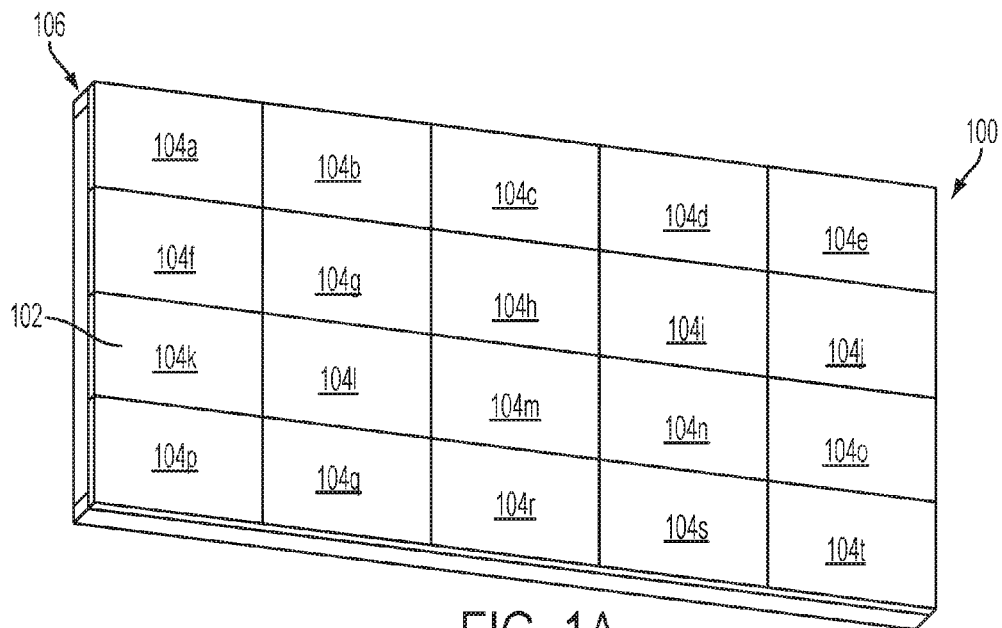


FIG. 1A

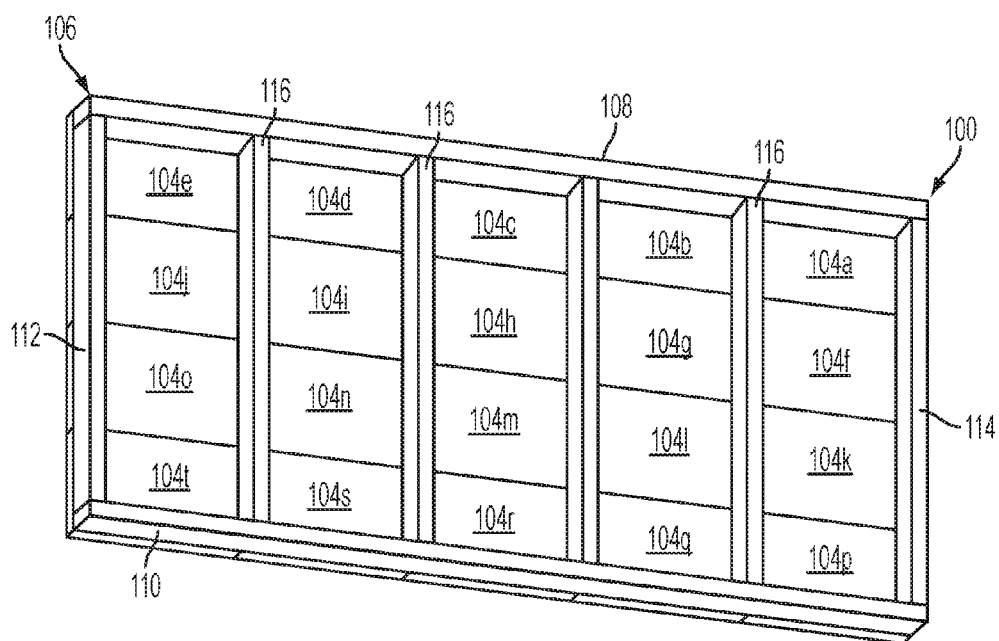


FIG. 1B

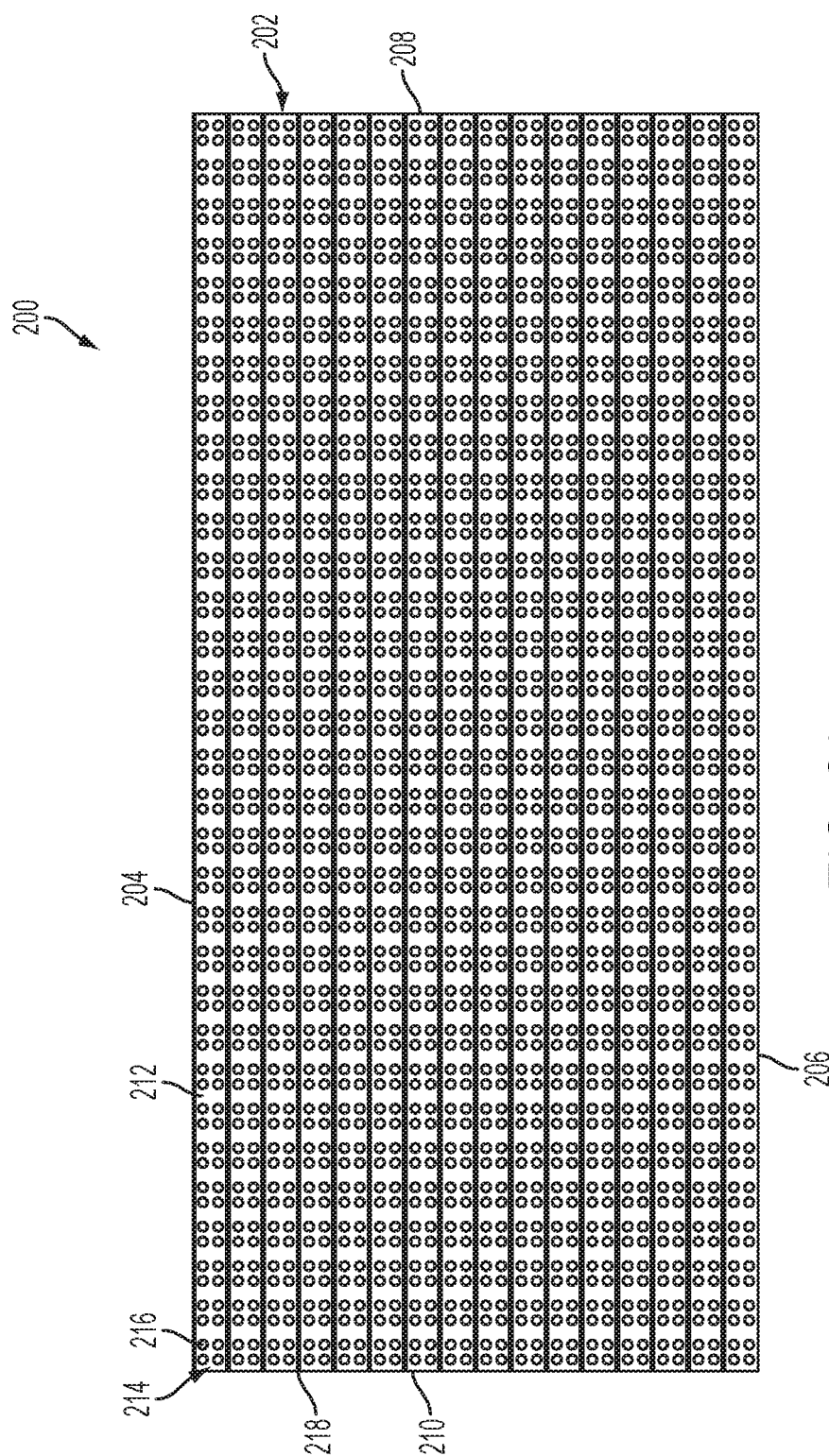


FIG. 2A

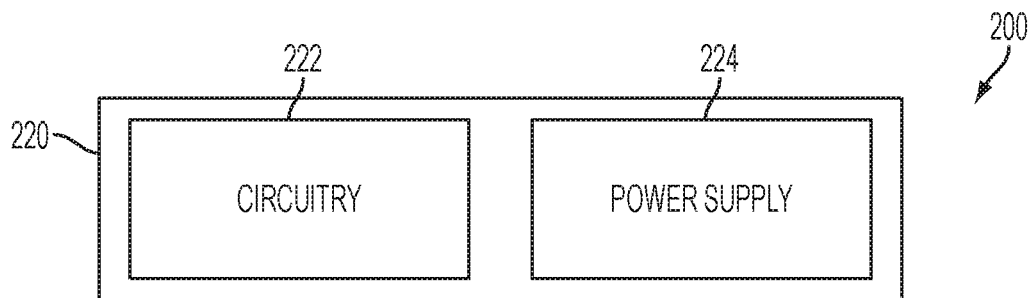


FIG. 2B

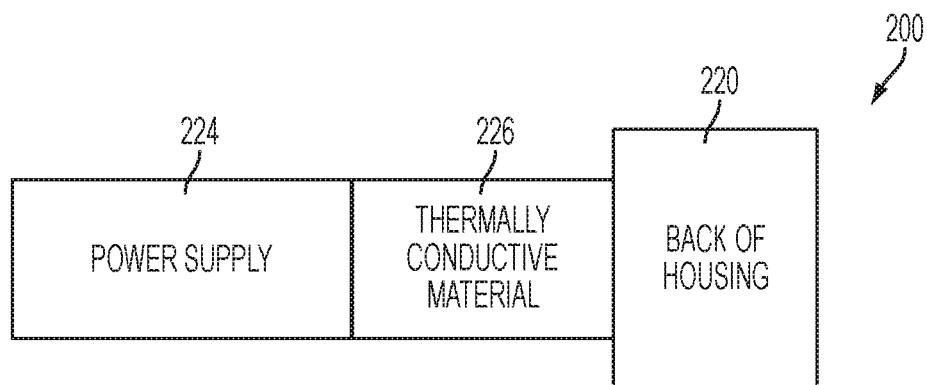


FIG. 2C

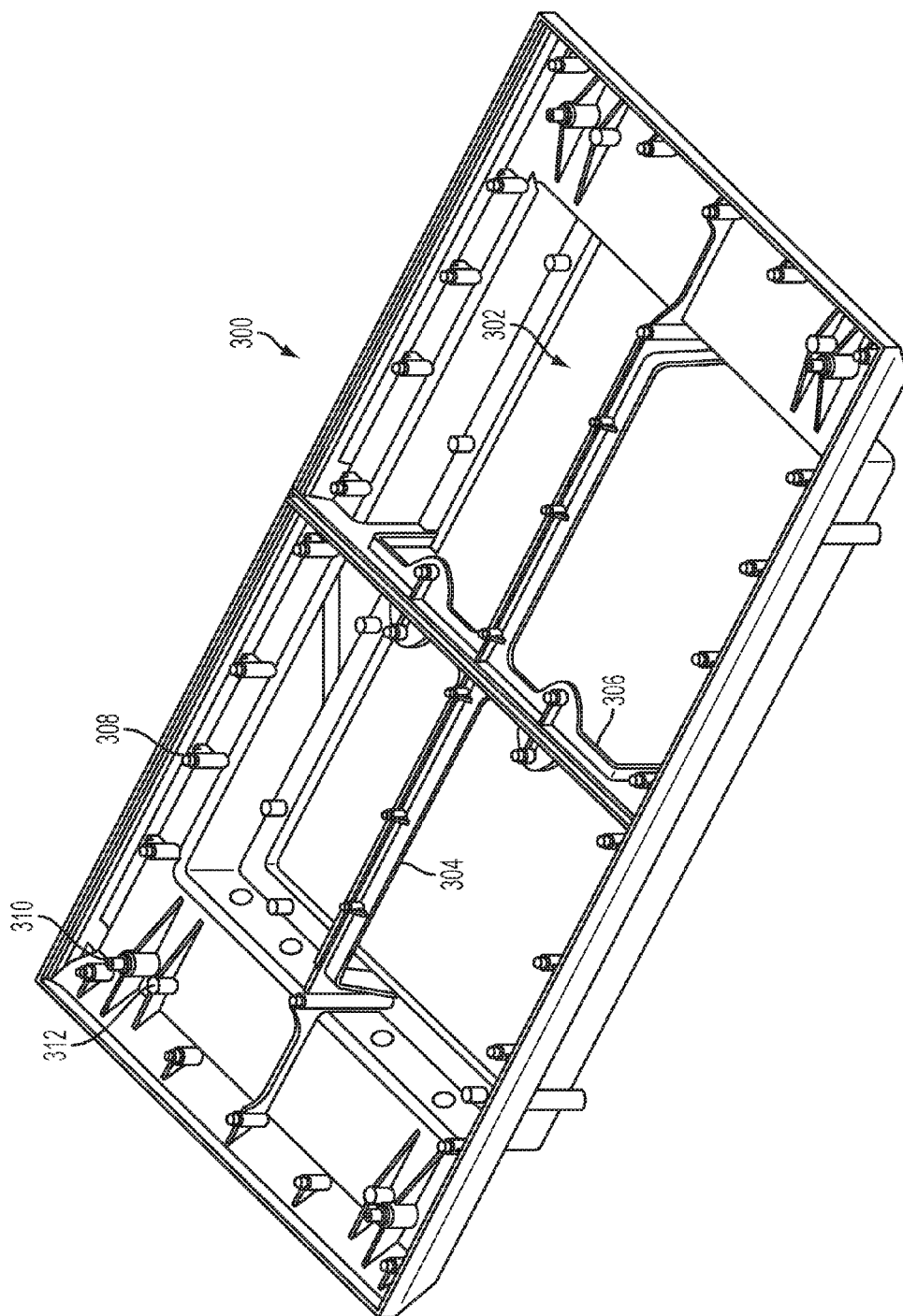


FIG. 3A

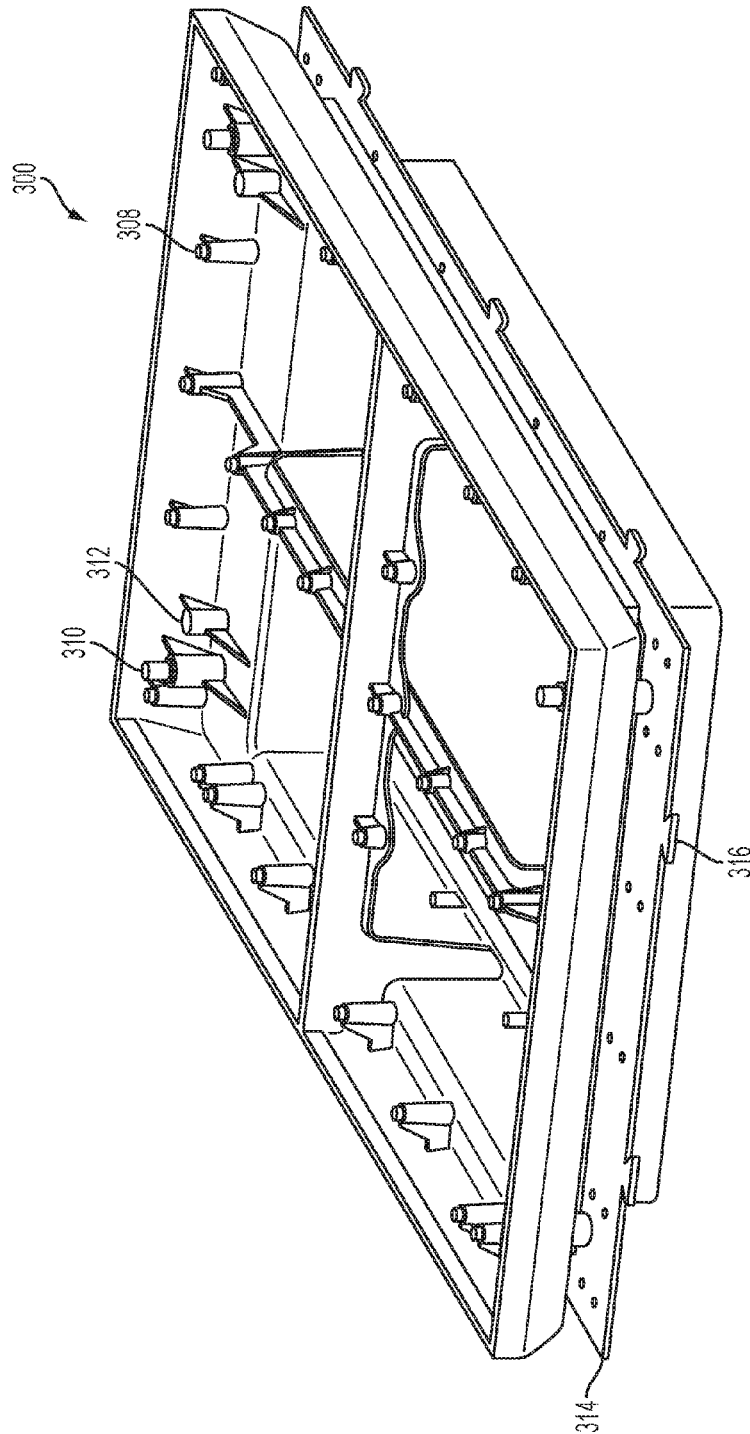


FIG. 3B



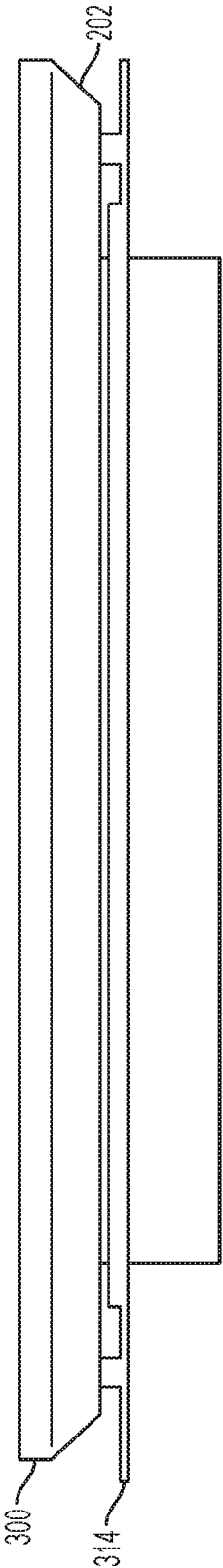


FIG. 3C

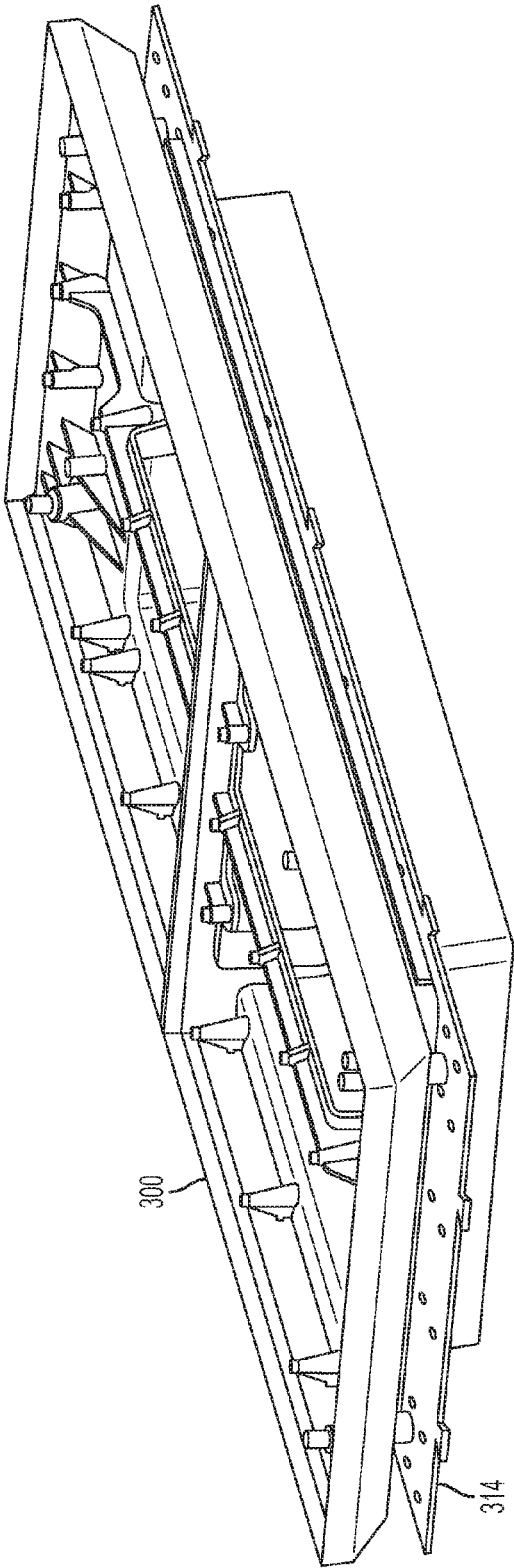


FIG. 3D

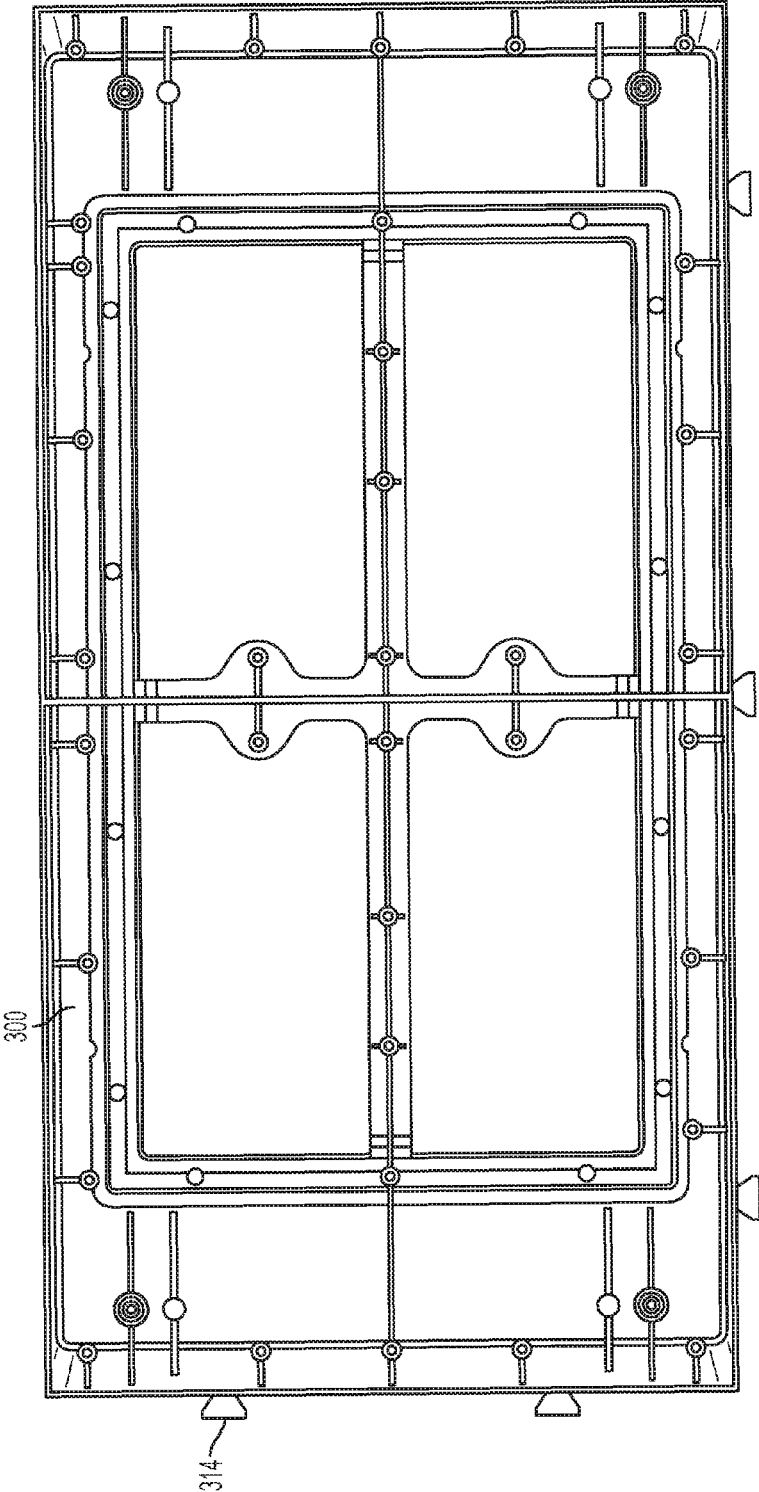


FIG. 3E

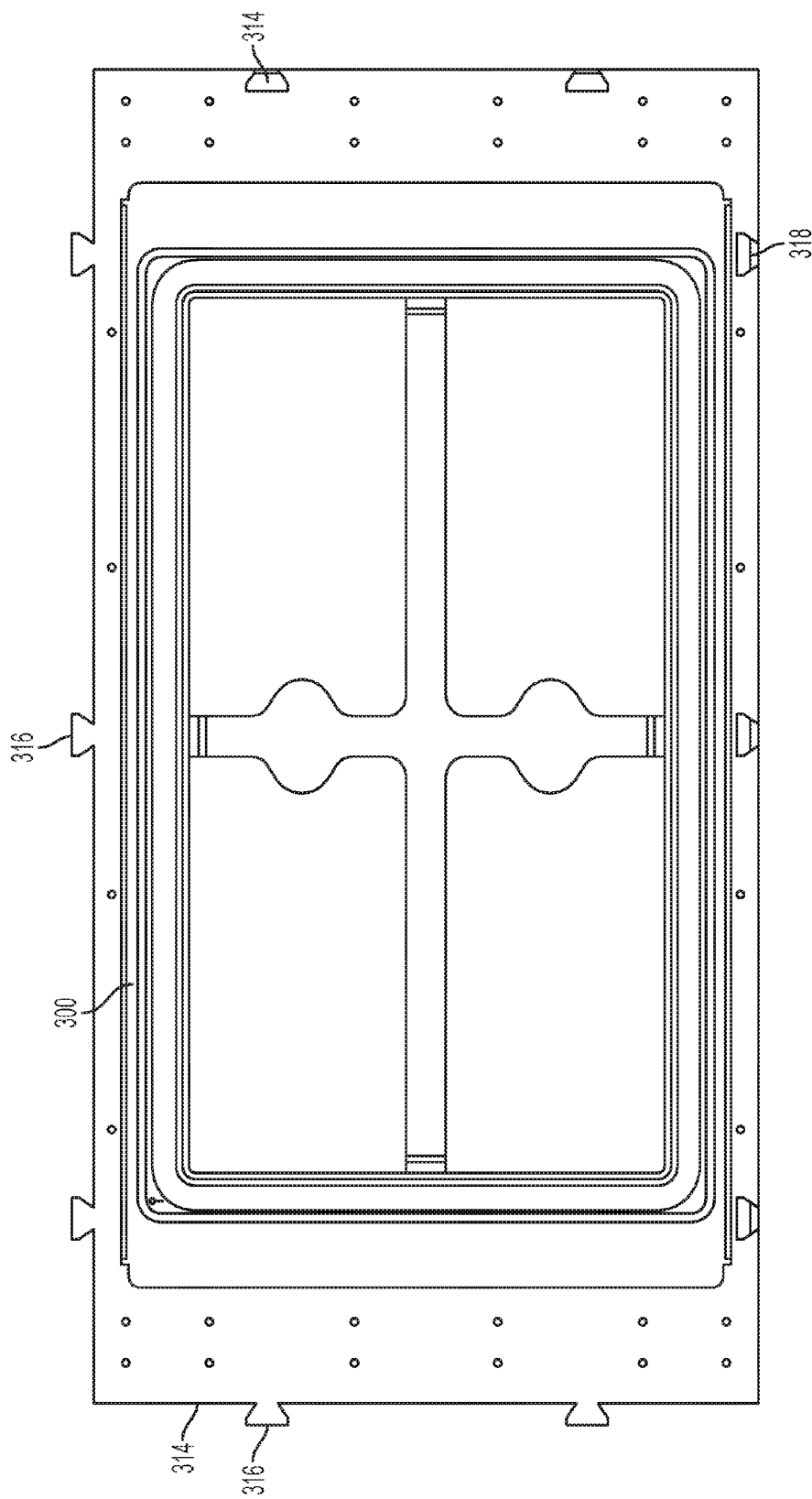


FIG. 3F

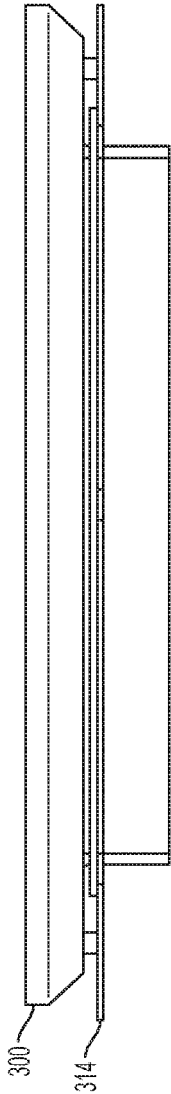


FIG. 3G

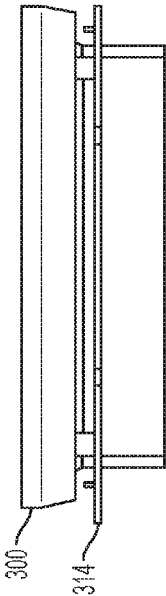


FIG. 3H

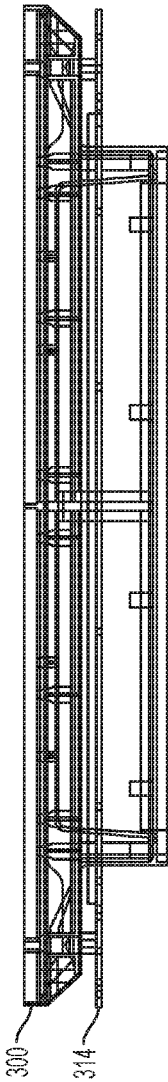


FIG. 3I

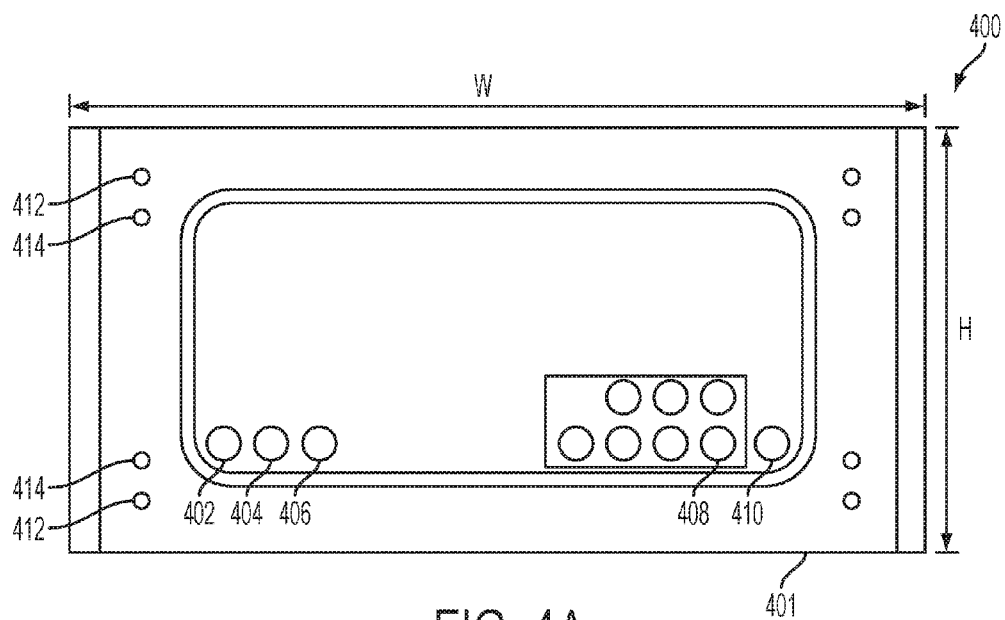


FIG. 4A

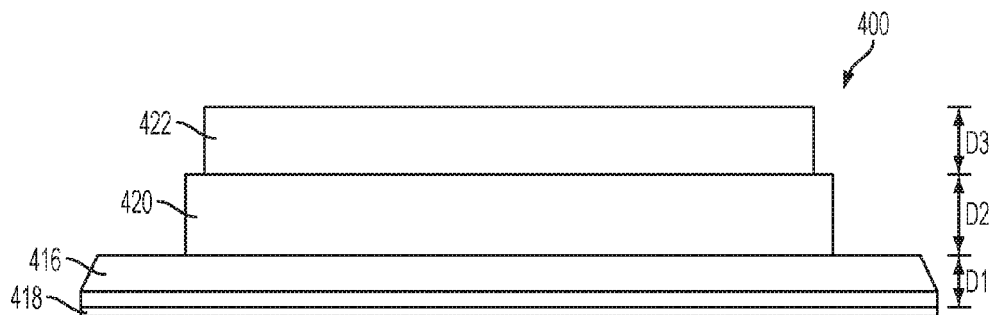


FIG. 4B

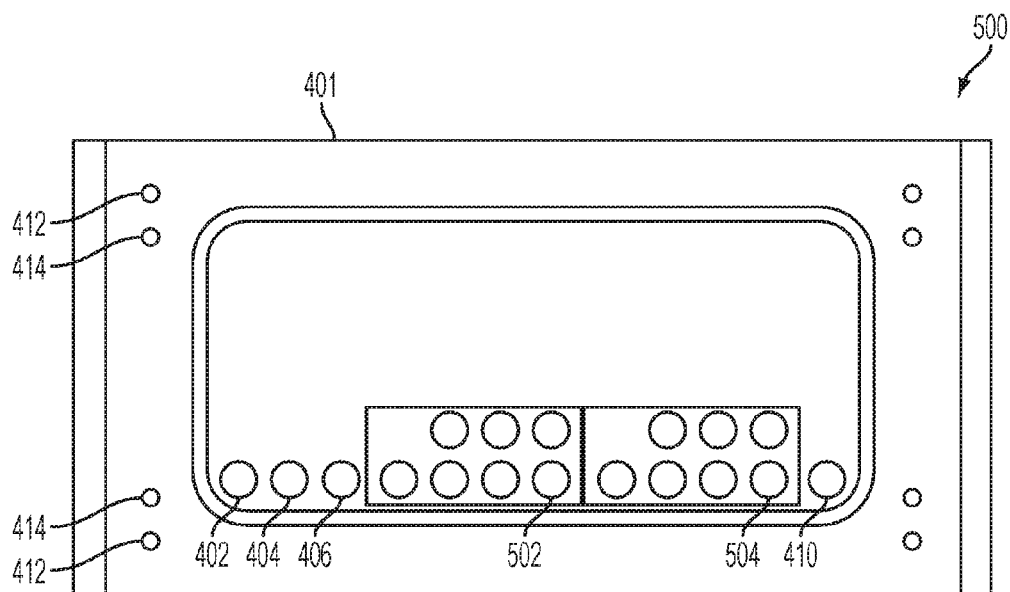


FIG. 5

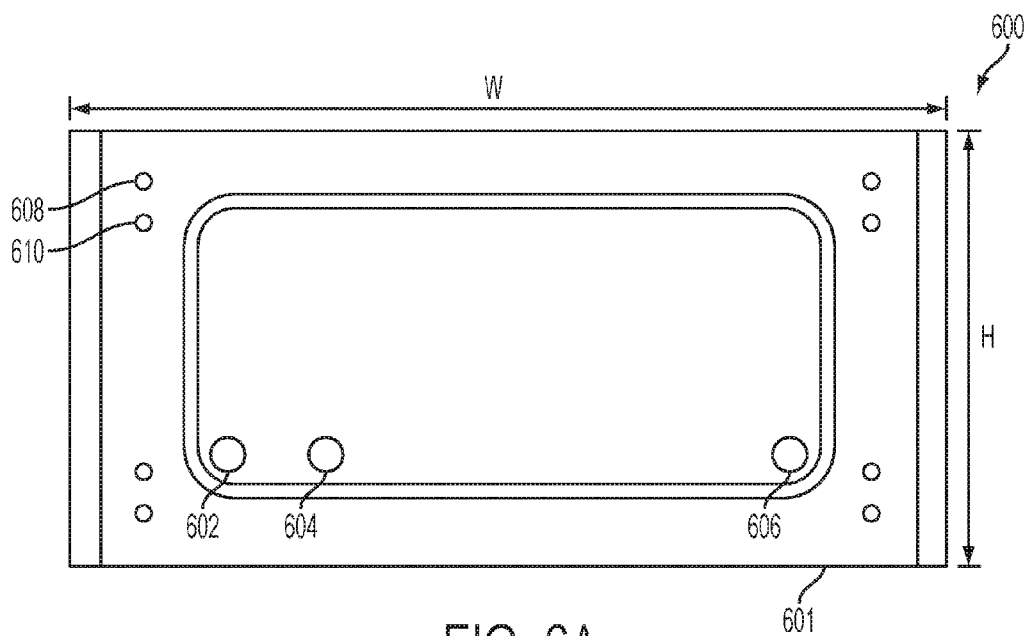


FIG. 6A

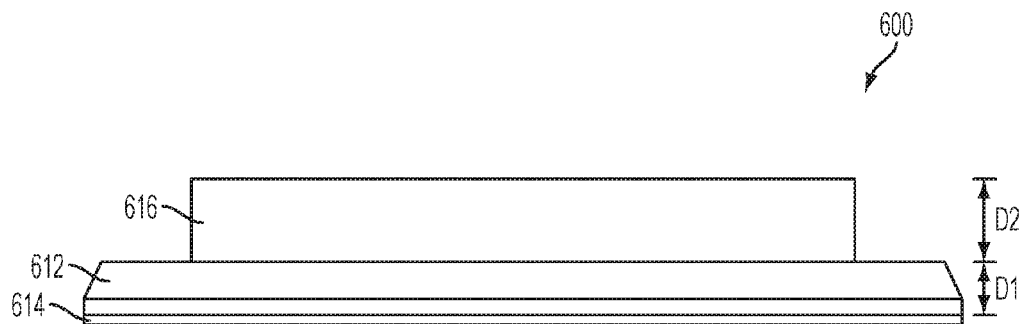


FIG. 6B



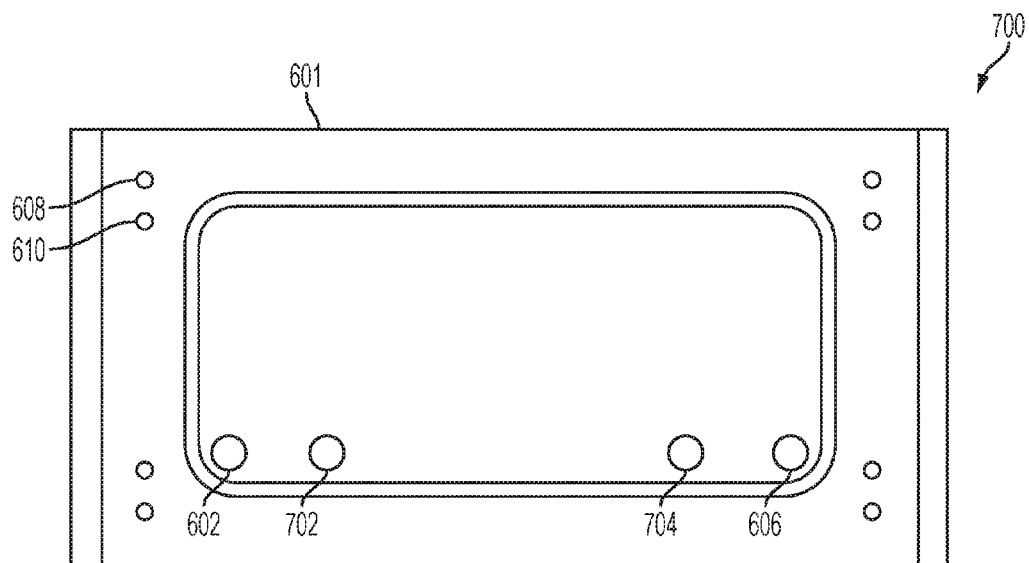


FIG. 7

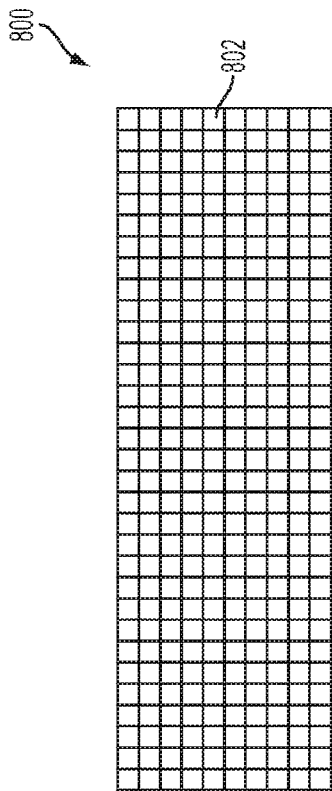


FIG. 8A

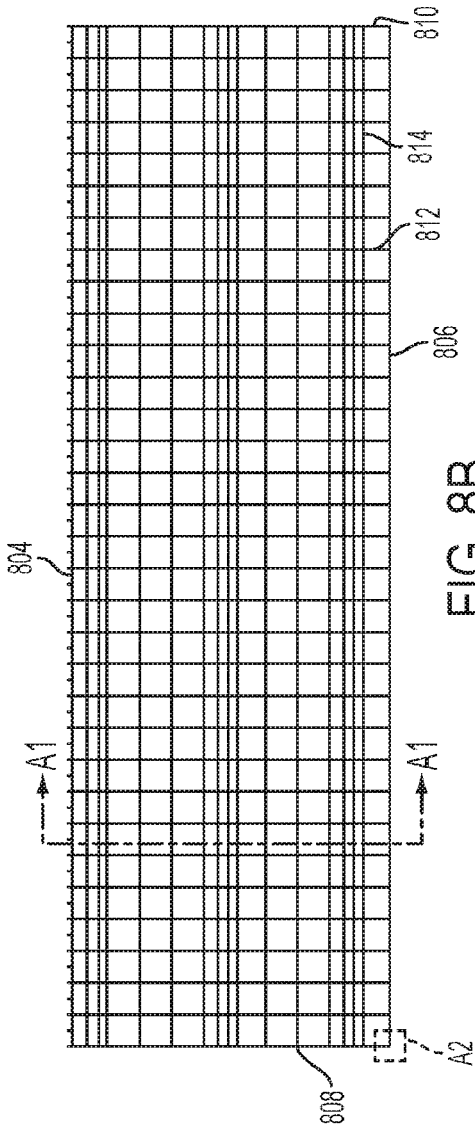


FIG. 8B

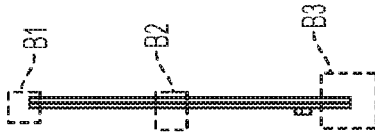


FIG. 8C

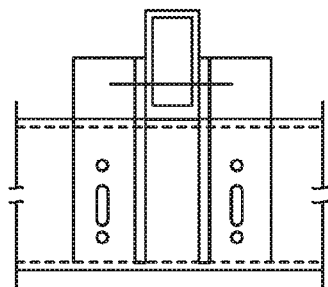


FIG. 8F

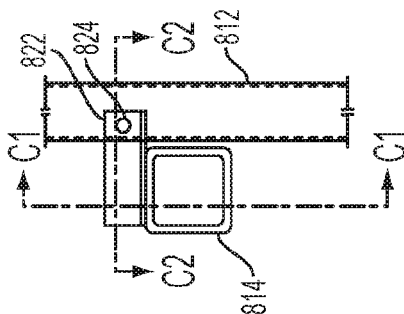


FIG. 8E

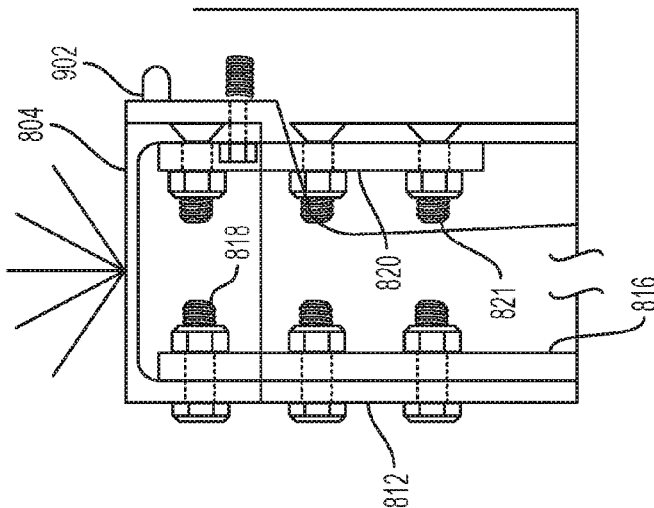
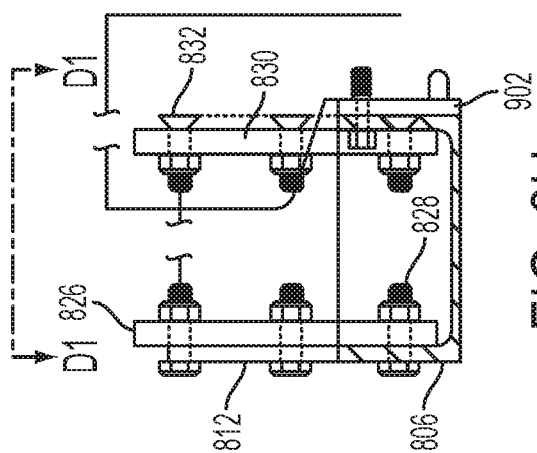
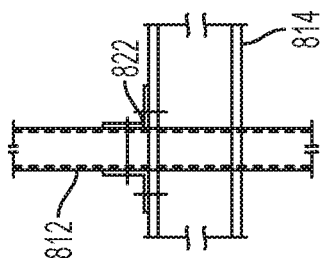
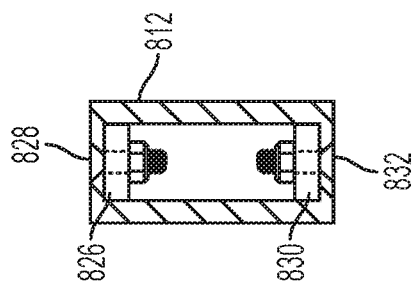


FIG. 8D



1  
 2  
 3  
 4  
 5  
 6  
 7  
 8  
 9  
 10  
 11  
 12  
 13  
 14  
 15  
 16  
 17  
 18  
 19  
 20  
 21  
 22  
 23  
 24  
 25  
 26  
 27  
 28  
 29  
 30  
 31  
 32  
 33  
 34  
 35  
 36  
 37  
 38  
 39  
 40  
 41  
 42  
 43  
 44  
 45  
 46  
 47  
 48  
 49  
 50  
 51  
 52  
 53  
 54  
 55  
 56  
 57  
 58  
 59  
 60  
 61  
 62  
 63  
 64  
 65  
 66  
 67  
 68  
 69  
 70  
 71  
 72  
 73  
 74  
 75  
 76  
 77  
 78  
 79  
 80  
 81  
 82  
 83  
 84  
 85  
 86  
 87  
 88  
 89  
 90  
 91  
 92  
 93  
 94  
 95  
 96  
 97  
 98  
 99  
 100  
 101  
 102  
 103  
 104  
 105  
 106  
 107  
 108  
 109  
 110  
 111  
 112  
 113  
 114  
 115  
 116  
 117  
 118  
 119  
 120  
 121  
 122  
 123  
 124  
 125  
 126  
 127  
 128  
 129  
 130  
 131  
 132  
 133  
 134  
 135  
 136  
 137  
 138  
 139  
 140  
 141  
 142  
 143  
 144  
 145  
 146  
 147  
 148  
 149  
 150  
 151  
 152  
 153  
 154  
 155  
 156  
 157  
 158  
 159  
 160  
 161  
 162  
 163  
 164  
 165  
 166  
 167  
 168  
 169  
 170  
 171  
 172  
 173  
 174  
 175  
 176  
 177  
 178  
 179  
 180  
 181  
 182  
 183  
 184  
 185  
 186  
 187  
 188  
 189  
 190  
 191  
 192  
 193  
 194  
 195  
 196  
 197  
 198  
 199  
 200  
 201  
 202  
 203  
 204  
 205  
 206  
 207  
 208  
 209  
 210  
 211  
 212  
 213  
 214  
 215  
 216  
 217  
 218  
 219  
 220  
 221  
 222  
 223  
 224  
 225  
 226  
 227  
 228  
 229  
 230  
 231  
 232  
 233  
 234  
 235  
 236  
 237  
 238  
 239  
 240  
 241  
 242  
 243  
 244  
 245  
 246  
 247  
 248  
 249  
 250  
 251  
 252  
 253  
 254  
 255  
 256  
 257  
 258  
 259  
 260  
 261  
 262  
 263  
 264  
 265  
 266  
 267  
 268  
 269  
 270  
 271  
 272  
 273  
 274  
 275  
 276  
 277  
 278  
 279  
 280  
 281  
 282  
 283  
 284  
 285  
 286  
 287  
 288  
 289  
 290  
 291  
 292  
 293  
 294  
 295  
 296  
 297  
 298  
 299  
 300  
 301  
 302  
 303  
 304  
 305  
 306  
 307  
 308  
 309  
 310  
 311  
 312  
 313  
 314  
 315  
 316  
 317  
 318  
 319  
 320  
 321  
 322  
 323  
 324  
 325  
 326  
 327  
 328  
 329  
 330  
 331  
 332  
 333  
 334  
 335  
 336  
 337  
 338  
 339  
 340  
 341  
 342  
 343  
 344  
 345  
 346  
 347  
 348  
 349  
 350  
 351  
 352  
 353  
 354  
 355  
 356  
 357  
 358  
 359  
 360  
 361  
 362  
 363  
 364  
 365  
 366  
 367  
 368  
 369  
 370  
 371  
 372  
 373  
 374  
 375  
 376  
 377  
 378  
 379  
 380  
 381  
 382  
 383  
 384  
 385  
 386  
 387  
 388  
 389  
 390  
 391  
 392  
 393  
 394  
 395  
 396  
 397  
 398  
 399  
 400  
 401  
 402  
 403  
 404  
 405  
 406  
 407  
 408  
 409  
 410  
 411  
 412  
 413  
 414  
 415  
 416  
 417  
 418  
 419  
 420  
 421  
 422  
 423  
 424  
 425  
 426  
 427  
 428  
 429  
 430  
 431  
 432  
 433  
 434  
 435  
 436  
 437  
 438  
 439  
 440  
 441  
 442  
 443  
 444  
 445  
 446  
 447  
 448  
 449  
 450  
 451  
 452  
 453  
 454  
 455  
 456  
 457  
 458  
 459  
 460  
 461  
 462  
 463  
 464  
 465  
 466  
 467  
 468  
 469  
 470  
 471  
 472  
 473  
 474  
 475  
 476  
 477  
 478  
 479  
 480  
 481  
 482  
 483  
 484  
 485  
 486  
 487  
 488  
 489  
 490  
 491  
 492  
 493  
 494  
 495  
 496  
 497  
 498  
 499  
 500  
 501  
 502  
 503  
 504  
 505  
 506  
 507  
 508  
 509  
 510  
 511  
 512  
 513  
 514  
 515  
 516  
 517  
 518  
 519  
 520  
 521  
 522  
 523  
 524  
 525



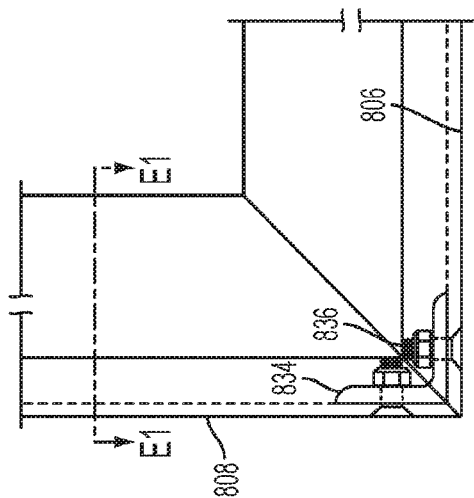


FIG. 8J

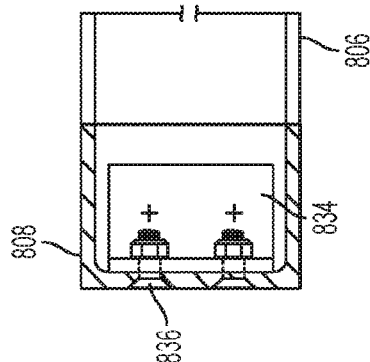


FIG. 8K

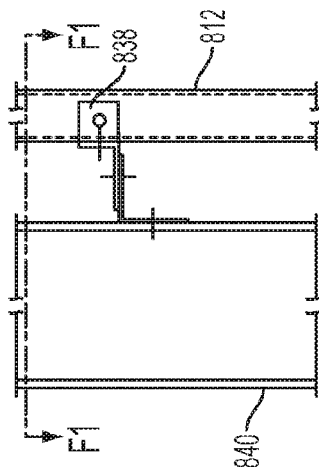


FIG. 8L

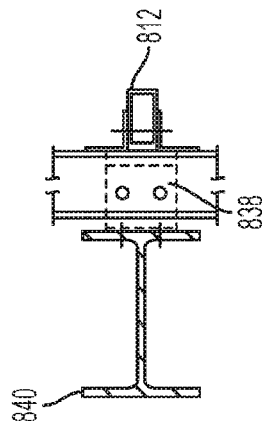
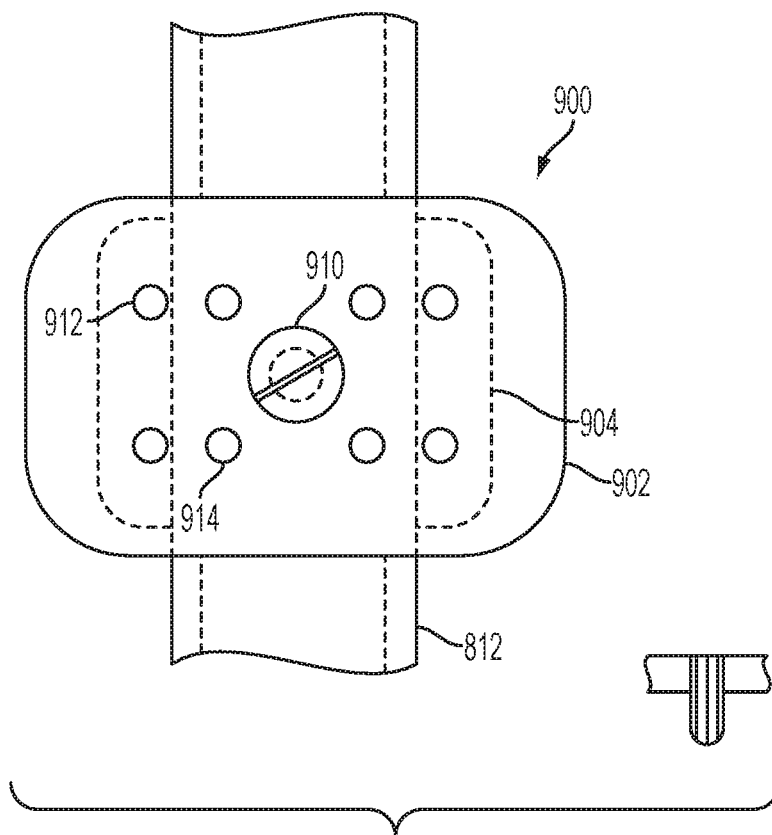


FIG. 8M



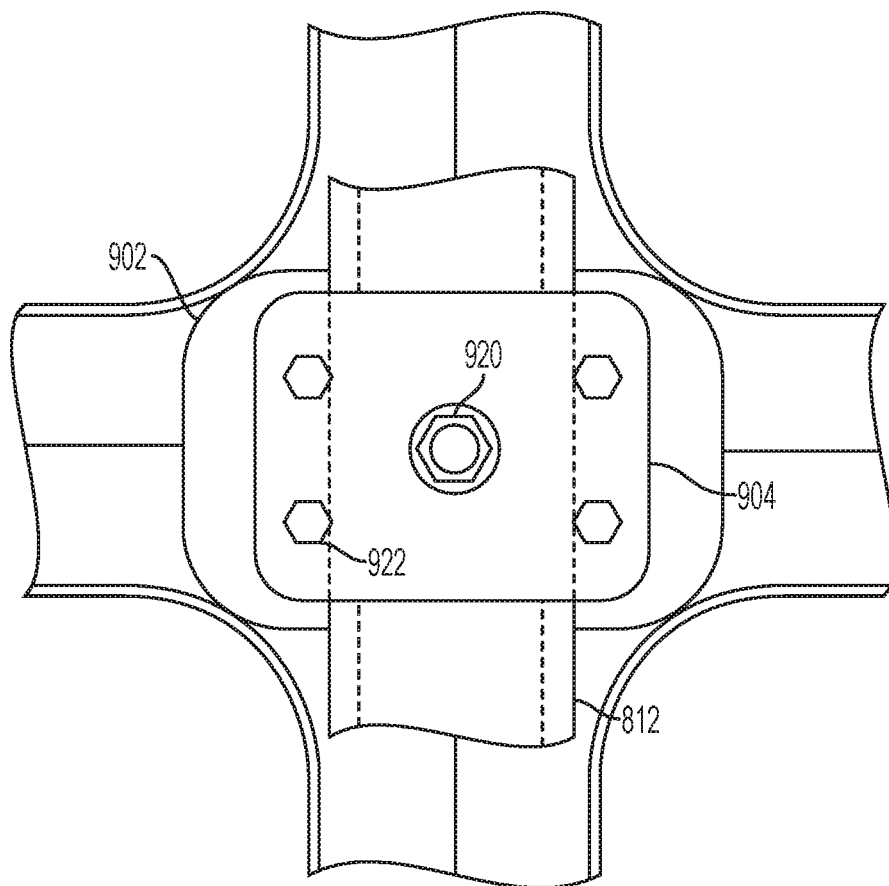


FIG. 9B

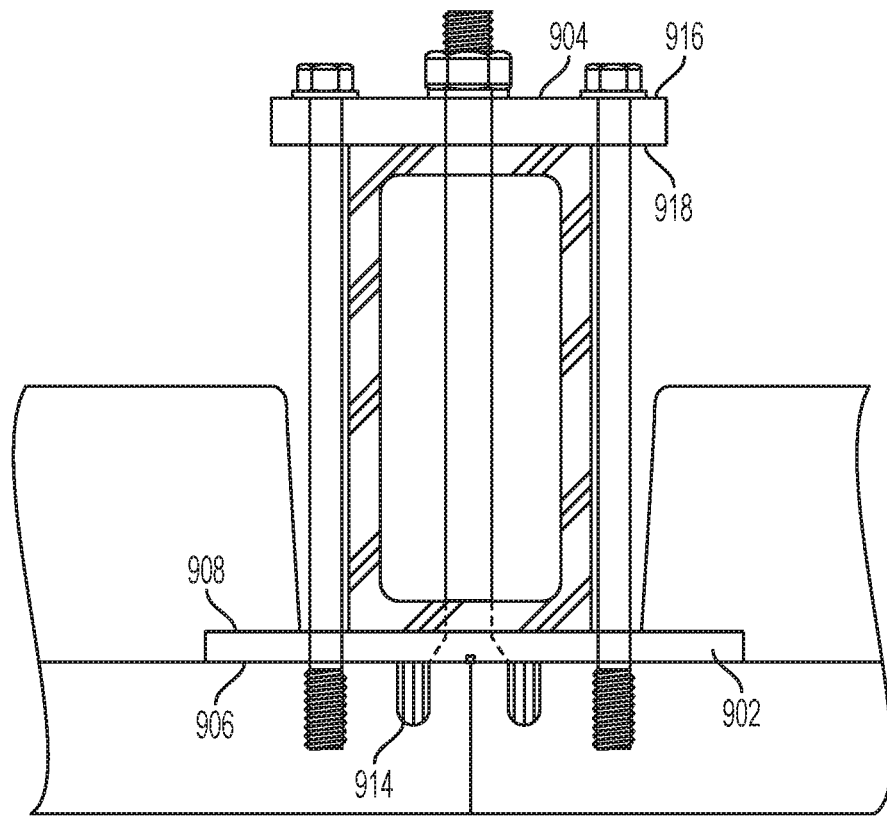


FIG. 9C





FIG. 10A



FIG. 10B

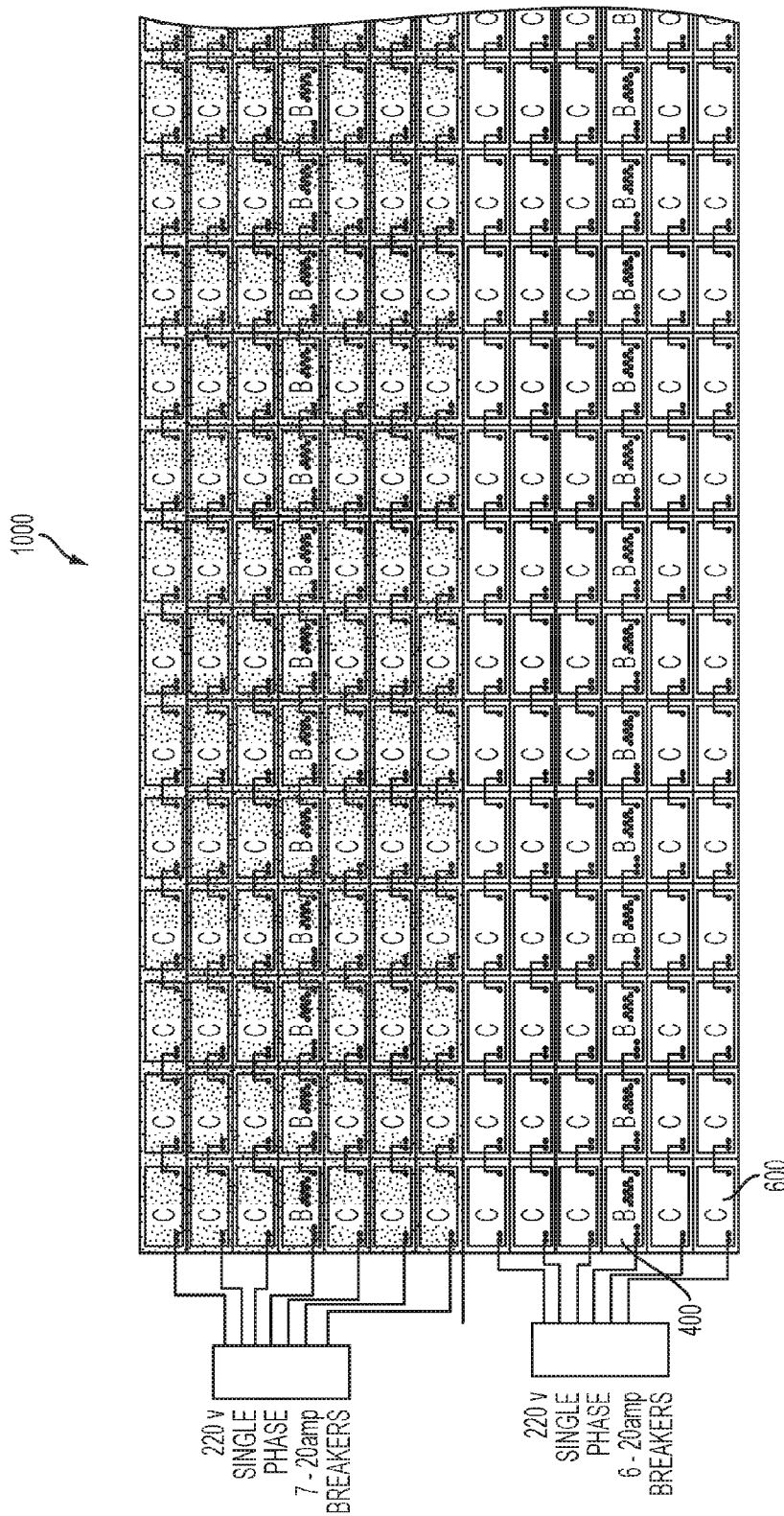


FIG. 10C



FIG. 10D

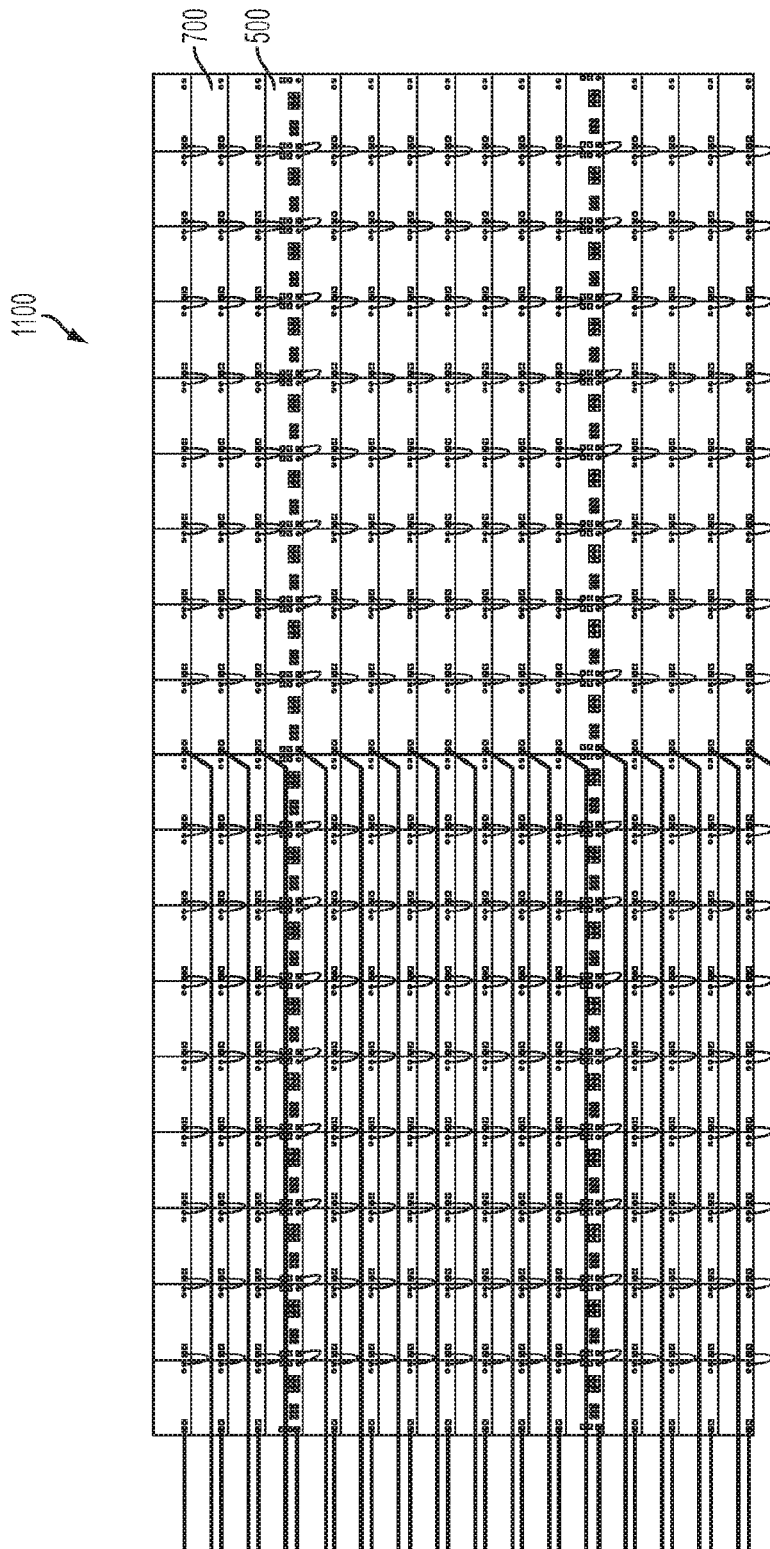


FIG. 11A

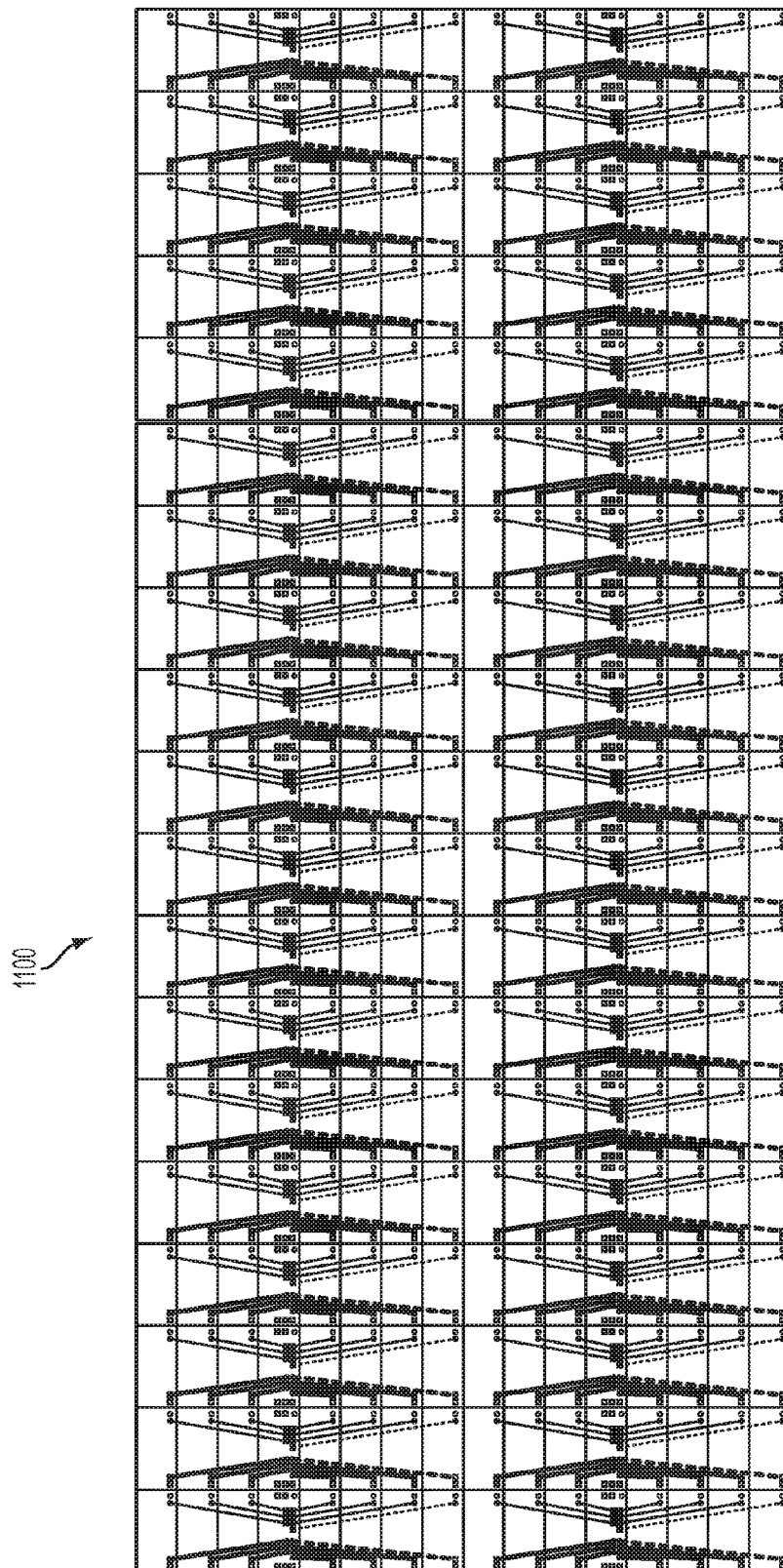


FIG. 11B

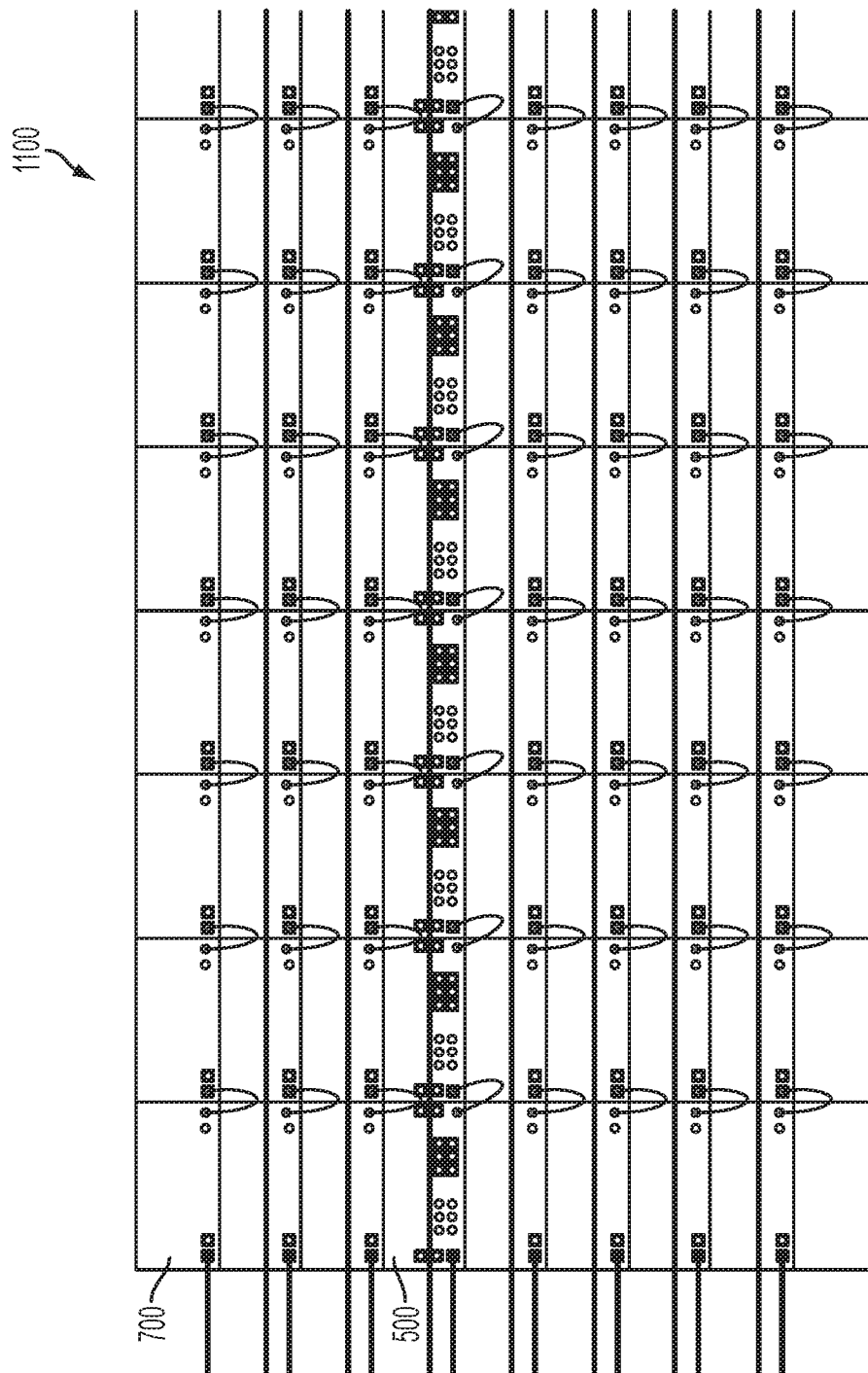


FIG. 11C

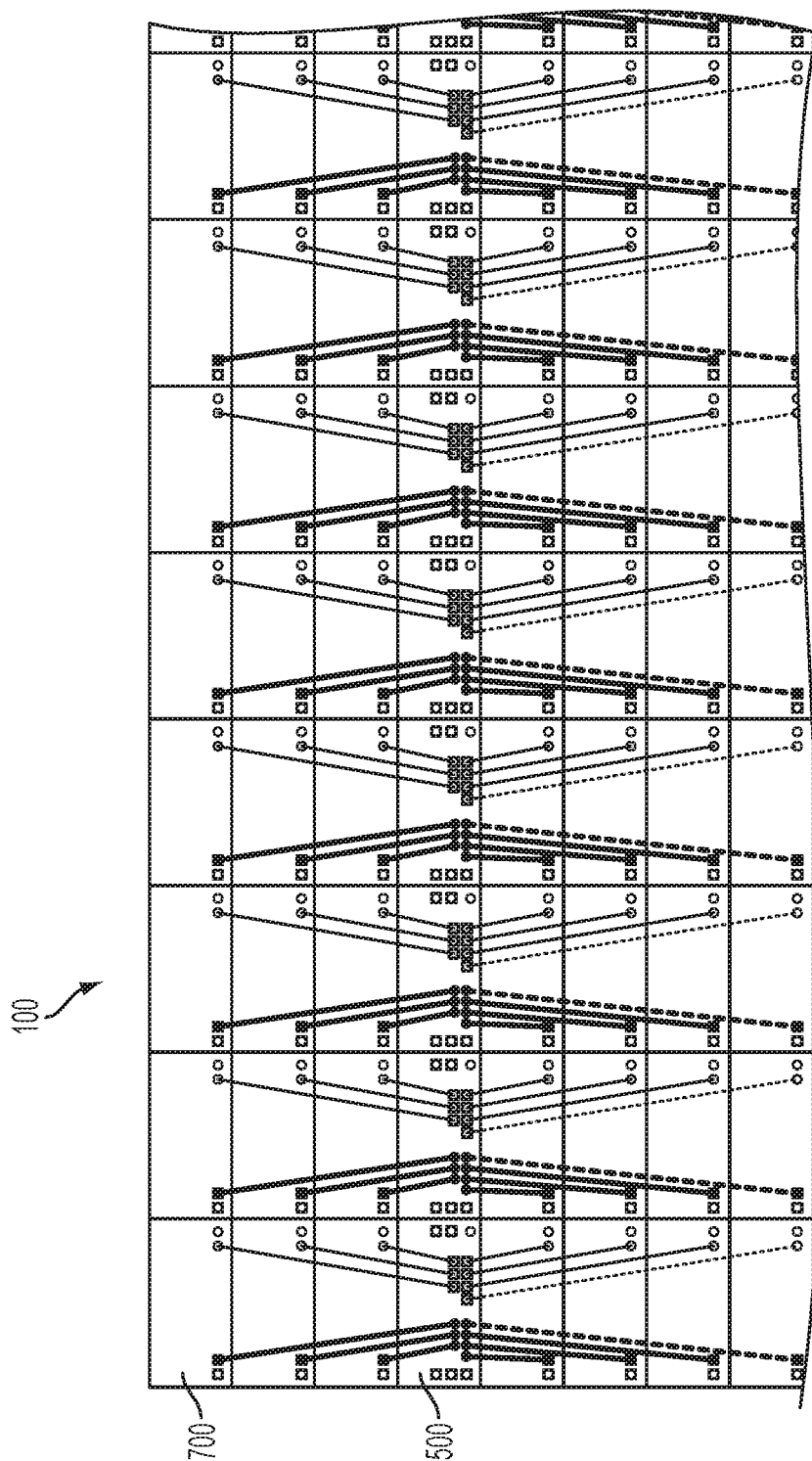


FIG. 1D

1200

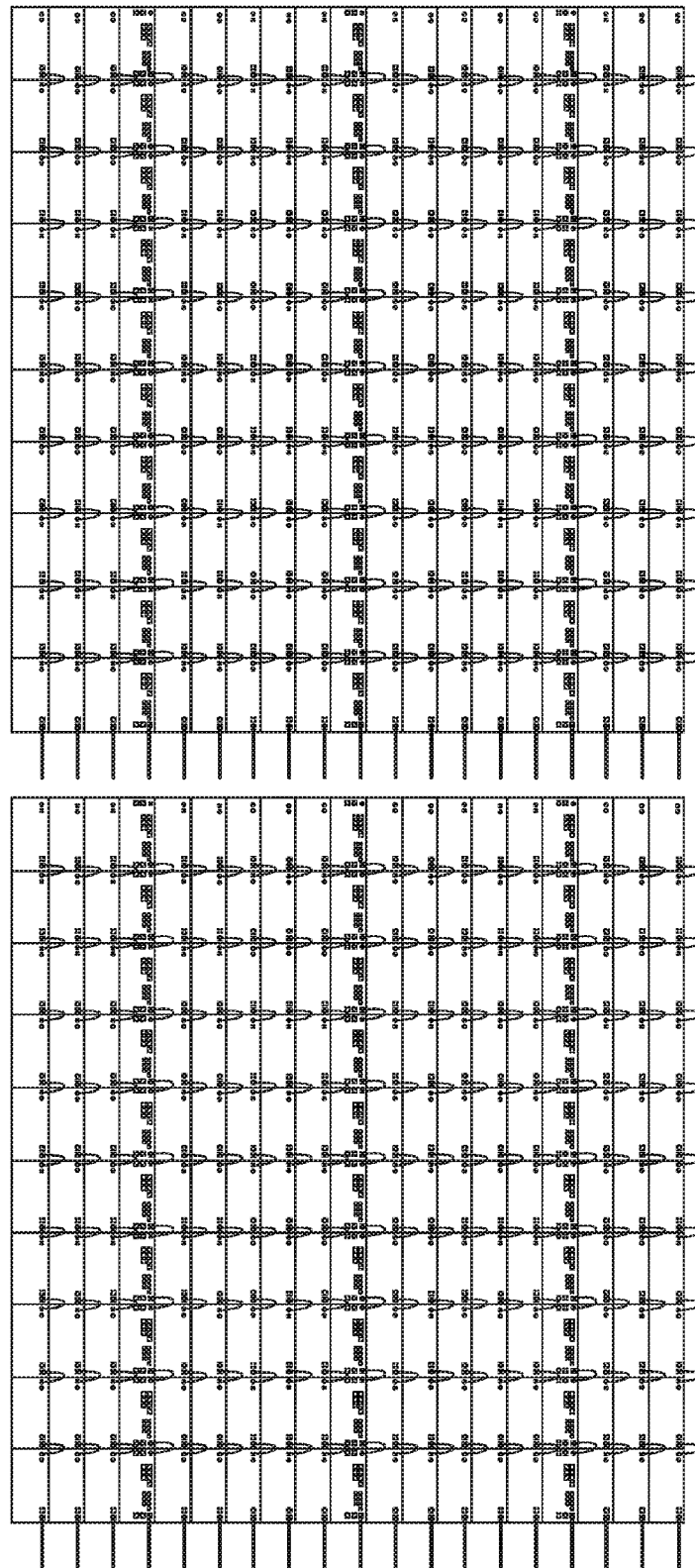


FIG. 12A



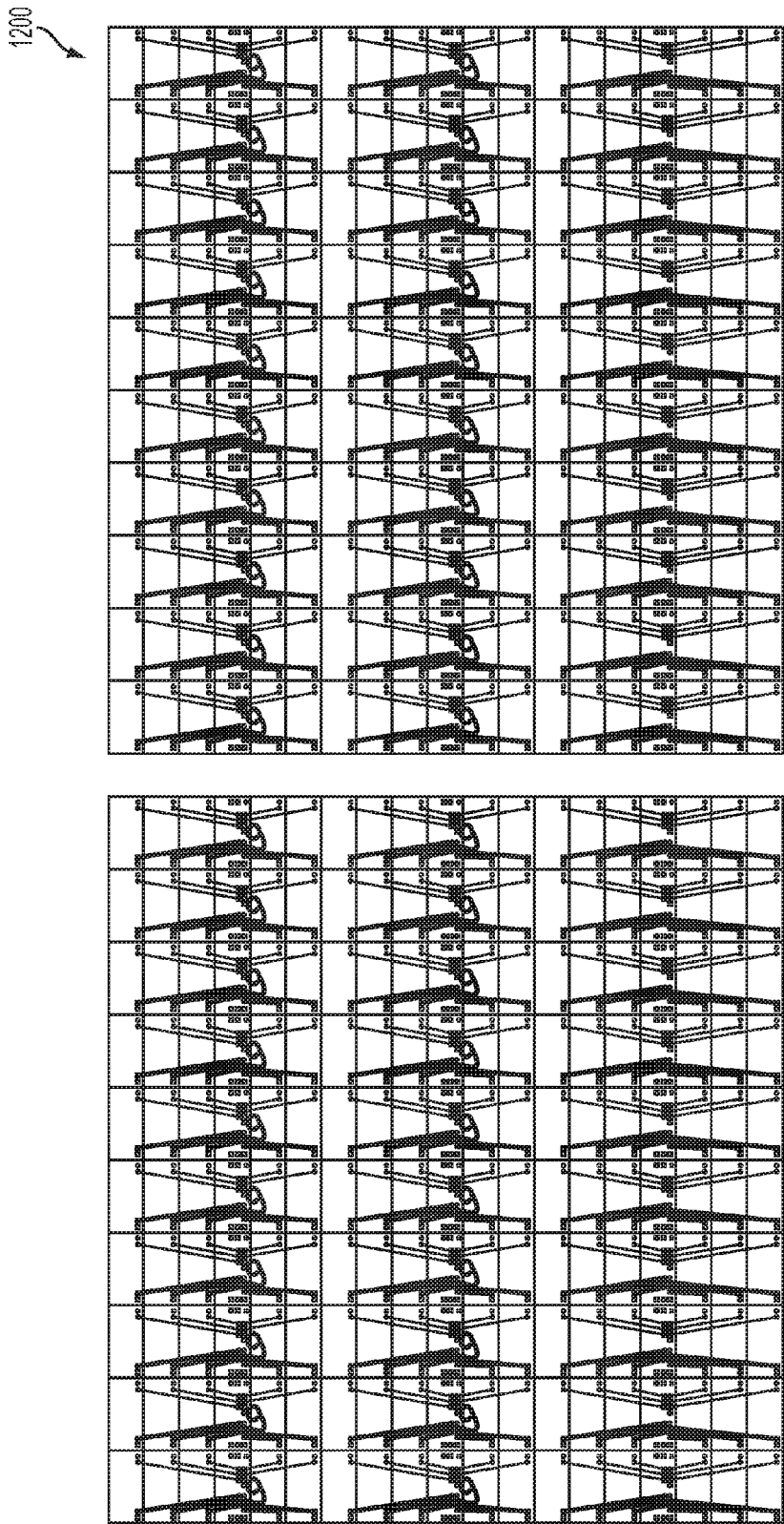


FIG. 12B

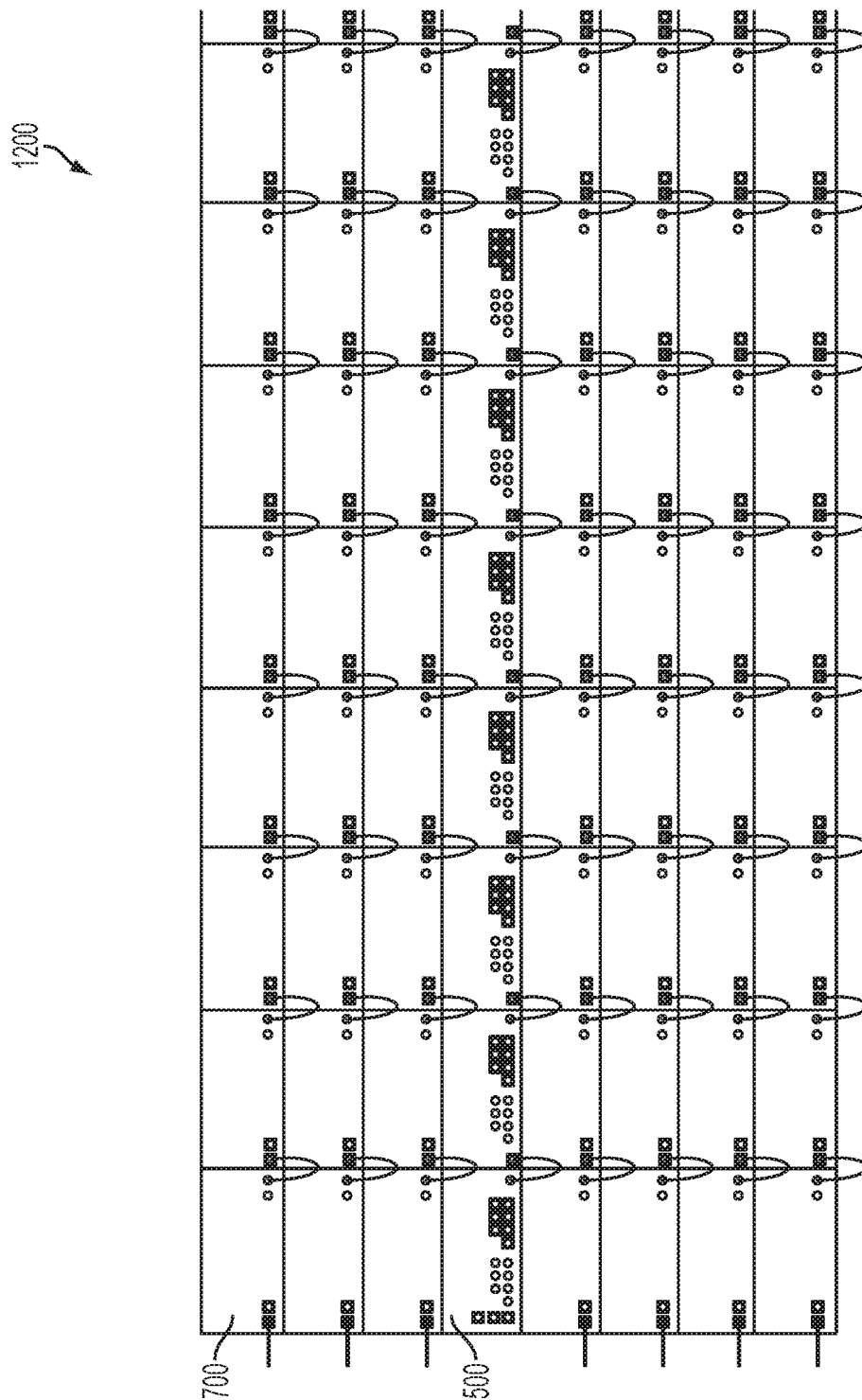


FIG. 12C

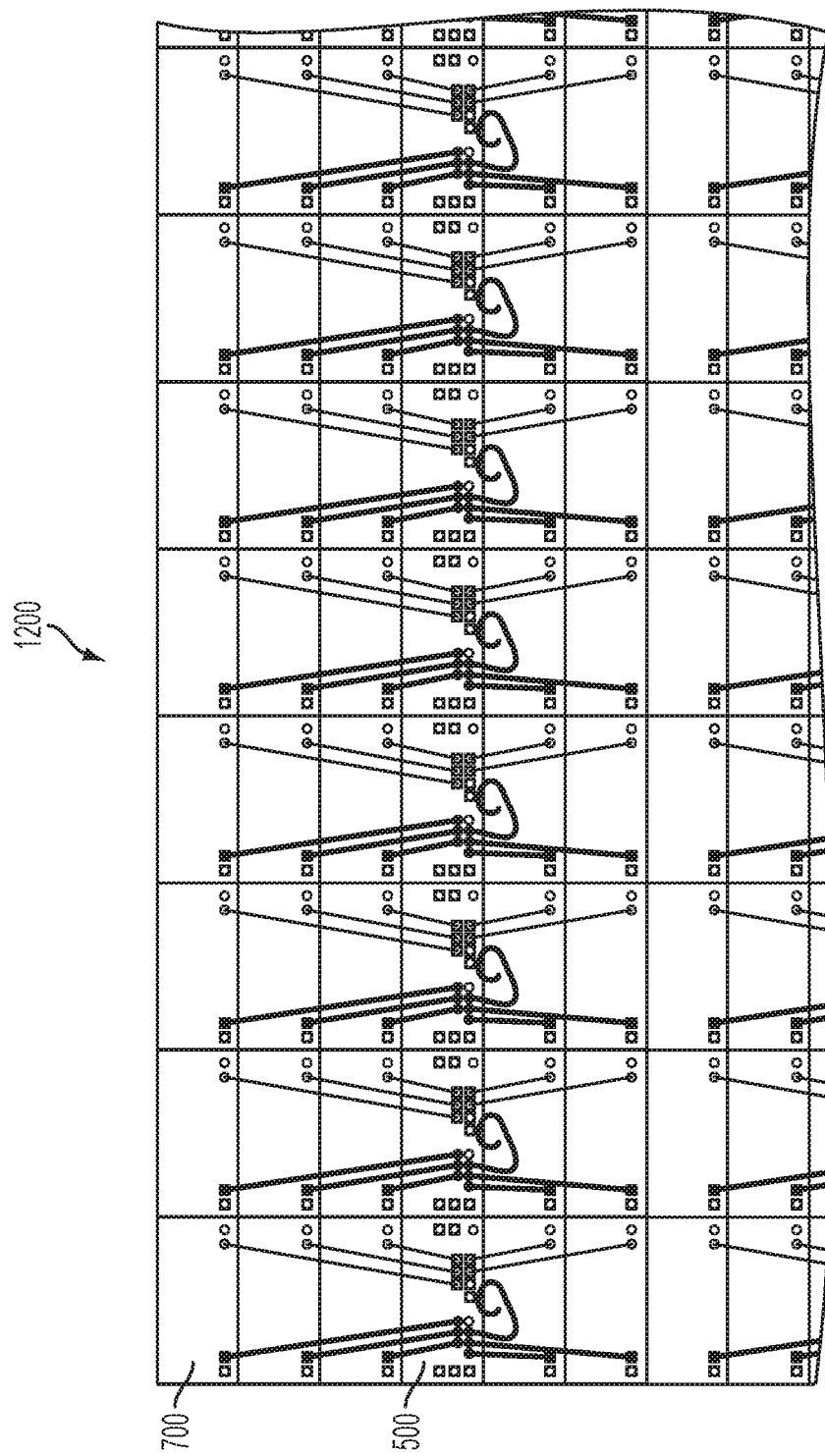


FIG. 12D

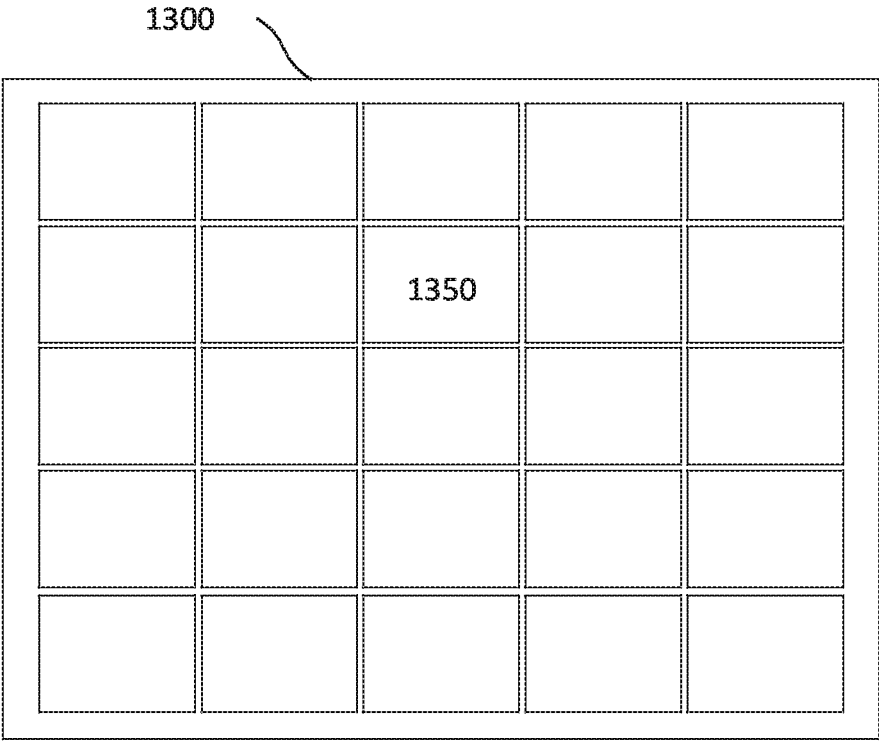


FIG. 13

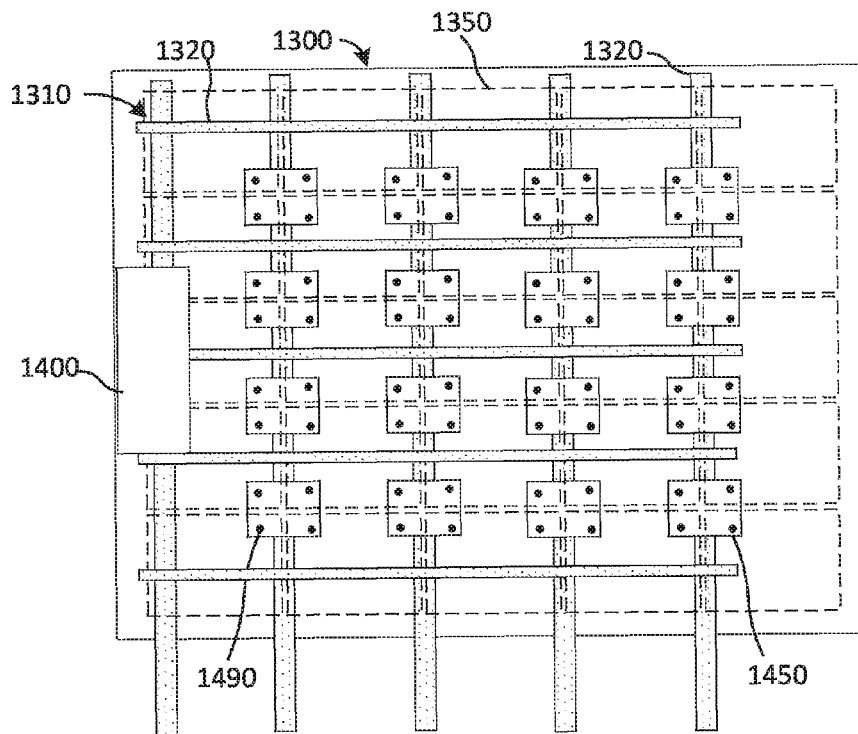


FIG. 14

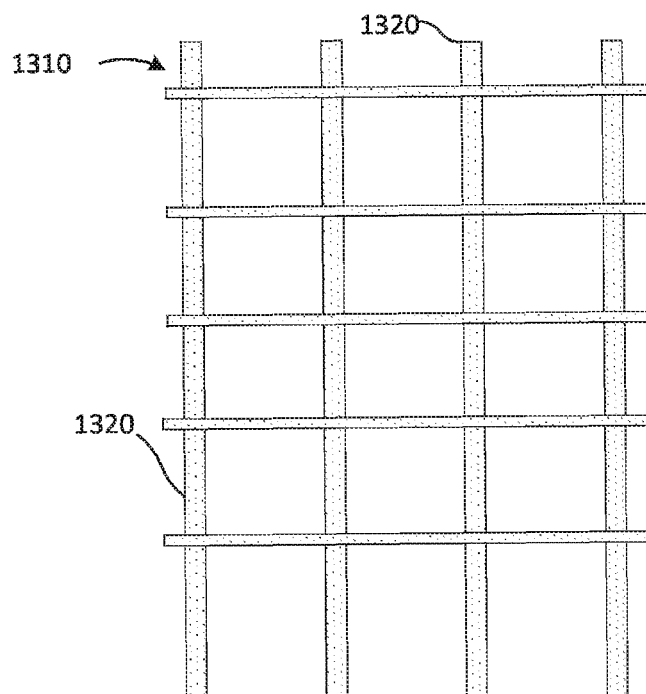


FIG. 15

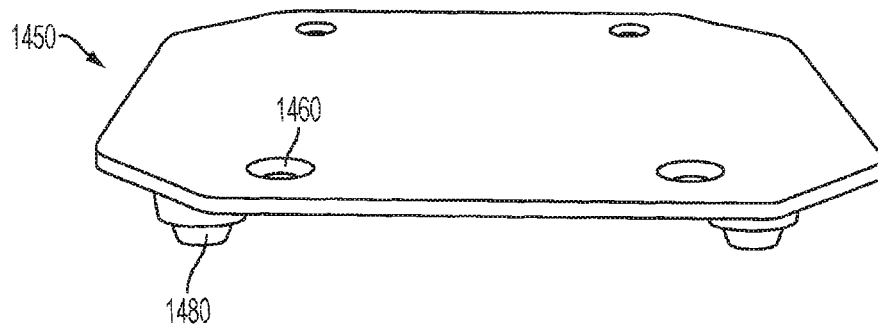


FIG. 16A

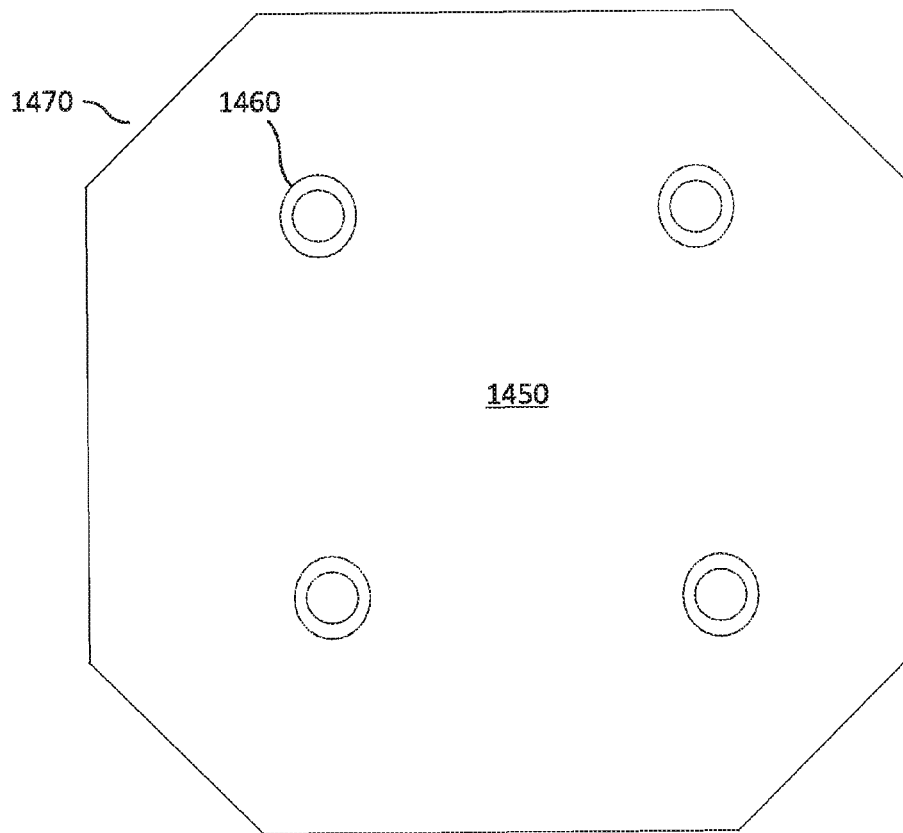


FIG. 16B

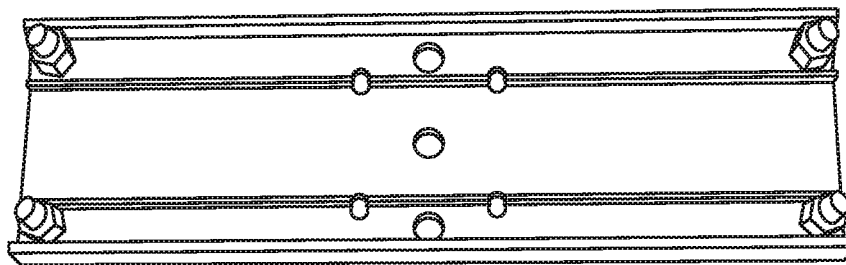


FIG. 16D

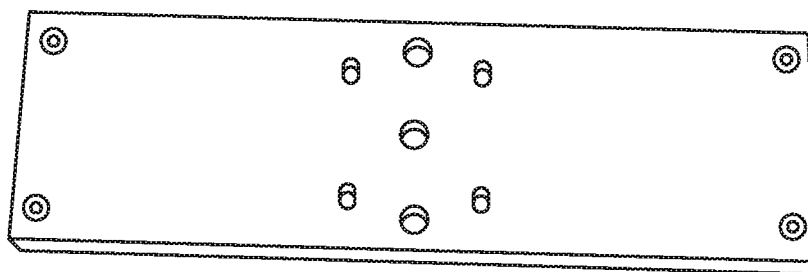


FIG. 16E

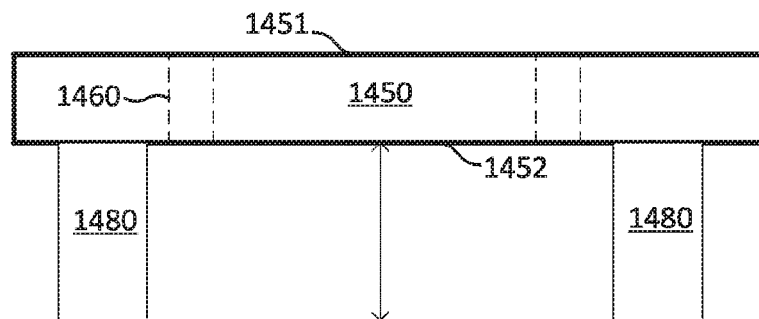


FIG. 16C

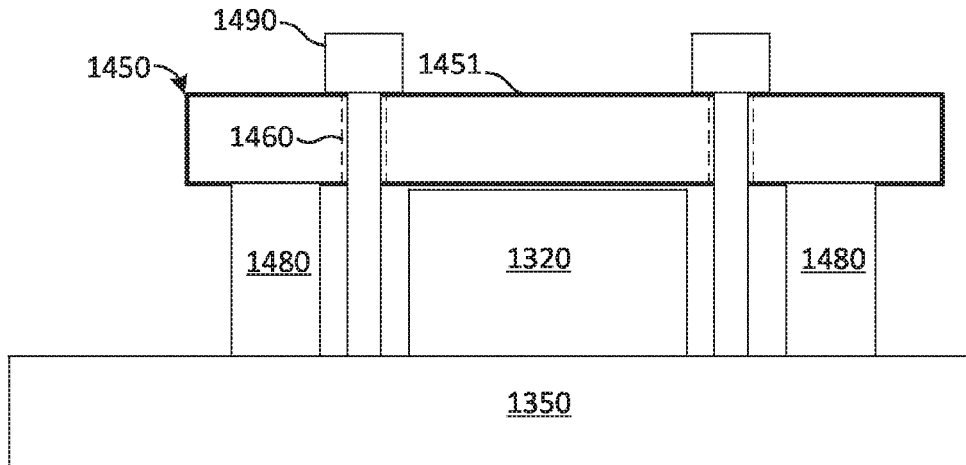
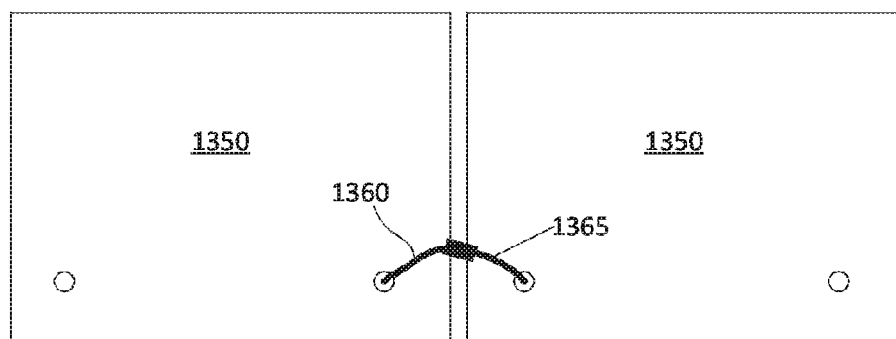
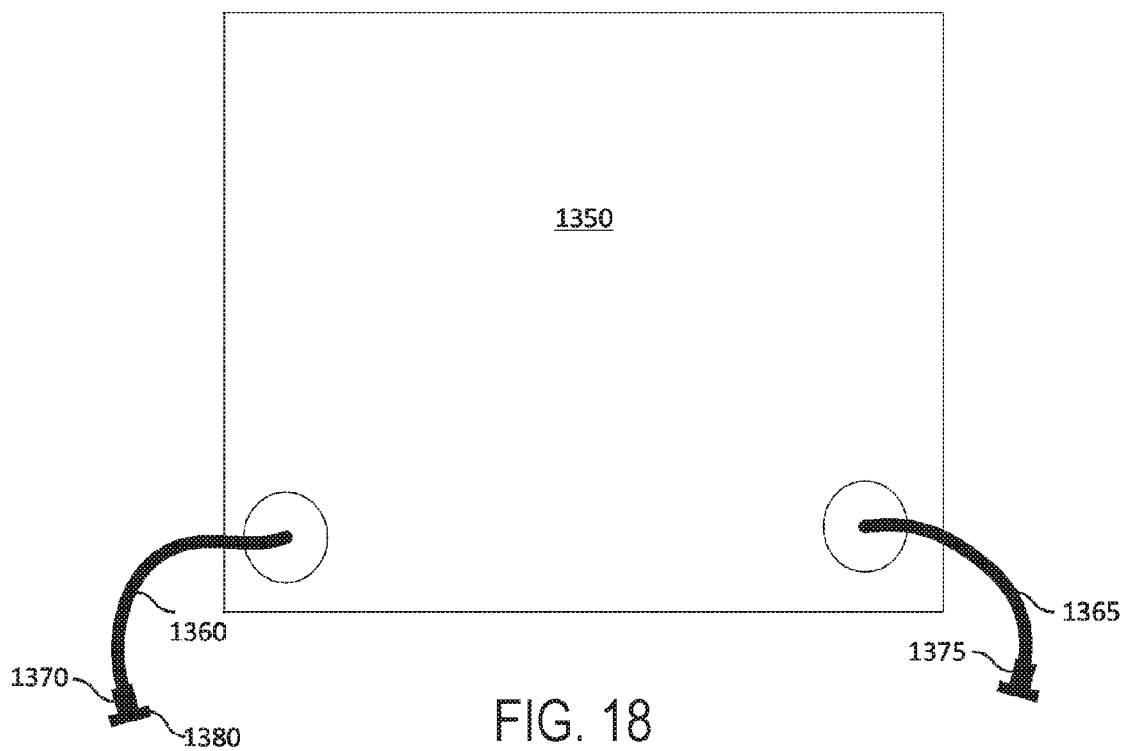


FIG. 17





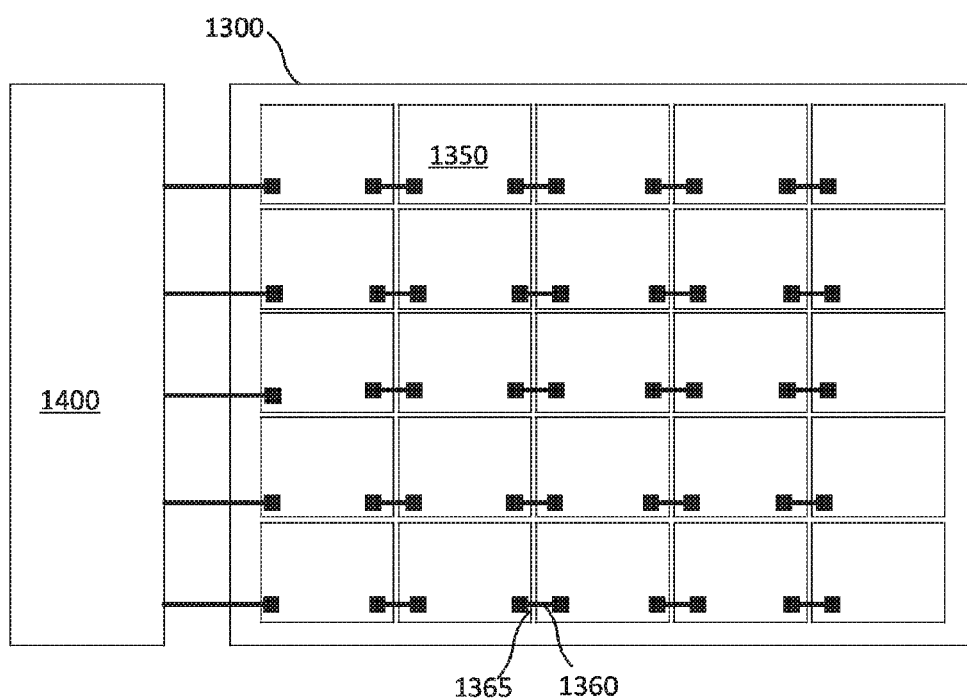


FIG. 20

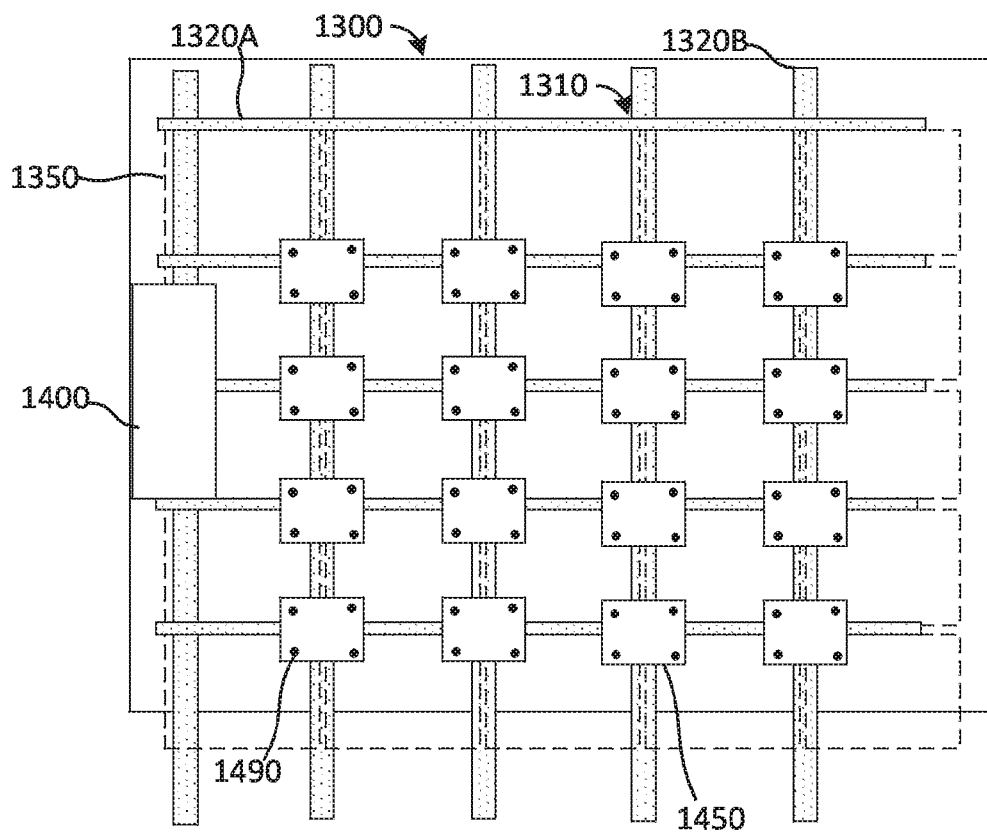


FIG. 21A

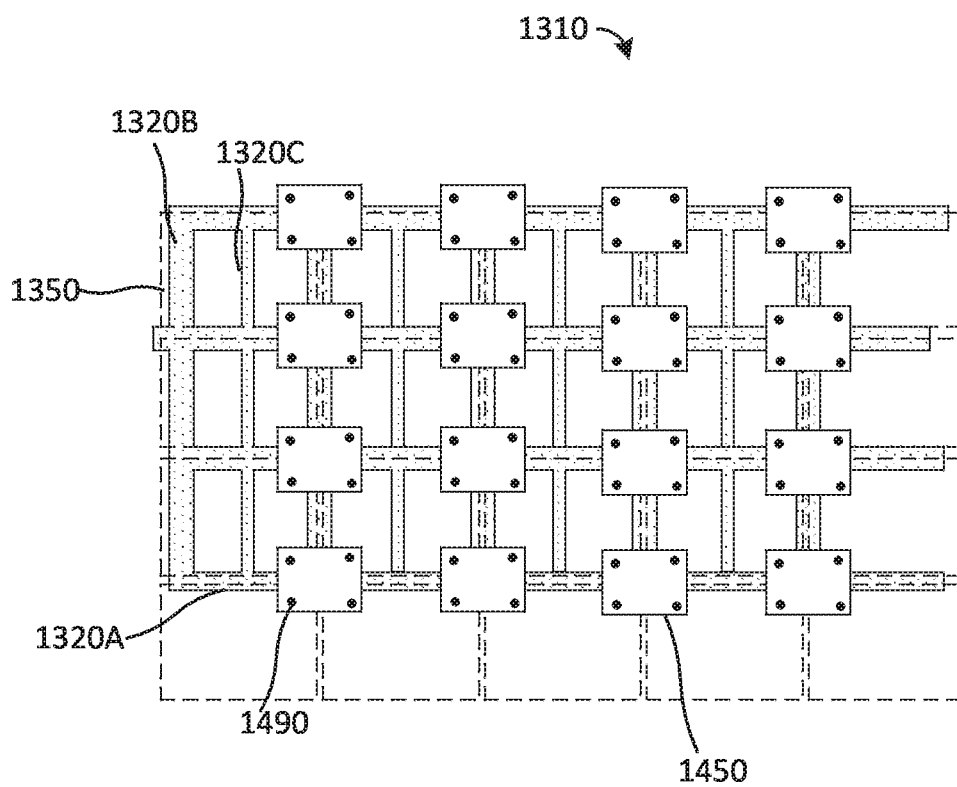


FIG. 21B

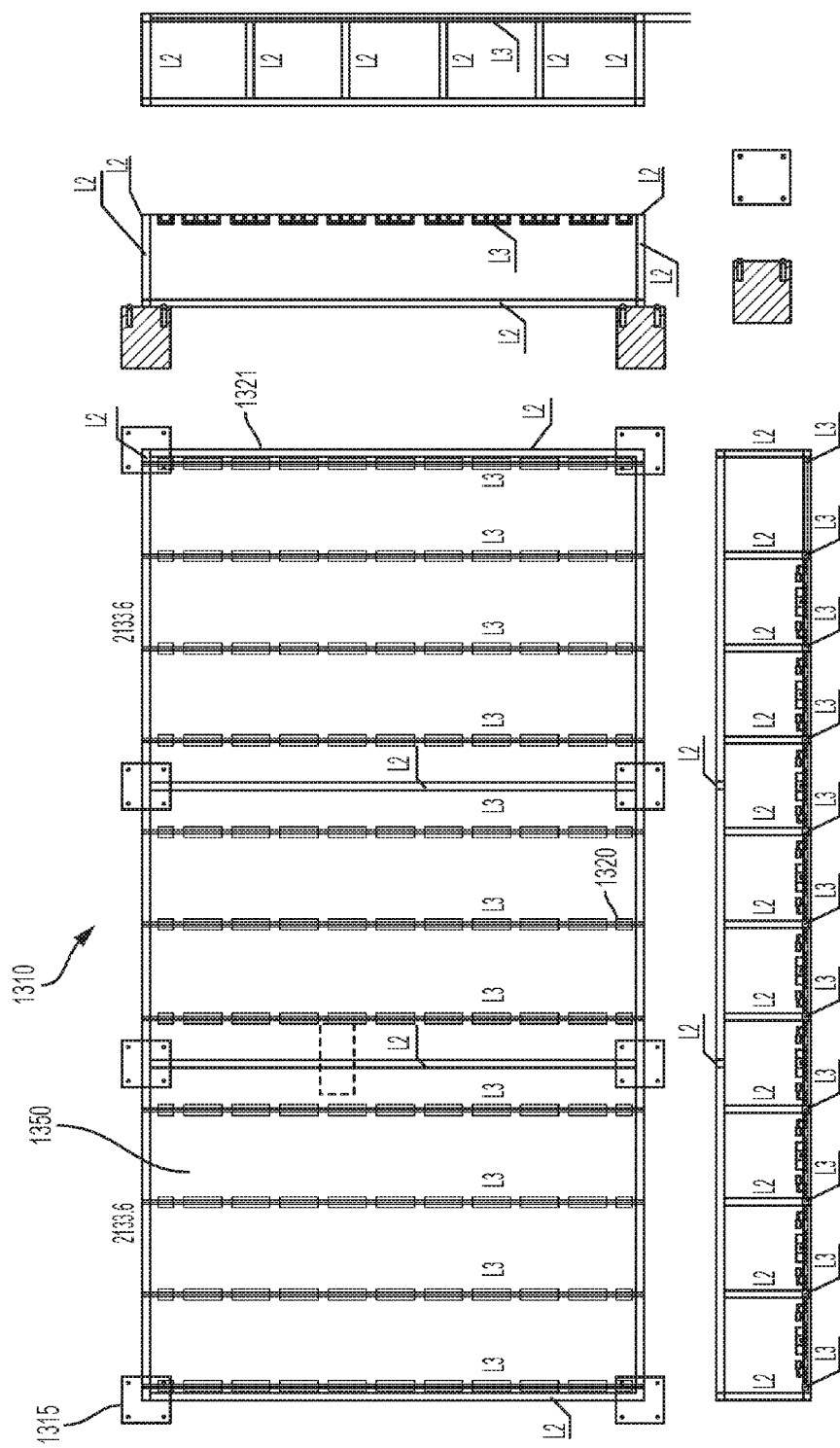


FIG. 21C

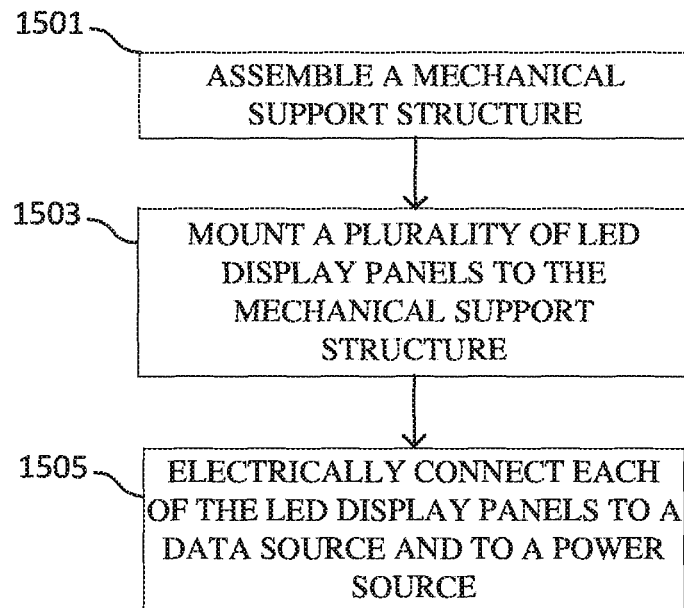


FIG. 22

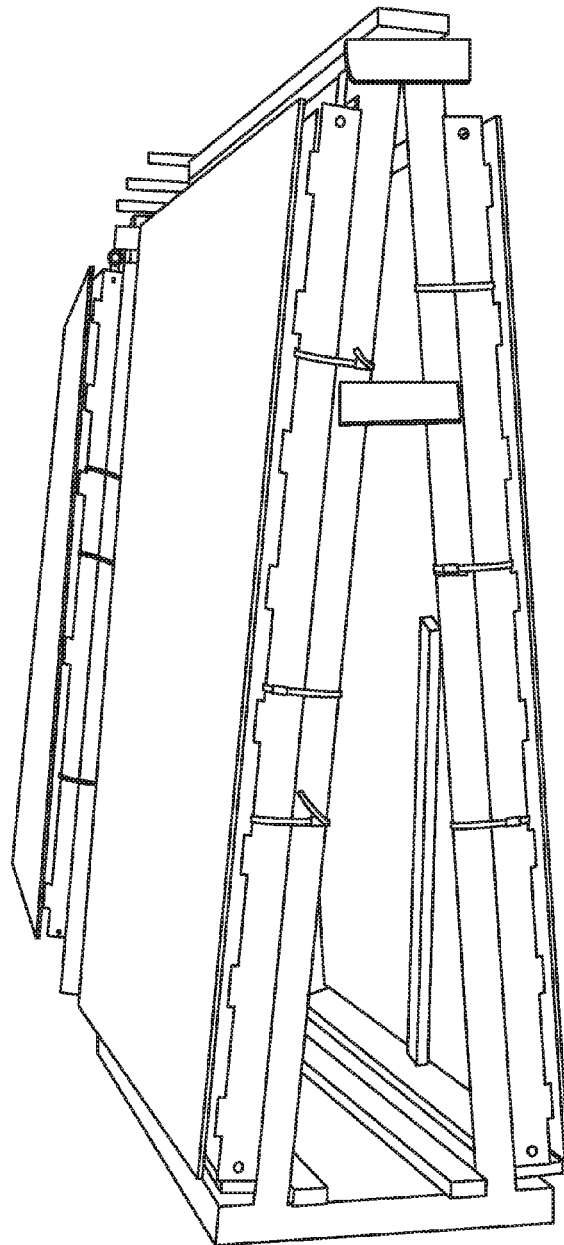


FIG. 23

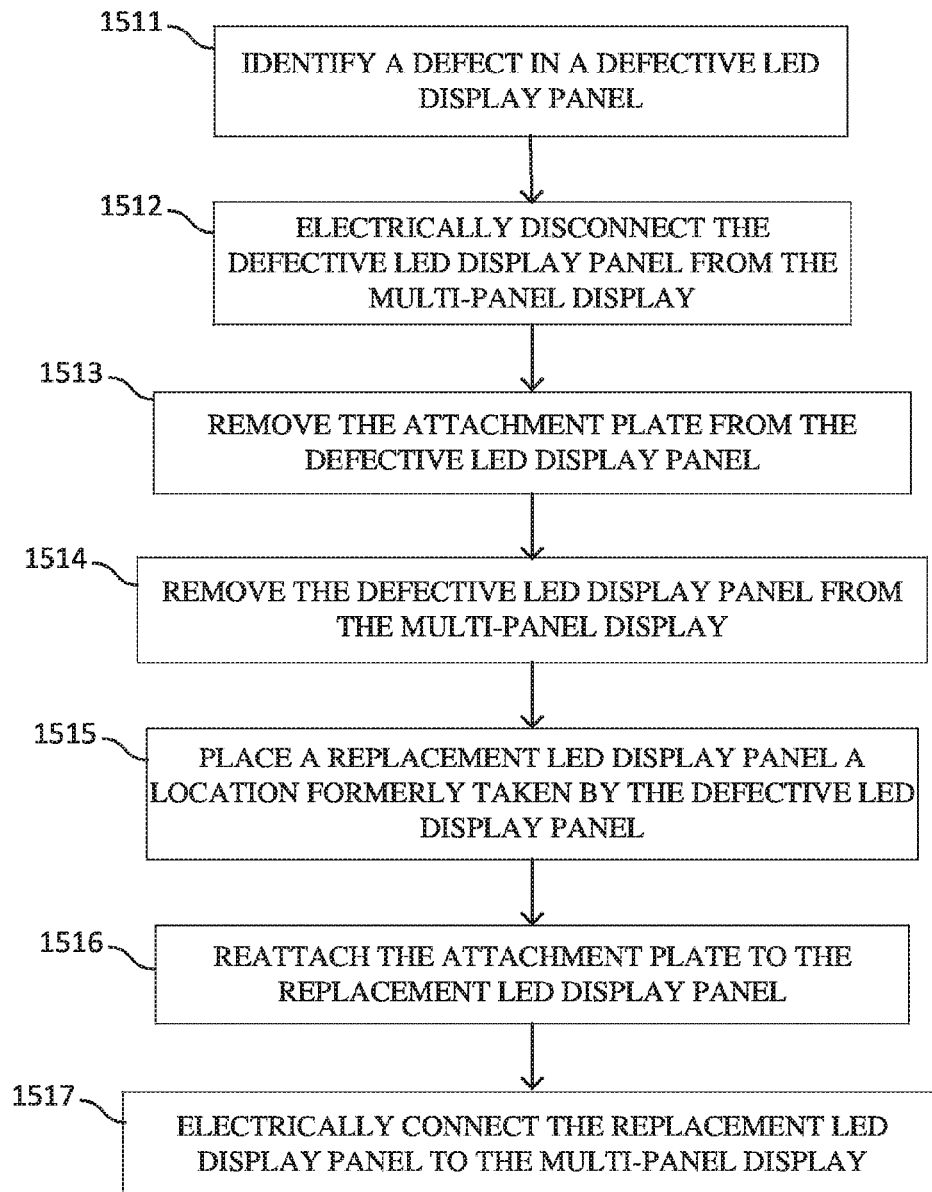


FIG. 24



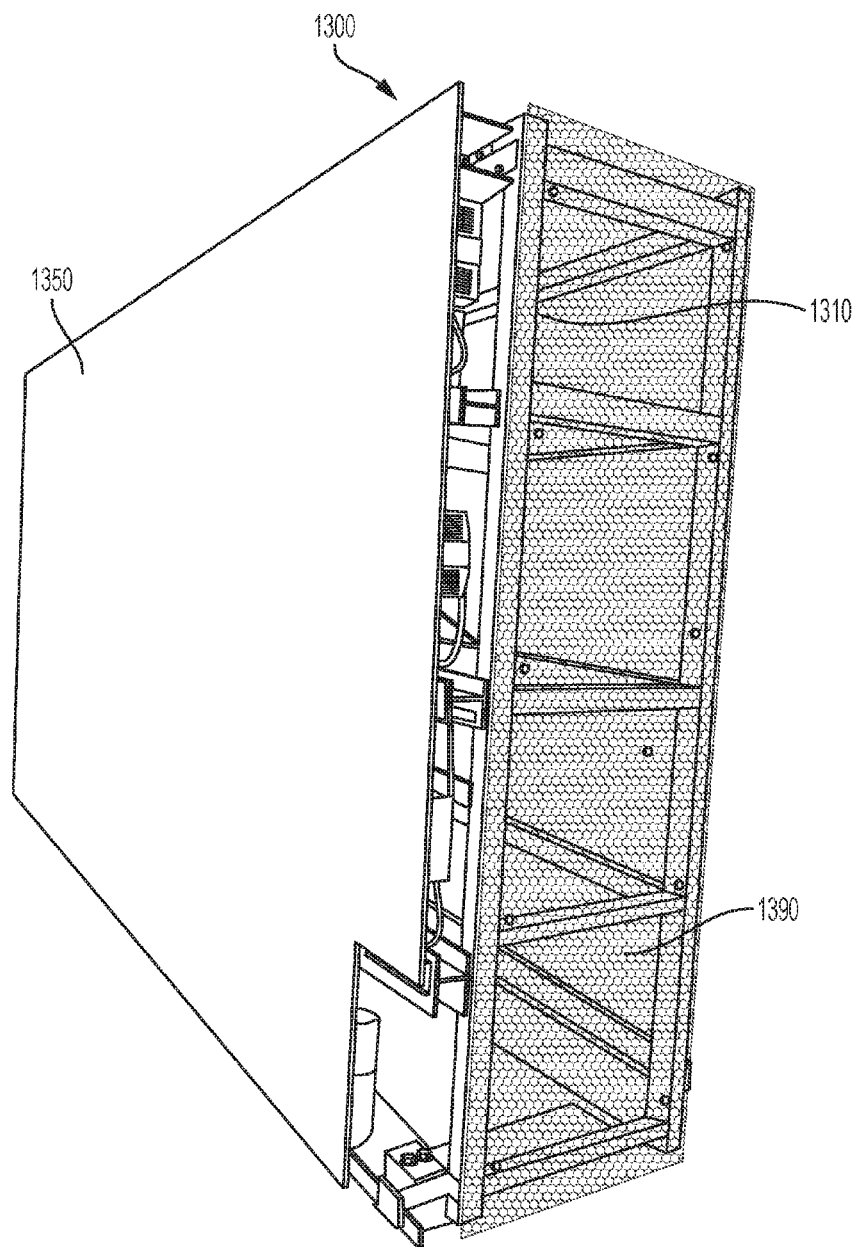


FIG. 25A

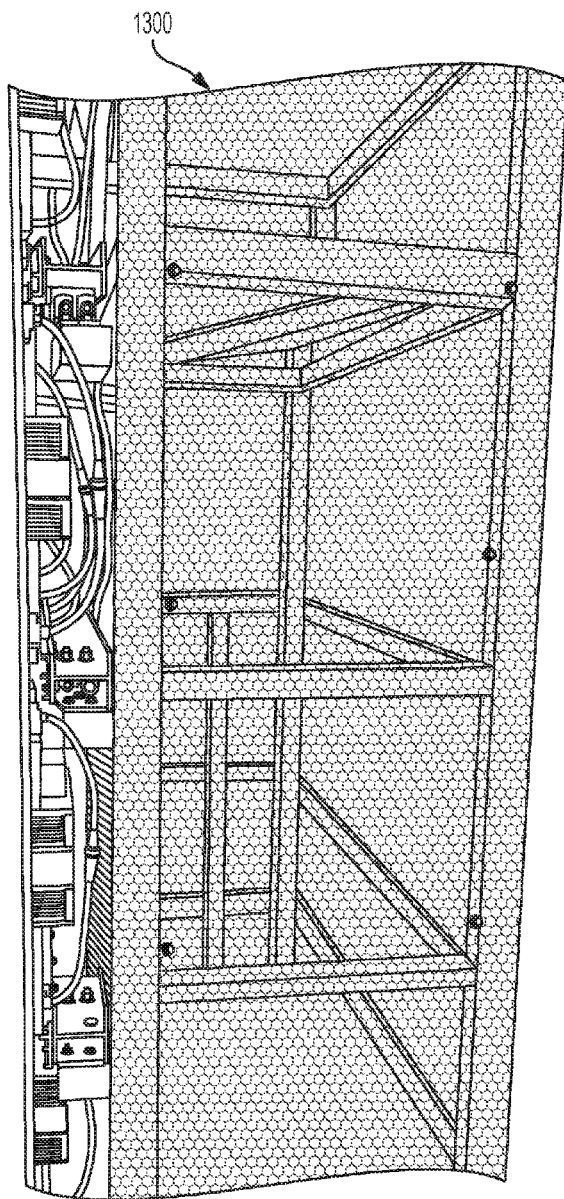


FIG. 25B

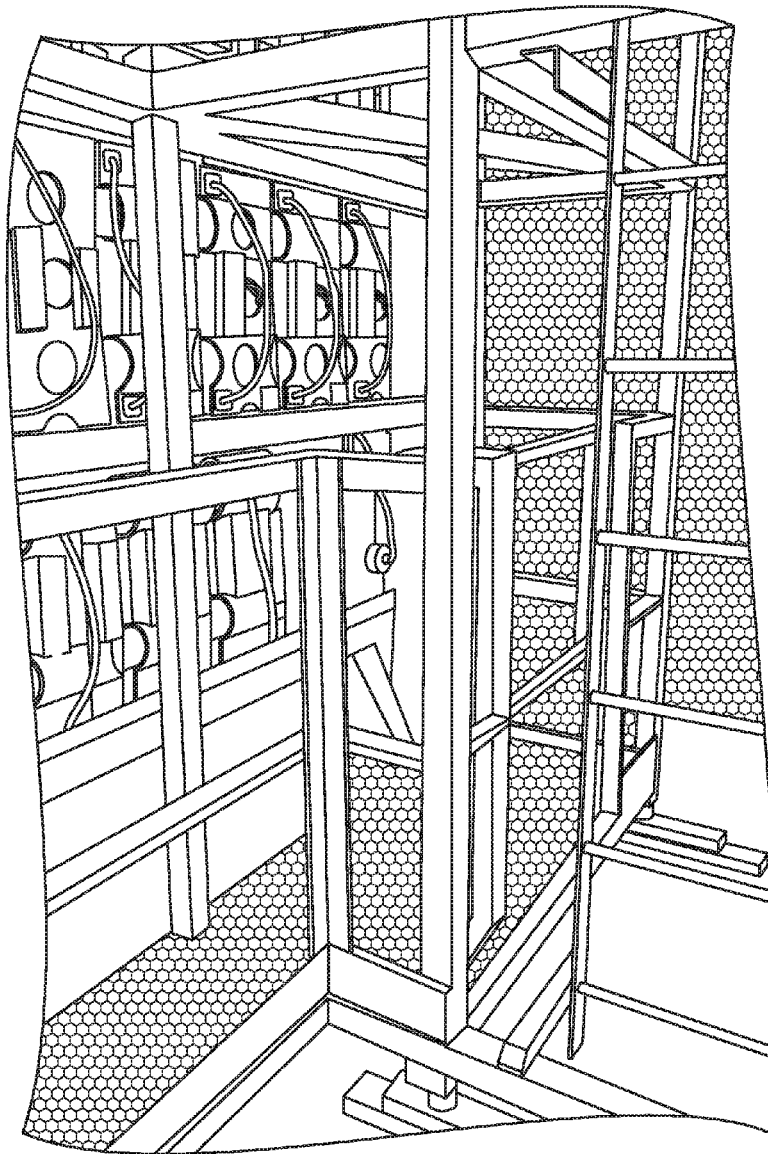


FIG. 25C

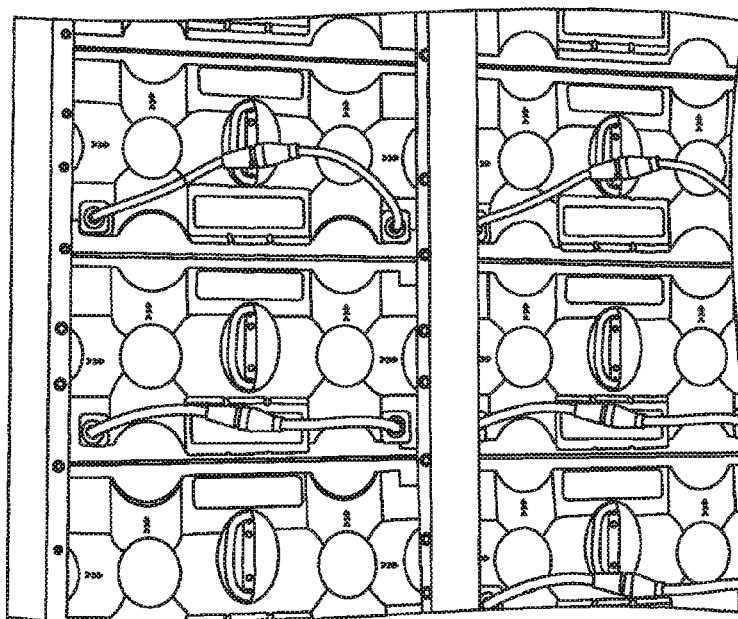


FIG. 25D

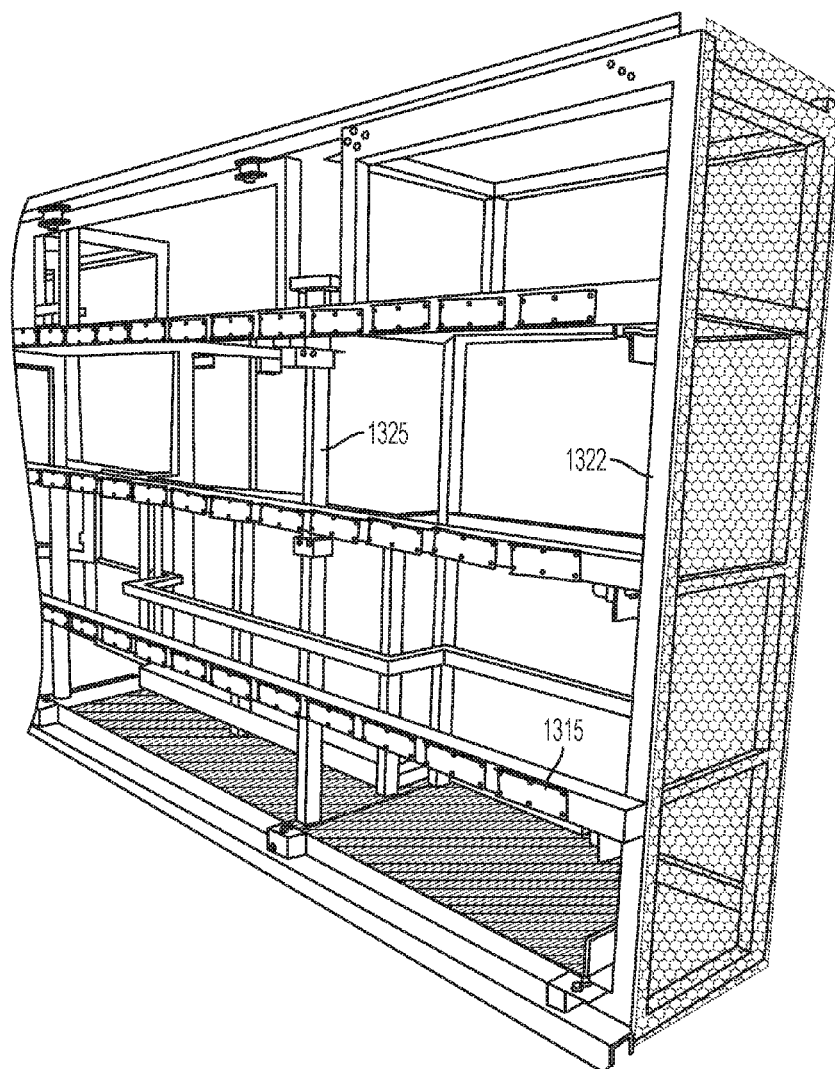


FIG. 26

1

**SYSTEM FOR MODULAR MULTI-PANEL  
DISPLAY WHEREIN EACH DISPLAY IS  
SEALED TO BE WATERPROOF AND  
INCLUDES ARRAY OF DISPLAY ELEMENTS  
ARRANGED TO FORM DISPLAY PANEL  
SURFACE**

The application is a continuation of application Ser. No. 14/341,678 filed on Jul. 25, 2014 (now U.S. Pat. No. 9,195,281), which claims the benefit of U.S. Provisional Application No. 62/025,463, filed on Jul. 16, 2014 and also the benefit of U.S. Provisional Application No. 61/922,631, filed on Dec. 31, 2013, which applications are hereby incorporated herein by reference.

U.S. patent application Ser. No. 14/328,624, filed Jul. 10, 2014, also claims priority to U.S. Provisional Application No. 61/922,631 and is also incorporated herein by reference. The following applications are also related to this provisional application: U.S. patent application Ser. No. 14/444,719; U.S. patent application Ser. No. 14/444,747; U.S. patent application Ser. No. 14/444,775; U.S. patent application Ser. No. 14/550,685; U.S. patent application Ser. No. 14/582,908; U.S. patent application Ser. No. 14/627,923; U.S. patent application Ser. No. 14/641,130; U.S. patent application Ser. No. 14/641,189; U.S. patent application Ser. No. 14/664,526; U.S. patent application Ser. No. 14/720,544; U.S. patent application Ser. No. 14/720,560; U.S. patent application Ser. No. 14/720,610; U.S. patent application Ser. No. 14/829,469; U.S. patent application Ser. No. 14/850,632; U.S. Patent Application No. 62/065,510; U.S. Patent Application No. 62/093,157; U.S. Patent Application No. 62/113,342; U.S. Patent Application No. 62/158,707; U.S. Patent Application No. 62/158,989; and PCT Patent Application No. PCT/US14/72373.

#### TECHNICAL FIELD

The present invention relates generally to displays, and, in particular embodiments, to a system and method for a modular multi-panel display.

#### BACKGROUND

Large displays (e.g., billboards), such as those commonly used for advertising in cities and along roads, generally have one or more pictures and/or text that are to be displayed under various light and weather conditions. As technology has advanced and introduced new lighting devices such as the light emitting diode (LED), such advances have been applied to large displays. An LED display is a flat panel display, which uses an array of light-emitting diodes. A large display may be made of a single LED display or a panel of smaller LED panels. LED panels may be conventional panels made using discrete LEDs or surface-mounted device (SMD) panels. Most outdoor screens and some indoor screens are built around discrete LEDs, which are also known as individually mounted LEDs. A cluster of red, green, and blue diodes is driven together to form a full-color pixel, usually square in shape. These pixels are spaced evenly apart and are measured from center to center for absolute pixel resolution.

#### SUMMARY

Embodiments of the invention relate to lighting systems and, more particularly, to multi-panel lighting systems for providing interior or exterior displays.

2

In one embodiment, a modular multi-panel display system comprises a mechanical support structure. A plurality of LED display panels is detachably mounted to the mechanical support structure so as to form an integrated display panel. Each LED panel includes an LED array and a receiver circuit disposed within a housing. The receiver circuit includes an LED driver coupled to the LED array. Each panel further includes a power supply unit disposed outside the housing and electrically coupled to the receiver circuit. The mechanical structure is configured to provide mechanical support to the plurality of LED display panels without providing hermetic sealing. Each of the plurality of LED display panels is hermetically sealed.

In one embodiment, a modular multi-panel display system comprises an outer frame including a top beam, a bottom beam, a left outside beam, and a right outside beam. A plurality of vertical beams extends from the top beam to the bottom beam within the outer frame. Each of the vertical beams has a smaller diameter and weighs less than any beam of the outer frame. An array of LED display panels arranged in rows and columns. Each LED display panel attached to at least one of the vertical beams. The array forms an integrated display panel. The display system includes no cabinets, and is cooled passively and includes no air conditioning, fans, or heating units.

In another embodiment, a method of assembling a modular multi-panel display system, the method comprises assembling a mechanical support structure that includes an outer frame including a top beam, a bottom beam, a left outside beam, and a right outside beam. A plurality of vertical beams extends from the top beam to the bottom beam within the outer frame. Each of the vertical beams has a smaller diameter and weigh less than any beam of the outer frame. A plurality of LED display panels is mounted to the mechanical support structure so as to form an integrated display panel that includes an array of rows and columns of LED display panels. Each of the LED display panels is hermetically sealed. Each of the LED display panels is electrically connected to a data source and to a power source. The assembled multi-panel display system includes no cabinets, and is cooled passively and includes no air conditioning or fans.

In yet another embodiment, a method of maintaining a modular multi-panel display that includes a mechanical support structure and a plurality of LED display panels detachably coupled to the mechanical support structure without a cabinet. Each LED display panel is mechanically coupled to the mechanical support structure and three other lighting panels by a corner plate. The method further includes determining that a defective LED display panel has a defect and electrically disconnecting the defective LED display panel from the multi-panel display. The corner plate is removed from the defective LED display panel. The defective LED display panel is removed from the multi-panel display. A replacement LED display panel is placed at a location formerly taken by the defective LED display panel. The corner plate is attached to the replacement LED display panel. The replacement LED display panel is electrically connected to the multi-panel display.

#### BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding, reference is now made to the following description taken in conjunction with the accompanying drawings in which:

FIGS. 1A and 1B illustrate one embodiment of a display that may be provided according to the present disclosure;

3

FIGS. 2A-2C illustrate one embodiment of a lighting panel that may be used with the display of FIGS. 1A and 1B;

FIGS. 3A-3I illustrate one embodiment of a housing and an alignment plate that may be used with the panel of FIG. 2A;

FIGS. 4A and 4B illustrate a more detailed embodiment of the panel of FIG. 2A;

FIG. 5 illustrates an alternative embodiment of the panel of FIG. 4A;

FIGS. 6A and 6B illustrate a more detailed embodiment of the panel of FIG. 2A;

FIG. 7 illustrates an alternative embodiment of the panel of FIG. 6A;

FIGS. 8A-8M illustrate one embodiment of a frame that may be used with the display of FIGS. 1A and 1B;

FIGS. 9A-9C illustrate one embodiment of a locking mechanism that may be used with the display of FIGS. 1A and 1B;

FIGS. 10A-10D illustrate one embodiment of a display configuration;

FIGS. 11A-11D illustrate another embodiment of a display configuration;

FIGS. 12A-12D illustrate yet another embodiment of a display configuration;

FIG. 13 illustrates a modular display panel in accordance with an embodiment of the present invention;

FIG. 14 illustrates a modular display panel attached to a supporting frame in accordance with an embodiment of the present invention;

FIG. 15 illustrates a frame used to provide mechanical support to the modular display panel in accordance with an embodiment of the present invention;

FIGS. 16A-16E illustrate an attachment plate used to attach one or more modular display panels to the frame in accordance with an embodiment of the present invention, wherein FIG. 16A illustrates a projection view while FIG. 16B illustrates a top view and FIG. 16C illustrates a cross-sectional view of a first embodiment while FIG. 16D illustrates a bottom view and FIG. 16E illustrates a bottom view of a second embodiment;

FIG. 17 illustrates a magnified view of the attachment plate or a connecting plate, frame, and display panel after mounting in accordance with embodiments of the present invention;

FIG. 18 illustrates one unit of the modular display panel in accordance with an embodiment of the present invention;

FIG. 19 illustrates a magnified view of two display panels next to each other and connected through the cables such that the output cable of the left display panel is connected with the input cable of the next display panel in accordance with an embodiment of the present invention;

FIG. 20 illustrates a modular multi-panel display system comprising a plurality of LED display panels connected together using the afore-mentioned cables in accordance with an embodiment of the present invention;

FIGS. 21A-21C illustrate an alternative embodiment of the modular display panel attached to a supporting frame in accordance with an embodiment of the present invention, wherein FIGS. 21B and 21C illustrate alternative structural embodiments of the supporting frame;

FIG. 22 illustrates a method of assembling a modular multi-panel display system in accordance with an embodiment of the present invention;

FIG. 23 illustrates an assembled multi-panel display that is ready for shipment;

FIG. 24 illustrates a method of maintaining a modular multi-panel display that includes a mechanical support struc-

4

ture and a plurality of LED display panels detachably coupled to the mechanical support structure without a cabinet in accordance with an embodiment of the present invention;

FIGS. 25A-25D illustrate specific examples of an assembled display system; and

FIG. 26 illustrates a specific example of a frame that can be used with the system of FIGS. 25A-25D.

#### DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

In the following discussion, exterior displays are used herein for purposes of example. It is understood that the present disclosure may be applied to lighting for any type of interior and/or exterior display.

Embodiments of the invention provide a display panels, each of which provides a completely self-contained building block that is lightweight. These displays are designed to protect against weather, without a heavy cabinet. The panel can be constructed of aluminum or plastic so that it will about 50% lighter than typical panels that are commercially available. The lightweight design allows for easier installation and maintenance, thus lowering total cost of ownership.

In certain embodiments, the display is IP 67 rated and therefore waterproof and corrosion resistant. Because weather is the number one culprit for damage to LED displays, and IP 67 rating provides weatherproofing with significant weather protection. These panels are completely waterproof against submersion in up to 3 feet of water. In other embodiments, the equipment can be designed with an IP 68 rating to operate completely underwater. In lower-cost embodiments where weatherproofing is not as significant, the panels can have an IP 65 or IP 66 rating.

One aspect takes advantage of a no cabinet design-new technology that replaces cabinets, which are necessary in commercial embodiments. Older technology incorporates the use of cabinets in order to protect the LED display electronics from rain. This creates an innate problem in that the cabinet must not allow rain to get inside to the electronics, while at the same time the cabinet must allow for heat created by the electronics and ambient heat to escape.

Embodiments that do not use this cabinet technology avoid a multitude of problems inherent to cabinet-designed displays. One of the problems that has been solved is the need to effectively cool the LED display. Most LED manufacturers must use air-conditioning (HVAC) to keep their displays cool. This technology greatly increases the cost of installation and performance.

Displays of the present invention can be designed to be light weight and easy to handle. For example, the average total weight of a 20 mm, 14'x48' panel can be 5,500 pounds or less while typical commercially available panels are at 10,000 to 12,000 pounds. These units are more maneuverable and easier to install saving time and money in the process.

Embodiments of the invention provide building block panels that are configurable with future expandability. These displays can offer complete expandability to upgrade in the future without having to replace the entire display. Installation is fast and easy with very little down-time, which allows any electronic message to be presented more quickly.

In some embodiments, the display panels are "hot swappable." By removing one screw in each of the four corners of the panel, servicing the display is fast and easy. Since a

highly-trained, highly-paid electrician or LED technician is not needed to correct a problem, cost benefits can be achieved.

Various embodiments utilize enhanced pixel technology (EPT), which increases image capability. EPT allows image displays in the physical pitch spacing, but also has the ability to display the image in a resolution that is four-times greater. Images will be as sharp and crisp when viewed close as when viewed from a distance, and at angles.

In some embodiments is advantageous to build multipanel displays where each of the LEDs is provided by a single LED manufacturer, so that diodes of different origin in the manufacture are not mixed. It has been discovered that diode consistency can aid in the quality of the visual image. While this feature is not necessary, it is helpful because displays made from different diodes from different suppliers can create patchy inconsistent color, e.g., “pink” reds and pink looking casts to the overall image.

Referring to FIGS. 1A and 1B, one embodiment of a multi-panel display 100 is illustrated. The display 100 includes a display surface 102 that is formed by multiple lighting panels 104a-104t. In the present embodiment, the panels 104a-104t use light emitting diodes (LEDs) for illumination, but it is understood that other light sources may be used in other embodiments. The panels 104a-104t typically operate together to form a single image, although multiple images may be simultaneously presented by the display 100. In the present example, the panels 104a-104t are individually attached to a frame 106, which enables each panel to be installed or removed from the frame 106 without affecting the other panels.

Each panel 104a-104t is a self-contained unit that couples directly to the frame 106. By “directly,” it is understood that another component or components may be positioned between the panel 104a-104t and the frame 106, but the panel is not placed inside a cabinet that is coupled to the frame 106. For example, an alignment plate (described later but not shown in the present figure) may be coupled to a panel and/or the frame 106 to aid in aligning a panel with other panels. Further a corner plate could be used. The panel may then be coupled to the frame 106 or the alignment plate and/or corner plate, and either coupling approach would be “direct” according to the present disclosure.

Two or more panels 104a-104t can be coupled for power and/or data purposes, with a panel 104a-104t receiving power and/or data from a central source or another panel and passing through at least some of the power and/or data to one or more other panels. This further improves the modular aspect of the display 100, as a single panel 104a-104t can be easily connected to the display 100 when being installed and easily disconnected when being removed by decoupling the power and data connections from neighboring panels.

The power and data connections for the panels 104a-104t may be configured using one or more layouts, such as a ring, mesh, star, bus, tree, line, or fully-connected layout, or a combination thereof. In some embodiments the LED panels 104a-104t may be in a single network, while in other embodiments the LED panels 104a-104t may be divided into multiple networks. Power and data may be distributed using identical or different layouts. For example, power may be distributed in a line layout, while data may use a combination of line and star layouts.

The frame 106 may be relatively light in weight compared to frames needed to support cabinet mounted LED assemblies. In the present example, the frame 106 includes only a top horizontal member 108, a bottom horizontal member 110, a left vertical member 112, a right vertical member 114,

and intermediate vertical members 116. Power cables and data cables (not shown) for the panels 104a-104t may route around and/or through the frame 106.

In one example, the display 100 includes 336 panels 104a-104t, e.g., to create a 14'x48' display. As will be discussed below, because each panel is lighter than typical panels, the entire display could be built to weigh only 5500 pounds. This compares favorably to commercially available displays of the size, which generally weigh from 10,000 to 12,000 pounds.

Referring to FIGS. 2A-2C, one embodiment of an LED panel 200 is illustrated that may be used as one of the LED panels 104a-104t of FIGS. 1A and 1B. FIG. 2A illustrates a front view of the panel 200 with LEDs aligned in a 16x32 configuration. FIG. 2B illustrates a diagram of internal components within the panel 200. FIG. 2C illustrates one possible configuration of a power supply positioned within the panel 200 relative to a back plate of the panel 200.

Referring specifically to FIG. 2A, in the present example, the LED panel 200 includes a substrate 202 that forms a front surface of the panel 200. The substrate 202 in the present embodiment is rectangular in shape, with a top edge 204, a bottom edge 206, a right edge 208, and a left edge 210. A substrate surface 212 includes “pixels” 214 that are formed by one or more LEDs 216 on or within the substrate 202. In the present example, each pixel 214 includes four LEDs 216 arranged in a pattern (e.g., a square). For example, the four LEDs 216 that form a pixel 214 may include a red LED, a green LED, a blue LED, and one other LED (e.g., a white LED). In some embodiments, the other LED may be a sensor. It is understood that more or fewer LEDs 216 may be used to form a single pixel 214, and the use of four LEDs 216 and their relative positioning as a square is for purposes of illustration only.

In some embodiments, the substrate 202 may form the entire front surface of the panel 200, with no other part of the panel 200 being visible from the front when the substrate 202 is in place. In other embodiments, a housing 220 (FIG. 2B) may be partially visible at one or more of the edges of the substrate 202. The substrate 202 may form the front surface of the panel 202, but may not be the outer surface in some embodiments. For example, a transparent or translucent material or coating may overlay the substrate 202 and the LEDs 216, thereby being positioned between the substrate 202/LEDs 216 and the environment.

As one example, a potting material can be formed over the LEDs 216. This material can be applied as a liquid, e.g., while heated, and then harden over the surface, e.g., when cooled. This potting material is useful for environmental protection, e.g., to achieve an IP rating of IP 65 or higher.

Louvers 218 may be positioned above each row of pixels 214 to block or minimize light from directly striking the LEDs 216 from certain angles. For example, the louvers 218 may be configured to extend from the substrate 202 to a particular distance and/or at a particular angle needed to completely shade each pixel 214 when a light source (e.g., the sun) is at a certain position (e.g., ten degrees off vertical). In the present example, the louvers 208 extend the entire length of the substrate 202, but it is understood that other louver configurations may be used.

Referring specifically to FIG. 2B, one embodiment of the panel 200 illustrates a housing 220. The housing 220 contains circuitry 222 and a power supply 224. The circuitry 222 is coupled to the LEDs 216 and is used to control the LEDs. The power supply 224 provides power to the LEDs 216 and circuitry 222. As will be described later in greater detail with respect to two embodiments of the panel 200, data and/or



power may be received for only the panel 200 or may be passed on to one or more other panels as well. Accordingly, the circuitry 222 and/or power supply 224 may be configured to pass data and/or power to other panels in some embodiments.

In the present example, the housing 220 is sealed to prevent water from entering the housing. For example, the housing 220 may be sealed to have an ingress protection (IP) rating such as IP 67, which defines a level of protection against both solid particles and liquid. This ensures that the panel 200 can be mounted in inclement weather situations without being adversely affected. In such embodiments, the cooling is passive as there are no vent openings for air intakes or exhausts. In other embodiments, the housing may be sealed to have an IP rating of IP 65 or higher, e.g. IP 65, IP 66, IP 67, or IP 68.

Referring specifically to FIG. 2C, one embodiment of the panel 200 illustrates how the power supply 224 may be thermally coupled to the housing 220 via a thermally conductive material 226 (e.g., aluminum). This configuration may be particularly relevant in embodiments where the panel 200 is sealed and cooling is passive.

Referring to FIGS. 3A-3I, one embodiment of a housing 300 is illustrated that may be used with one of the LED panels 104a-104t of FIGS. 1A and 1B. For example, the housing 300 may be a more specific example of the housing 220 of FIG. 2B. In FIGS. 3B-3I, the housing 300 is shown with an alignment plate, which may be separate from the housing 300 or formed as part of the housing 300. In the present example, the housing 300 may be made of a thermally conductive material (e.g., aluminum) that is relatively light weight and rigid. In other embodiments, the housing 300 could be made out of industrial plastic, which is even lighter than aluminum.

As shown in the orthogonal view of FIG. 3A, the housing 300 defines a cavity 302. Structural cross-members 304 and 306 may be used to provide support to a substrate (e.g., the substrate 202 of FIG. 2A) (not shown). The cross-members 304 and 306, as well as other areas of the housing 300, may include supports 308 against which the substrate can rest when placed into position. As shown, the supports 308 may include a relatively narrow tip section that can be inserted into a receiving hole in the back of the substrate and then a wider section against which the substrate can rest.

The housing 300 may also include multiple extensions 310 (e.g., sleeves) that provide screw holes or locations for captive screws that can be used to couple the substrate to the housing 300. Other extensions 312 may be configured to receive pins or other protrusions from a locking plate and/or fasteners, which will be described later in greater detail. Some or all of the extensions 312 may be accessible only from the rear side of the housing 300 and so are not shown as openings in FIG. 3A.

As shown in FIG. 3B, an alignment plate 314 may be used with the housing 300. The alignment plate is optional. The alignment plate 314, when used, aids in aligning multiple panels on the frame 106 to ensure that the resulting display surface has correctly aligned pixels both horizontally and vertically. To accomplish this, the alignment plate 314 includes tabs 316 and slots 318 (FIG. 3F). Each tab 316 fits into the slot 318 of an adjoining alignment plate (if present) and each slot 318 receives a tab from an adjoining alignment plate (if present). This provides an interlocking series of alignment plates. As each alignment plate 314 is coupled to or part of a housing 300, this results in correctly aligning the panels on the frame 106.

It is understood that, in some embodiments, the alignment plate 314 may be formed as part of the panel or the alignment functionality provided by the alignment plate 314 may be achieved in other ways. In still other embodiments, a single alignment panel 314 may be formed to receive multiple panels, rather than a single panel as shown in FIG. 3B.

In other embodiments, the alignment functionality is eliminated. The design choice of whether to use alignment mechanisms (e.g., slots and grooves) is based upon a tradeoff between the additional alignment capability and the ease of assembly.

As shown in FIG. 3C, the housing 300 may include beveled or otherwise non-squared edges 320. This shaping of the edges enables panels to be positioned in a curved display without having large gaps appear as would occur if the edges were squared.

Referring to FIGS. 4A and 4B, one embodiment of a panel 400 is illustrated that may be similar or identical to one of the LED panels 104a-104t of FIGS. 1A and 1B. The panel 400 may be based on a housing 401 that is similar or identical to the housing 300 of FIG. 3A. FIG. 4A illustrates a back view of the panel 400 and FIG. 4B illustrates a top view. The panel 400 has a width W and a height H.

In the present example, the back includes a number of connection points that include a "power in" point 402, a "data in" point 404, a main "data out" point 406, multiple slave data points 408, and a "power out" point 410. As will be discussed below, one embodiment of the invention provides for an integrated data and power cable, which reduces the number of ports. The power in point 402 enables the panel 400 to receive power from a power source, which may be another panel. The data in point 404 enables the panel to receive data from a data source, which may be another panel. The main data out point 406 enables the panel 400 to send data to another main panel. The multiple slave data points 408, which are bi-directional in this example, enable the panel 400 to send data to one or more slave panels and to receive data from those slave panels. In some embodiments, the main data out point 406 and the slave data out points 408 may be combined. The power out point 410 enables the panel 400 to send power to another panel.

The connection points may be provided in various ways. For example, in one embodiment, the connection points may be jacks configured to receive corresponding plugs. In another embodiment, a cable may extend from the back panel with a connector (e.g., a jack or plug) affixed to the external end of the cable to provide an interface for another connector. It is understood that the connection points may be positioned and organized in many different ways.

Inside the panel, the power in point 402 and power out point 410 may be coupled to circuitry (not shown) as well as to a power supply. For example, the power in point 402 and power out point 410 may be coupled to the circuitry 222 of FIG. 2B, as well as to the power supply 224. In such embodiments, the circuitry 222 may aid in regulating the reception and transmission of power. In other embodiments, the power in point 402 and power out point 410 may be coupled only to the power supply 224 with a pass through power connection allowing some of the received power to be passed from the power in point 402 to the power out point 410.

The data in point 404, main data out point 406, and slave data out points 408 may be coupled to the circuitry 222. The circuitry 222 may aid in regulating the reception and transmission of the data. In some embodiments, the circuitry 222 may identify data used for the panel 400 and also send all

data on to other coupled main and slave panels via the main data out point **406** and slave data out points **408**, respectively. In such embodiments, the other main and slave panels would then identify the information relevant to that particular panel from the data. In other embodiments, the circuitry **222** may remove the data needed for the panel **400** and selectively send data on to other coupled main and slave panels via the main data out point **406** and slave data out points **408**, respectively. For example, the circuitry **222** may send only data corresponding to a particular slave panel to that slave panel rather than sending all data and letting the slave panel identify the corresponding data.

The back panel also has coupling points **412** and **414**. In the example where the housing is supplied by the housing **300** of FIG. 3A, the coupling points **412** and **414** may correspond to extensions **310** and **312**, respectively.

Referring specifically to FIG. 4B, a top view of the panel **400** illustrates three sections of the housing **401**. The first section **416** includes the LEDs (not shown) and louvers **418**. The second section **420** and third section **422** may be used to house the circuitry **222** and power supply **224**. In the present example, the third section **422** is an extended section that may exist on main panels, but not slave panels, due to extra components needed by a main panel to distribute data. Depths **D1**, **D2**, and **D3** correspond to sections **416**, **420**, and **422**, respectively.

Referring to FIG. 5, one embodiment of a panel **500** is illustrated that may be similar or identical to the panel **400** of FIG. 4A with the exception of a change in the slave data points **408**. In the embodiment of FIG. 4A, the slave data points **408** are bi-directional connection points. In the present embodiment, separate slave “data in” points **502** and slave “data out” points **504** are provided. In other embodiments, the data points can be directional connection points.

Referring to FIGS. 6A and 6B, one embodiment of a panel **600** is illustrated that may be similar or identical to the panel **400** of FIG. 4A except that the panel **600** is a slave panel. FIG. 6A illustrates a back view of the panel **600** and FIG. 6B illustrates a top view. The panel **400** has a width **W** and a height **H**. In the present embodiment, these are identical to the width **W** and height **H** of the panel **400** of FIG. 4A. In one example, the width **W** can be between 1 and 4 feet and the height **H** can be between 0.5 and 4 feet, for example 1 foot by 2 feet. Of course, the invention is not limited to these specific dimensions.

In contrast to the main panel of FIG. 4A, the back of the slave panel **600** has a more limited number of connection points that include a “power in” point **602**, a data point **604**, and a “power out” point **606**. The power in point **602** enables the panel **600** to receive power from a power source, which may be another panel. The data point **604** enables the panel to receive data from a data source, which may be another panel. The power out point **606** enables the panel **600** to send power to another main panel. In the present example, the data point **604** is bi-directional, which corresponds to the main panel configuration illustrated in FIG. 4A. The back panel also has coupling points **608** and **610**, which correspond to coupling points **412** and **414**, respectively, of FIG. 4A. As discussed above, other embodiments use directional data connections.

Referring specifically to FIG. 6B, a top view of the panel **600** illustrates two sections of the housing **601**. The first section **612** includes the LEDs (not shown) and louvers **614**. The second section **616** may be used to house the circuitry **222** and power supply **224**. In the present example, the extended section provided by the third section **422** of FIG. 4A is not needed as the panel **600** does not pass data on to

other panels. Depths **D1** and **D2** correspond to sections **612** and **616**, respectively. In the present embodiment, depths **D1** and **D2** are identical to depths **D1** and **D2** of the panel **400** of FIG. 4B. In one example, the depth **D1** can be between 1 and 4 inches and the depths **D2** can be between 1 and 4 inches.

It is noted that the similarity in size of the panels **400** of FIG. 4A and the panel **600** of FIG. 6A enables the panels to be interchanged as needed. More specifically, as main panels and slave panels have an identical footprint in terms of height **H**, width **W**, and depth **D1**, their position on the frame **106** of FIGS. 1A and 1B does not matter from a size standpoint, but only from a functionality standpoint. Accordingly, the display **100** can be designed as desired using main panels and slave panels without the need to be concerned with how a particular panel will physically fit into a position on the frame. The design may then focus on issues such as the required functionality (e.g., whether a main panel is needed or a slave panel is sufficient) for a particular position and/or other issues such as weight and cost.

In some embodiments, the main panel **400** of FIG. 4A may weigh more than the slave panel **600** due to the additional components present in the main panel **400**. The additional components may also make the main panel **400** more expensive to produce than the slave panel **600**. Therefore, a display that uses as many slave panels as possible while still meeting required criteria will generally cost less and weigh less than a display that uses more main panels.

Referring to FIG. 7, one embodiment of a panel **700** is illustrated that may be similar or identical to the panel **600** of FIG. 6A with the exception of a change in the data point **604**. In the embodiment of FIG. 6A, the data point **604** is a bi-directional connection. In the present embodiment, a separate “data out” point **702** and a “data in” point **704** are provided, which corresponds to the main panel configuration illustrated in FIG. 5.

Referring to FIGS. 8A-8M, embodiments of a frame **800** are illustrated. For example, the frame **800** may provide a more detailed embodiment of the frame **106** of FIG. 1B. As described previously, LED panels, such as the panels **104a-104t** of FIGS. 1A and 1B, may be mounted directly to the frame **800**. Accordingly, the frame **800** does not need to be designed to support heavy cabinets, but need only be able to support the panels **104a-104t** and associated cabling (e.g., power and data cables), and the frame **800** may be lighter than conventional frames that have to support cabinet based structures. For purposes of example, various references may be made to the panel **200** of FIG. 2A, the housing **300** of FIG. 3A, and the panel **400** of FIG. 4A.

In the present example, the frame **800** is designed to support LED panels **802** in a configuration that is ten panels high and thirty-two panels wide. While the size of the panels **802** may vary, in the current embodiment this provides a display surface that is approximately fifty feet and four inches wide (50' 4") and fifteen feet and eight and three-quarters inches high (15' 8.75").

It is understood that all measurements and materials described with respect to FIGS. 8A-8M are for purposes of example only and are not intended to be limiting. Accordingly, many different lengths, heights, thicknesses, and other dimensional and/or material changes may be made to the embodiments of FIGS. 8A-8M.

Referring specifically to FIG. 8B, a back view of the frame **800** is illustrated. The frame **800** includes a top bar **804**, a bottom bar **806**, a left bar **808**, a right bar **810**, and

## 11

multiple vertical bars **812** that connect the top bar **804** and bottom bar **806**. In some embodiments, additional horizontal bars **814** may be present.

The frame **800** may be constructed of various materials, including metals. For example, the top bar **804**, the bottom bar **806**, the left bar **808**, and the right bar **810** (e.g., the perimeter bars) may be made using a four inch aluminum association standard channel capable of bearing 1.738 lb/ft. The vertical bars **812** may be made using 2"x4"x½" aluminum tube capable of bearing a load of 3.23 lb/ft. it is understood that other embodiments will utilize other size components.

It is understood that these sizes and load bearing capacities are for purposes of illustration and are not intended to be limiting. However, conventional steel display frames needed to support conventional cabinet-based displays are typically much heavier than the frame **800**, which would likely not be strong enough to support a traditional cabinet-based display. For example, the frame **800** combined with the panels described herein may weigh at least fifty percent less than equivalent steel cabinet-based displays.

Referring to FIG. **8C**, a cutaway view of the frame **800** of FIG. **8B** taken along lines A1-A1 is illustrated. The horizontal bars **810** are more clearly visible. More detailed views of FIG. **8C** are described below.

Referring to FIG. **8D**, a more detailed view of the frame **800** of FIG. **8C** at location B1 is illustrated. The cutaway view shows the top bar **804** and a vertical bar **812**. A first flat bar **816** may be used with multiple fasteners **818** to couple the top bar **804** to the vertical bar **812** at the back of the frame **800**. A second flat bar **820** may be used with fasteners **821** to couple the top bar **804** to the vertical bar **812** at the front of the frame **800**. A front plate **902** belonging to a coupling mechanism **900** (described below with respect to FIG. **9A**) is illustrated. The second flat bar **820** may replace a back plate of the coupling mechanism **900**. In embodiments where the second flat bar **820** replaces the back plate, the second flat bar **820** may include one or more holes to provide accessibility to fasteners of the coupling mechanism **900**.

Referring to FIGS. **8E-8G**, various more detailed views of the frame **800** of FIG. **8C** are illustrated. FIG. **8E** provides a more detailed view of the frame **800** of FIG. **8C** at location B2. FIG. **8F** provides a cutaway view of the frame **800** of FIG. **8E** taken along lines C1-C1. FIG. **8G** provides a cutaway view of the frame **800** of FIG. **8E** taken along lines C2-C2.

A clip **822** may be coupled to a vertical bar **812** via one or more fasteners **824** and to the horizontal bar **814** via one or more fasteners **824**. In the present example, the clip **822** is positioned above the horizontal bar **814**, but it is understood that the clip **822** may be positioned below the horizontal bar **814** in other embodiments. In still other embodiments, the clip **822** may be placed partially inside the horizontal bar **814** (e.g., a portion of the clip **822** may be placed through a slot or other opening in the horizontal bar **814**).

Referring to FIGS. **8H** and **8I**, various more detailed views of the frame **800** of FIG. **8C** are illustrated. FIG. **8H** provides a more detailed view of the frame **800** of FIG. **8C** at location B3. FIG. **8I** provides a cutaway view of the frame **800** of FIG. **8H** taken along lines D1-D1.

The cutaway view shows the bottom bar **806** and a vertical bar **812**. A first flat bar **826** may be used with multiple fasteners **828** to couple the bottom bar **806** to the vertical bar **812** at the back of the frame **800**. A second flat bar **830** may be used with fasteners **832** to couple the bottom

## 12

bar **806** to the vertical bar **812** at the front of the frame **800**. A front plate **902** belonging to a coupling mechanism **900** (described below with respect to FIG. **9A**) is illustrated. The second flat bar **830** may replace a back plate of the coupling mechanism **900**. In embodiments where the second flat bar **830** replaces the back plate, the second flat bar **830** may include one or more holes to provide accessibility to fasteners of the coupling mechanism **900**.

Referring to FIGS. **8J** and **8K**, various more detailed views of the frame **800** of FIG. **8A** are illustrated. FIG. **8H** provides a more detailed view of the frame **800** of FIG. **8B** at location A2. FIG. **8K** provides a cutaway view of the frame **800** of FIG. **8J** taken along lines E1-E1. The two views show the bottom bar **806** and the left bar **808**. A clip **834** may be used with multiple fasteners **836** to couple the bottom bar **806** to the left bar **808** at the corner of the frame **800**.

Referring to FIGS. **8L** and **8M**, an alternative embodiment to FIG. **8E** is illustrated. FIG. **8L** provides a more detailed view of the frame **800** in the alternate embodiment. FIG. **8M** provides a cutaway view of the frame **800** of FIG. **8L** taken along lines F1-F1. In this embodiment, rather than using a horizontal bar **814**, a vertical bar **812** is coupled directly to a beam **840** using a clip **838**.

Referring to FIGS. **9A-9C**, one embodiment of a coupling mechanism **900** is illustrated that may be used to attach an LED panel (e.g., one of the panels **104a-104t** of FIGS. **1A** and **1B**) to a frame (e.g., the frame **106** or the frame **800** of FIGS. **8A** and **8B**). For purposes of example, the coupling mechanism **900** is described as attaching the panel **200** of FIG. **2A** to the frame **800** of FIG. **8B**. In the present example, a single coupling mechanism **900** may attach up to four panels to the frame **800**. To accomplish this, the coupling mechanism **900** is positioned where the corners of four panels meet.

The coupling mechanism **900** includes a front plate **902** and a back plate **904**. The front plate **902** has an outer surface **906** that faces the back of a panel and an inner surface **908** that faces the frame **106**. The front plate **902** may include a center hole **910** and holes **912**. The center hole **910** may be countersunk relative to the outer surface **906** to allow a bolt head to sit at or below the outer surface **906**. Mounting pins **914** may extend from the outer surface **906**. The back plate **904** has an outer surface **916** that faces away from the frame **106** and an inner surface **918** that faces the frame **106**. The back plate **904** includes a center hole **920** and holes **922**.

In operation, the front plate **902** and back plate **904** are mounted on opposite sides of one of the vertical bars **808**, **810**, or **812** with the front plate **902** mounted on the panel side of the frame **800** and the back plate **904** mounted on the back side of the frame **800**. For purposes of example, a vertical bar **812** will be used. When mounted in this manner, the inner surface **908** of the front plate **902** and the inner surface **918** of the back plate **904** face one another. A fastener (e.g., a bolt) may be placed through the center hole **910** of the front plate **902**, through a hole in the vertical bar **812** of the frame **800**, and through the center hole **920** of the back plate **904**. This secures the front plate **902** and back plate **904** to the frame **800** with the mounting pins **914** extending away from the frame.

Using the housing **300** of FIG. **3A** as an example, a panel is aligned on the frame **800** by inserting the appropriate mounting pin **914** into one of the holes in the back of the housing **300** provided by an extension **310/312**. It is understood that this occurs at each corner of the panel, so that the panel will be aligned with the frame **800** using four mount-

## 13

ing pins **914** that correspond to four different coupling mechanisms **900**. It is noted that the pins **914** illustrated in FIG. **9C** are horizontally aligned with the holes **912**, while the extensions illustrated in FIG. **3A** are vertically aligned. As described previously, these are alternate embodiments and it is understood that the holes **912**/pins **914** and extensions **310/312** should have a matching orientation and spacing.

Once in position, a fastener is inserted through the hole **922** of the back plate **904**, through the corresponding hole **912** of the front plate **902**, and into a threaded hole provided by an extension **310/312** in the panel **300**. This secures the panel to the frame **800**. It is understood that this occurs at each corner of the panel, so that the panel will be secured to the frame **800** using four different coupling mechanisms **900**. Accordingly, to attach or remove a panel, only four fasteners need be manipulated. The coupling mechanism **900** can remain in place to support up to three other panels.

In other embodiments, the front plate **902** is not needed. For example, in displays that are lighter in weight the back of the panel can abut directly with the beam. In other embodiments, the center hole **920** and corresponding bolt are not necessary. In other words the entire connection is made by the screws through the plate **904** into the panel.

The embodiment illustrated here shows a connection from the back of the display. In certain applications, access to the back of the panels is not available. For example, the display may be mounted directly on a building without a catwalk or other access. In this case, the holes in the panel can extend all the way through the panel with the bolts being applied through the panel and secured on the back. This is the opposite direction of what is shown in FIG. **9C**.

More precise alignment may be provided by using an alignment plate, such as the alignment plate **314** of FIG. **3B**, with each panel. For example, while positioning the panel and prior to tightening the coupling mechanism **900**, the tabs **316** of the alignment plate **314** for that panel may be inserted into slots **318** in surrounding alignment plates. The coupling mechanism **900** may then be tightened to secure the panel into place.

It is understood that many different configurations may be used for the coupling mechanism **400**. For example, the locations of holes and/or pins may be moved, more or fewer holes and/or pins may be provided, and other modifications may be made. It is further understood that many different coupling mechanisms may be used to attach an panel to the frame **106**. Such coupling mechanisms may use bolts, screws, latches, clips, and/or any other fastener suitable for removably attaching a panel to the frame **800**.

FIG. **10A** illustrates the power connections, FIG. **10B** illustrates data connections, FIG. **10C** illustrates power connections, and FIG. **10D** illustrates data connections.

Referring to FIGS. **10A** and **10B**, one embodiment of a 13x22 panel display **1000** is illustrated that includes two hundred and eighty-six panels arranged in thirteen rows and twenty-two columns. For purposes of example, the display **1000** uses the previously described main panel **400** of FIG. **4A** (a 'B' panel) and the slave panel **600** of FIG. **6A** (a 'C' panel). As described previously, these panels have a bi-directional input/output connection point for data communications between the main panel and the slave panels. The rows are divided into two sections with the top section having seven rows and the bottom section having six rows. The B panels form the fourth row of each section and the remaining rows are C panels. FIGS. **10C** and **10D** provide enlarged views of a portion of FIGS. **10A** and **10B**, respectively.

## 14

As illustrated in FIG. **10A**, power (e.g., 220V single phase) is provided to the top section via seven breakers (e.g., twenty amp breakers), with a breaker assigned to each of the seven rows. Power is provided to the bottom section via six breakers, with a breaker assigned to each of the six rows. In the present example, the power is provided in a serial manner along a row, with power provided to the first column panel via the power source, to the second column panel via the first panel, to the third column panel via the second panel, and so on for the entire row. Accordingly, if a panel is removed or the power for a panel is unplugged, the remainder of the panels in the row will lose power.

As illustrated in FIG. **10B**, data is sent from a data source **1002** (e.g., a computer) to the top section via one line and to the bottom section via another line. In some embodiments, as illustrated, the data lines may be connected to provide a loop. In the present example, the data is provided to the B panels that form the fourth row of each section. The B panels in the fourth row feed the data both vertically along the column and in a serial manner along the row. For example, the B panel at row four, column two (r4:c2), sends data to the C panels in rows one, two, three, five, six, and seven of column two (r1-3:c2 and r5-7:c2), as well as to the B panel at row four, column three (r4:c3). Accordingly, if a B panel in row four is removed or the data cables are unplugged, the remainder of the panels in the column fed by that panel will lose their data connection. The next columns will also lose their data connections unless the loop allows data to reach them in the opposite direction.

It is understood that the data lines may be bi-directional. In some embodiments, an input line and an output line may be provided, rather than a single bi-directional line as illustrated in FIGS. **10A** and **10B**. In such embodiments, the panels may be configured with additional input and/or output connections. An example of this is provided below in FIGS. **11A** and **11B**.

Referring to FIGS. **11A** and **11B**, one embodiment of a 16x18 panel display **1100** is illustrated that includes two hundred and eighty-eight panels arranged in sixteen rows and eighteen columns. Each power line connects to a single 110v 20 amp breaker. All external power cables are 14 AWG SOW UL while internal power cables must be 14 AWG UL. For purposes of example, the display **1100** uses the previously described main panel **500** of FIG. **5** (a 'B' panel) and the slave panel **700** of FIG. **7** (a 'C' panel). As described previously, these panels have separate input and output connection points for data communications between the main panel and the slave panels. FIGS. **11C** and **11D** provide enlarged views of a portion of FIGS. **11A** and **11B**, respectively.

As illustrated in FIG. **11A**, power is provided from a power source directly to the first column panel and the tenth column panel of each row via a power line connected to a single 110V, 20 A breaker. Those panels then feed the power along the rows in a serial manner. For example, the power is provided to the first column panel via the power source, to the second column panel via the first panel, to the third column panel via the second panel, and so on until the ninth column panel is reached for that row. The ninth column panel does not feed power to another panel because power is provided directly to the tenth column panel via the power source. Power is then provided to the eleventh column panel via the tenth panel, to the twelfth column panel via the eleventh panel, and so on until the end of the row is reached. Accordingly, if a panel is removed or the power for a panel is unplugged, the remainder of the panels in the row that rely on that panel for power will lose power.

## 15

Although not shown in FIG. 11B, the panels of the display **1100** may be divided into two sections for data purposes as illustrated previously with respect to FIG. 10B. Accordingly, as illustrated in FIG. 10B, data may be sent from a data source (e.g., a computer) to a top section via one line and to a bottom section via another line. As the present example illustrates the use of separate input and output connection points for data communications between the main panel and the slave panels, data connections between B panels have been omitted for purposes of clarity.

In the present example, the data is provided to the B panels that form the fourth row of each section. The B panels in the fourth row feed the data both vertically along the column and in a serial manner along the row (as shown in FIG. 10B). For example, the B panel at row four, column two (r4:c2), sends data to the C panels in rows one, two, three, five, six, seven, and eight of column two (r1-3:c2 and r5-8:c2), as well as to the B panel at row four, column three (r4:c3). Accordingly, if a B panel in row four is removed or the data cables are unplugged, the remainder of the panels in the column fed by that panel will lose their data connection. The next columns will also lose their data connections unless the loop allows data to reach them in the opposite direction.

Referring to FIGS. 12A and 12B, one embodiment of a 19x10 panel two face display **1100** is illustrated that includes three hundred and eighty panels arranged in two displays of nineteen rows and ten columns. Each face requires 19 110 V 20 AMP circuit breakers. For purposes of example, the display **1100** uses the previously described main panel **500** of FIG. 5 (a 'B' panel) and the slave panel **700** of FIG. 7 (a 'C' panel). As described previously, these panels have separate input and output connection points for data communications between the main panel and the slave panels. FIGS. 12C and 12D provide enlarged views of a portion of FIGS. 12A and 12B, respectively.

As illustrated in FIG. 12A, power is provided from a power source directly to the first column panel of each face via a power line connected to a single 110V, 20 A breaker. Those panels then feed the power along the rows in a serial manner. For example, the power is provided to the first column panel of the first face via the power source, to the second column panel via the first panel, to the third column panel via the second panel, and so on until the last panel is reached for that row of that face. The tenth column panel does not feed power to the next face because power is provided directly to the first column of the second face via the power source. Power is then provided to the second column panel via the first panel, to the third column panel via the second panel, and so on until the last panel is reached for that row of that face. Accordingly, if a panel is removed or the power for a panel is unplugged, the remainder of the panels in the row that rely on that panel for power will lose power.

Although not shown in FIG. 12B, the panels of the display **1200** may be divided into three sections for data purposes as illustrated previously with respect to FIG. 10B. Accordingly, as illustrated in FIG. 10B, data may be sent from a data source (e.g., a computer) to the top section via one line, to a middle section via a second line, and to a bottom section via a third line. Each master control cabinet has six data cables and is configured to be in row 4. Two rows of cabinets use only 5 cables while the sixth cable is unused and tied back.

As the present example illustrates the use of separate input and output connection points for data communications between the main panel and the slave panels, data

## 16

connections between B panels have been omitted for purposes of clarity. However, a separate line may be run to the B panels in the first column of each face (which would require six lines in FIG. 12B), or the B panel in the last column of a row of one face may pass data to the B panel in the first column of a row of the next face (which would require three lines in FIG. 12B).

In the present example, the data is provided to the B panels that form the fourth row of each section. The B panels in the fourth row feed the data both vertically along the column and in a serial manner along the row (as shown in FIG. 10B). For example, the B panel at row four, column two (r4:c2), sends data to the C panels in rows one, two, three, five, and six of column two (r1-3:c2 and r5-6:c2), as well as to the B panel at row four, column three (r4:c3). Accordingly, if a B panel in row four is removed or the data cables are unplugged, the remainder of the panels in the column fed by that panel will lose their data connection. The next columns will also lose their data connections unless the loop allows data to reach them in the opposite direction.

FIG. 13 illustrates a modular display panel in accordance with embodiments of the present invention. FIG. 14 illustrates a modular display panel attached to a supporting frame in accordance with an embodiment of the present invention. FIG. 15 illustrates a frame used to provide mechanical support to the modular display panel in accordance with an embodiment of the present invention.

The multi-panel modular display panel **1300** comprises a plurality of LED display panels **1350**. In various embodiments describe herein, the light emitting diode (LED) display panels **1350** are attached to a frame **1310** or skeletal structure that provides the framework for supporting the LED display panels **1350**. The LED display panels **1350** are stacked next to each other and securely attached to the frame **1310** using attachment plate **1450**, which may be a corner plate in one embodiment. The attachment plate **1450** may comprise holes through which attachment features **1490** may be screwed in, for example.

Referring to FIGS. 13 and 14, the LED display panels **1350** are arranged in an array of rows and columns. Each LED display panel **1350** of each row is electrically connected to an adjacent LED display panel **1350** within that row.

Referring to FIG. 15, the frame **1310** provides mechanical support and electrical connectivity to each of the LED display panels **1350**. The frame **1310** comprises a plurality of beams **1320** forming the mechanical structure. The frame **1310** comprises a top bar, a bottom bar, a left bar, a right bar, and a plurality of vertical bars extending from the top bar to the bottom bar, the vertical bars disposed between the left bar and the right bar. The top bar, the bottom bar, the left bar and the right bar comprise four inch aluminum bars and wherein the vertical bars comprise 2"x4"x1/2" aluminum tubes. The top bar, the bottom bar, the left bar and the right bar are each capable of bearing a load of 1.738 lb/ft and wherein the vertical bars are each capable of bearing a load of 3.23 lb/ft.

The frame **1310** may include support structures for the electrical cables, data cables, electrical power box powering the LED displays panels **1350**, data receiver box controlling power, data, and communication to the LED displays panels **1350**.

However, the frame **1310** does not include any additional enclosures to protect the LED panels, data, power cables from the environment. Rather, the frame **1310** is exposed to the elements and further exposes the LED display panels **1350** to the environment. The frame **1310** also does not

17

include air conditioning, fans, heating units to maintain the temperature of the LED display panels 1350. Rather, the LED display panels 1350 are hermetically sealed themselves and are designed to be exposed to the outside ambient. Further, in various embodiments, there are not additional cabinets that are attached to the frame 1310 or used for housing the LED display panels 1350. Accordingly, in various embodiments, the multi-panel modular display panel 1300 is designed to be only passively cooled.

FIGS. 25A-25D illustrate specific examples of an assembled display system 1300 and FIG. 26 illustrates a specific example of a frame 1310. As shown in FIG. 25A, the modular display system 1300 includes a number of LED display panels 1350 mounted to frame 1310. One of the display panels has been removed in the lower corner to illustrate the modular nature of the display. In this particular example, access is provided to the back of the modular display through a cage 1390 that includes an enclosed catwalk. Since the display system 1300 is generally highly elevated, a ladder (see FIG. 25C) provides access to the catwalk. A side view of the display system is shown in FIG. 25B and back views are shown in FIGS. 25C and 25D.

FIG. 26 illustrates the frame 1310 without the display panels 1350. In this embodiment the beams 1320 that form that outer frame are bigger than the interior beams 1325. In this case, the interior beams 1325 are aligned in a plane outside those of the frame beams 1322. The plates 1315 are also shown in the figure. Upon installation, these plates will be rotated by 90 degrees and fasten to the display panels.

FIG. 16, which includes FIGS. 16A-16C, illustrates an attachment plate used to attach one or more modular display panels to the frame in accordance with an embodiment of the present invention. FIG. 16A illustrates a projection view while FIG. 16B illustrates a top view and FIG. 16C illustrates a cross-sectional view.

Referring to FIGS. 16A-16C, the attachment plate 1450 may comprise one or more through openings 1460 for enabling attachment features such as screws to go through. Referring to FIG. 16C, the attachment plate 1450 comprises a top surface 1451 and a bottom surface 1452. The height of the pillars 1480 may be adjusted to provide a good fit for the display panel. Advantageously, because the frame 1310 is not screw mounted to the display panel 1350, the display panel 1350 may be moved during mounting. This allows for improved alignment of the display panels resulting in improved picture output. An alignment plate could also be used as described above.

Accordingly, in various embodiments, the height of the pillars 1480 is about the same as the beams 1320 of the frame 1310. In one or more embodiments, the height of the pillars 1480 is slightly more than the thickness of the beams 1320 of the frame 1310.

FIGS. 16D and 16E illustrate another embodiment of the attachment plate 1450. In this example, the plate is rectangular shaped and not a square. For example, the length can be two to four times longer than the width. In one example, the length is about 9 inches while the width is about 3 inches. The holes in the center of the plate are optional. Conversely, these types of holes could be added to the embodiment of FIGS. 16A and 16B. In other embodiments, other shaped plates 1450 can be used.

FIG. 17 illustrates a magnified view of the attachment plate or a connecting plate, frame, and display panel after mounting in accordance with embodiments of the present invention.

Referring to FIG. 17, one or more attachment features 1490 may be used to connect the attachment plate 1450 to

18

the display panel 1350. In the embodiment illustrated in FIG. 17, the attachment plate 1450 is a corner plate. Each corner plate is mechanically connected to corners of four of the LED display panels 1350 to secure the LED display panels 1350 to the respective beams 1320 of the frame 1310.

FIG. 17 illustrates that the attachment features 1490 is attached using the through openings 1460 in the attachment plate 1450. The frame is between the attachment plate 1450 and the display panel 1350.

In the embodiment of FIG. 17, the beam 1320 physically contacts the display panel 1350. In another embodiment, a second plate (not shown here) could be included between the beam 1320 and the display panel 1350. The plate could be a solid material such as a metal plate or could be a conforming material such as a rubber material embedded with metal particles. In either case, it is desirable that the plate be thermally conductive.

FIG. 18 illustrates one unit of the modular display panel in accordance with an embodiment of the present invention.

FIG. 18 illustrates one of the multi-panel modular display panel 1300 comprising an input cable 1360 and an output cable 1365. The LED display panels 1350 are electrically connected together for data and for power using the input cable 1360 and the output cable 1365.

Each modular LED display panel 1350 is capable of receiving input using an integrated data and power cable from a preceding modular LED display panel and providing an output using another integrated data and power cable to a succeeding modular LED display panel. Each cable ends with an endpoint device or connector, which is a socket or alternatively a plug.

Referring to FIG. 18, in accordance with an embodiment, a LED display panel 1350 comprises an attached input cable 1360 and an output cable 1365, a first connector 1370, a second connector 1375, a sealing cover 1380. The sealing cover 1380 is configured to go over the second connector 1375 thereby hermetically sealing both ends (first connector 1370 and the second connector 1375). The sealing cover 1380, which also includes a locking feature, locks the two cables together securely. As will be described further, the input cable 1360 and the output cable 1365 comprise integrated data and power wires with appropriate insulation separating them.

FIG. 19 illustrates two display panels next to each other and connected through the cables such that the output cable 1365 of the left display panel 1350 is connected with the input cable 1360 of the next display panel 1350. The sealing cover 1380 locks the two cables together as described above.

FIG. 20 illustrates a modular multi-panel display system comprising a plurality of LED display panels connected together using the afore-mentioned cables.

Referring to FIG. 20, for each row, a LED display panel 1350 at a first end receives an input data connection from a data source and has an output data connection to a next LED display panel in the row. Each further LED display panel 1350 provides data to a next adjacent LED display panel until a LED display panel 1350 at second end of the row is reached. The power line is run across each row to power the LED display panels 1350 in that row.

In one embodiment, the plurality of LED display panels 1350 includes 320 LED display panels 1350 arranged in ten rows and thirty-two columns so that the integrated display panel 1300 has a display surface that is approximately fifty feet and four inches wide and fifteen feet and eight and three-quarters inches high.

In various embodiments, as illustrated in FIGS. 14 and 20, a data receiver box 1400 is mounted to the mechanical

19

support structure or frame **1310**. The data receiver box **1400** is configured to provide power, data, and communication to the LED display panels **1350**. With a shared receiver box **1400**, the panels themselves do not need their own receiver card. This configuration saves cost and weight.

FIG. **21**, which includes FIGS. **21A-21C**, illustrates an alternative embodiment of the modular display panel attached to a supporting frame in accordance with an embodiment of the present invention. FIGS. **21B** and **21C** illustrate alternative structural embodiments of the supporting frame.

This embodiment differs from embodiment described in FIG. **14** in that the horizontal beams **1320A** may be used to support the display panels **1350**. In one embodiment, both horizontal beams **1320A** and vertical beams **1320B** may be used to support the display panels **1350**. In another embodiment, horizontal beams **1320A** but not the vertical beams **1320B** may be used to support the display panels **1350**.

FIG. **21B** illustrates an alternative embodiment including additional beams **1320C**, which may be narrower than the other beams of the frame. One or more of the thinner beams **1320C** may be placed between the regular sized vertical beams **1320B**.

FIG. **21C** illustrates a further embodiment illustrating both a top view, bottom view and side view of a frame. The frame **1310** may be attached to a wall or other structure using plates **1315**. The frame **1310** may comprise a plurality of vertical beams and horizontal beams. In one embodiment, the frame **1310** comprises an outer frame having a top bar, a bottom bar, a left bar and a right bar. A display panel **1350** may be supported between two adjacent beams **1320** marked as L3 beams, which may be thinner (smaller diameter) and lighter than the thicker and heavier load bearing beams **1321** marked as L2 beams used for forming the outer frame. As an illustration, the L2 beams may be 4" while the L3 beams may be 3" in one example.

FIG. **22** illustrates a method of assembling a modular multi-panel display system in accordance with an embodiment of the present invention. FIG. **22** illustrates a method of assembling the multi-panel display system discussed in various embodiments, for example, FIG. **14**.

A mechanical support structure such as the frame **1310** described above is assembled taking into account various parameters such as the size and weight of the multi-panel display, location and zoning requirements, and others (box **1501**). For example, as previously described, the mechanical support structure includes a plurality of vertical bars and horizontal bars. The mechanical support structure may be fabricated from a corrosion resistant material in one or more embodiments. For example, the mechanical support structure may be coated with a weather-proofing coating that prevents the underlying substrate from corroding.

A plurality of LED display panels are mounted on to the mechanical support structure so as to form an integrated display panel that includes an array of rows and columns of LED display panels as described in various embodiments (box **1503**). Each of the LED display panels is hermetically sealed. Mounting the LED display panels may comprise mounting each LED display panel a respective vertical beam using an attachment plate.

Each of the LED display panels is electrically connected to a data source and to a power source (box **1505**). For example, a first LED display panel in each row is electrically coupled to the display source. The other LED display panels in each row may be daisy-chain coupled to an adjacent LED display panel (e.g., as illustrated in FIG. **20**).

20

Since the assembled display structure is light weight, significant assembly advantages can be achieved. For example, the panels can be assembled within a warehouse that is remote from the final location where the display will be utilized. In other words, the panels can be assembled at a first location, shipped to second location and finalized at the second location.

An illustration of two assembled displays that are ready for shipment is provided in FIG. **23**. These displays can be quite large, for example much larger than a 14x48 panel display. In some cases, a single display system is shipped as a series of sub-assemblies, e.g., as shown in the figure, and then assembled into a full display on location.

In various embodiments, the assembled multi-panel display system includes no cabinets. The assembled multi-panel display system is cooled passively and includes no air conditioning or fans.

Although the preferred embodiment has been described in detail, it should be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A method of assembling a modular multi-panel display system, the method comprising:

assembling a plurality of mechanical support structures that each include a plurality of beams;

mounting a plurality of display panels to the plurality of beams of each of the plurality of mechanical support so as to assemble a plurality of integrated display panel sub-assemblies, each sub-assembly including a plurality of display panels arranged in rows and columns, wherein each of the display panels is sealed to be waterproof, and wherein each of the display panels includes

an array of display elements arranged in a plurality of rows and a plurality of columns to form a display panel surface,

a display driver coupled to the array of display elements,

a housing comprising a cavity surrounded by an enclosure,

a receiver circuit disposed inside the cavity of the housing, and

a power supply electrically coupled to the receiver circuit and the display driver, wherein the power supply is configured to convert an alternative current (AC) received at an input and output a direct current (DC);

shipping the sub-assemblies to a second location remote from a location at which the sub-assemblies were assembled; and

at the second location, building a multi-panel display system by assembling the sub-assemblies into a 14x48 or larger panel display, the multi-panel display system including an outer frame with a top beam, a bottom beam, a left outside beam, and a right outside beam and a plurality of vertical beams extending from the top beam to the bottom beam within the outer frame, each of the vertical beams having a smaller diameter and weighing less than any beam of the outer frame, wherein the multi-panel display system include no cabinets, is cooled passively and includes no air conditioning, fans, or heating units.

2. The method of claim 1, wherein the mechanical support structure is assembled so that the outer frame extends within

a first vertical plane and the vertical beams extend in a second vertical plane laterally spaced from the first vertical plane.

3. The method of claim 1, wherein mounting the display panels comprises mounting each display panel to a respective beam using corner plates and wherein each display panel within an interior portion of the multi-panel display system is attached to two respective beams by four of the corner plates, each corner plate being mechanically connected to corners of four of the display panels to secure the display panels to the respective vertical beam.

4. The method of claim 1, further comprising mounting a data receiver box to the mechanical support structure, the data receiver box configured to provide power, data, and communication to the plurality of display panels.

5. The method of claim 1, wherein each display panel in each row is daisy-chain coupled to an adjacent display panel by a data cable.

6. The method of claim 5, wherein each display panel of each row is electrically coupled the adjacent panel through a respective integrated data and power cable, each integrated data and power cable comprising a plurality of male connectors surrounded by an end enclosure and a plurality of female connectors surrounded by the end enclosure, wherein each male connector is configured to fit into a female connector and each female connector is configured to receive a male connector, wherein the plurality of male connectors comprises three pins coupled to the power supply, wherein the plurality of female connectors are configured to carry data to the receiver circuit, and wherein the integrated data and power connector is configured to be waterproof when connected to another connector.

\* \* \* \* \*