US007507001B2

(12) **United States Patent**
Kit

(10) **Patent No.: US 7,507,001 B2**
(45) **Date of Patent: Mar. 24, 2009**

(54) **RETROFIT LED LAMP FOR FLUORESCENT FIXTURES WITHOUT BALLAST**

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(73) Assignee: **DeNovo Lighting, LLC**, Brooklyn, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 175 days.

(21) Appl. No.: **11/804,938**

(22) Filed: **May 21, 2007**

(65) **Prior Publication Data**

US 2007/0228999 A1 Oct. 4, 2007

Related U.S. Application Data

(63) Continuation-in-part of application No. 11/198,633, filed on Aug. 5, 2005, now Pat. No. 7,490,957.

(51) **Int. Cl.**
F21V 23/04 (2006.01)

(52) **U.S. Cl.** **362/276**; 362/252; 362/800; 362/802; 315/51

(58) **Field of Classification Search** 315/51, 315/250, 291, 307, 308, 312, 246; 362/217, 362/219, 221, 227, 240, 249, 251, 252, 800, 362/802, 276

See application file for complete search history.

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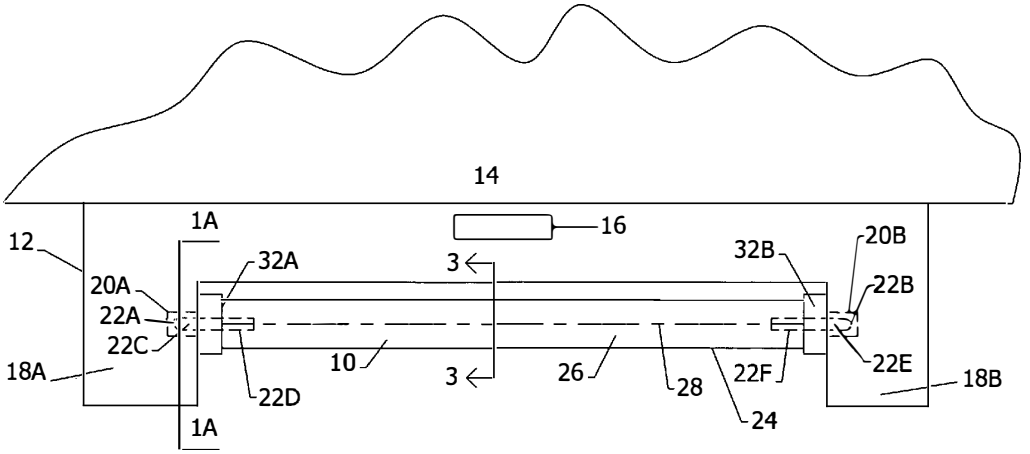
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Primary Examiner—John A Ward

(57) **ABSTRACT**

An energy saving device for an LED lamp mounted to an existing fixture for a fluorescent lamp where the ballast is removed or bypassed. The LEDs are positioned within a tube and electrical power is delivered from a power source to the LEDs. The LED lamp includes means for controlling the delivery of the electrical power from the power source to the LEDs, wherein the use of electrical power can be reduced or eliminated automatically during periods of non-use. Such means for controlling includes means for detecting the level of daylight in the illumination area of said least one LED, in particular a light level photosensor, and means for transmitting to the means for controlling relating to the detected level of daylight from the photosensor. The photosensor can be used in operative association with an on-off switch in power connection to the LEDs, a timer, or with a computer or logic gate array in operative association with a switch, timer, or dimmer that regulates the power to the LEDs. An occupancy sensor that detects motion or a person in the illumination area of the LEDs can be also be used in association with the photosensor and the computer, switch, timer, or dimmer, or in solo operation by itself. Two or more such LED lamps with a computer or logic gate array used with at least one of the lamps can be in network communication with at least one photosensor and/or at least one occupancy sensor to control the power to all the LEDs.

62 Claims, 128 Drawing Sheets



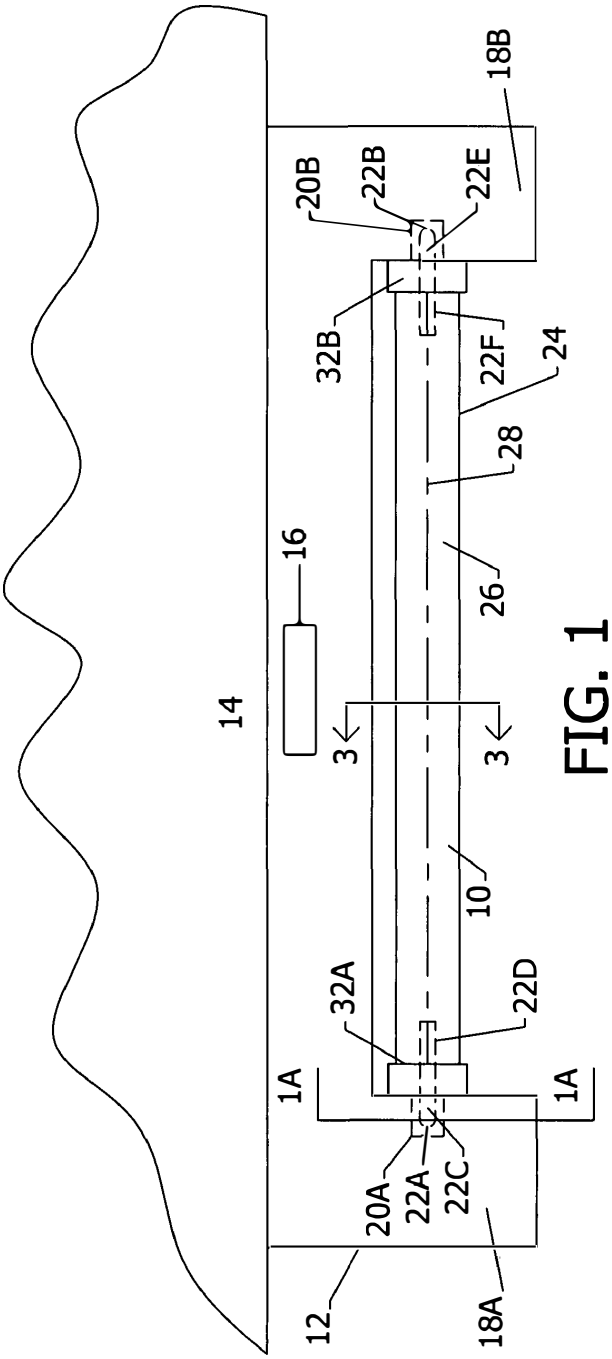

18B
20B
22B
22E
32B
22F
24
28
16
26
14
3
3
10
32A
22D
1A
1A
20A
22A
22C
12
18A

FIG. 1

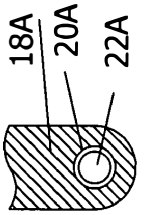

18A
20A
22A

FIG. 1A

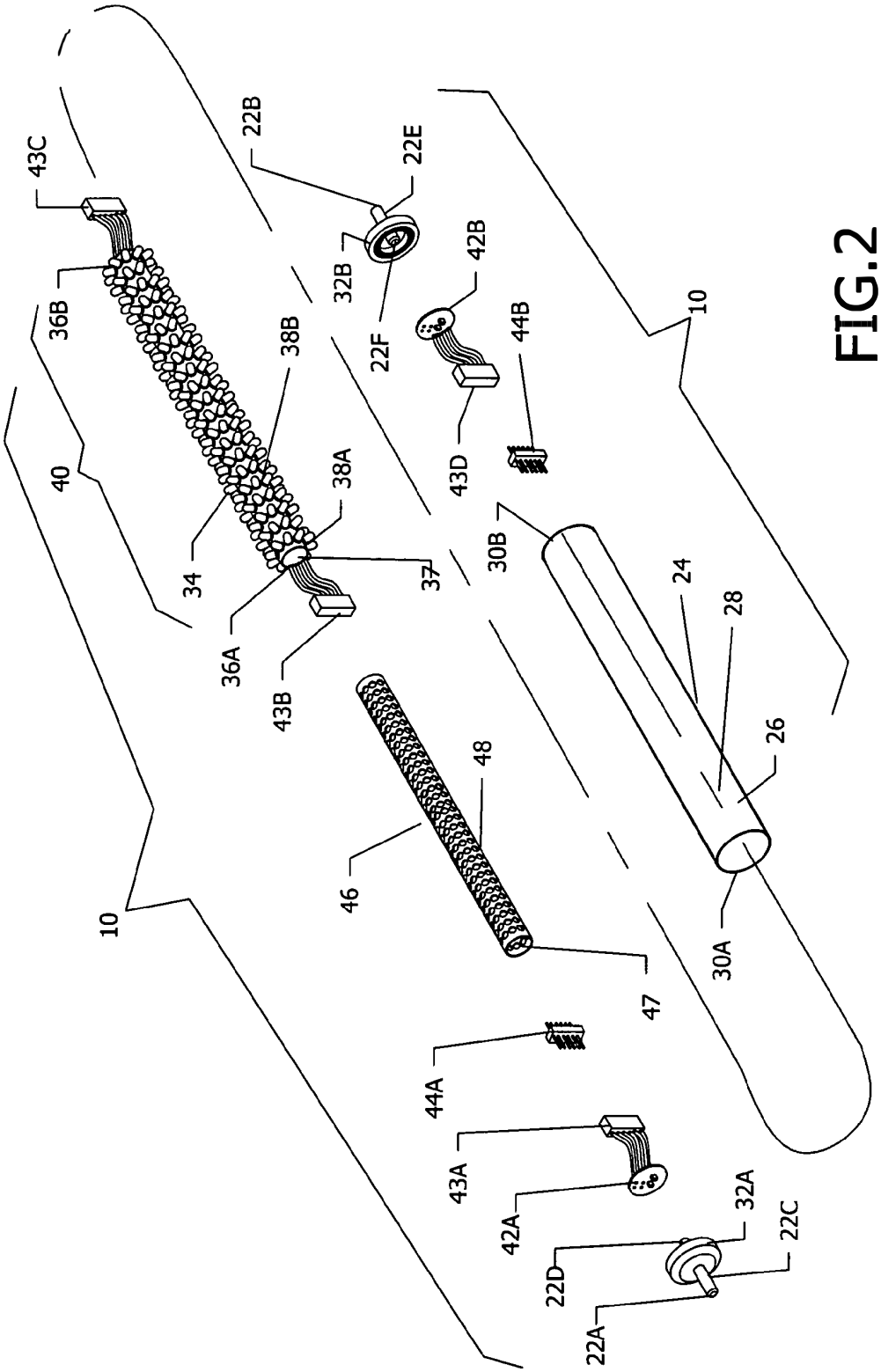

43C
22B
22E
32B
42B
36B
38B
22F
44B
10
40
38A
43D
34
37
30B
24
36A
28
43B
48
26
46
10
30A
47
44A
43A
32A
42A
22C
22D
22A

FIG.2

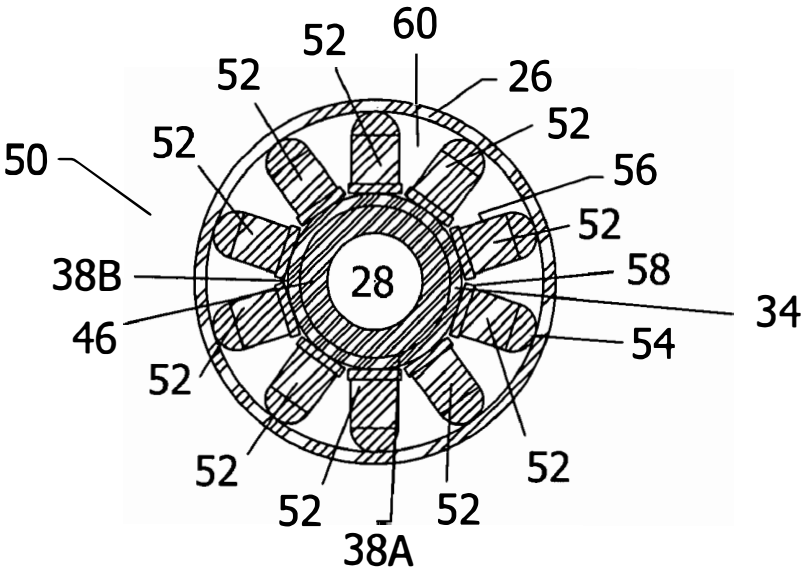

52
60
52
26
52
50
52
56
52
38B
28
58
34
46
54
52
52
52
52
52
38A

FIG. 3

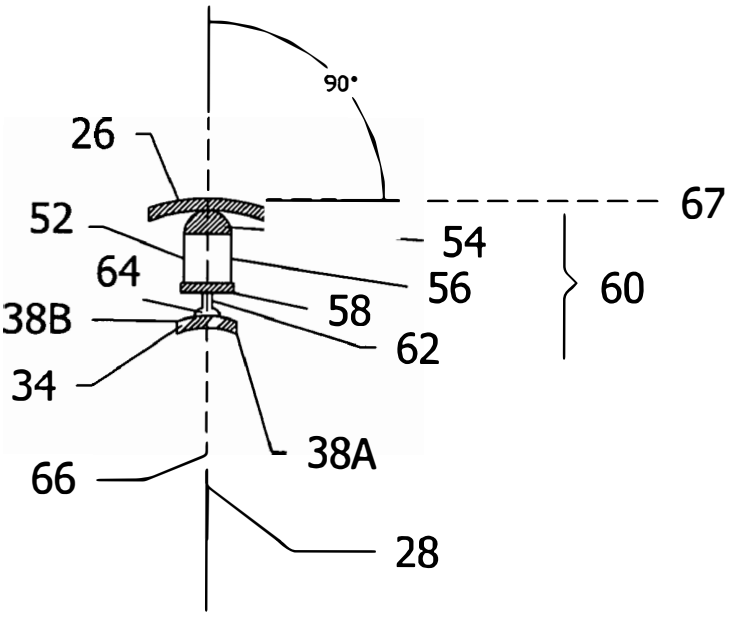

90°
26
67
52
54
64
56
60
58
38B
62
34
38A
66
28

FIG. 3A

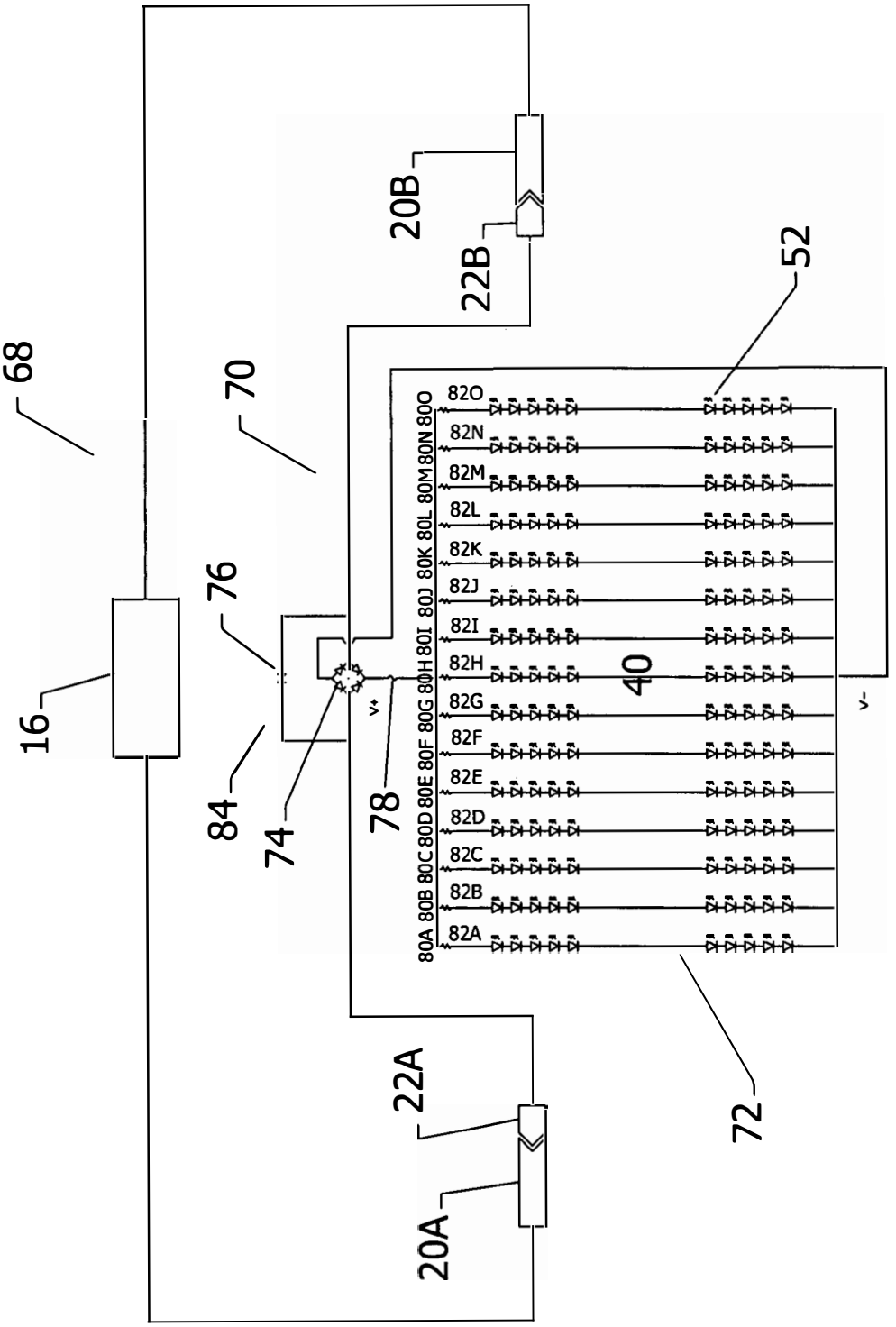

68
70
20B
22B
52
76
16
84
74
78
40
72
22A
20A
82O
82N
82M
82L
82K
82J
82I
82H
82G
82F
82E
82D
82C
82B
82A
80O
80N
80M
80L
80K
80J
80I
80H
80G
80F
80E
80D
80C
80B
80A
V+
V-

FIG. 4

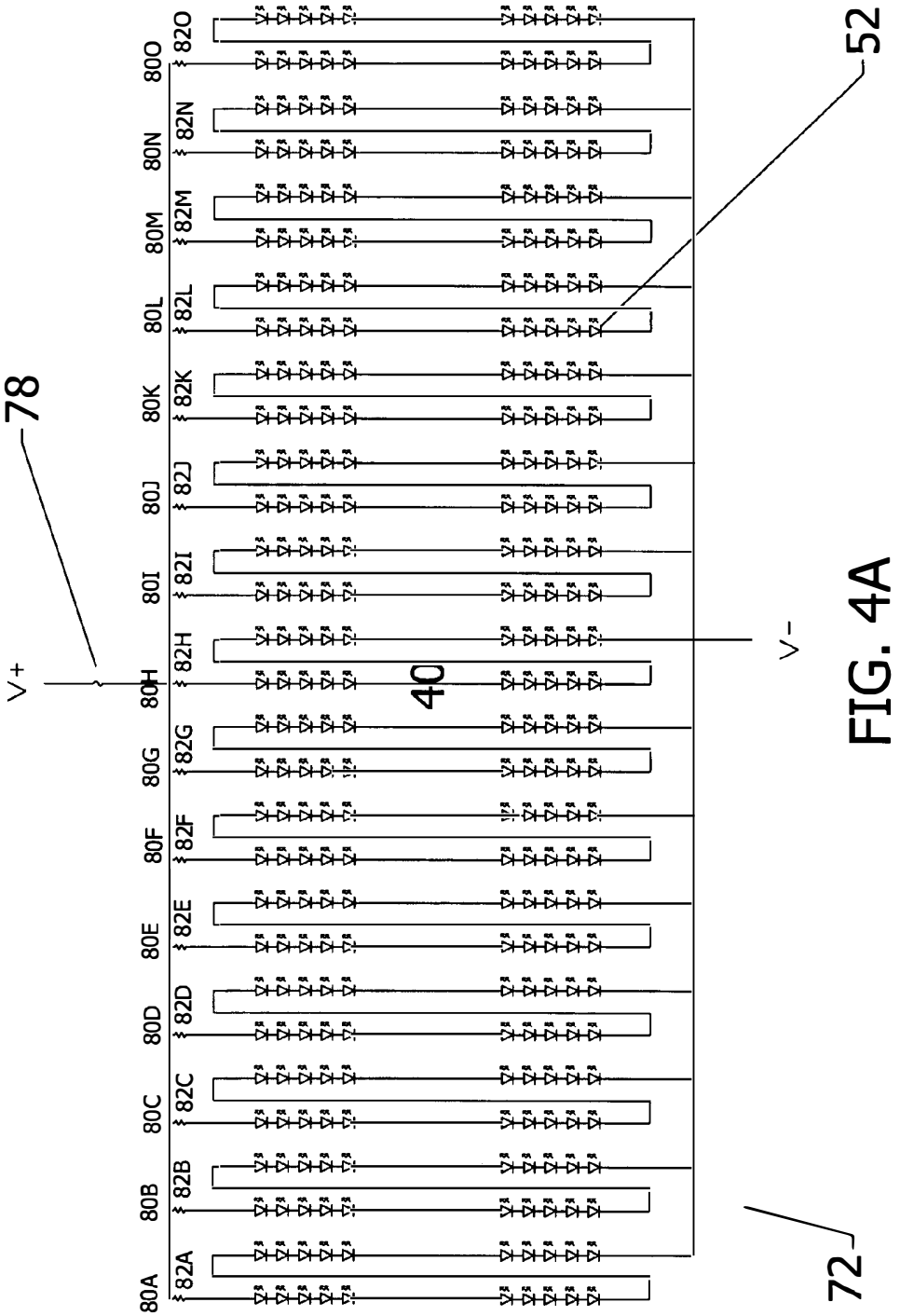

78
52
V+
V-
40
72
80A
80B
80C
80D
80E
80F
80G
80H
80I
80J
80K
80L
80M
80N
80O
82A
82B
82C
82D
82E
82F
82G
82H
82I
82J
82K
82L
82M
82N
82O

FIG. 4A

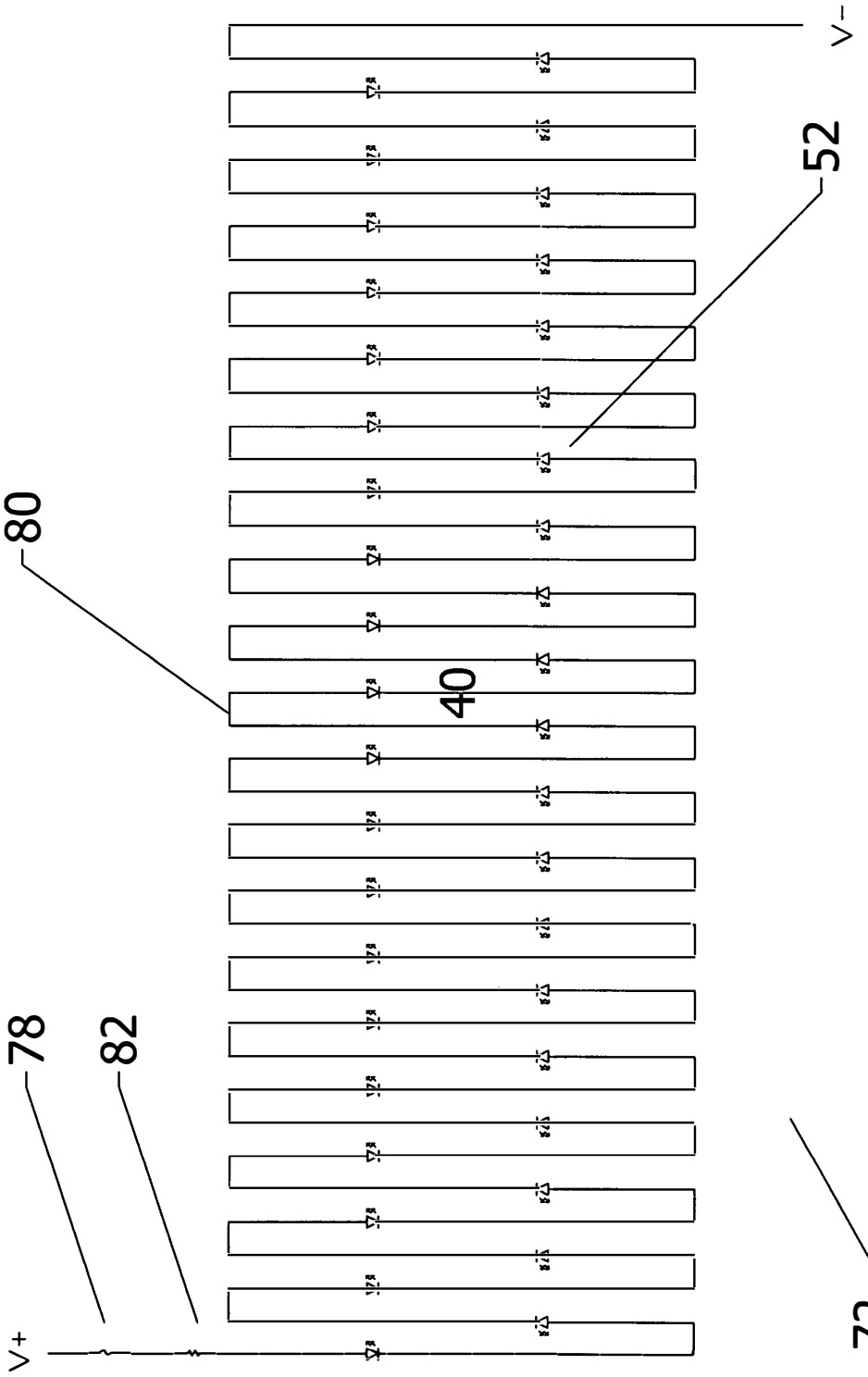


FIG. 4B

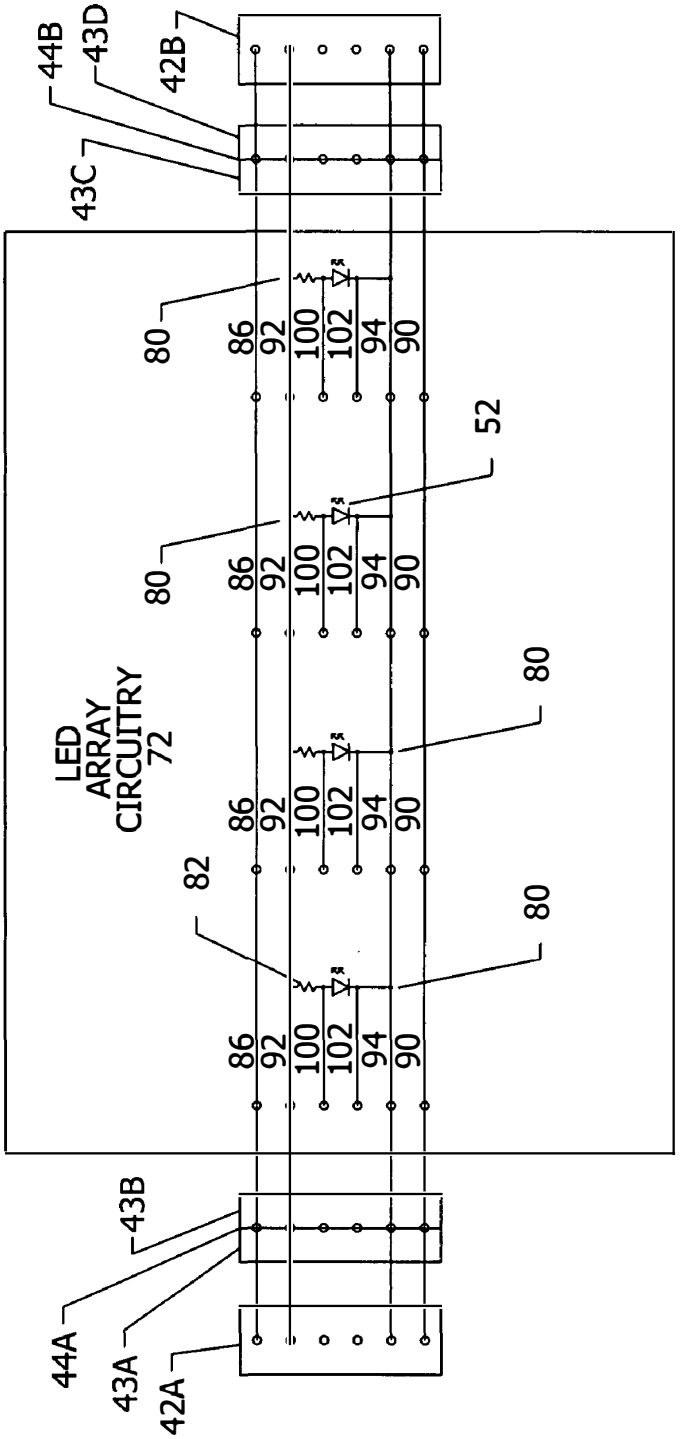

44B
43D
42B
43C
80
86
92
100
102
94
90
52
LED
ARRAY
CIRCUITRY
72
82
43B
44A
43A
42A

FIG. 4C

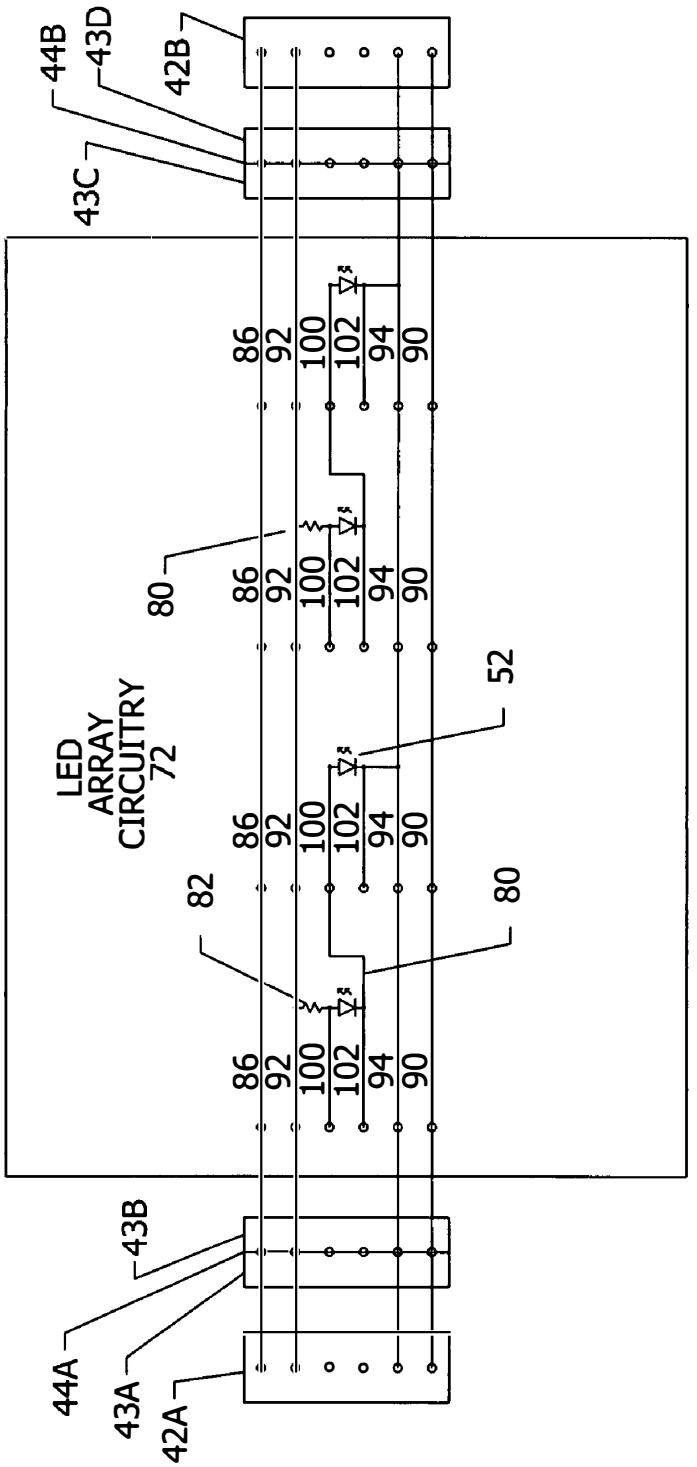

44B
43D
42B
43C
LED ARRAY CIRCUITRY 72
80
82
52
86
92
100
102
94
90
43B
44A
43A
42A

FIG. 4D

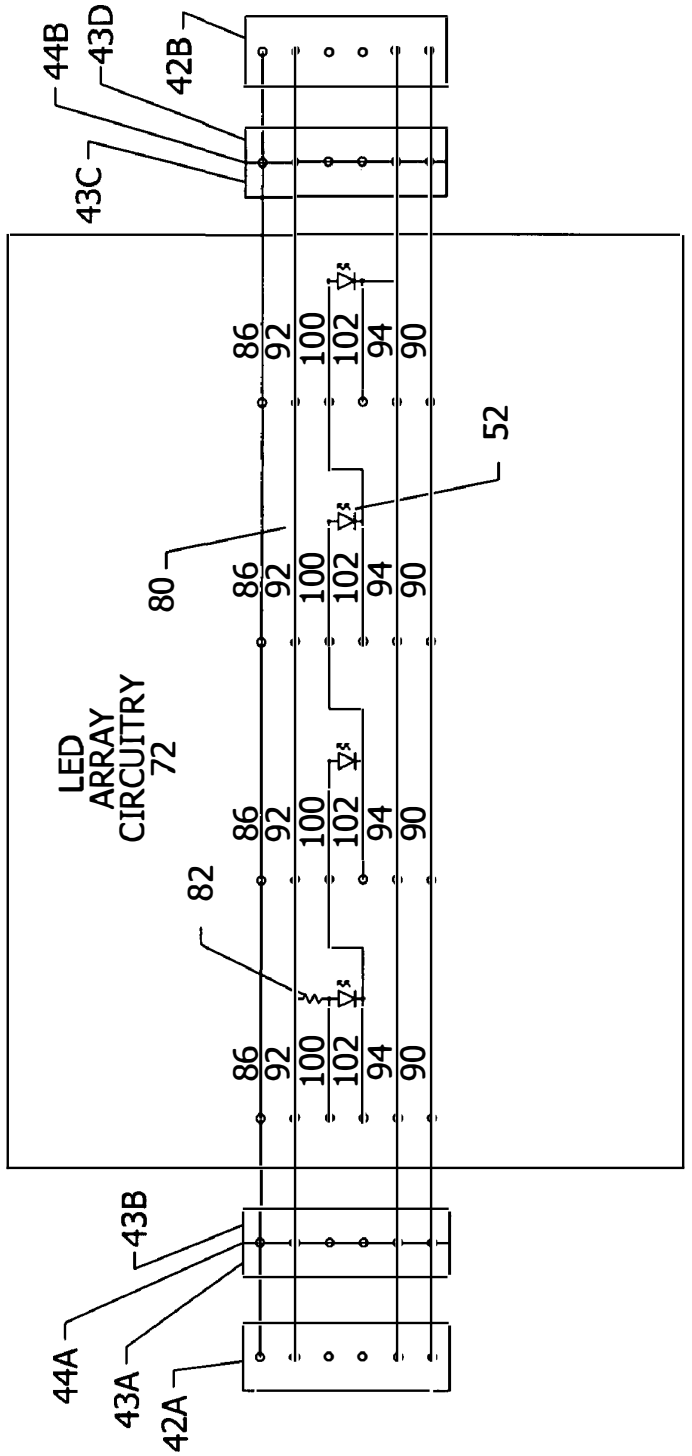

44B
43D
42B
43C
LED
ARRAY
CIRCUITRY
72
80
82
52
86
92
100
102
94
90
43B
44A
43A
42A

FIG. 4E

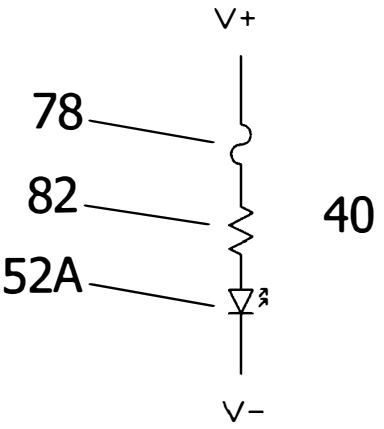


FIG. 4F

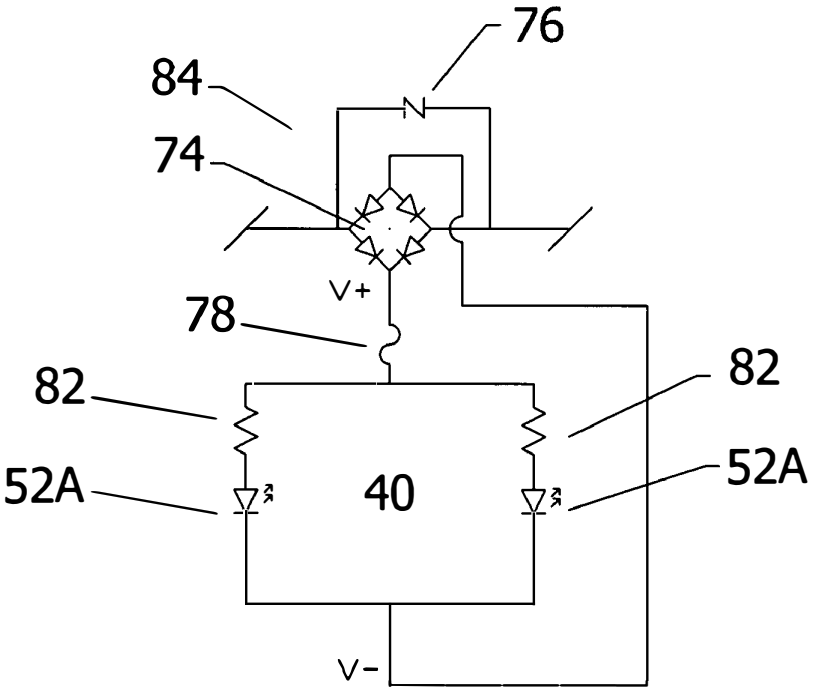


FIG. 4G

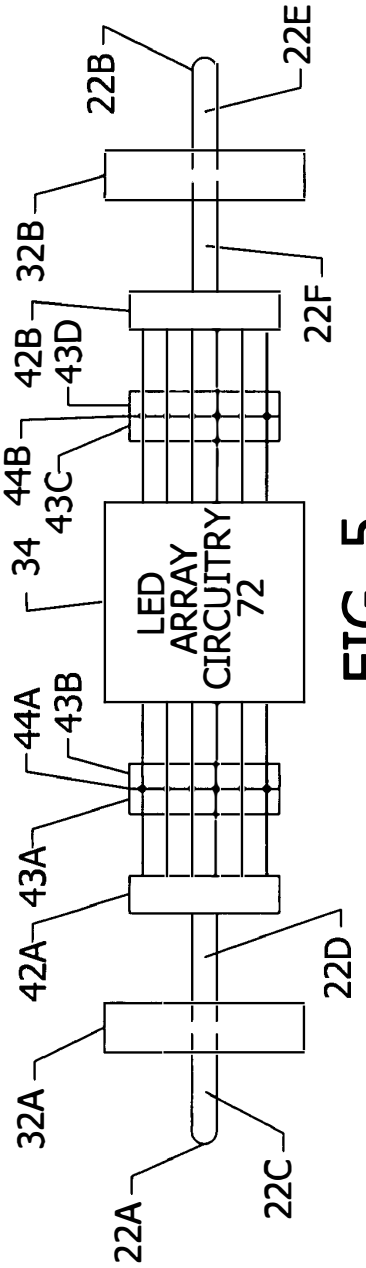


FIG. 5

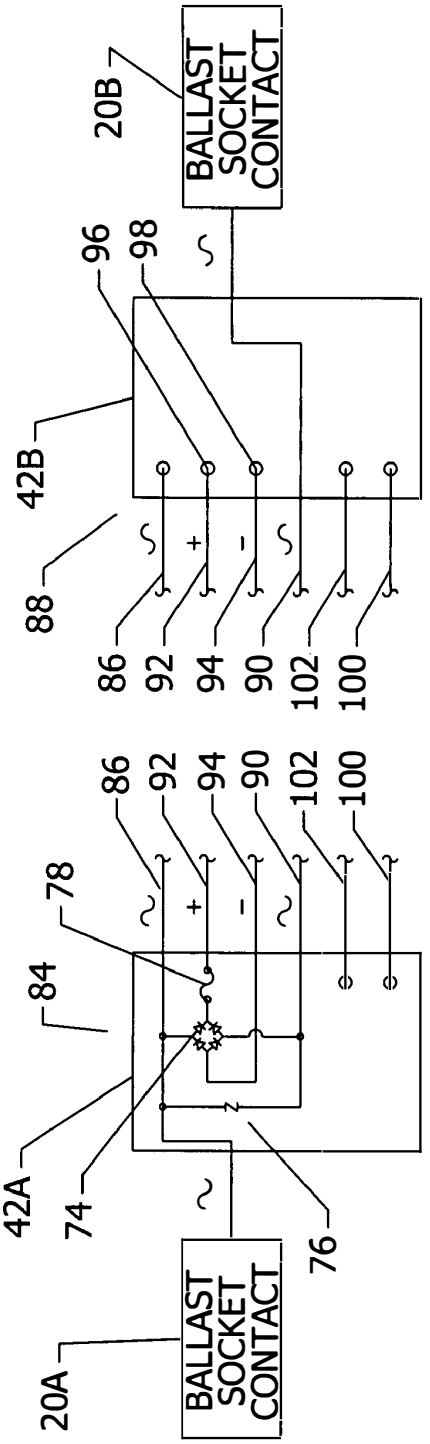


FIG. 6

FIG. 7

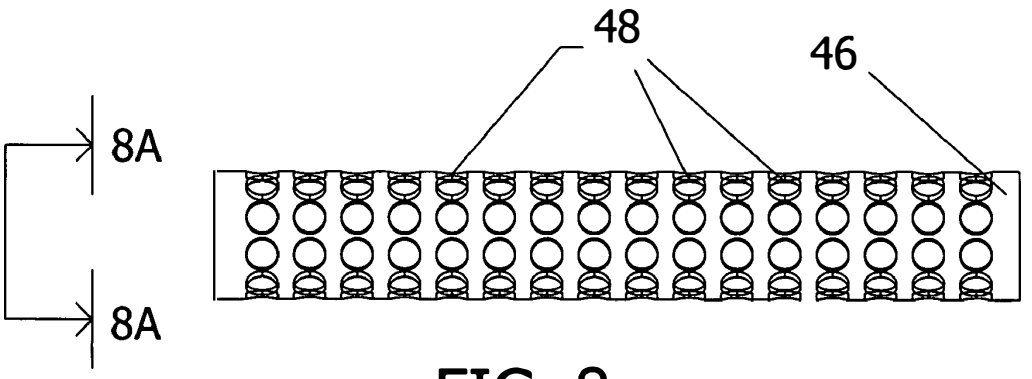


FIG. 8

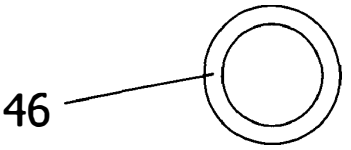


FIG. 8A

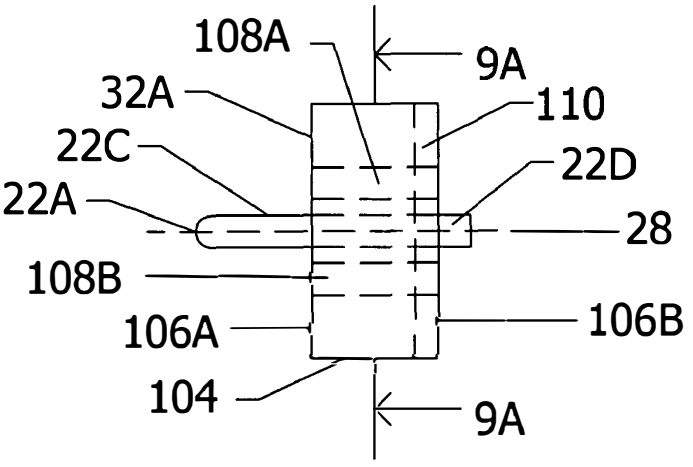


FIG. 9

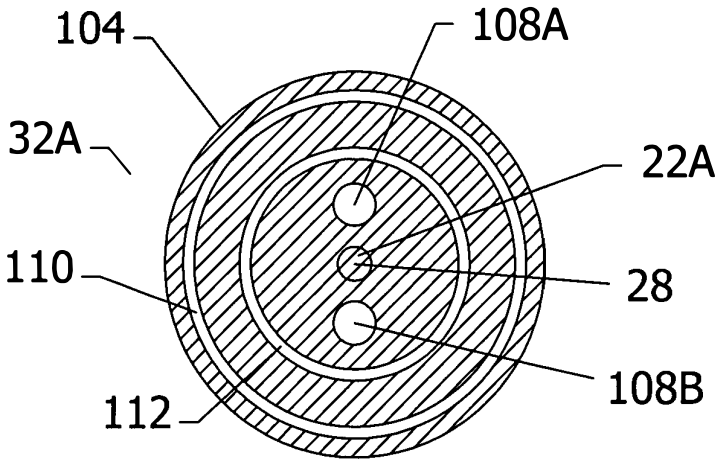

104
108A
32A
22A
110
28
108B
112

FIG. 9A

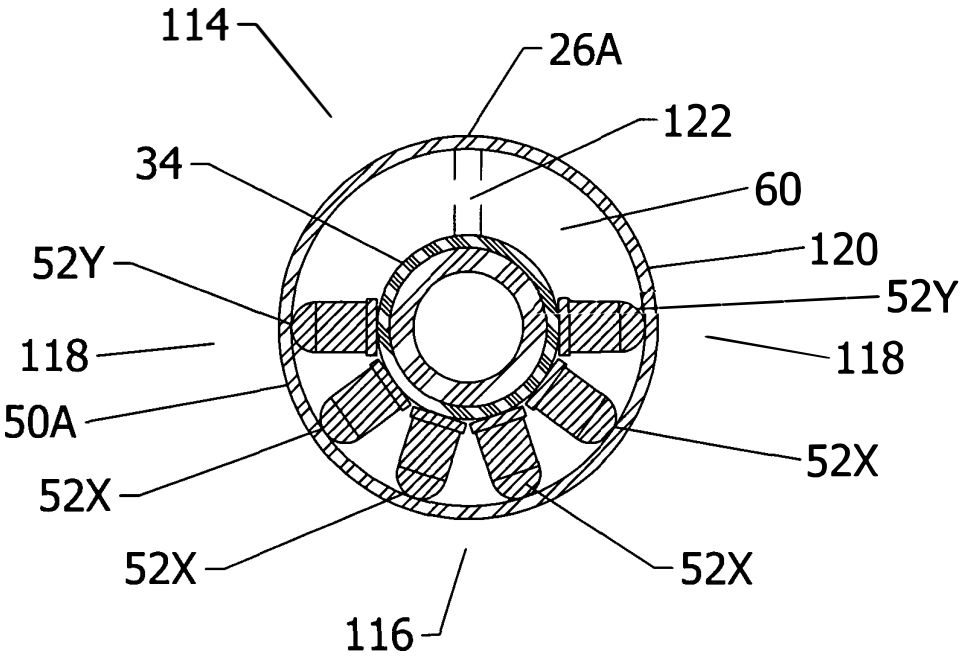

114
26A
122
34
60
120
52Y
52Y
118
118
50A
52X
52X
52X
52X
116

FIG. 10

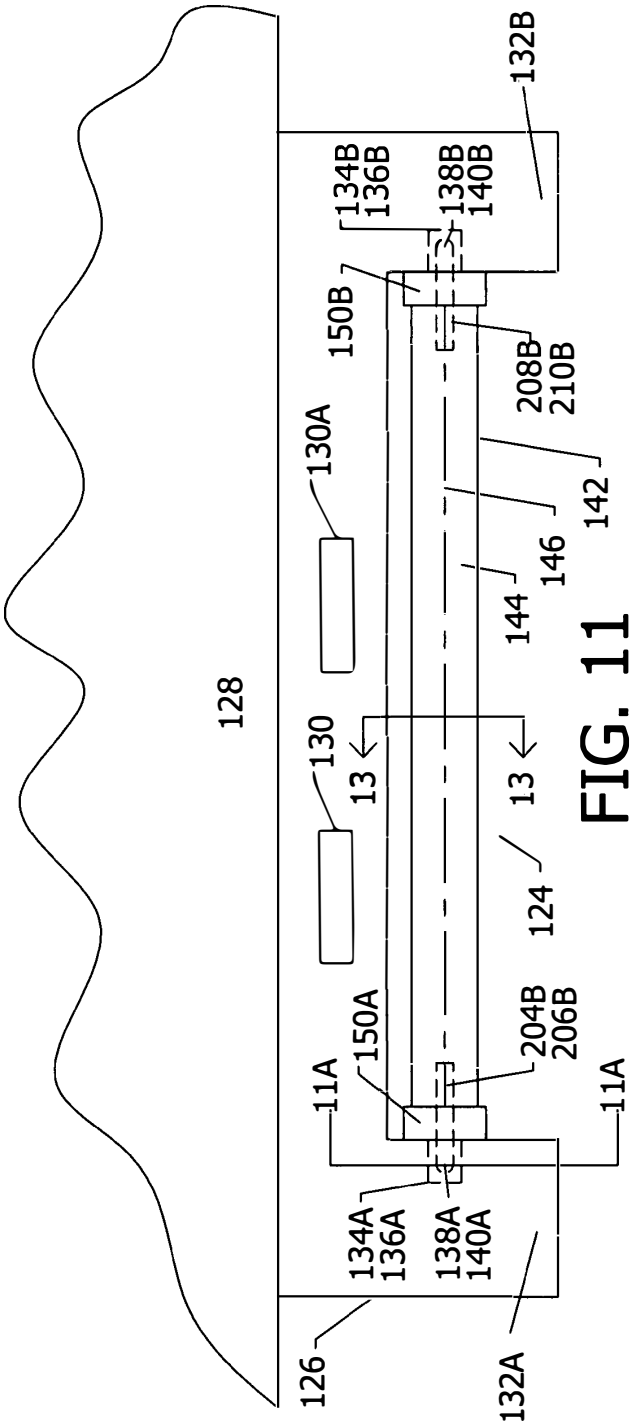


FIG. 11

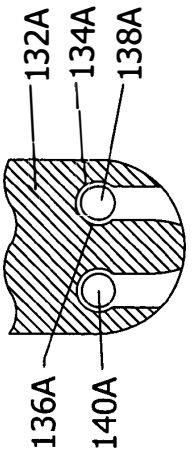


FIG. 11A

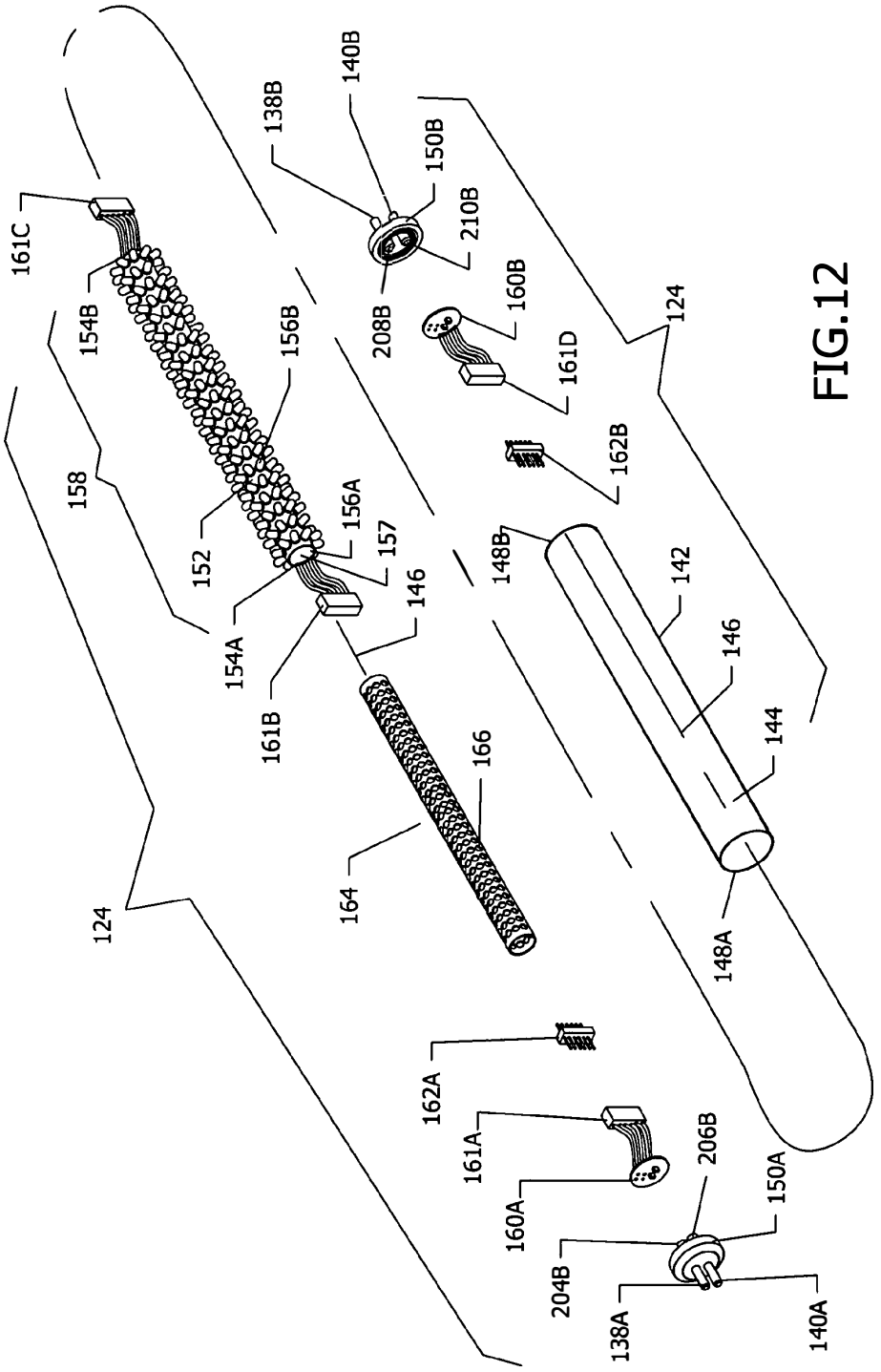

161C
154B
158
152
154A
161B
124
162A
161A
160A
204B
138A
140A
206B
150A
148A
164
166
144
146
142
148B
162B
124
161D
160B
208B
210B
150B
138B
140B
156B
156A
157
146

FIG.12

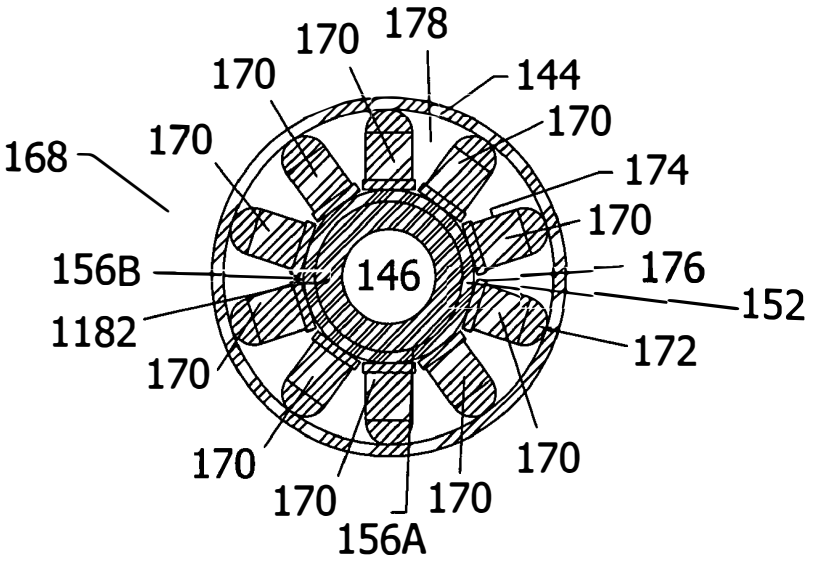


FIG. 13

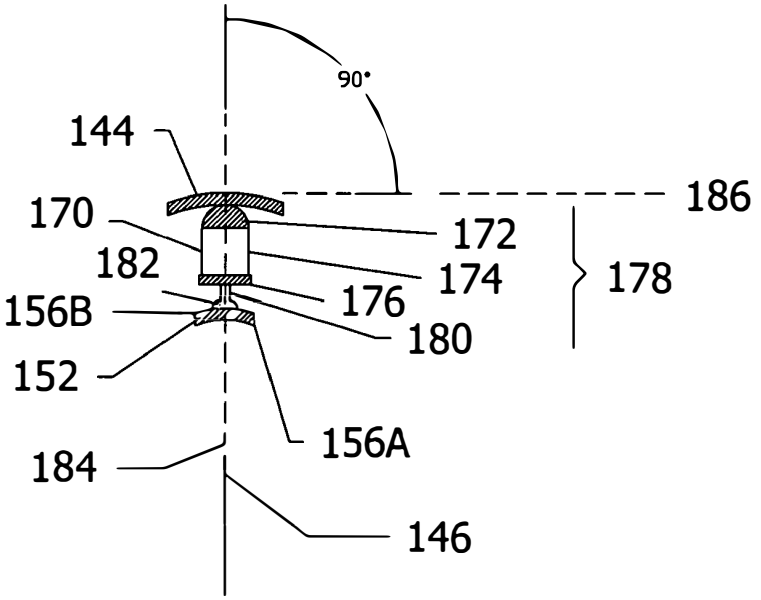


FIG. 13A

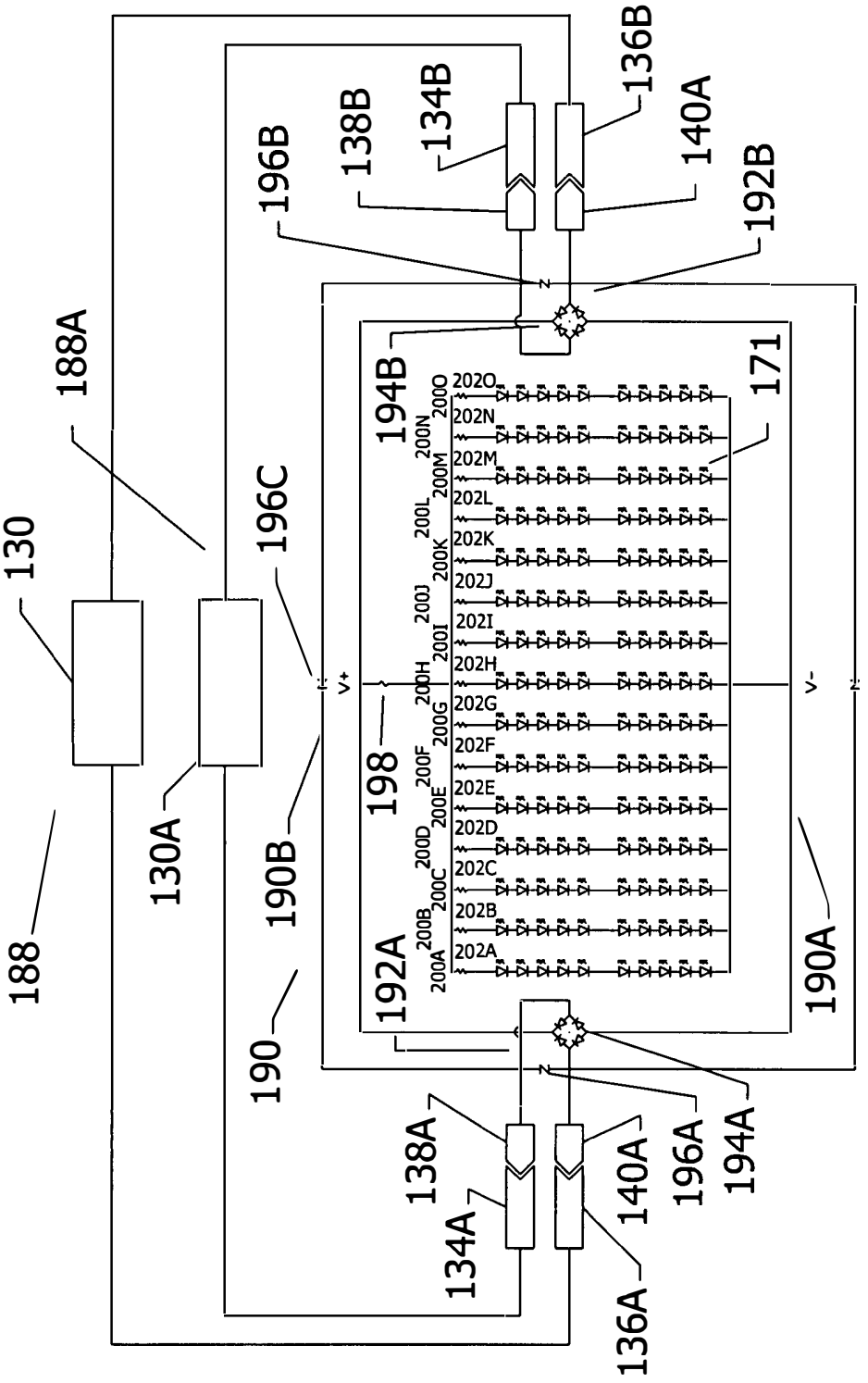

136B
134B
138B
196B
140A
192B
188A
194B
171
202O
202N
202M
202L
202K
202J
202I
202H
202G
202F
202E
202D
202C
202B
202A
200O
200N
200M
200L
200K
200J
200I
200H
200G
200F
200E
200D
200C
200B
200A
130
196C
196D
V+
V-
198
130A
190B
188
192A
190A
190
138A
140A
196A
194A
134A
136A

FIG. 14

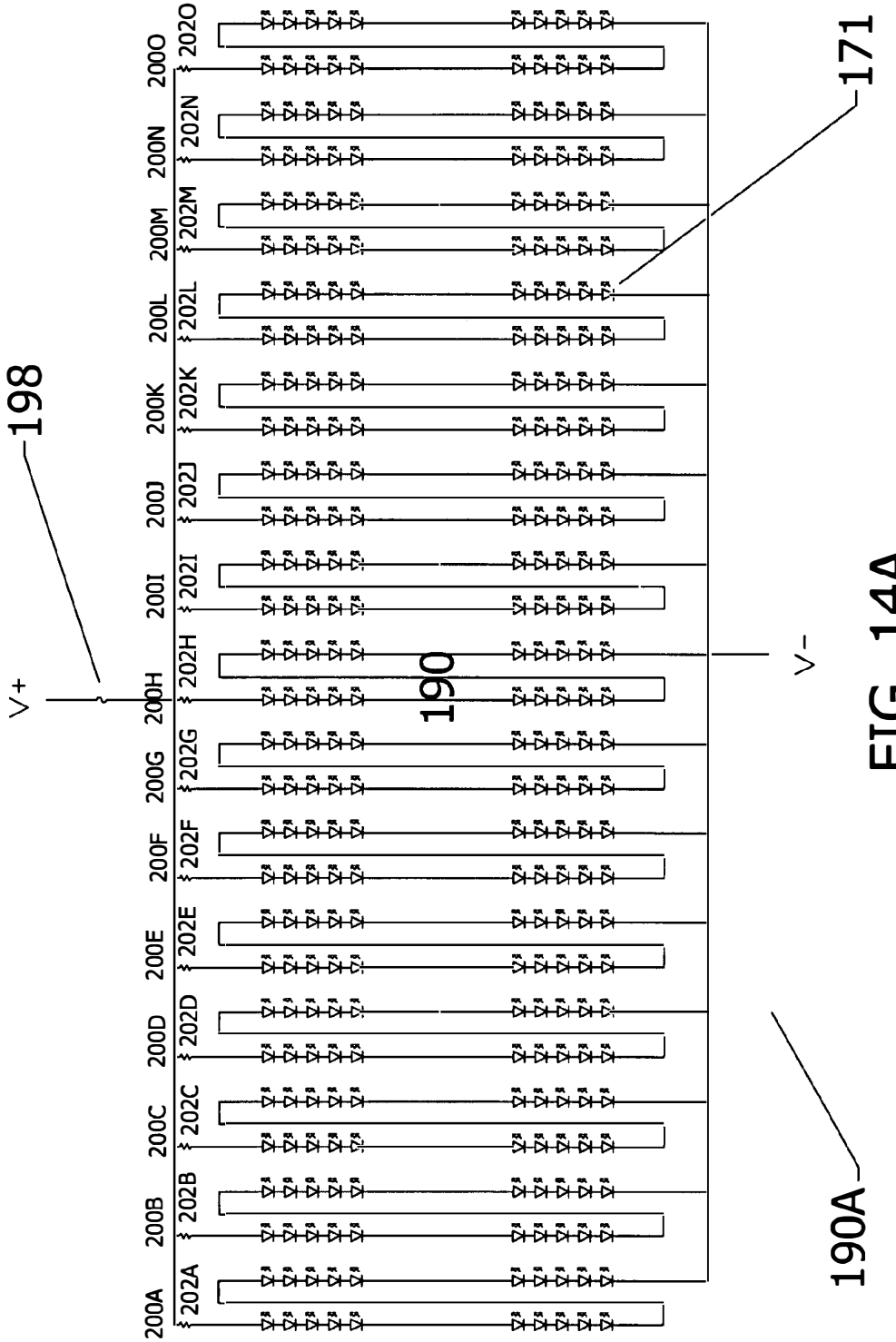

198
V+
190
V-
171
190A
200A
202A
200B
202B
200C
202C
200D
202D
200E
202E
200F
202F
200G
202G
200H
202H
200I
202I
200J
202J
200K
202K
200L
202L
200M
202M
200N
202N
200O
202O

FIG. 14A

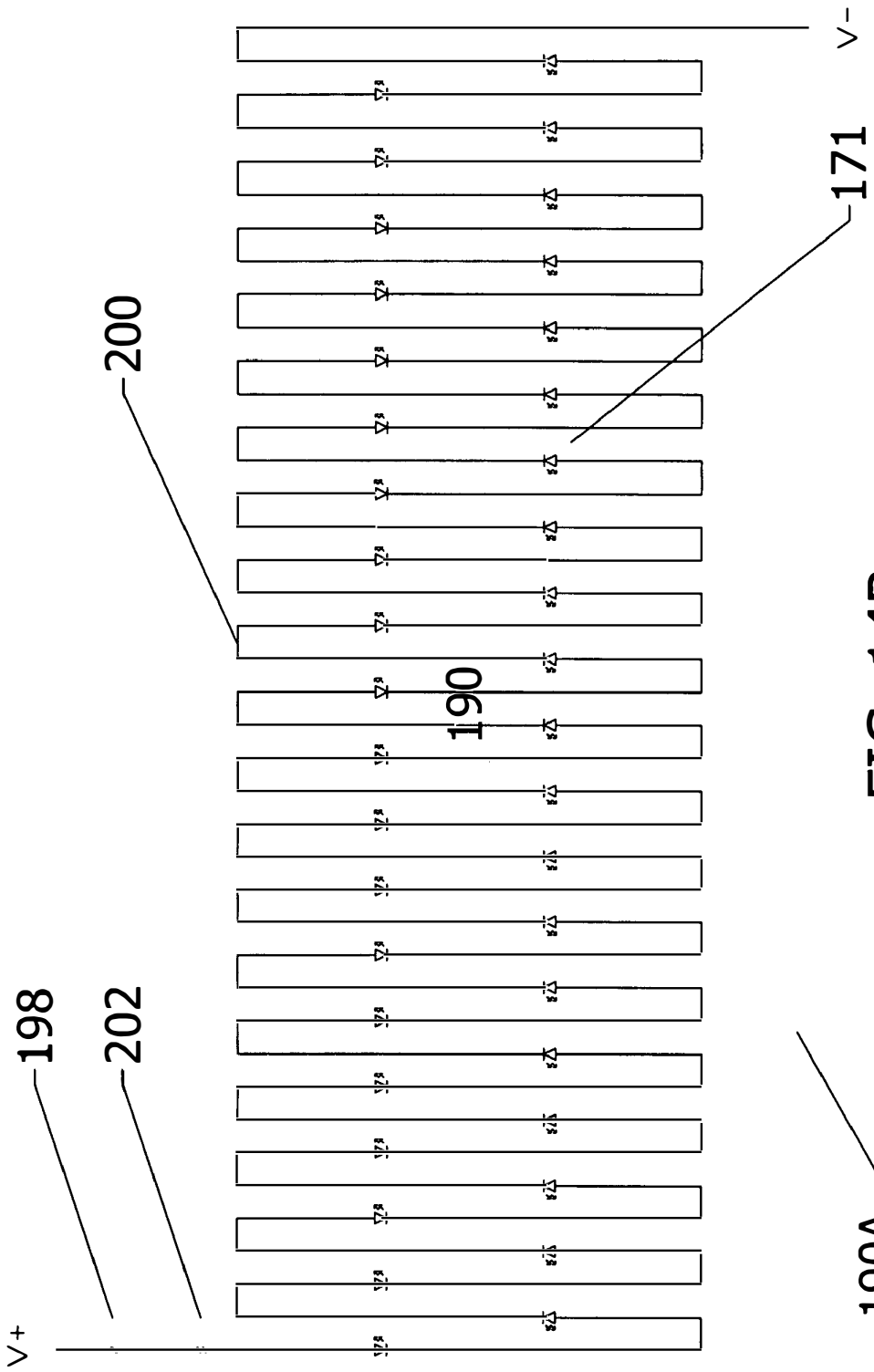


FIG. 14B

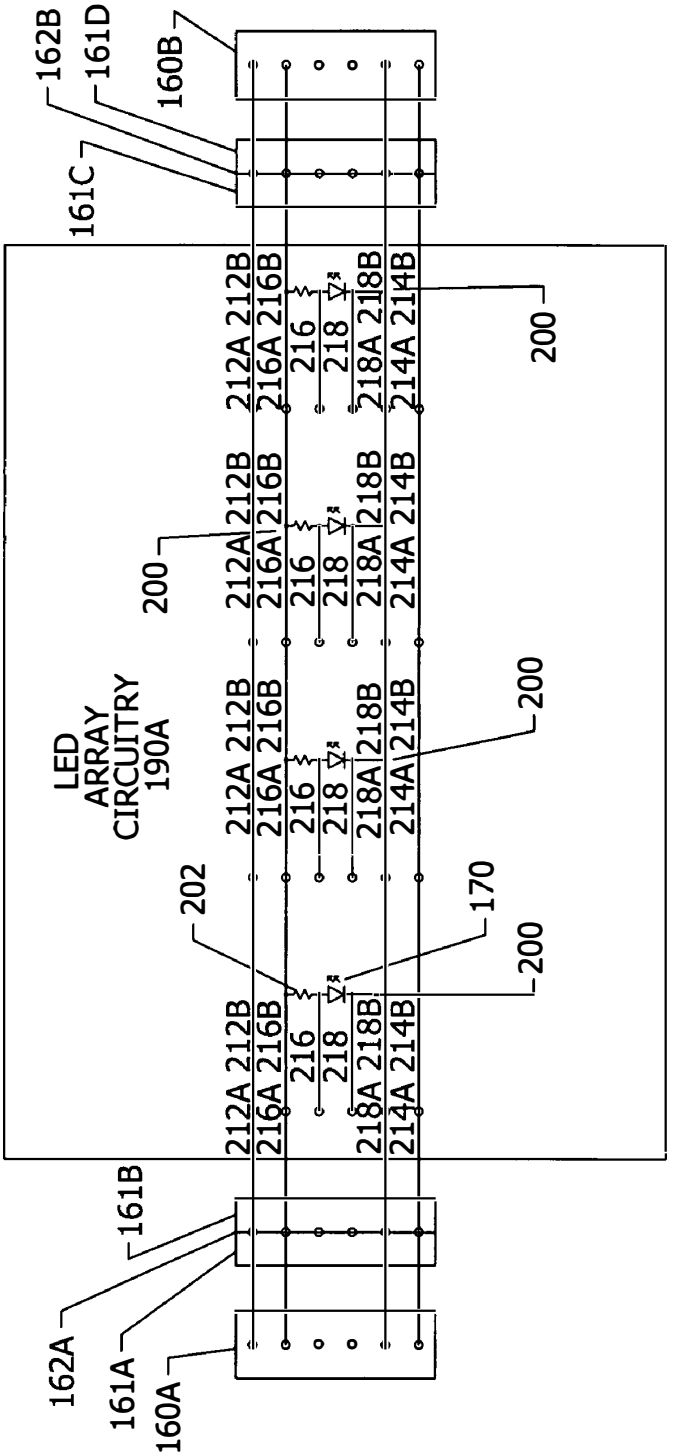

162B
161D
160B
161C
LED ARRAY CIRCUITRY 190A
200
202
170
212A 212B
216A 216B
216
218
218A 218B
214A 214B
161B
162A
161A
160A

FIG. 14C

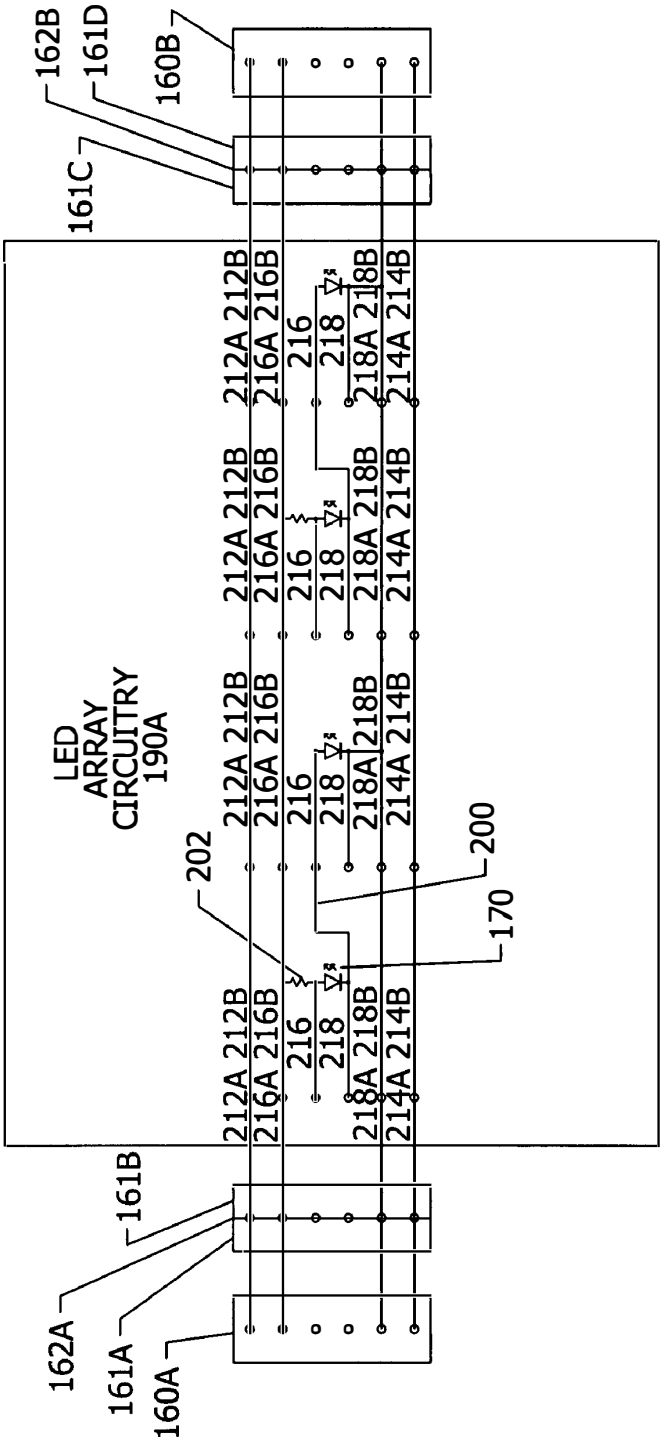

162B
161D
160B
161C
LED ARRAY CIRCUITRY 190A
202
200
170
212A 212B
216A 216B
216
218
218A 218B
214A 214B
161B
162A
161A
160A

FIG. 14D

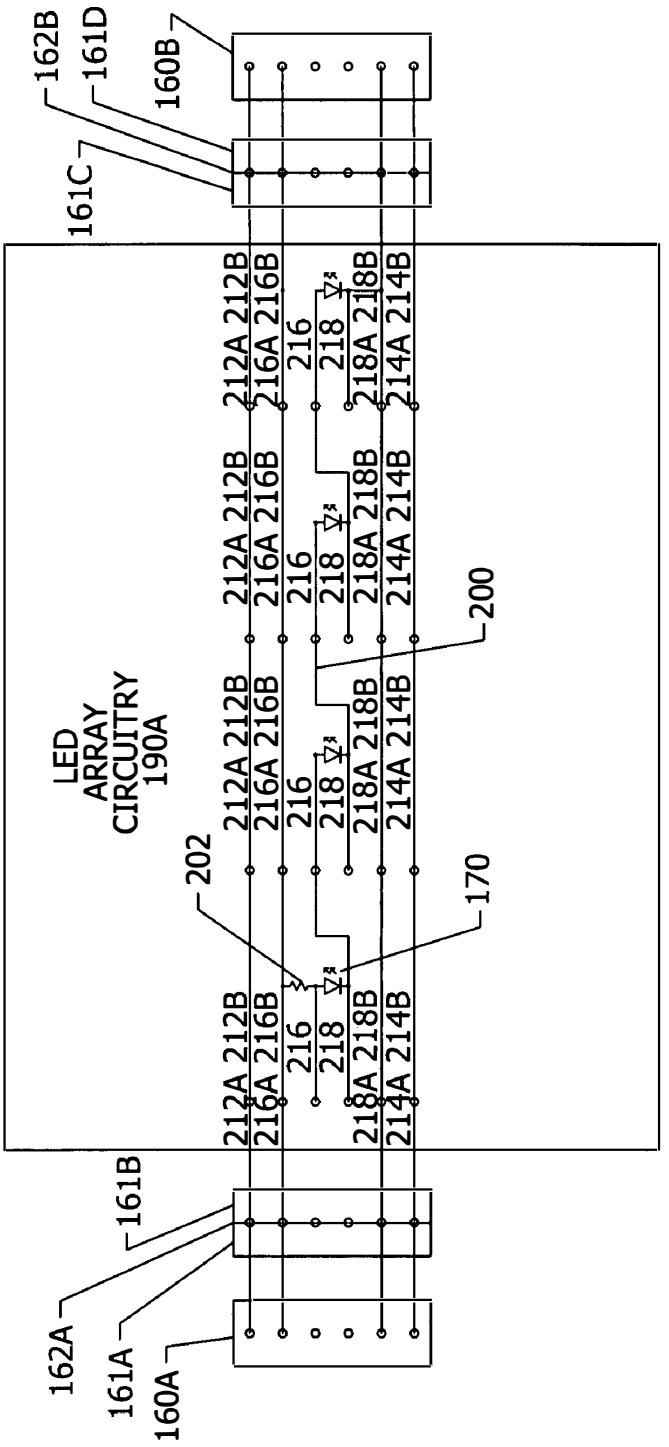

162B
161D
160B
161C
LED
ARRAY
CIRCUITRY
190A
202
200
170
212A 212B
216A 216B
216
218
218A 218B
214A 214B
161B
162A
161A
160A

FIG. 14E

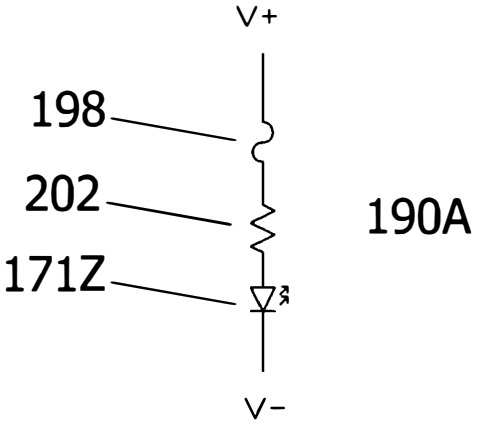


FIG. 14F

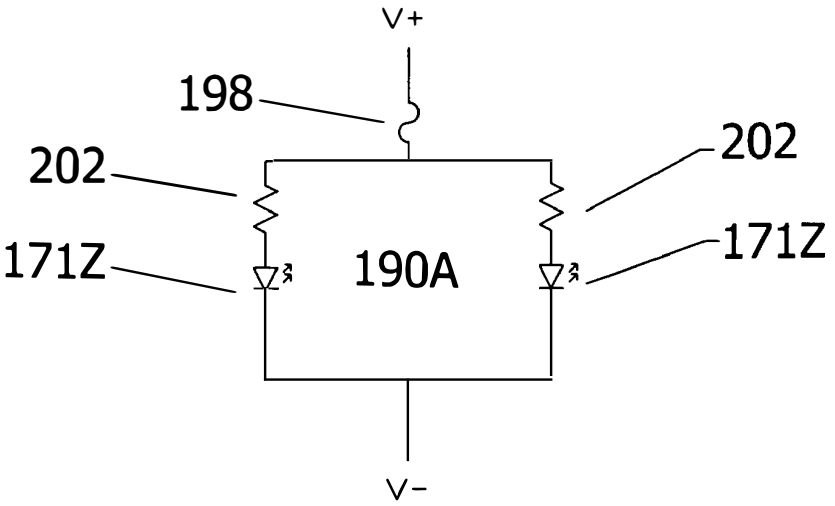


FIG. 14G

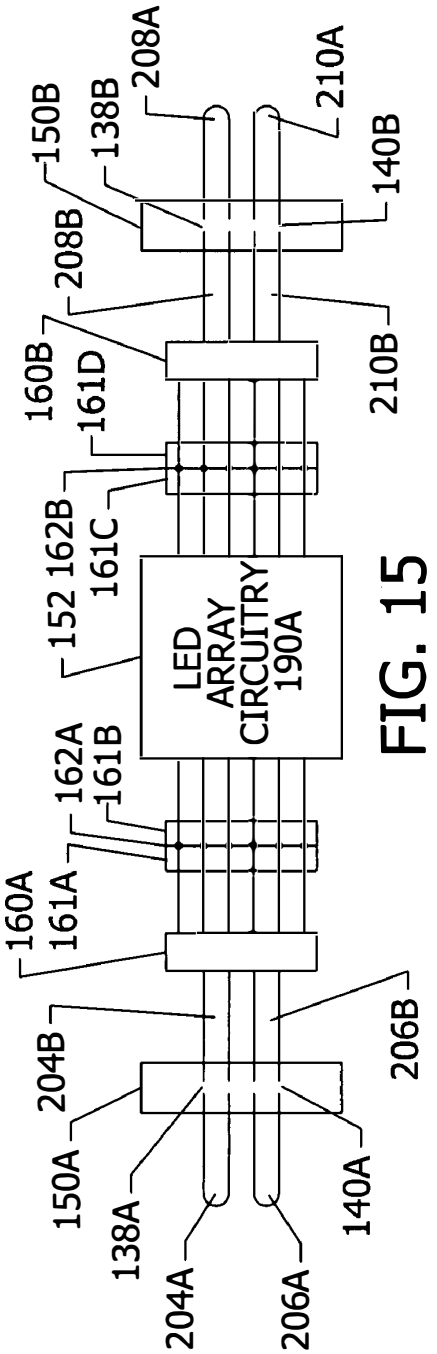


FIG. 15

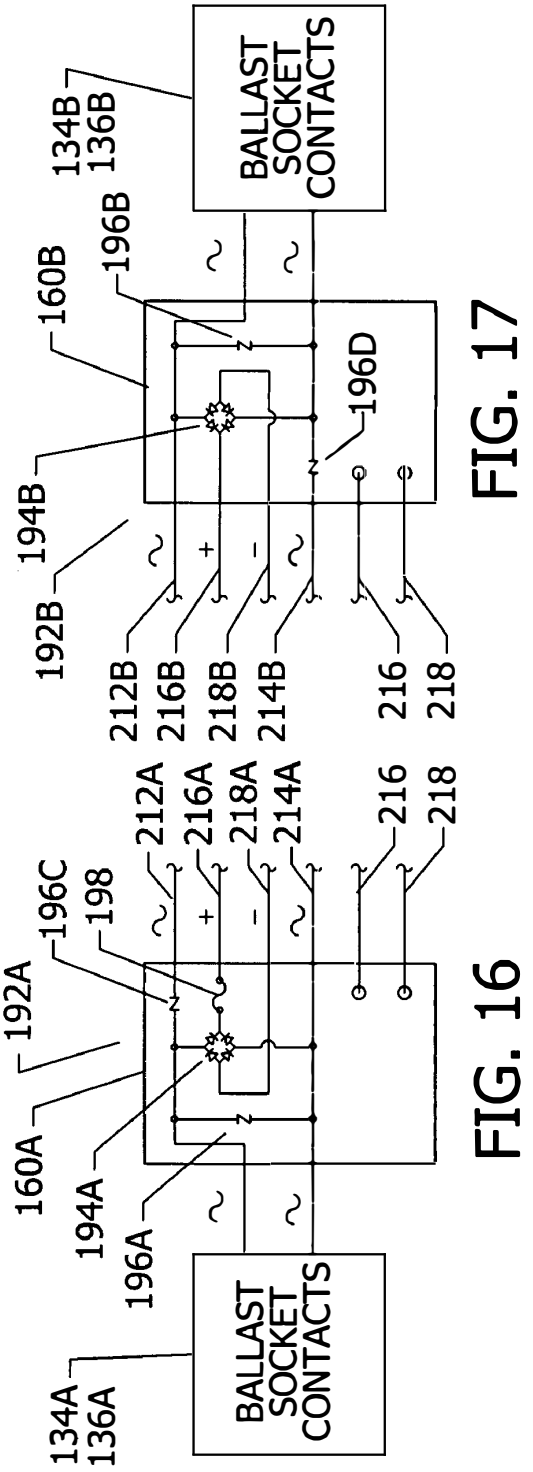


FIG. 16

FIG. 17

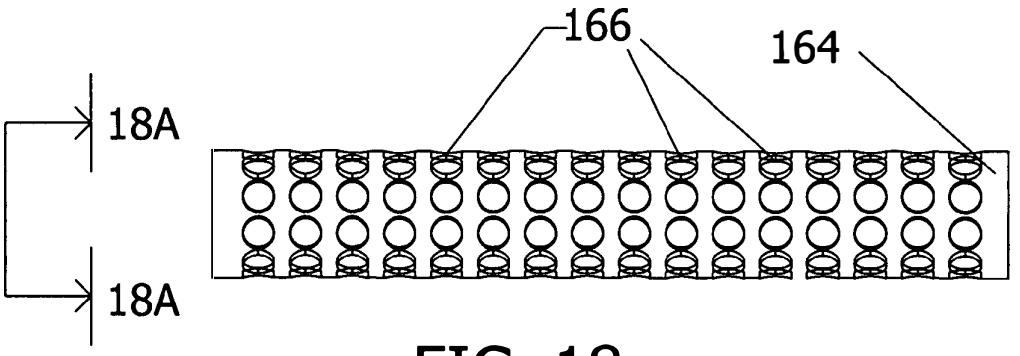


FIG. 18

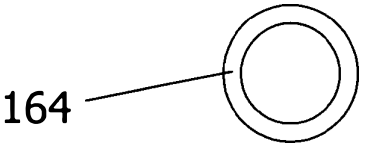


FIG. 18A

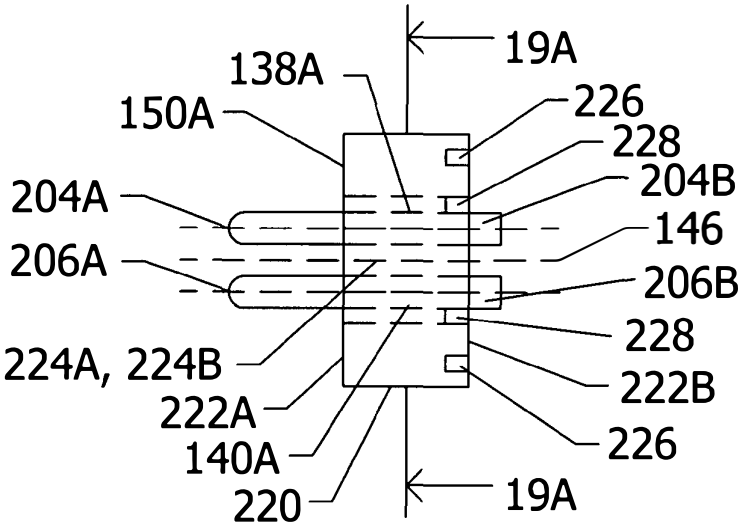


FIG. 19

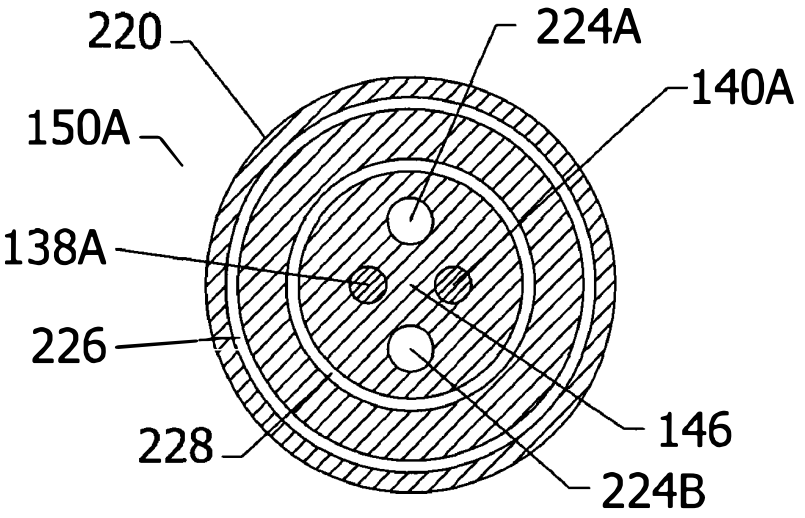


FIG. 19A

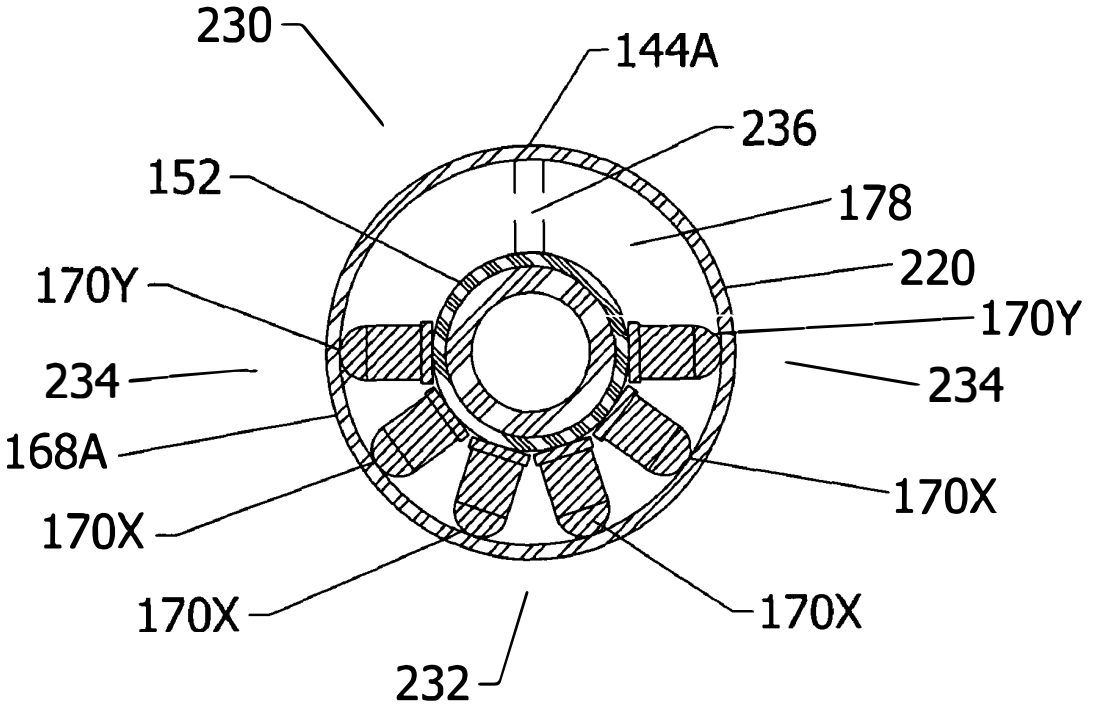


FIG. 20

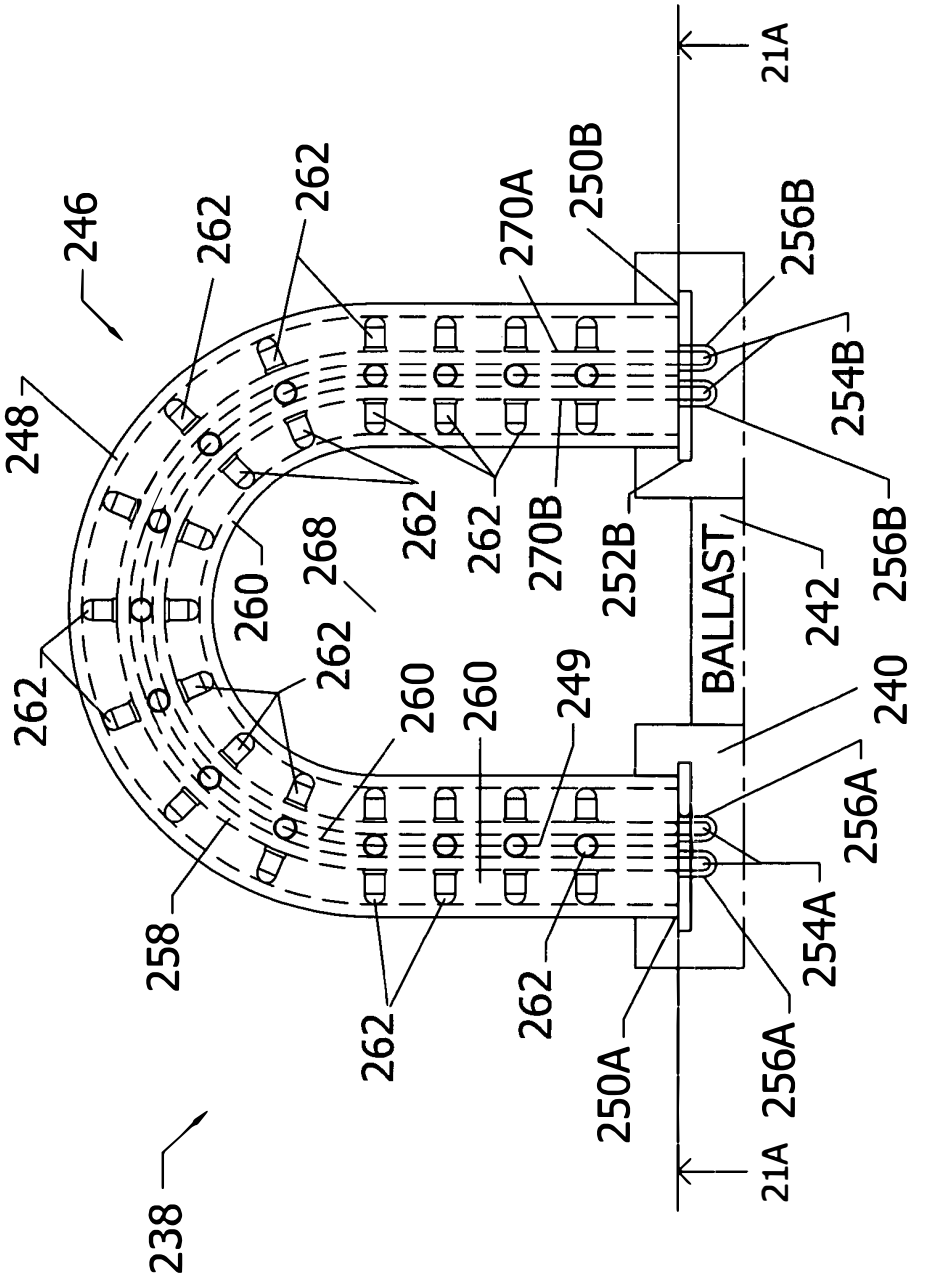

21A
246
262
262
270A
250B
256B
248
254B
262
262
270B
252B
BALLAST
242
256B
268
260
262
262
260
260
249
240
262
256A
258
254A
262
262
250A
256A
21A
238

FIG. 21

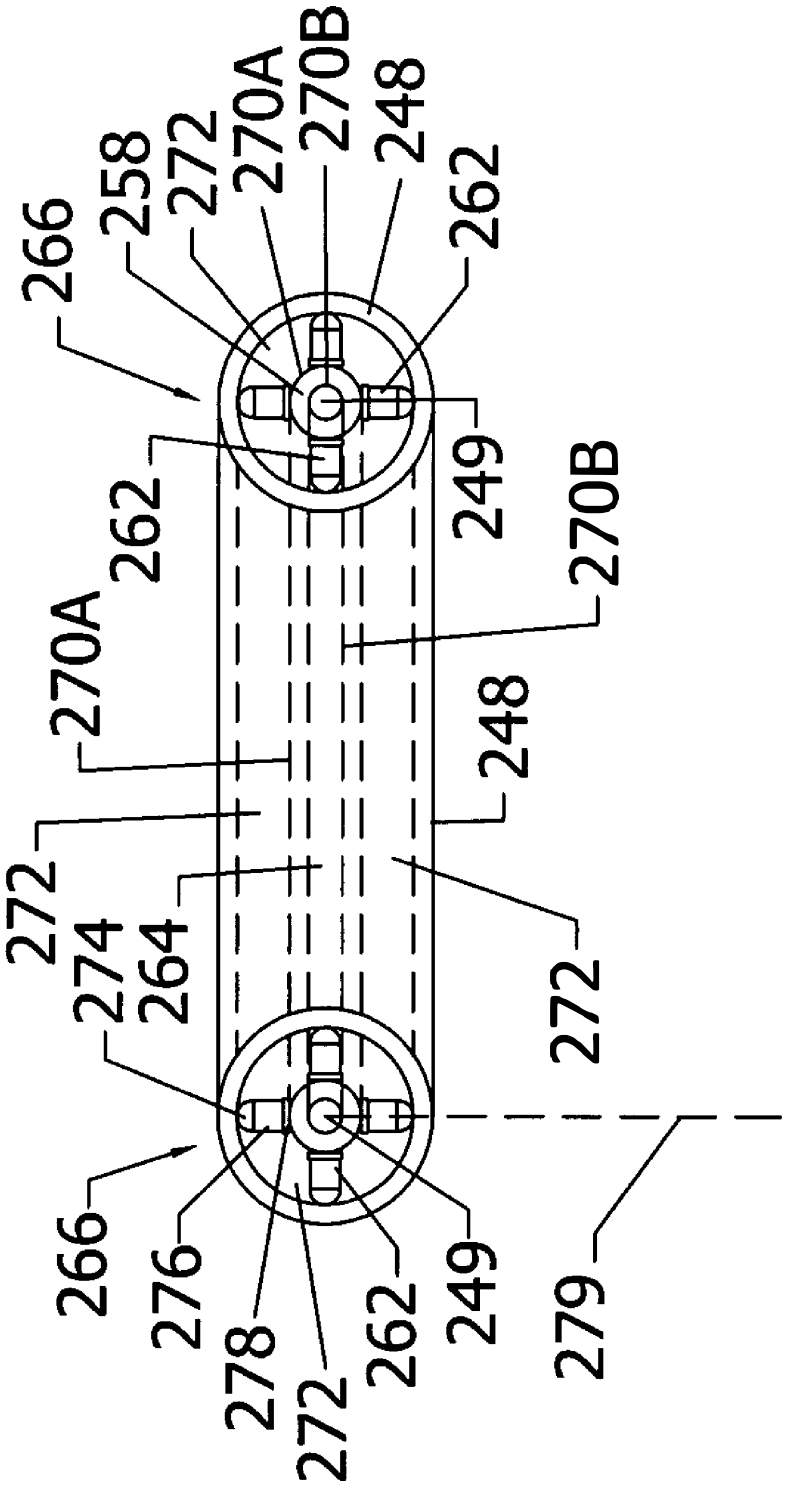

266
258
272
270A
270B
248
262
262
249
270B
270A
248
272
274
264
272
266
276
278
272
262
249
279

FIG 21A

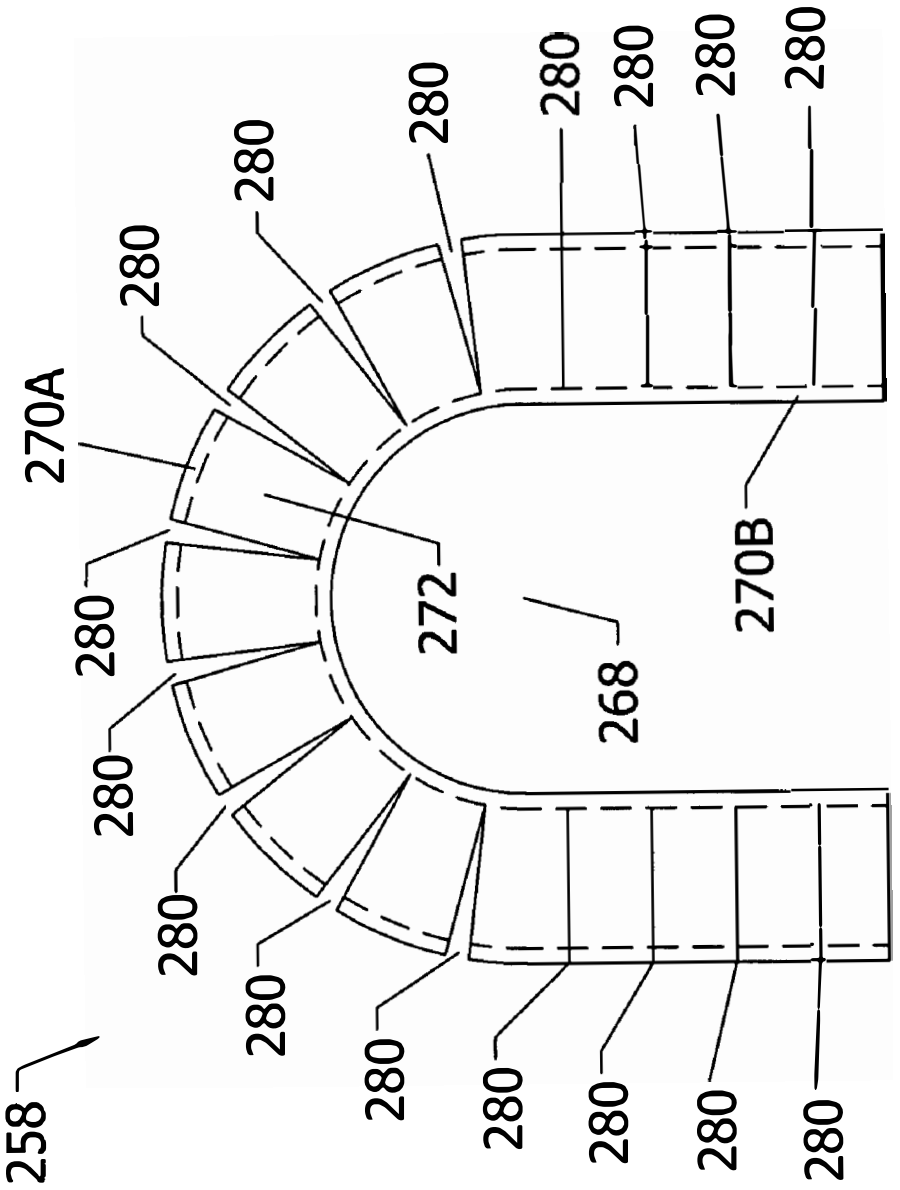

280
280
280
280
280
280
280
270A
280
280
280
280
280
280
280
280
280
272
268
270B
258

FIG 22

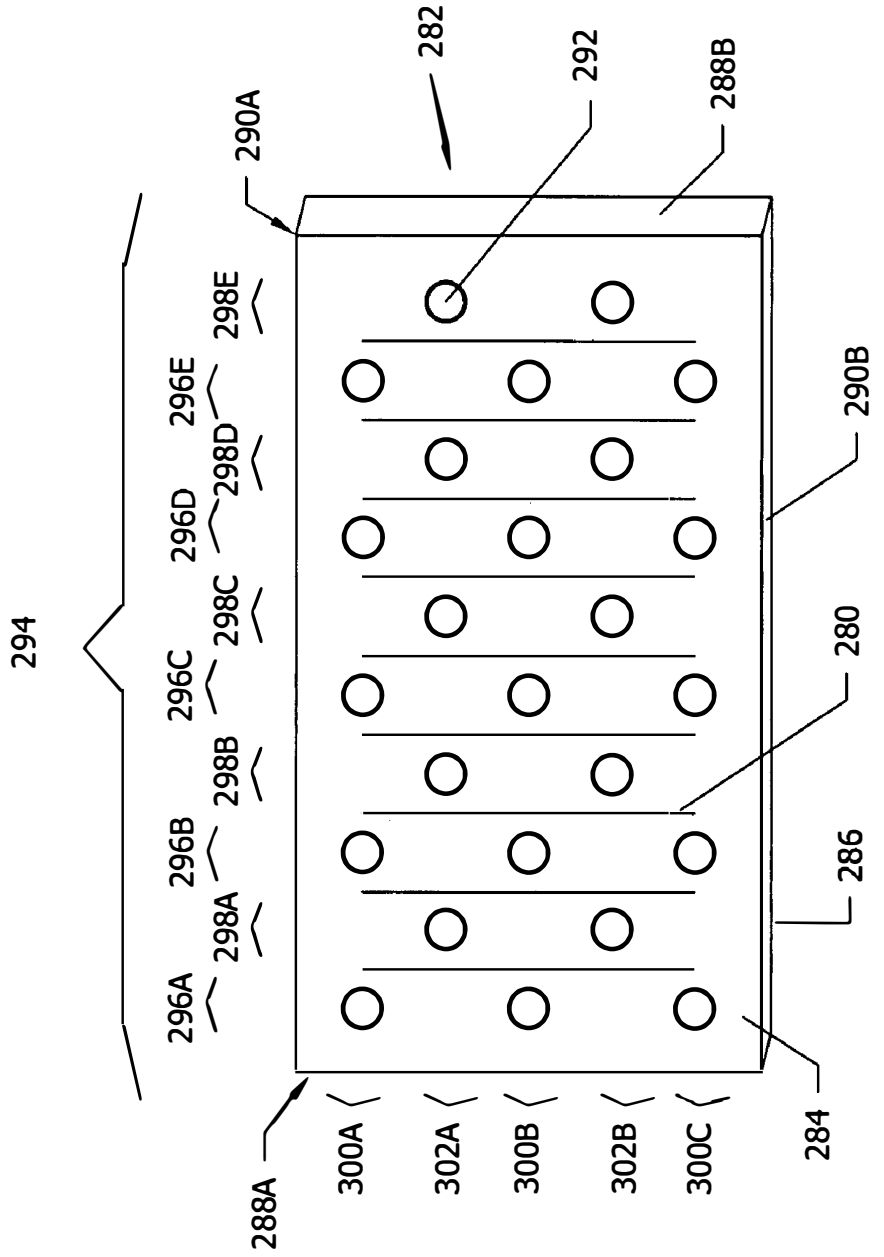

282
292
288B
290A
290B
280
286
284
288A
294
296A
296B
296C
296D
296E
298A
298B
298C
298D
298E
300A
302A
300B
302B
300C

FIG 23

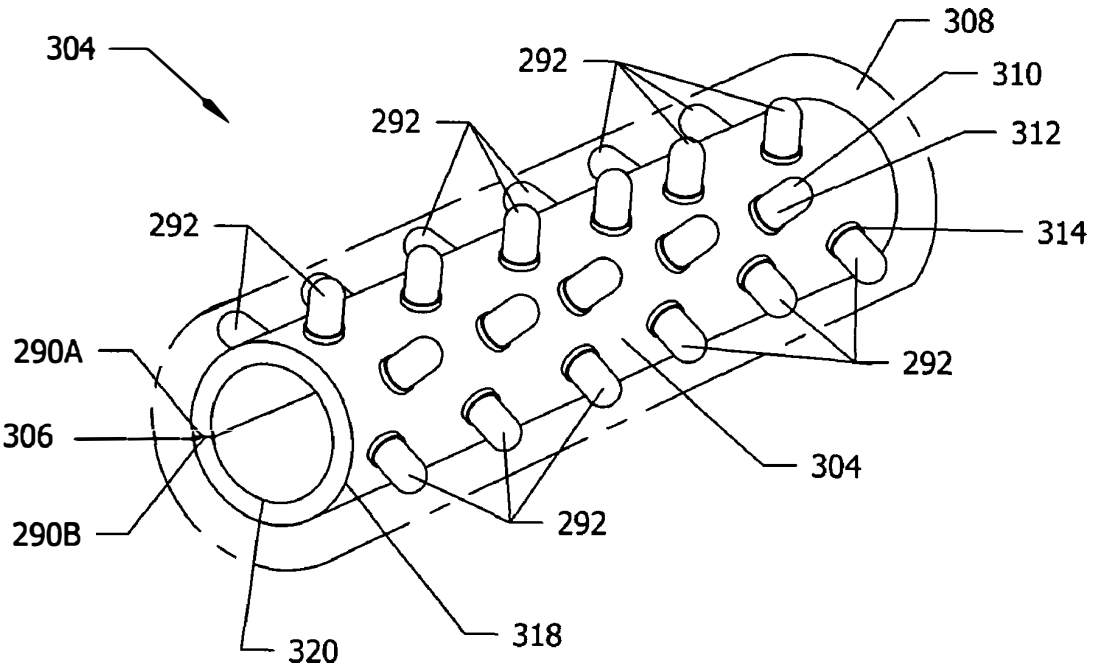

304
308
292
310
292
312
292
314
290A
292
306
304
290B
292
320
318

FIG 24

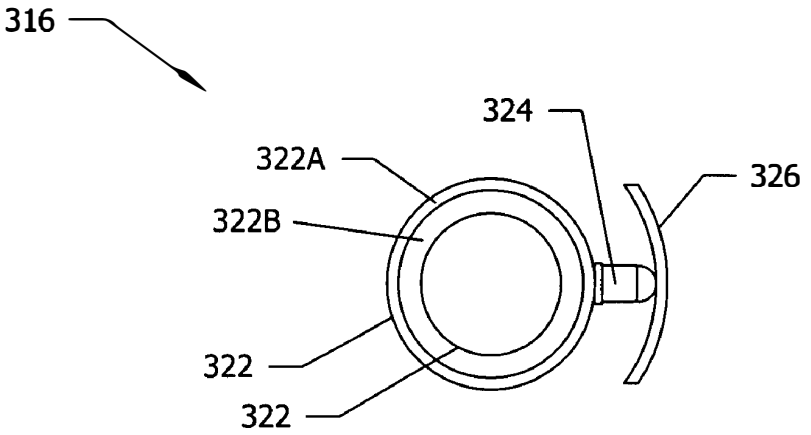

316
324
322A
326
322B
322
322

FIG 25

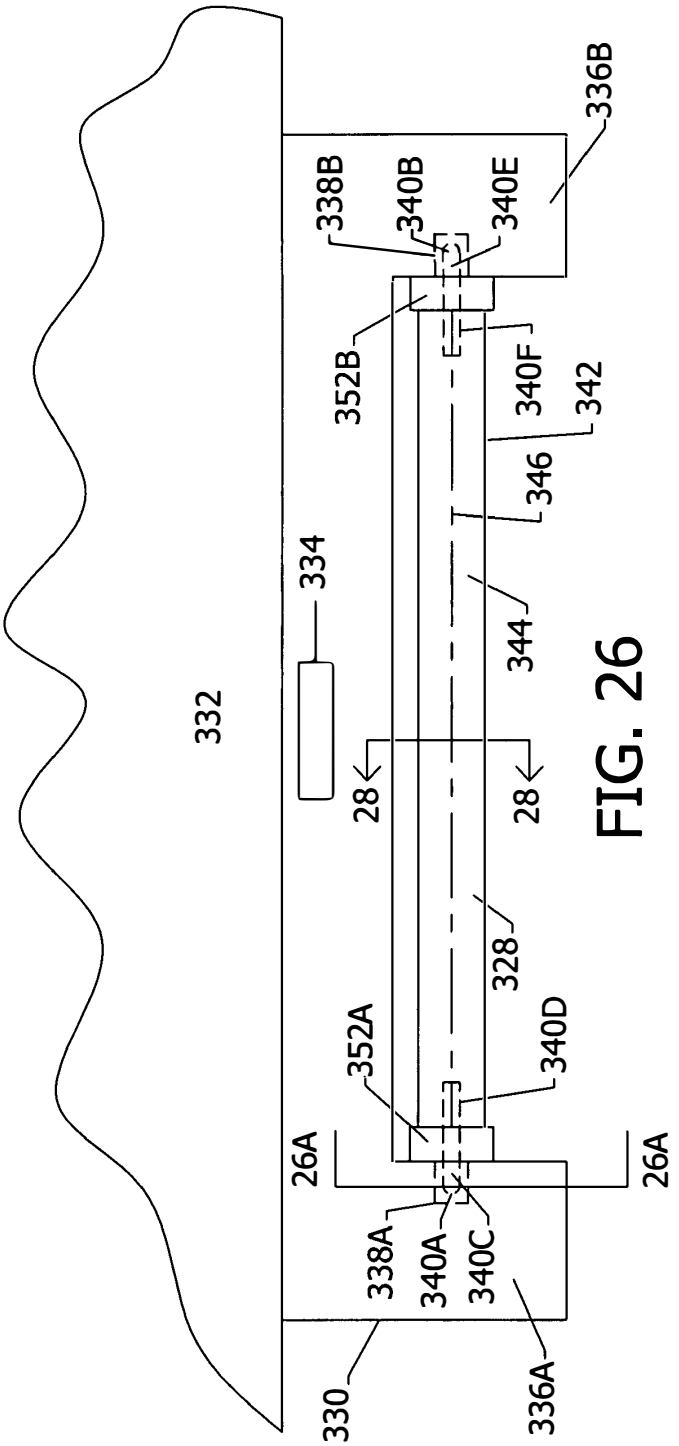


FIG. 26

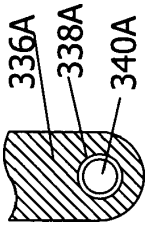


FIG. 26A

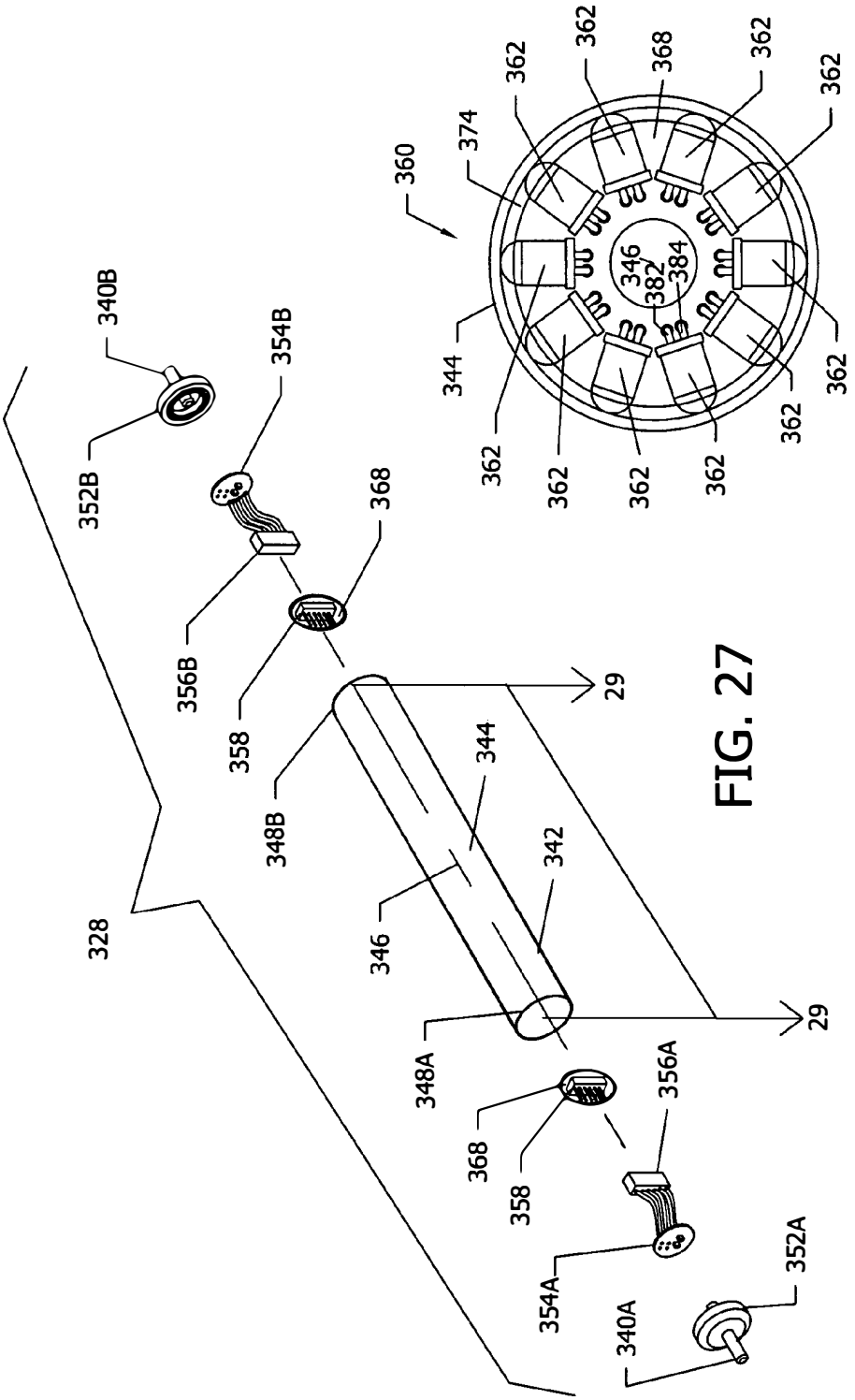

340B
354B
352B
368
356B
358
348B
344
342
346
328
29
29
348A
356A
368
358
354A
352A
340A
360
374
362
362
362
362
362
362
362
362
362
362
344
346
382
384

FIG. 27

FIG. 28

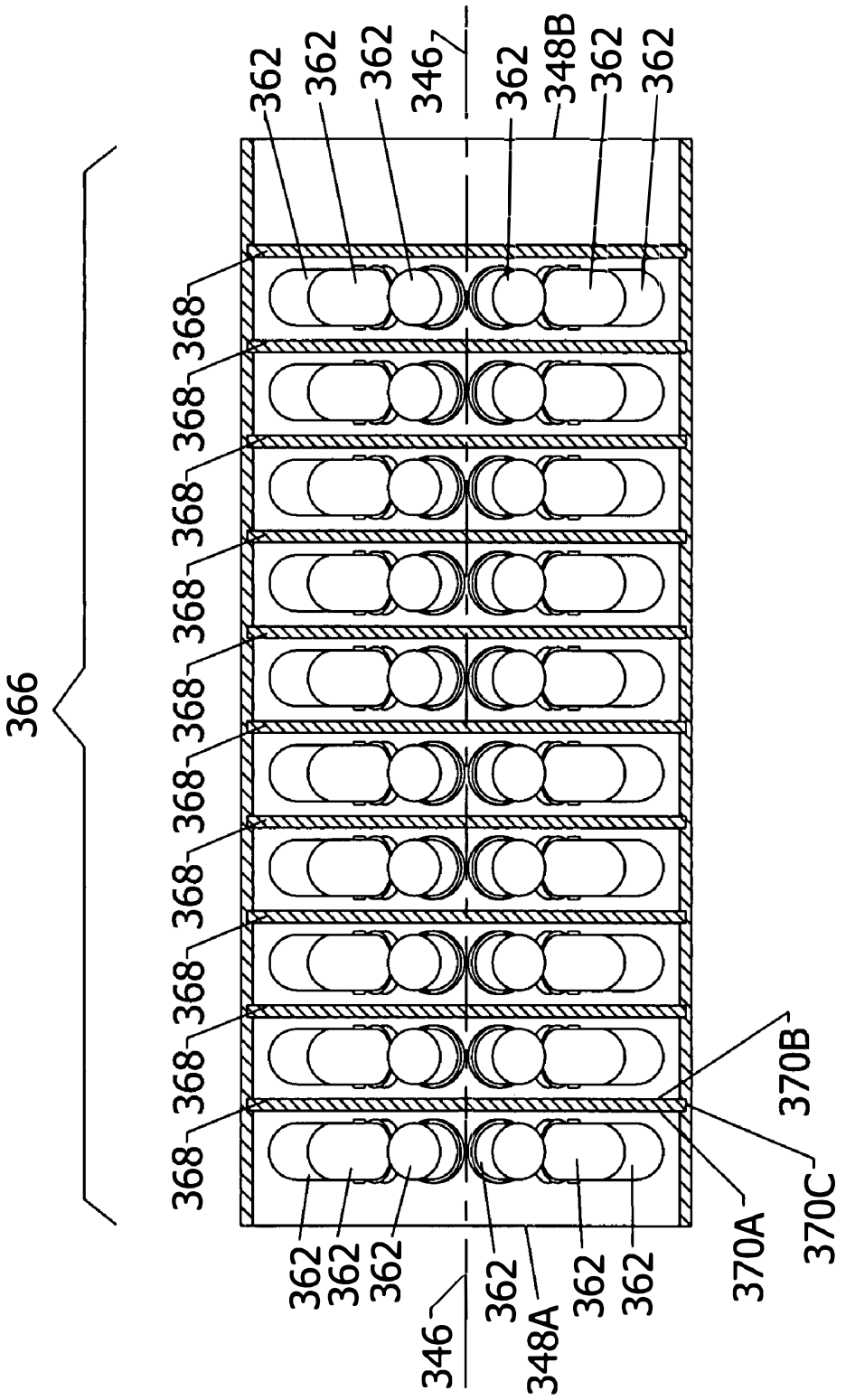

362
362
362
346
362
348B
362
362
368
368
368
368
368
368
368
368
368
366
362
362
362
346
362
348A
362
362
370A
370B
370C

FIG. 29

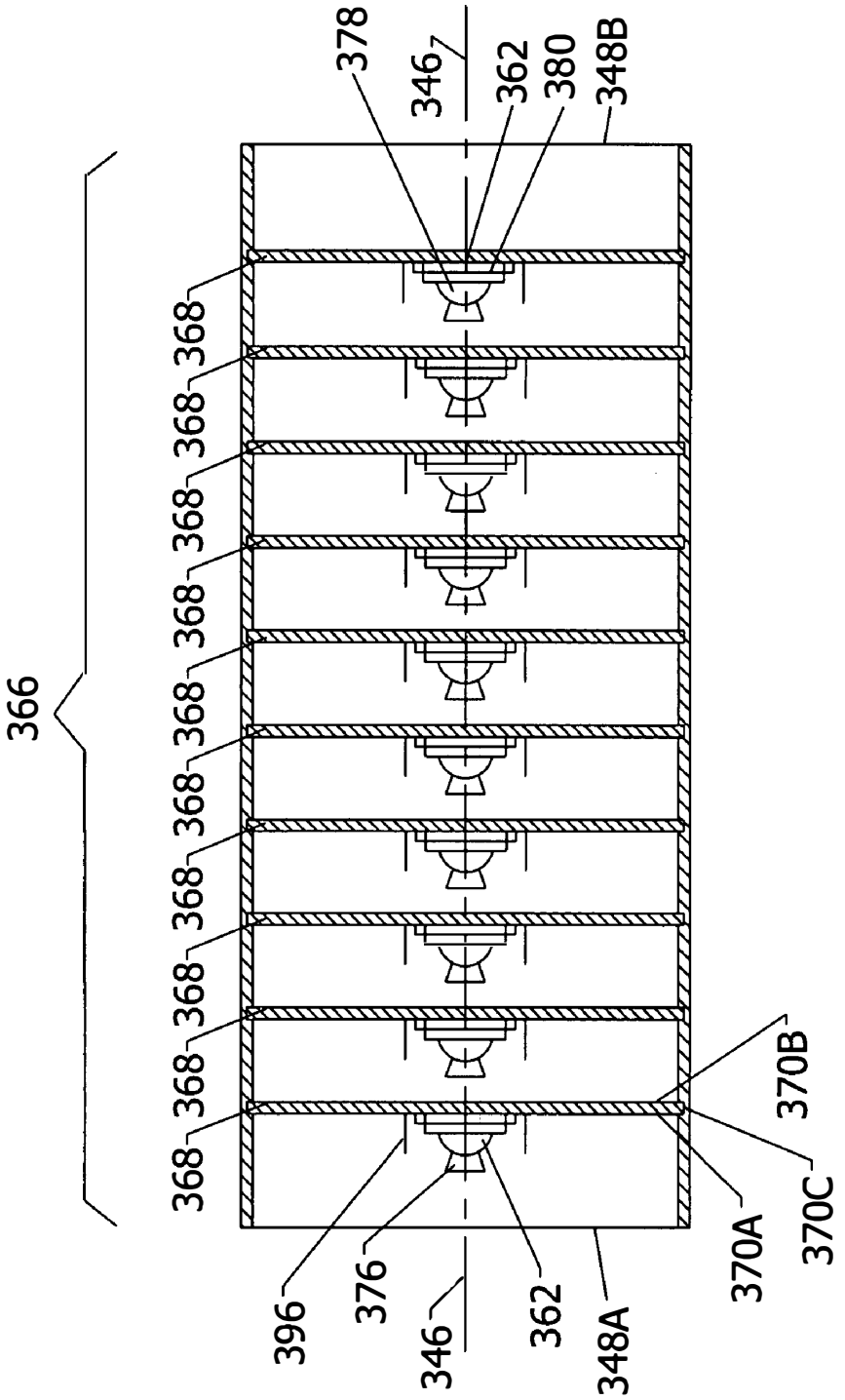

378
346
362
380
348B
366
368
368
368
368
368
368
368
368
368
370B
370C
370A
396
376
346
362
348A

FIG. 29A

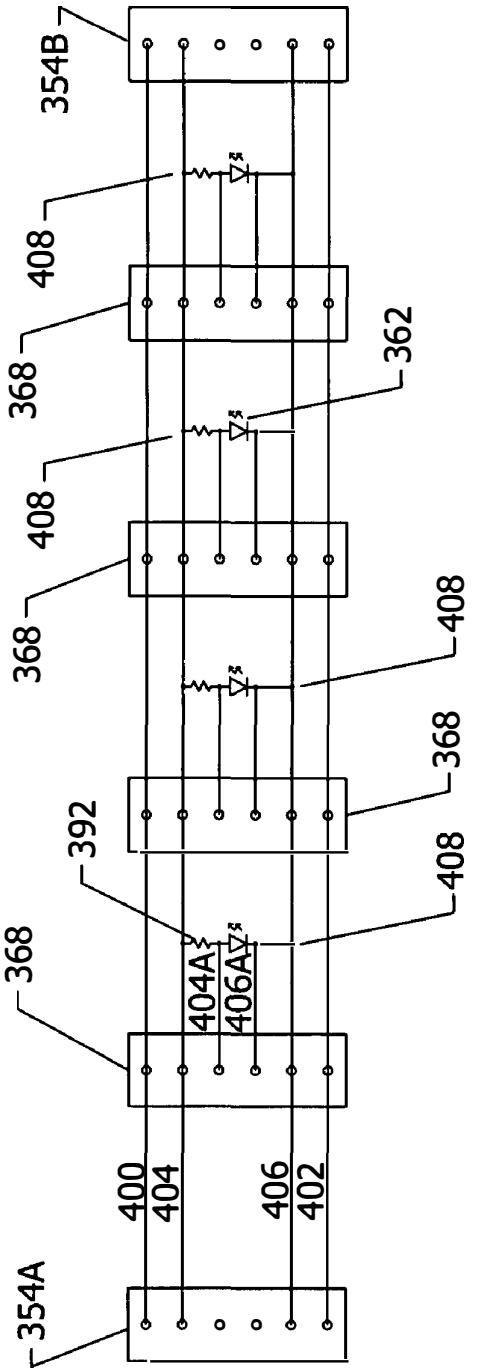

354B
408
368
362
408
368
408
368
392
408
368
404A
406A
400
404
406
402
354A

FIG. 29B

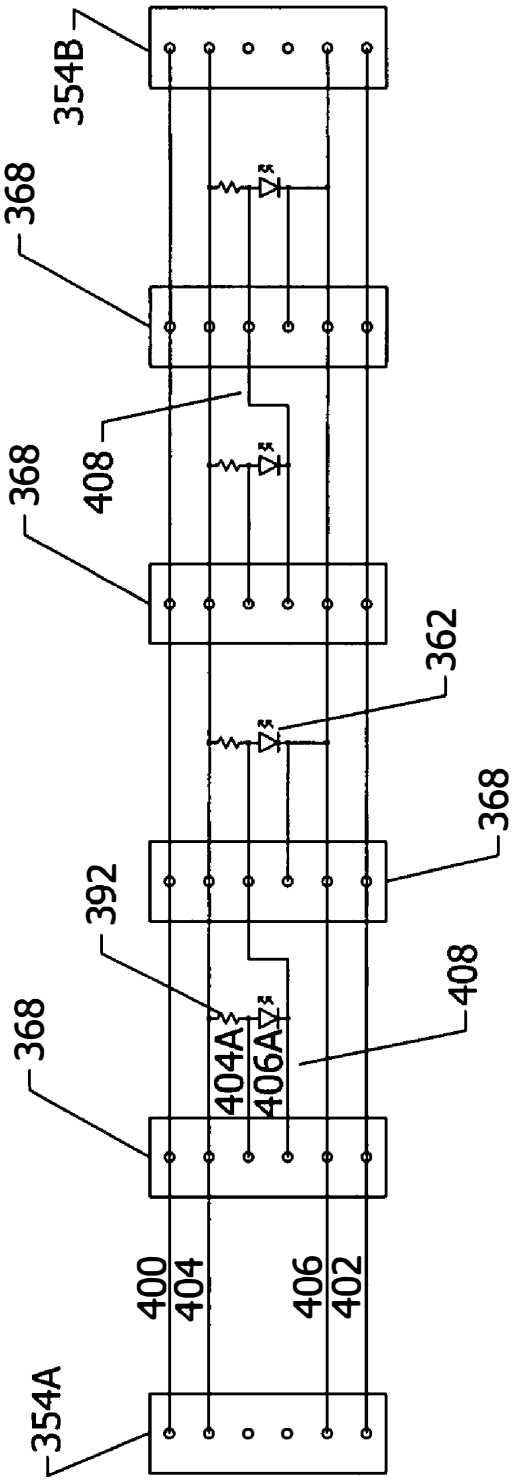

354B
368
408
368
362
368
392
408
368
404A
406A
400
404
406
402
354A

FIG. 29C

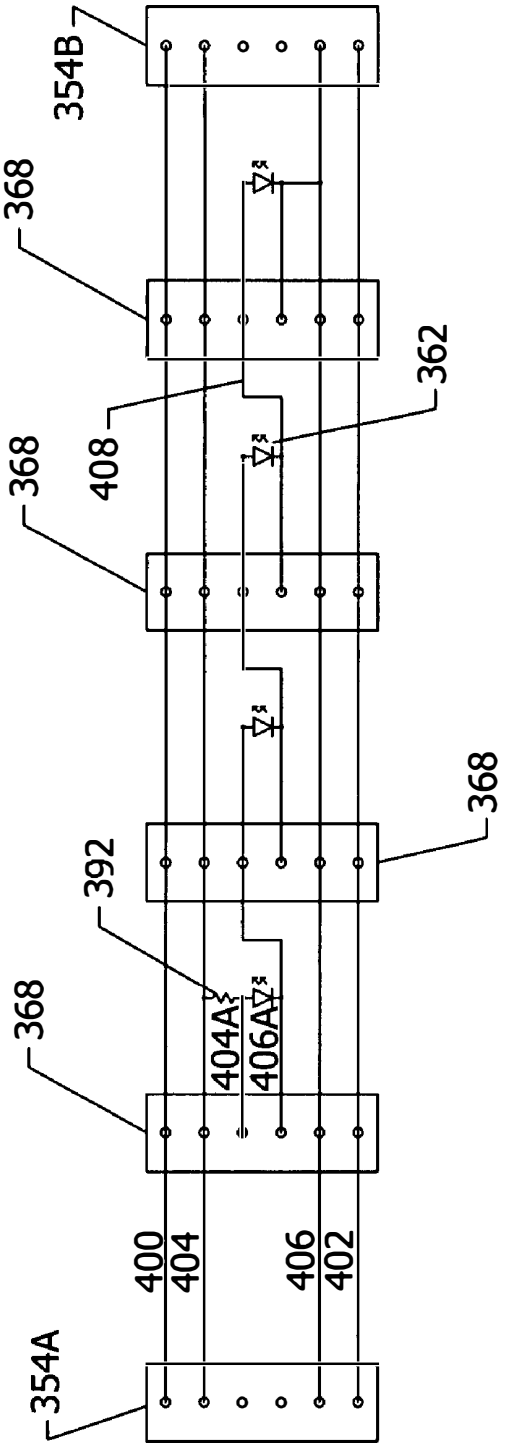


FIG. 29D

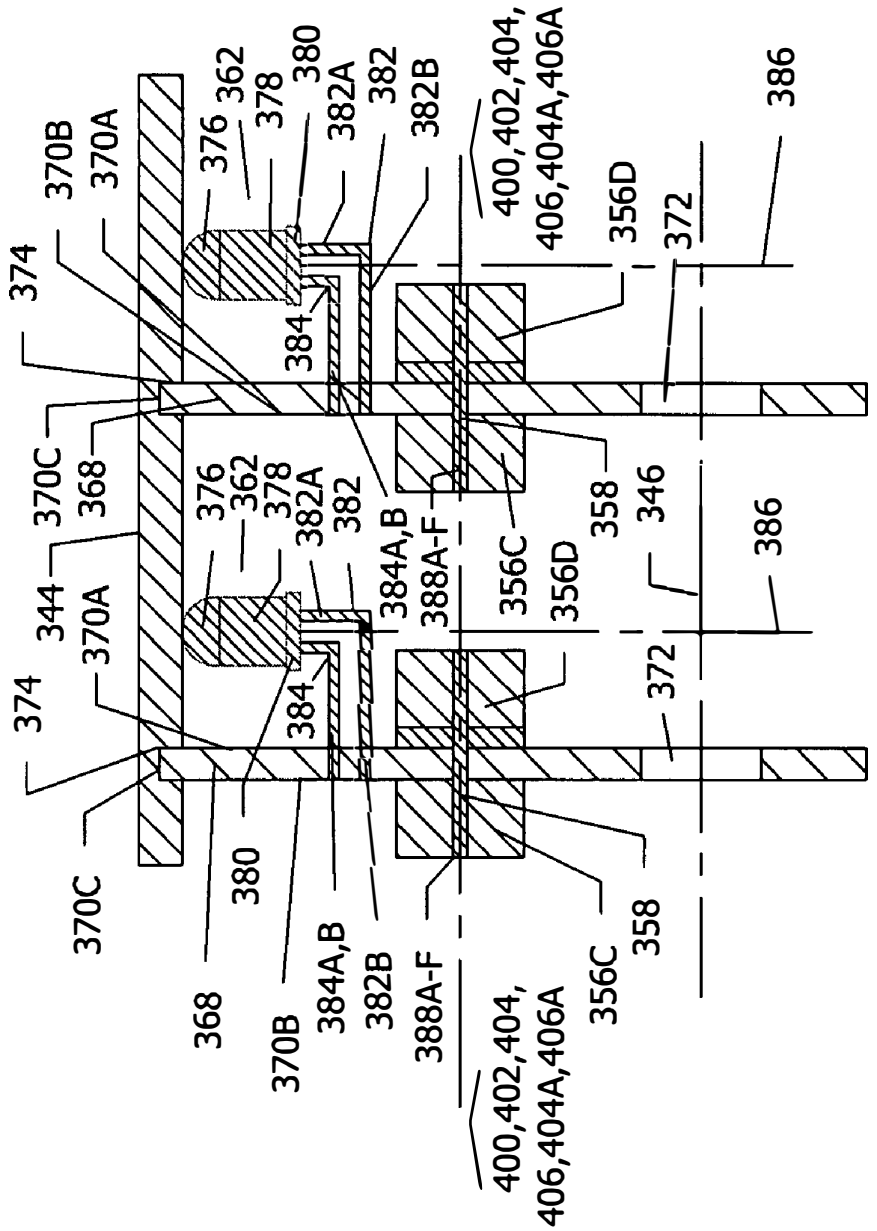

370B
370A
376
362
378
380
382A
382
382B
400,402,404,
406,404A,406A
356D
372
386
374
384
370C
368
344
358
346
382A,B
388A-F
356C
370C
380
384A,B
382B
388A-F
356C
358
368
370B
400,402,404,
406,404A,406A

FIG. 30

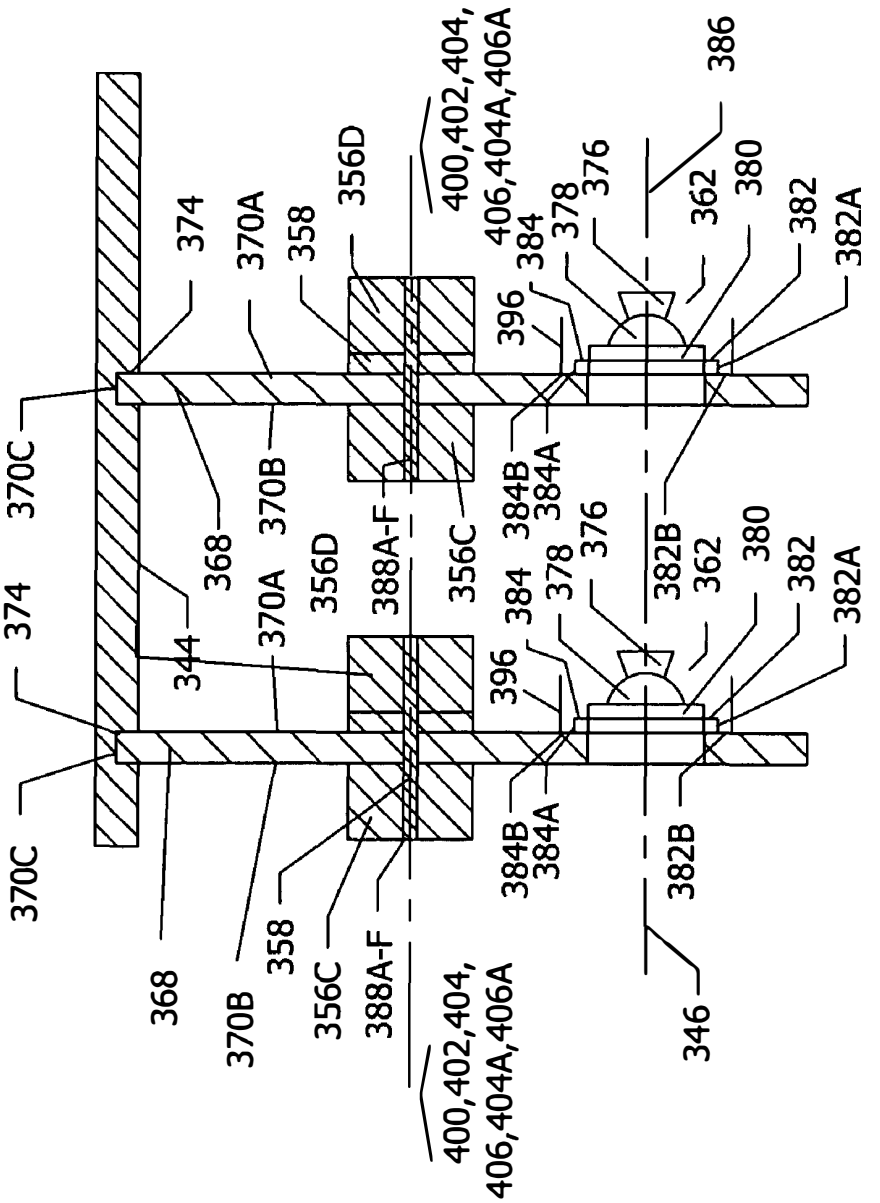

370C
374
368
370A
370B
358
356D
388A-F
356C
400,402,404,
406,404A,406A
384
384B
384A
396
376
378
382B
362
380
382
382A
386
346

FIG. 30A

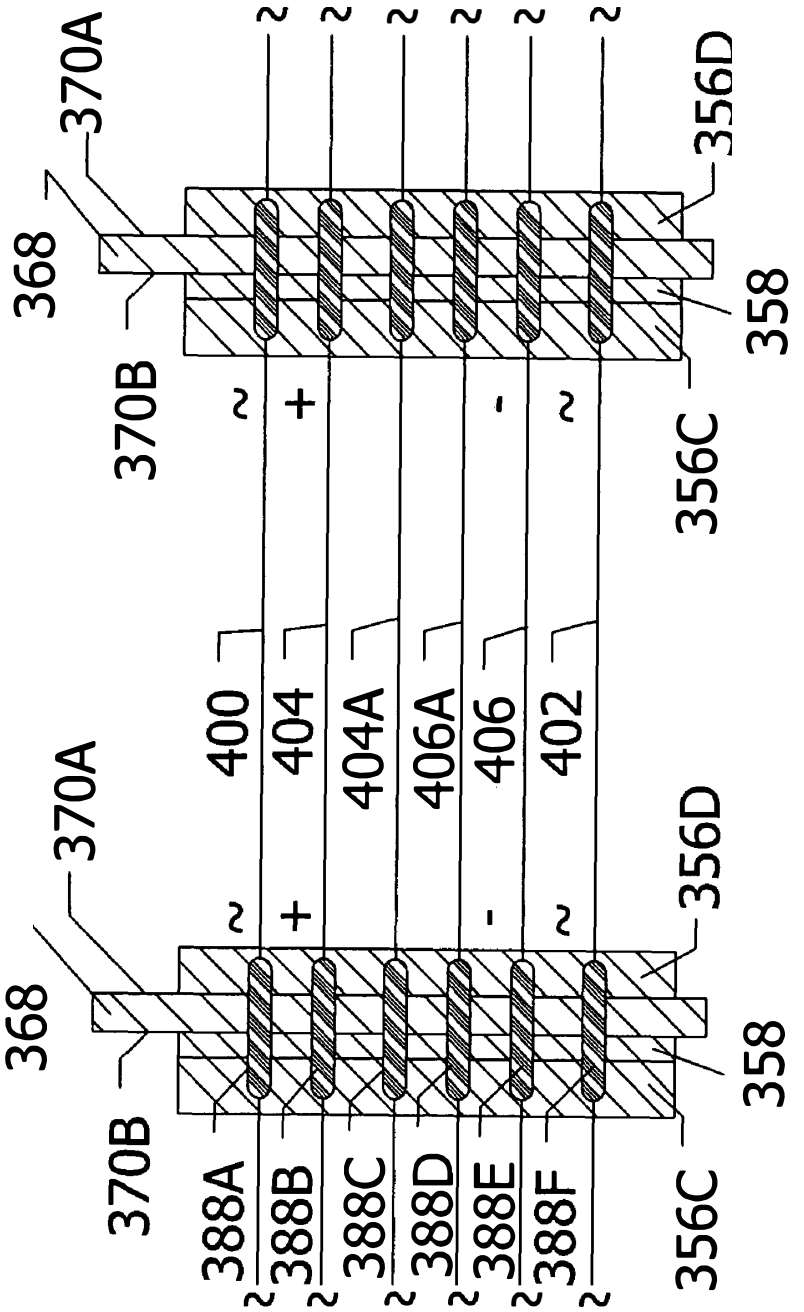

370A
368
370B
356D
358
356C
400
404
404A
406A
406
402
388A
388B
388C
388D
388E
388F
+
-

FIG. 30B

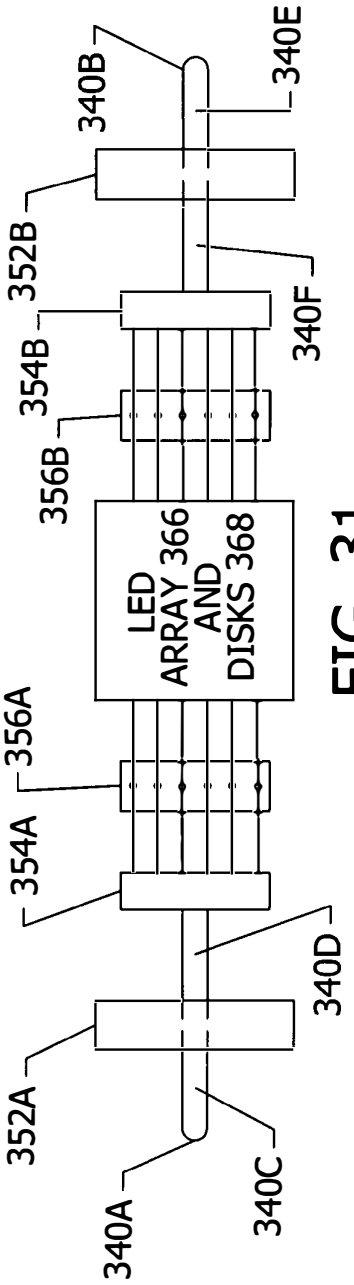


FIG. 31

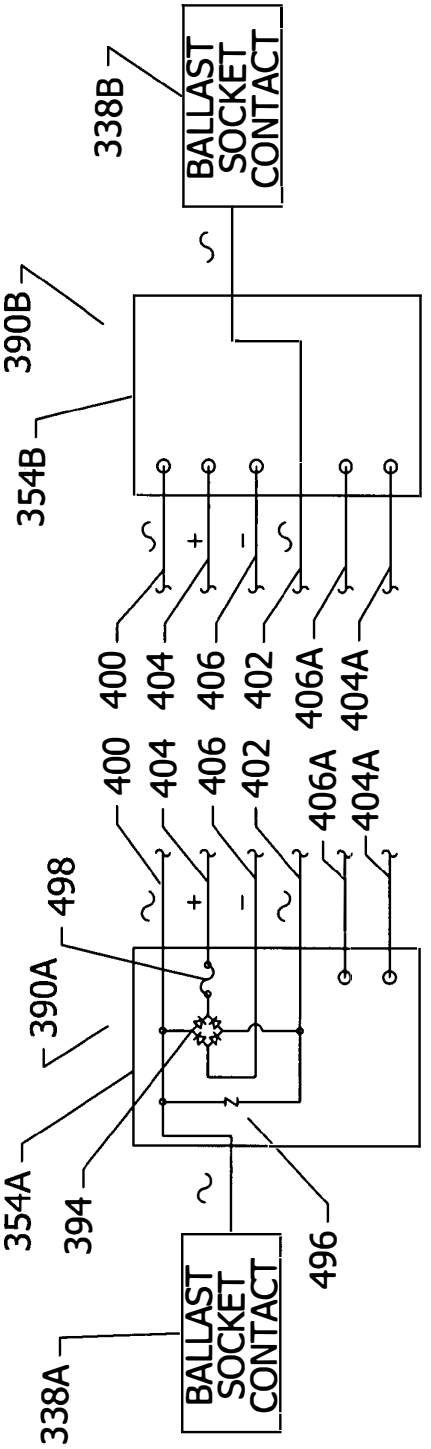


FIG. 33

FIG. 32

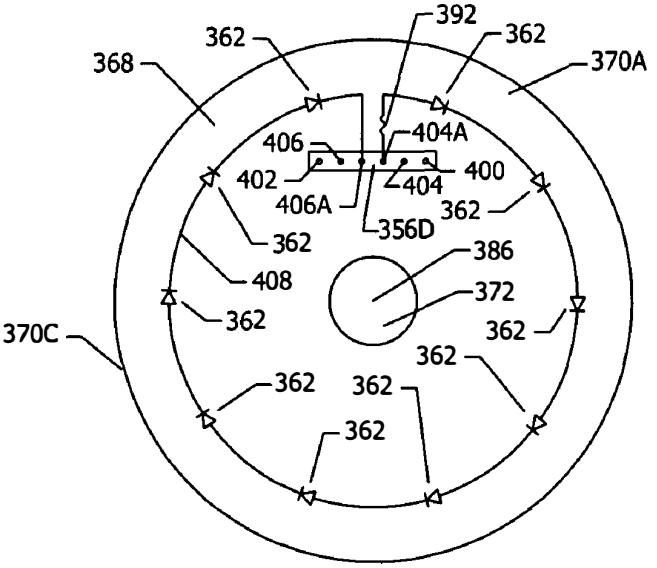


FIG. 34

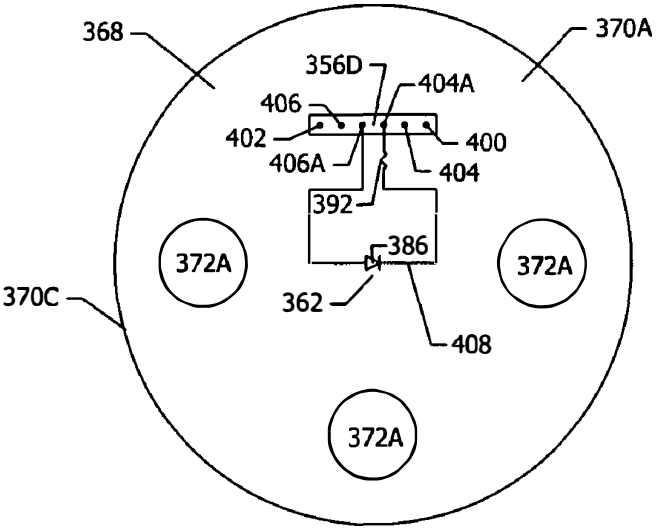


FIG. 34A

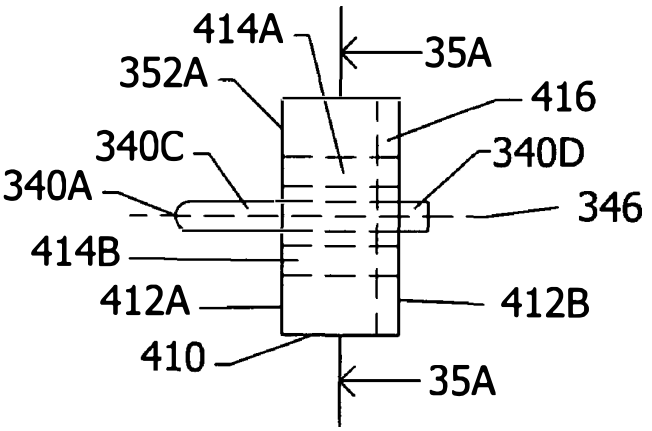


FIG. 35

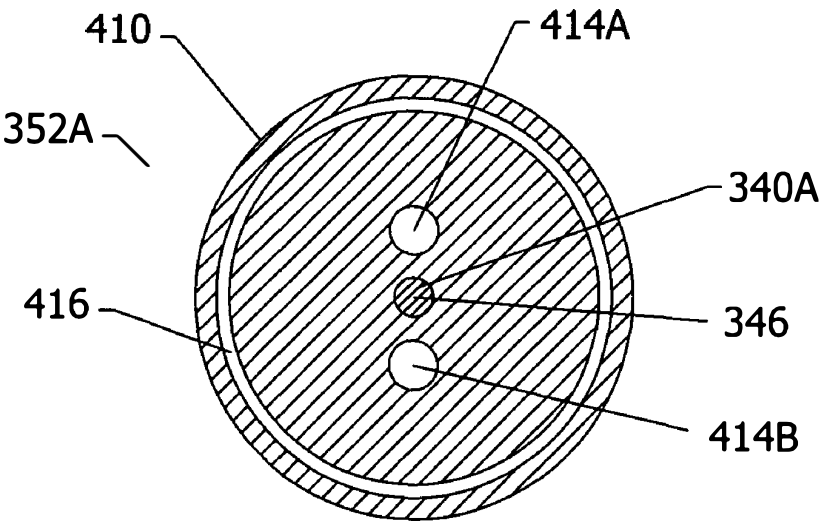


FIG. 35A

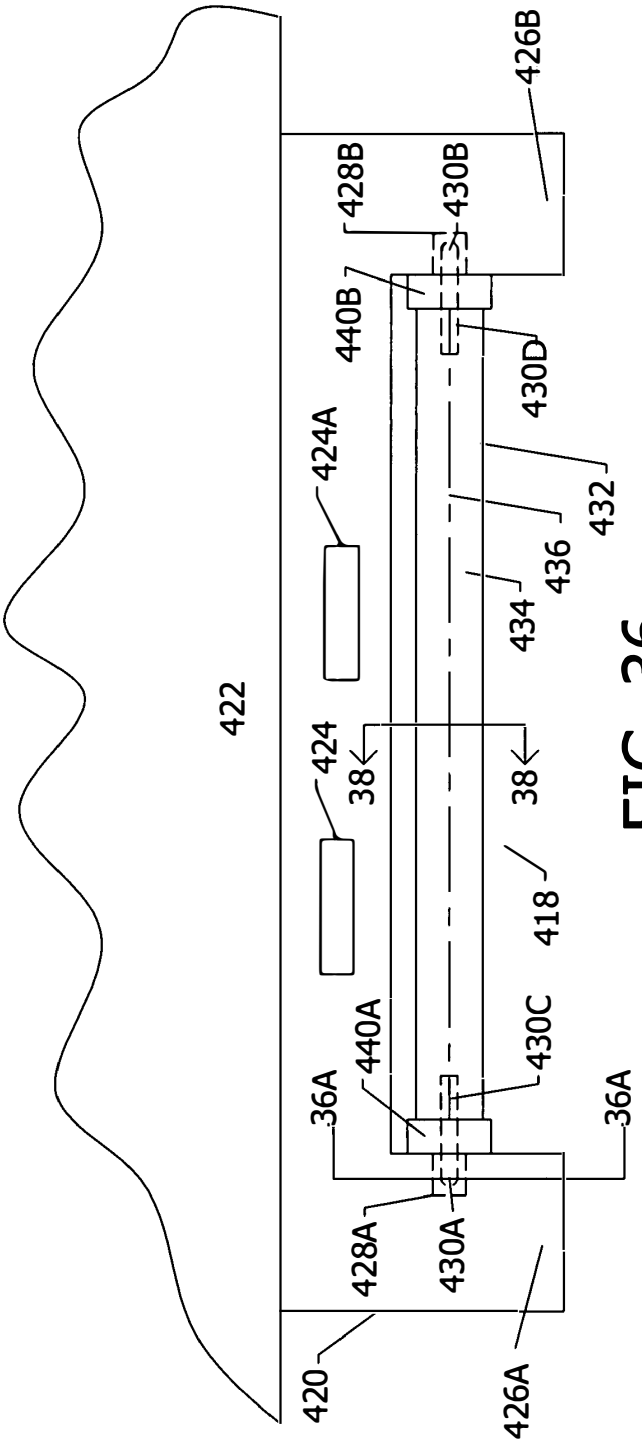


FIG. 36

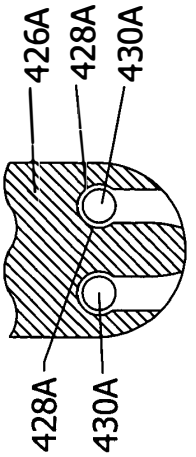


FIG. 36A

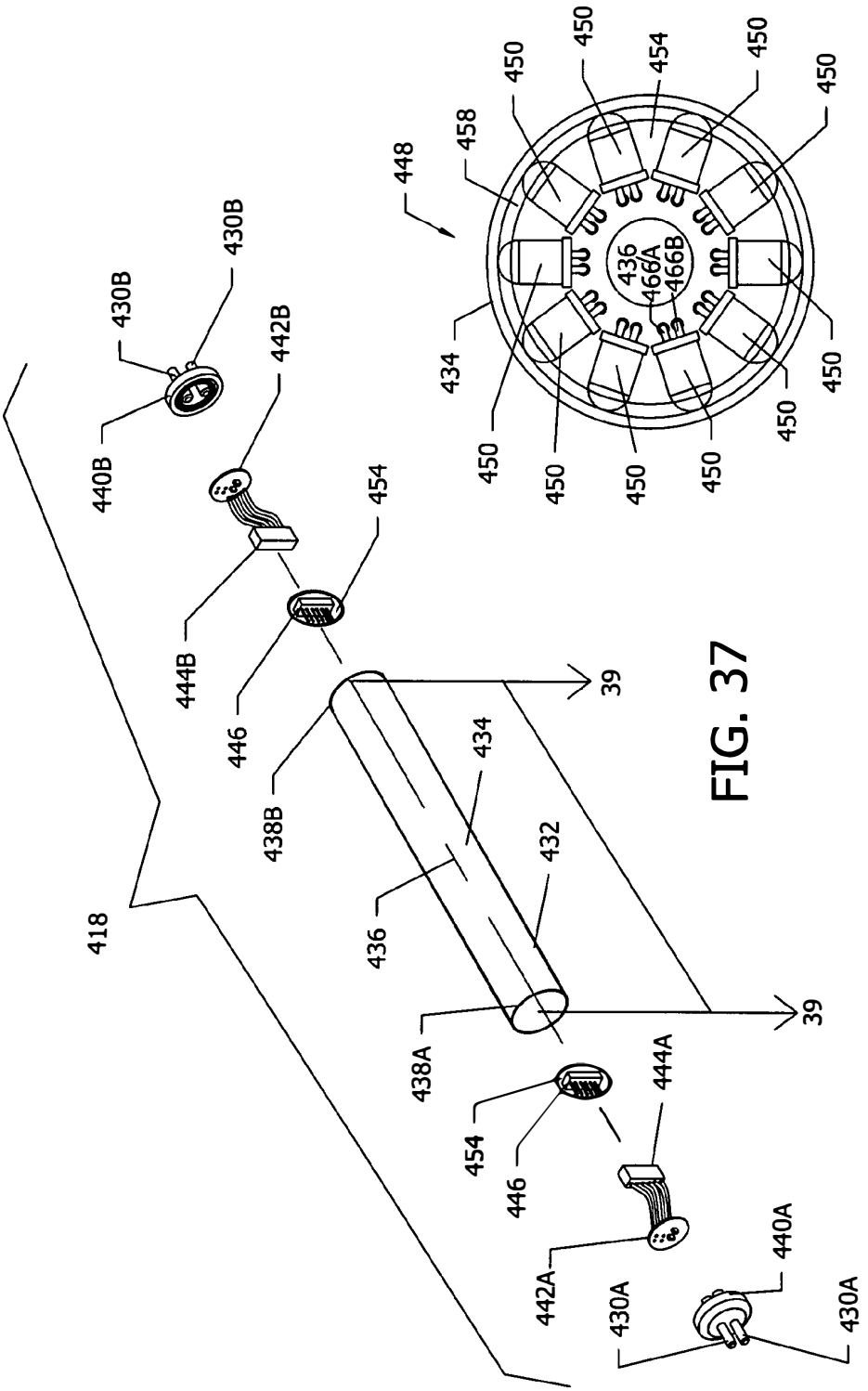

418
430B
430B
440B
442B
444B
446
454
438B
434
432
436
438A
39
39
454
446
444A
442A
440A
430A
430A
448
458
450
450
450
450
450
450
450
450
450
450
434
436
466A
466B

FIG. 37

FIG. 38

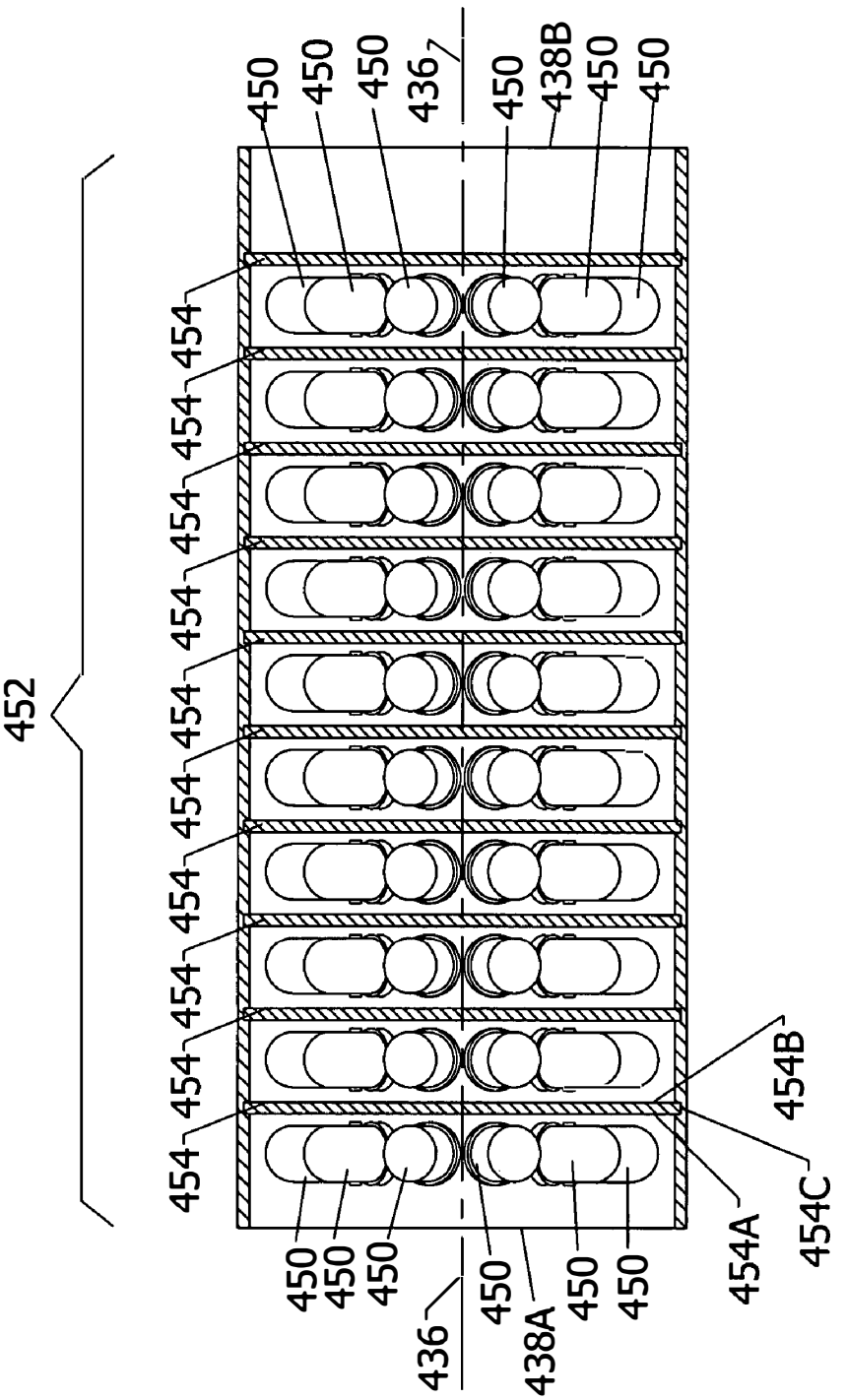


FIG. 39

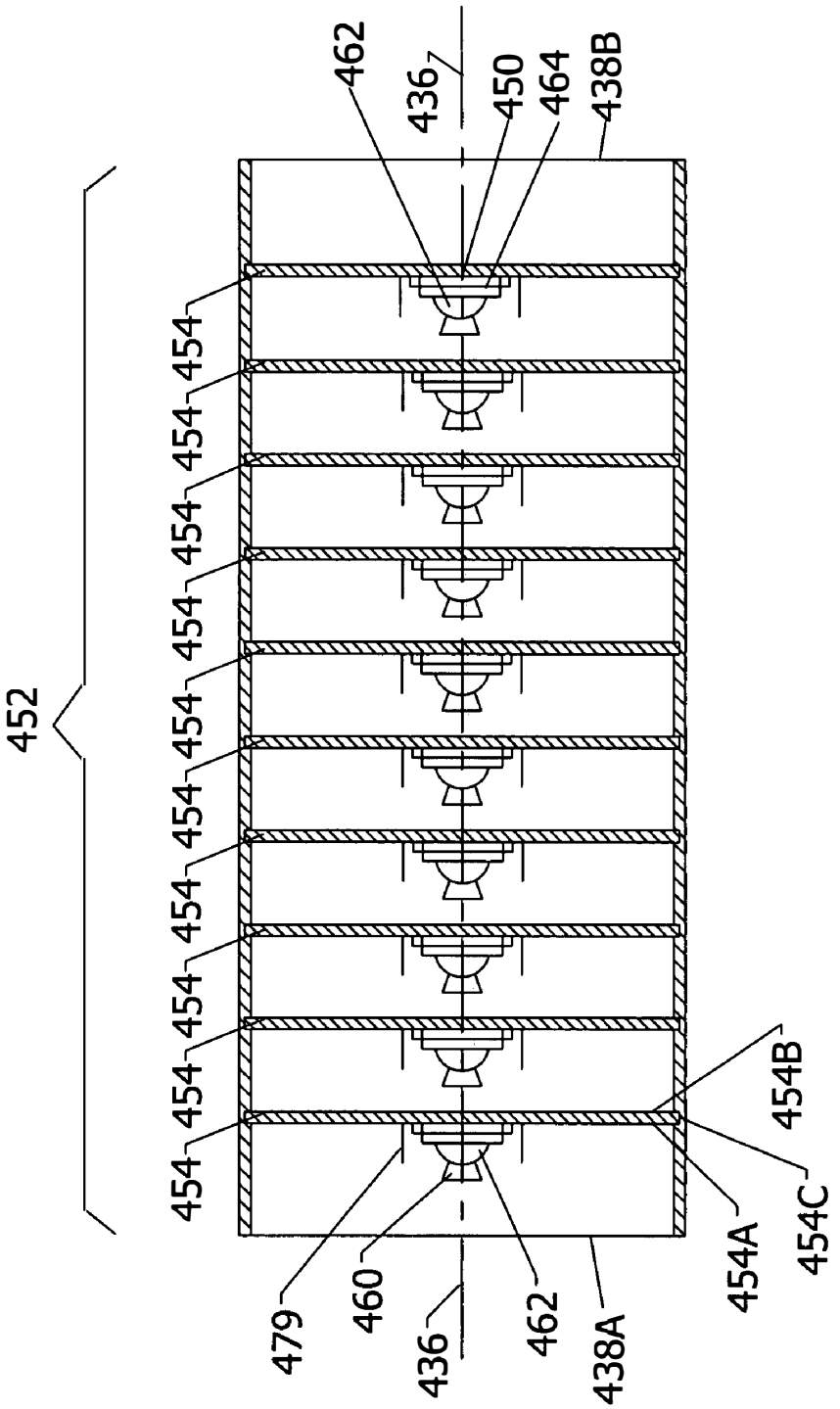

462
436
450
464
438B
454
454
454
454
454
454
454
454
454
452
454B
454C
454A
479
460
436
462
438A

FIG. 39A

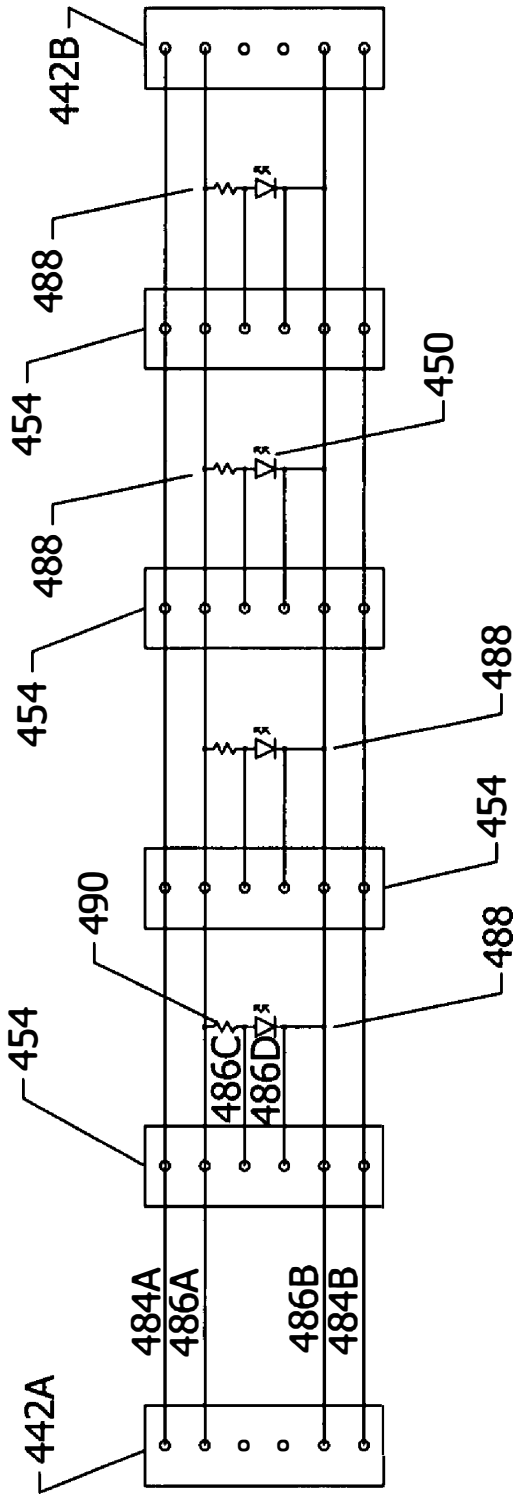

442B
488
454
450
488
454
488
454
490
488
454
486C
486D
484A
486A
486B
484B
442A

FIG. 39B

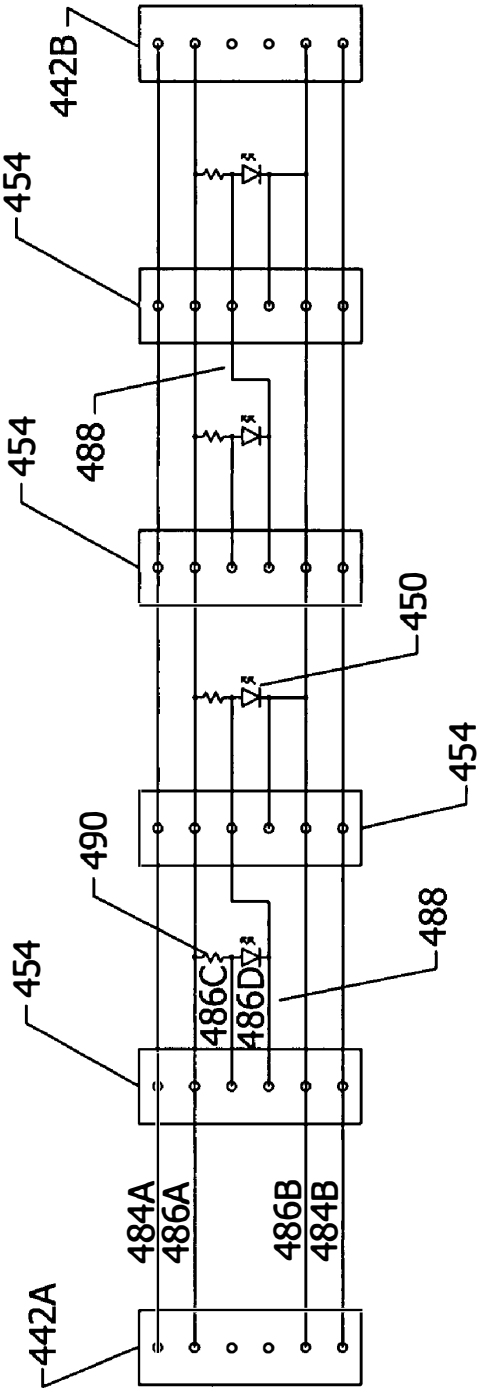

442B
454
488
454
450
454
490
488
454
486C
486D
484A
486A
486B
484B
442A

FIG. 39C

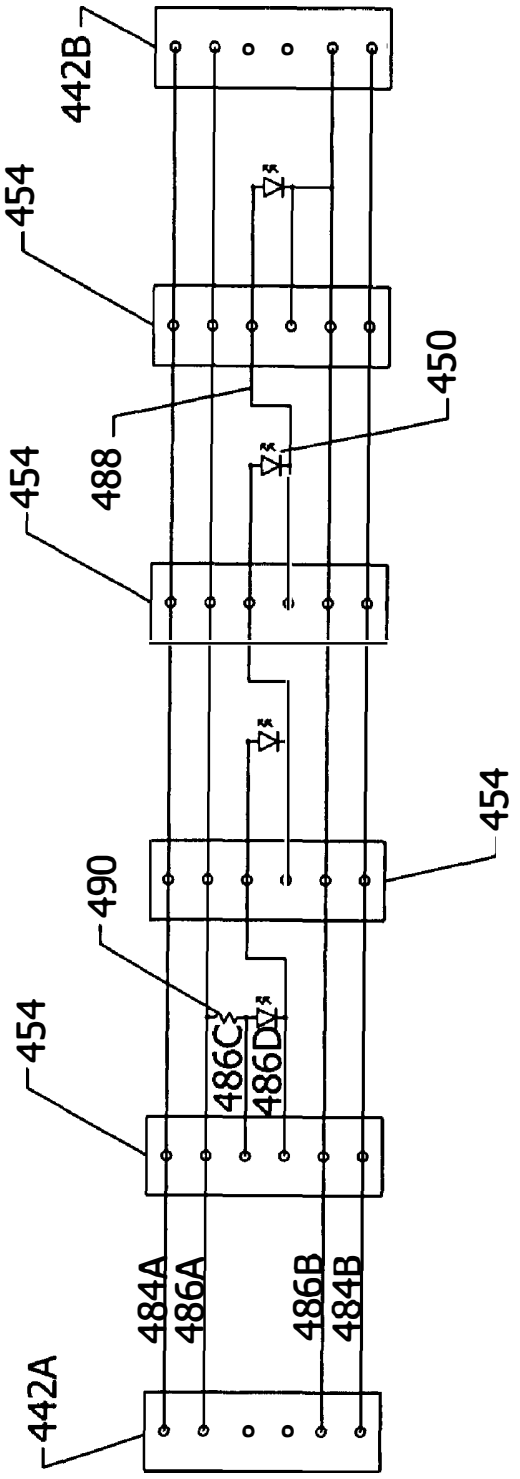

442B
454
450
488
454
454
490
486C
486D
454
484A
486A
486B
484B
442A

FIG. 39D

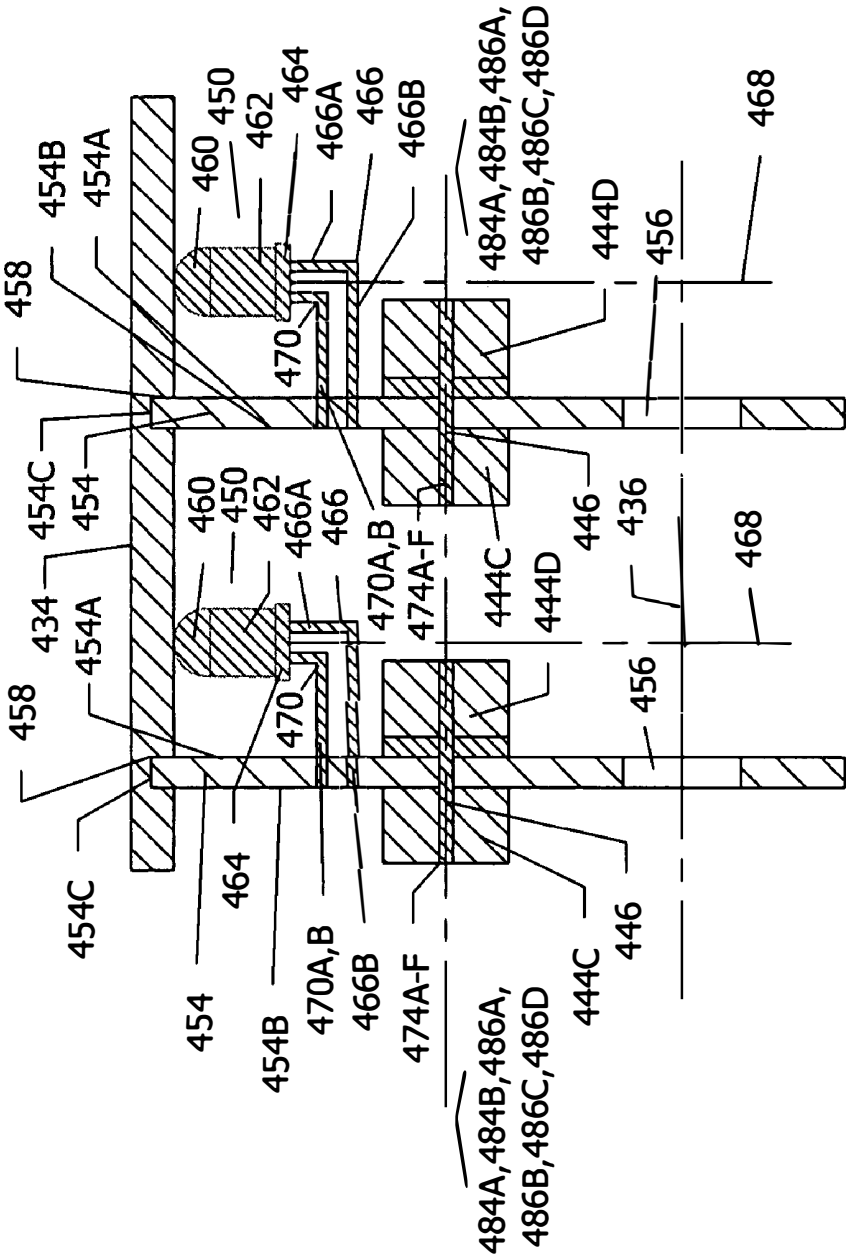

458
454B
454A
460
450
462
464
466A
466
466B
484A,484B,486A,
486B,486C,486D
444D
456
468
470
454C
454
460
450
462
466A
466
470A,B
474A-F
444C
444D
446
436
468
434
454A
458
470
456
454C
464
454
454B
470A,B
466B
474A-F
444C
446
484A,484B,486A,
486B,486C,486D

FIG. 40

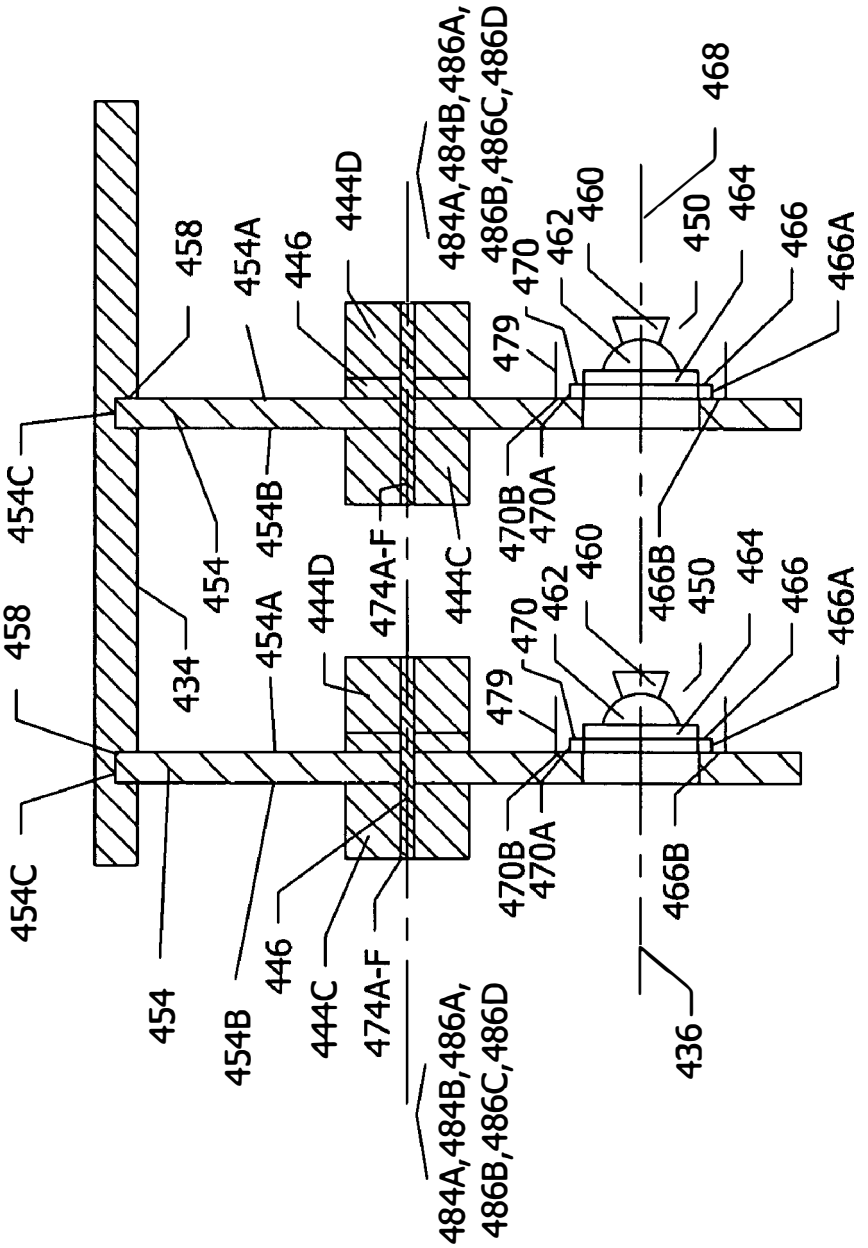

454C
458
434
454
454A
454B
444D
474A-F
444C
446
484A,484B,486A,
486B,486C,486D
470
462
460
479
470B
470A
466B
450
464
466
466A
468
436

FIG. 40A

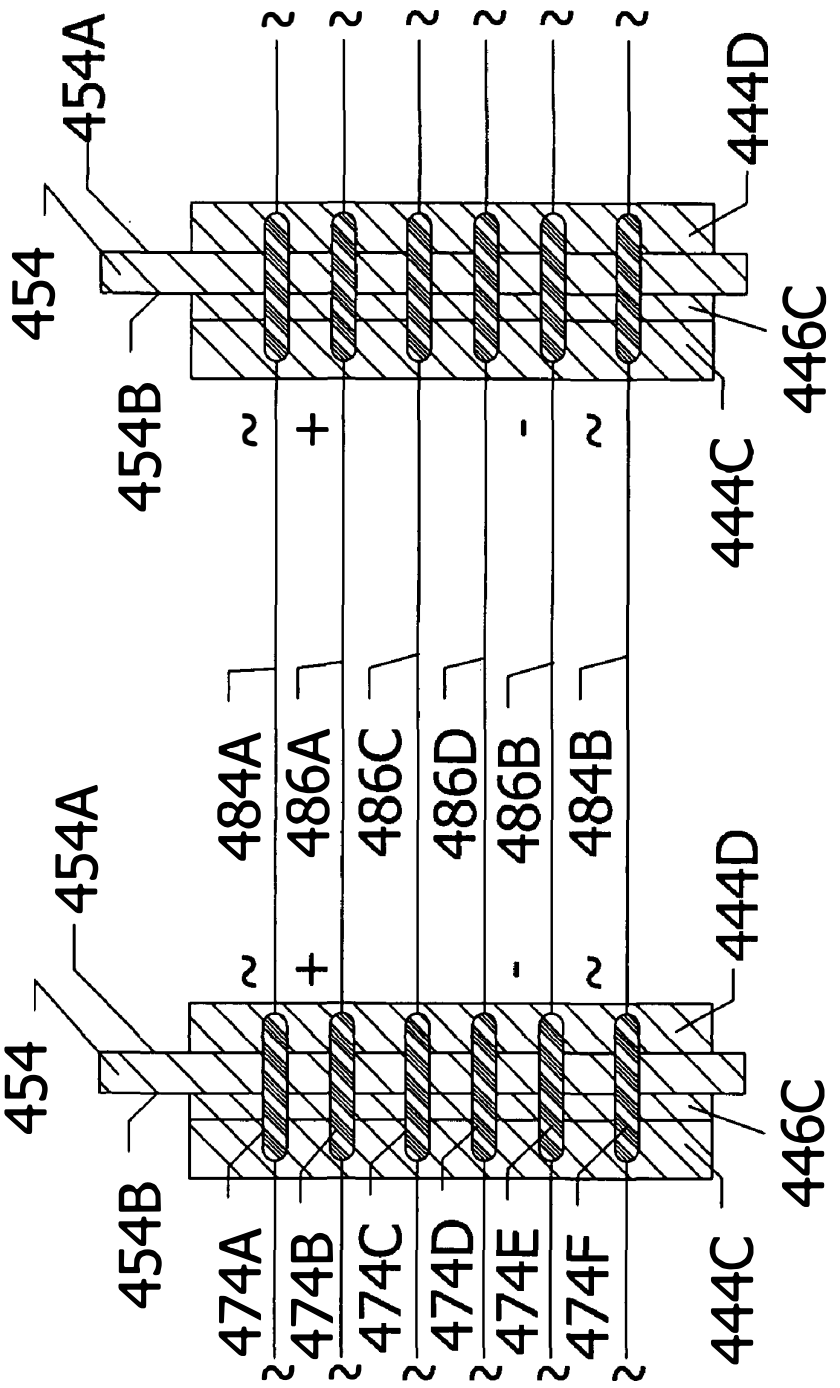

454A
454
454B
444D
446C
444C
484A
486A
486C
486D
486B
484B
474A
474B
474C
474D
474E
474F
+
-

FIG. 40B

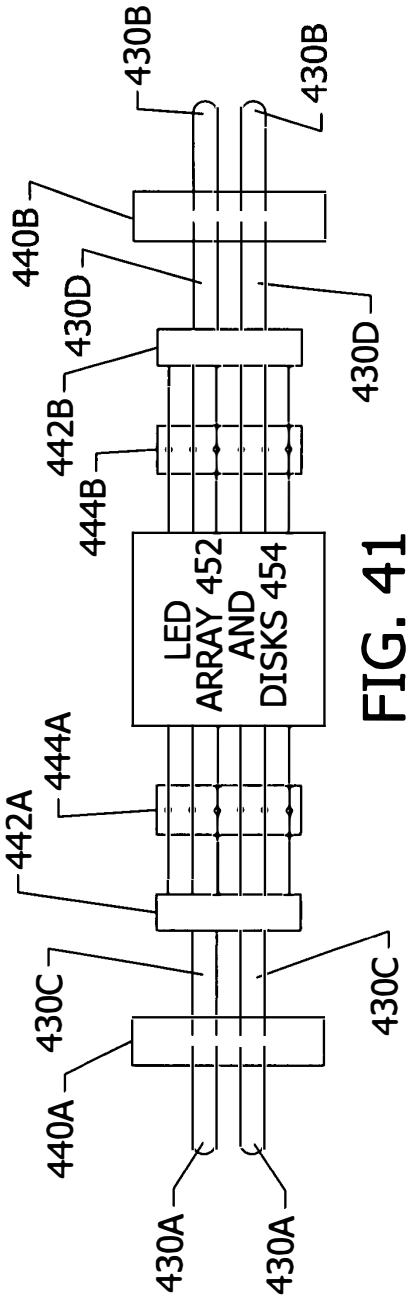


FIG. 41

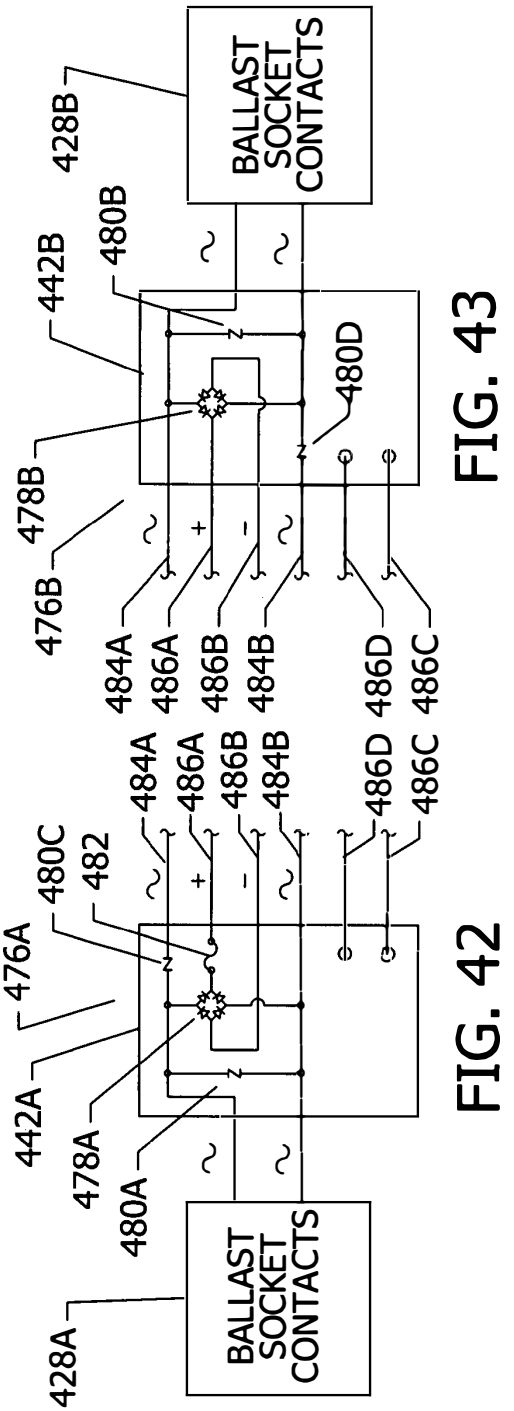


FIG. 42

FIG. 43

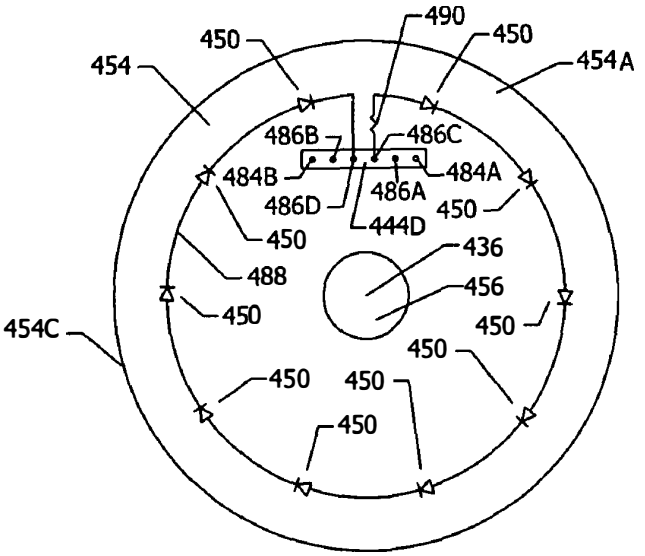


FIG. 44

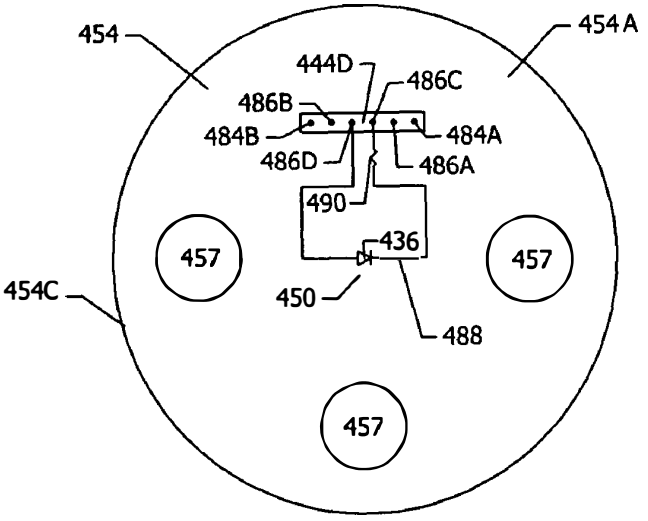


FIG. 44A

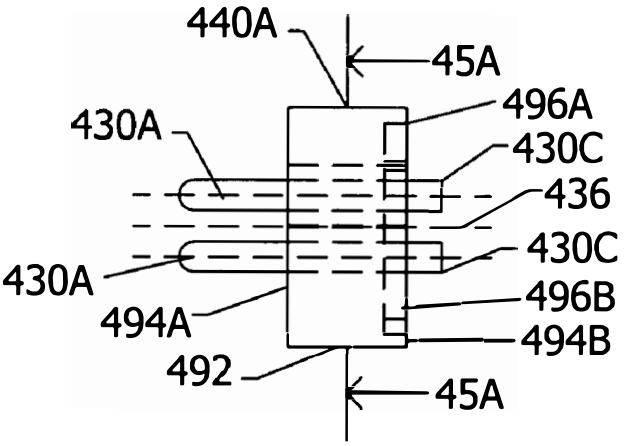


FIG. 45

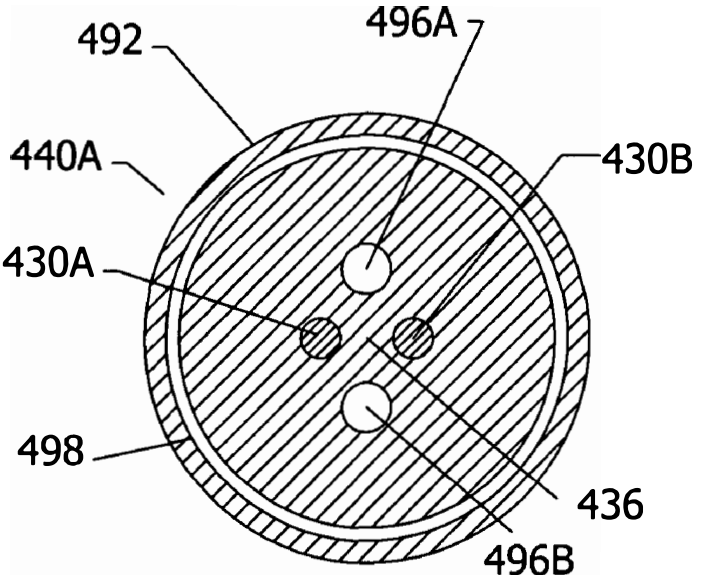


FIG. 45A

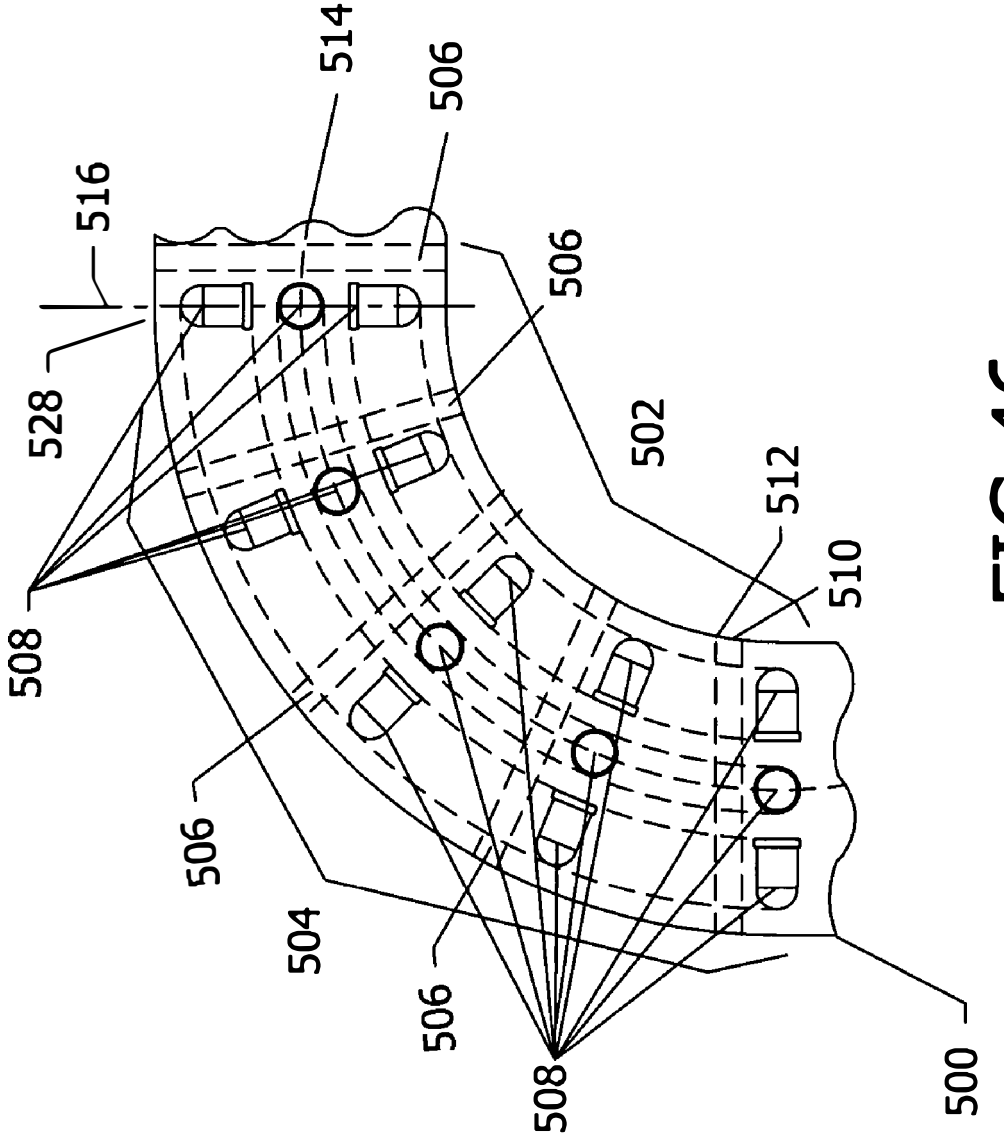


FIG 46

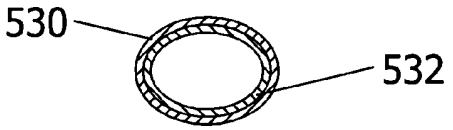


FIG. 47

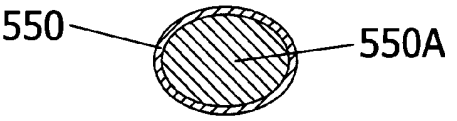


FIG. 48

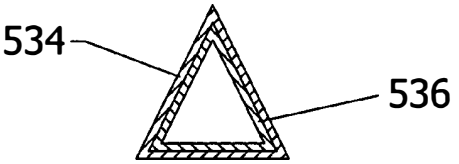


FIG. 47A

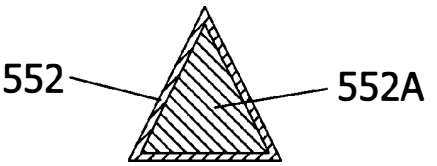


FIG. 48A

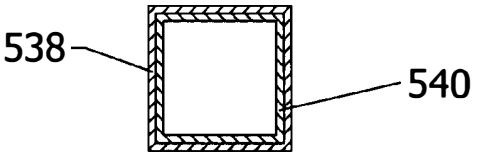


FIG. 47B

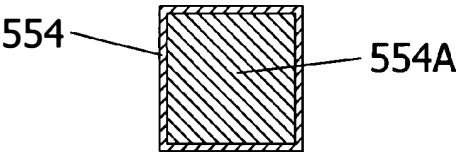


FIG. 48B

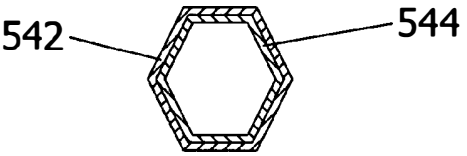


FIG. 47C

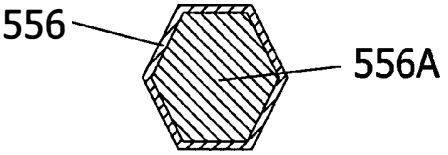


FIG. 48C

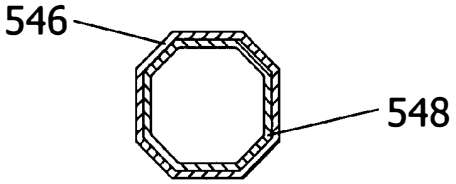


FIG. 47D

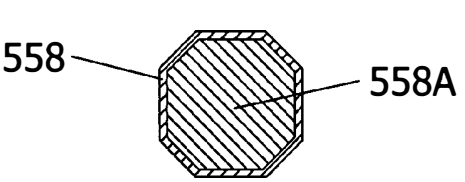


FIG. 48D

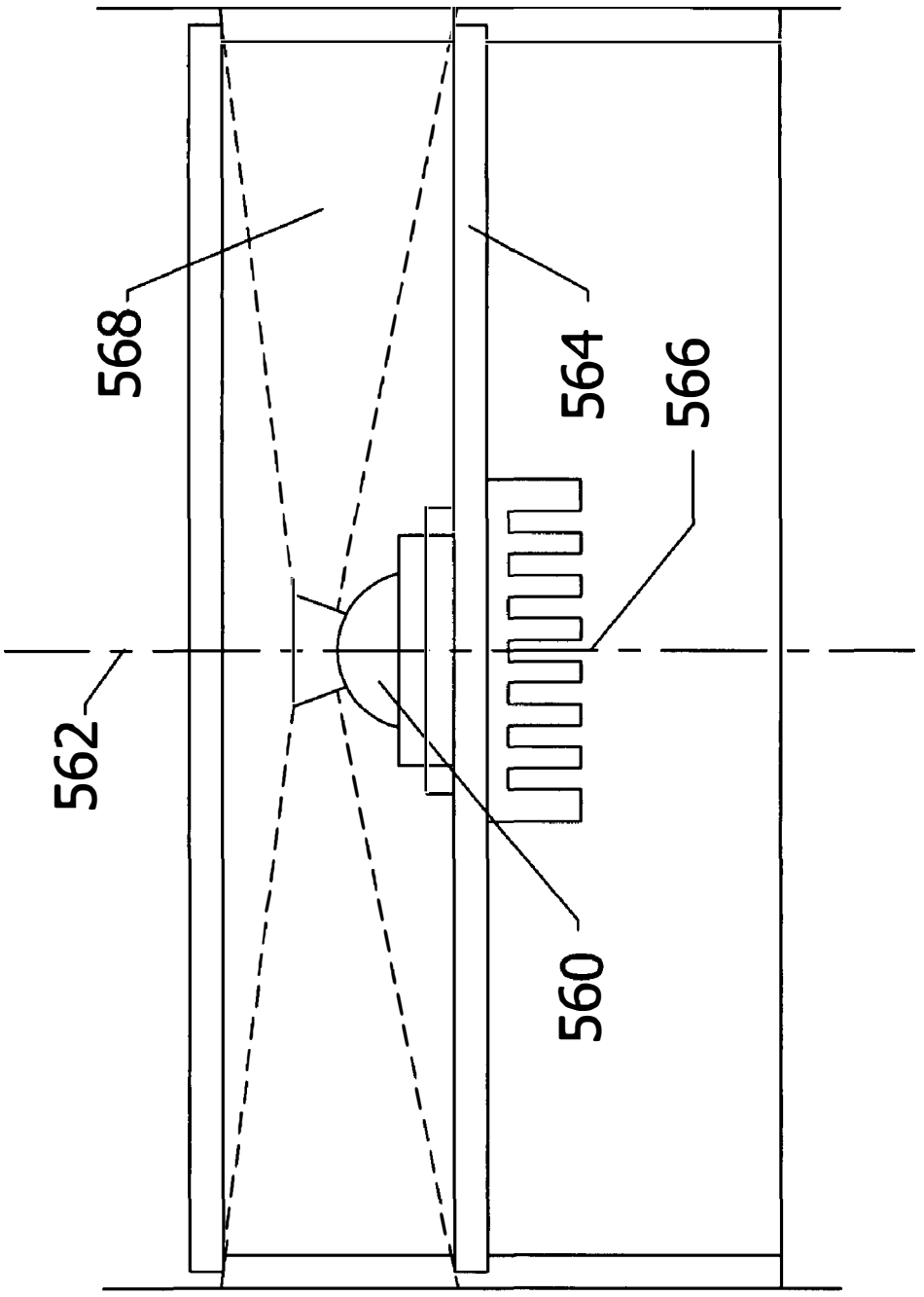


FIG. 49

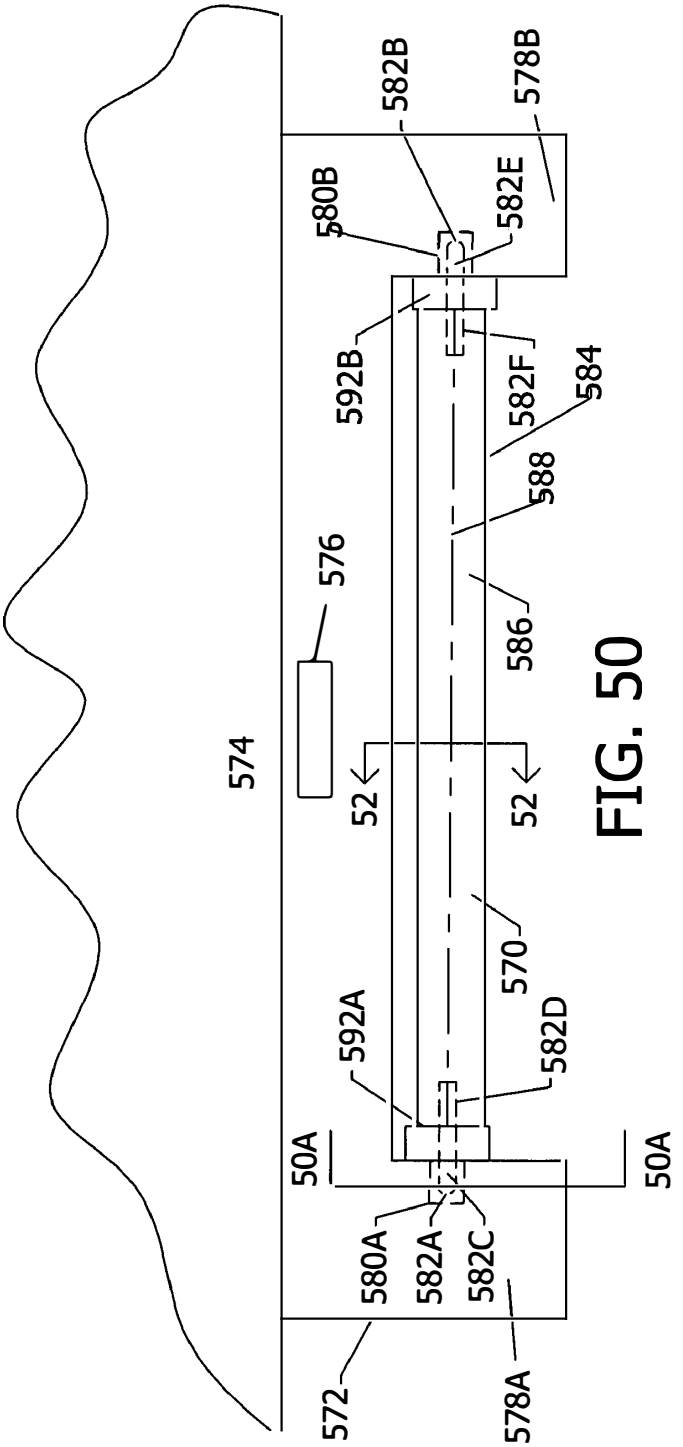


FIG. 50

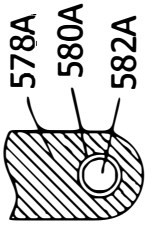


FIG. 50A

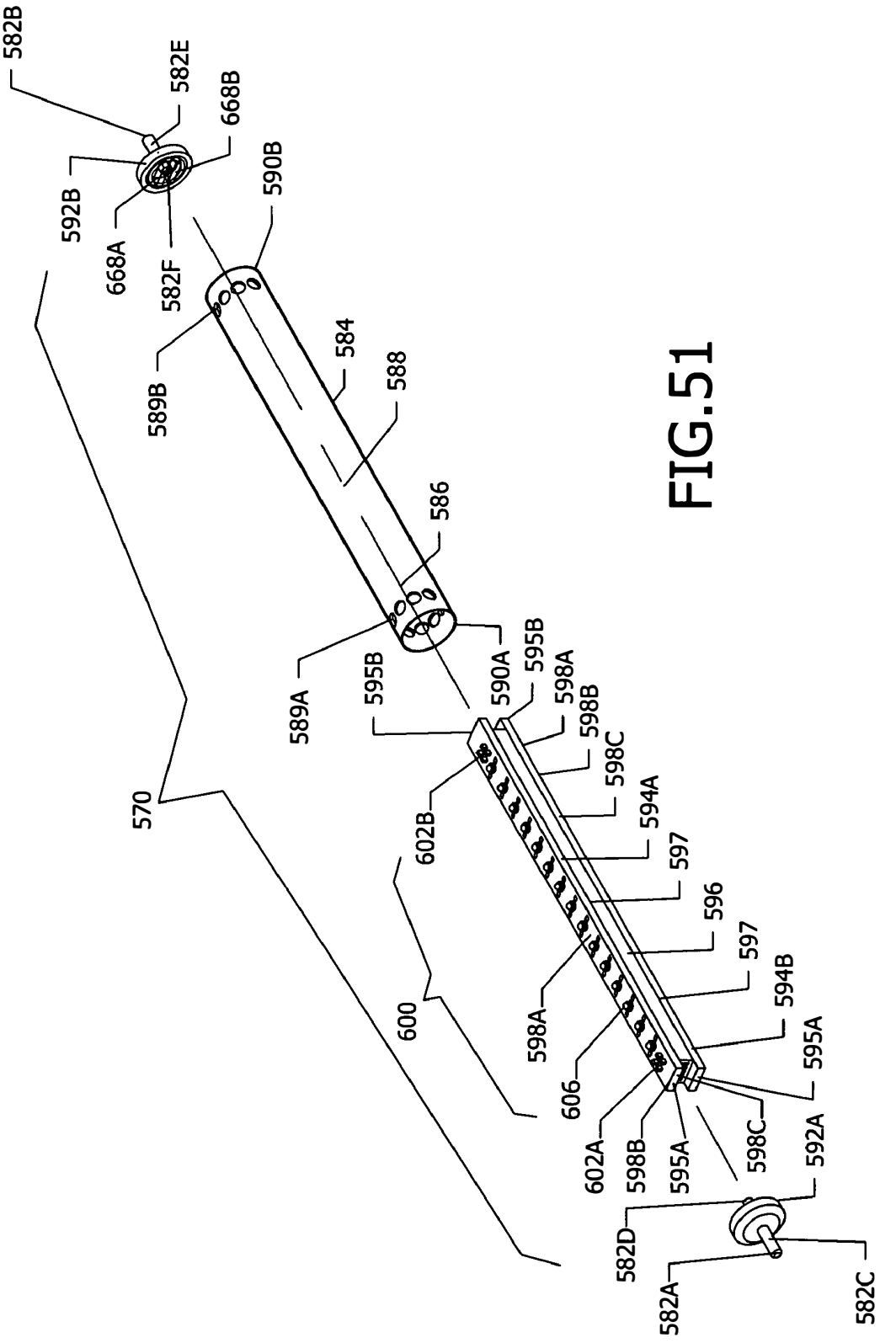

582B
582E
668B
590B
592B
668A
582F
589B
584
588
586
589A
595B
590A
595B
598A
598B
598C
594A
597
596
597
594B
595A
570
602B
600
598A
606
602A
598B
595A
598C
592A
582D
582A
582C

FIG.51

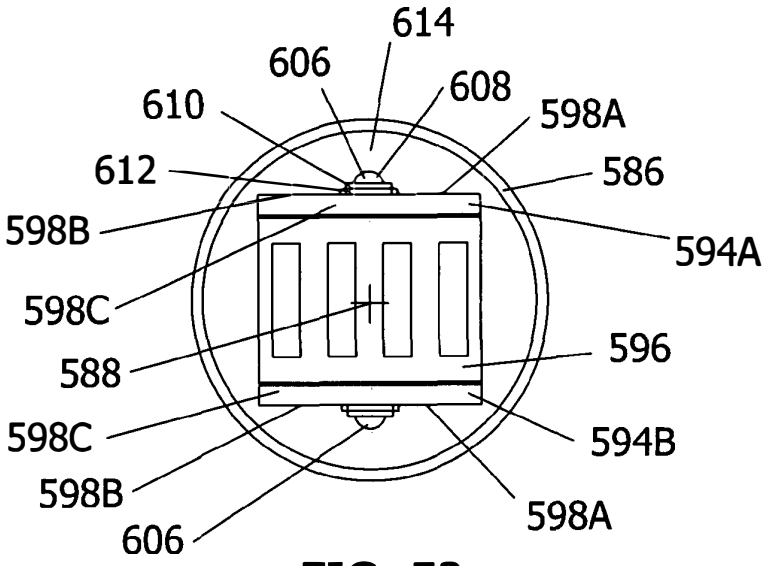


FIG. 52

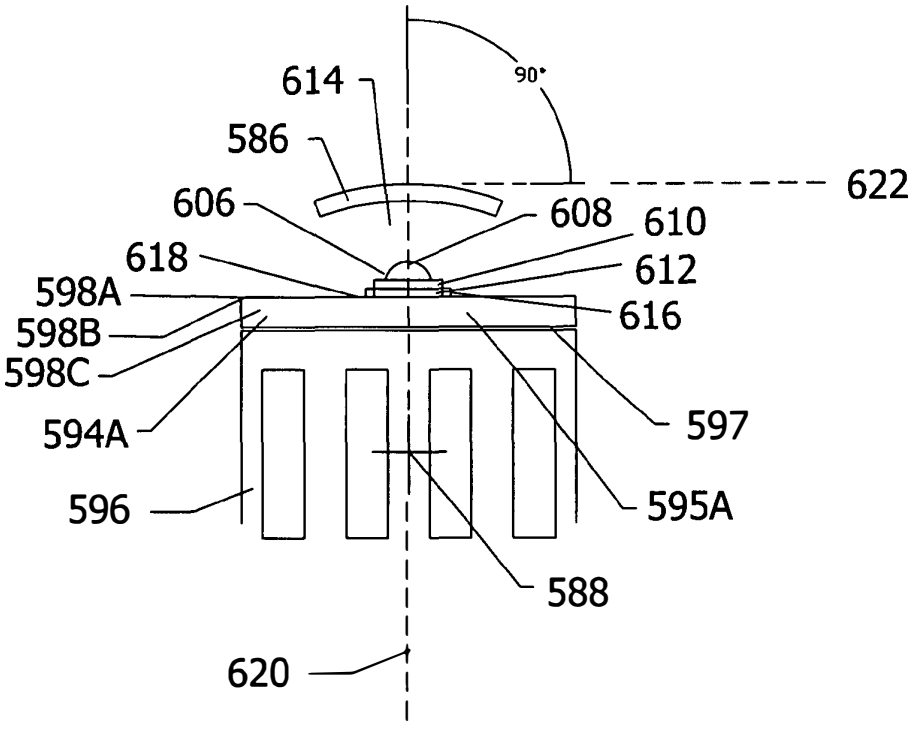


FIG. 52A

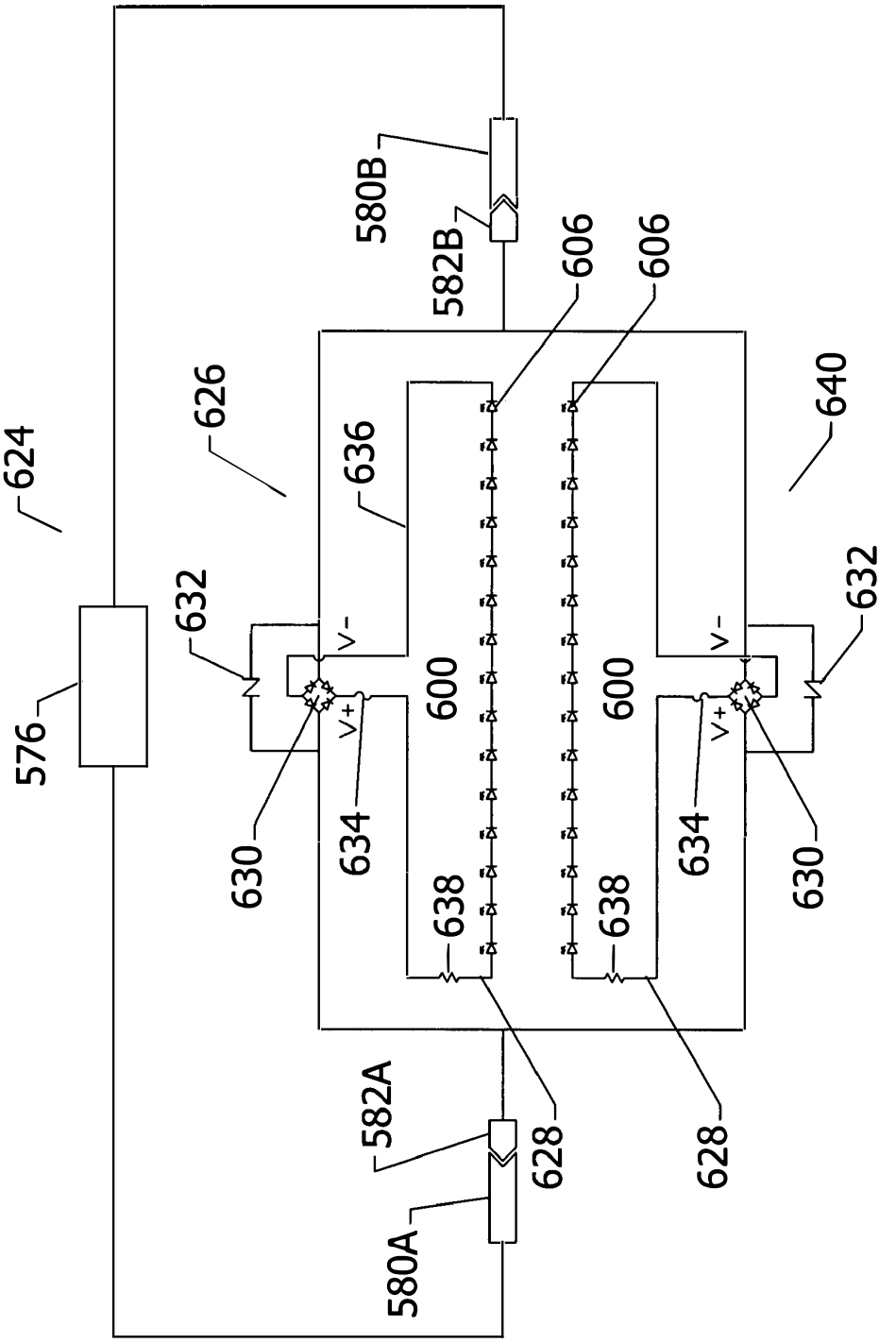

580B
582B
606
606
626
636
640
624
632
632
V-
V-
576
600
600
V+
V+
630
634
638
638
634
630
582A
628
628
580A

FIG. 53

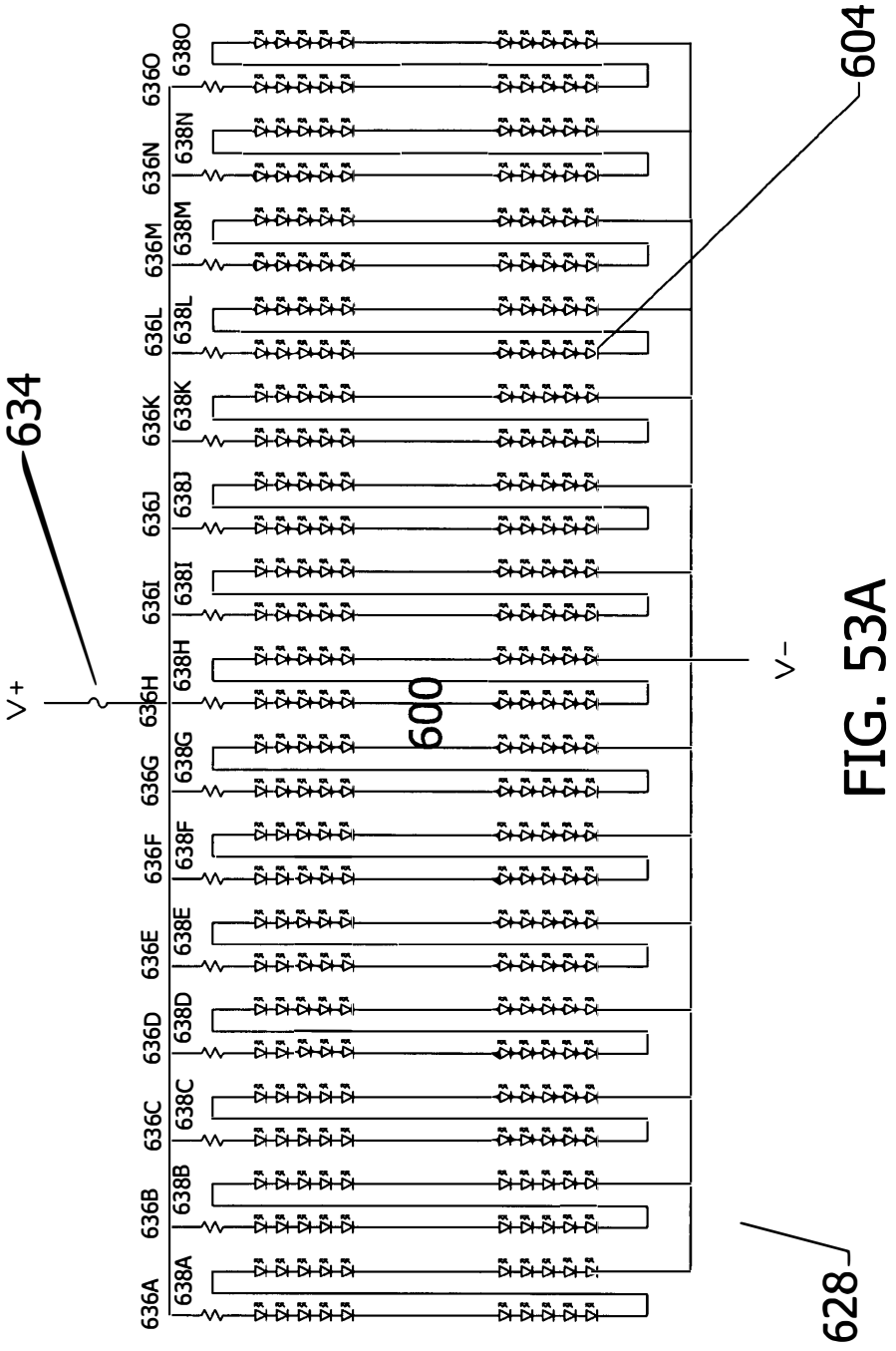

604
634
V+
V−
600
628
636O
636N
636M
636L
636K
636J
636I
636H
636G
636F
636E
636D
636C
636B
636A
638O
638N
638M
638L
638K
638J
638I
638H
638G
638F
638E
638D
638C
638B
638A

FIG. 53A

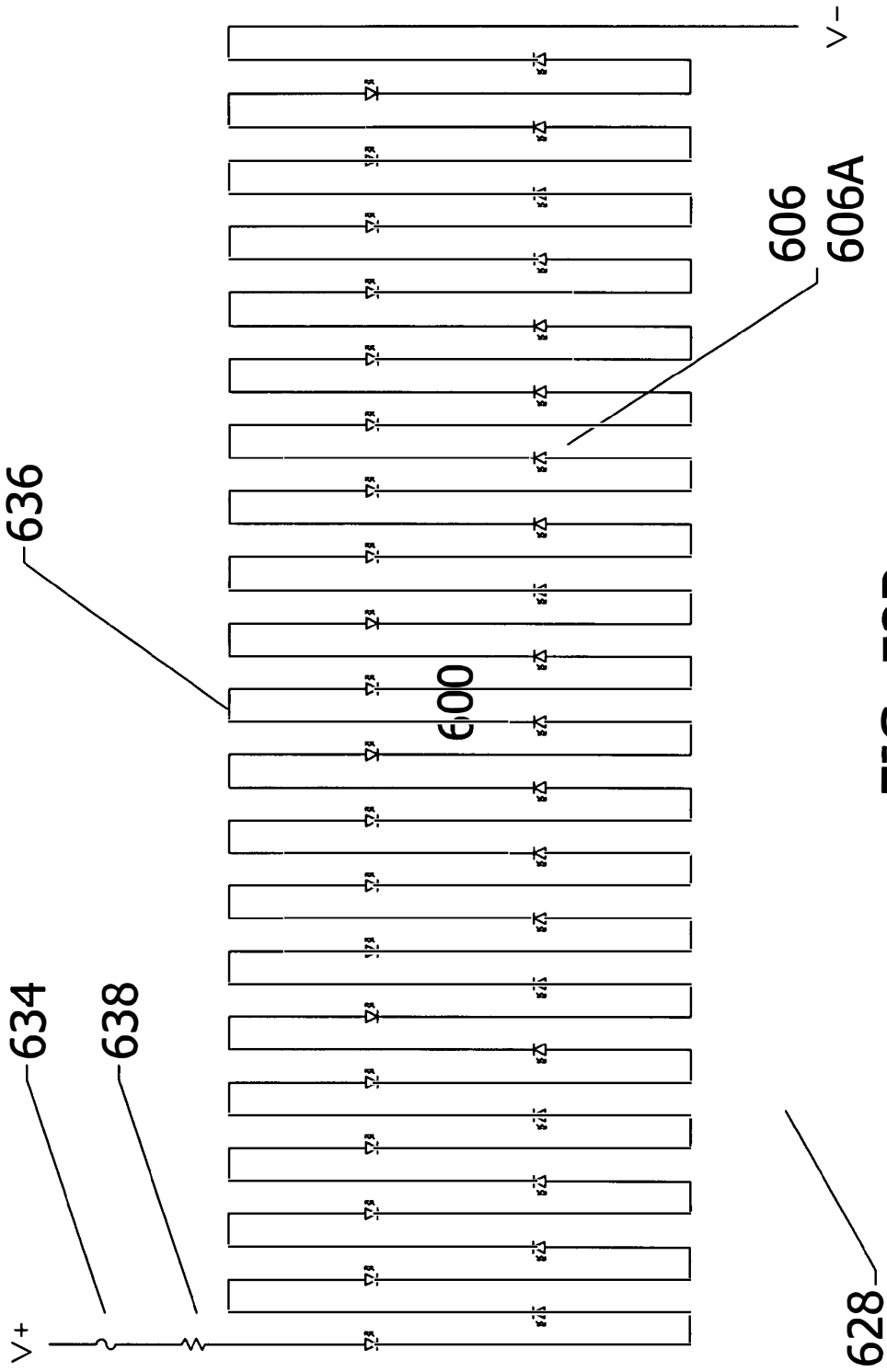


FIG. 53B

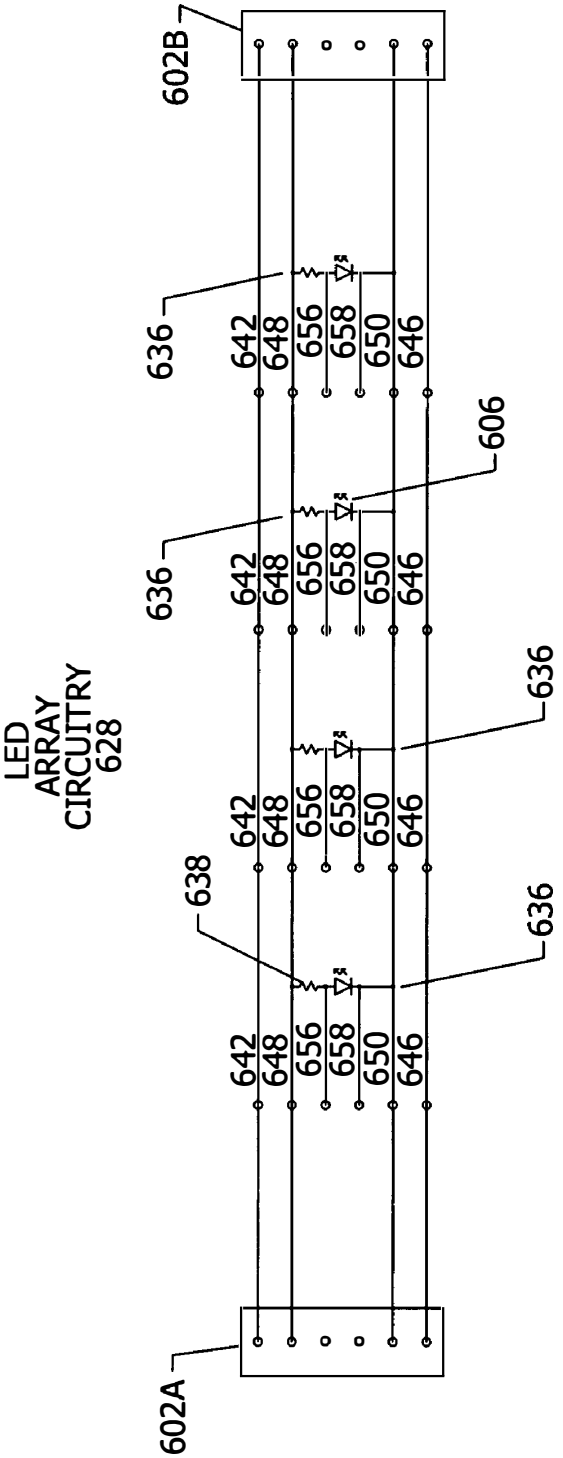

LED
ARRAY
CIRCUITRY
628
602B
602A
636
606
638
642
648
656
658
650
646

FIG. 53C

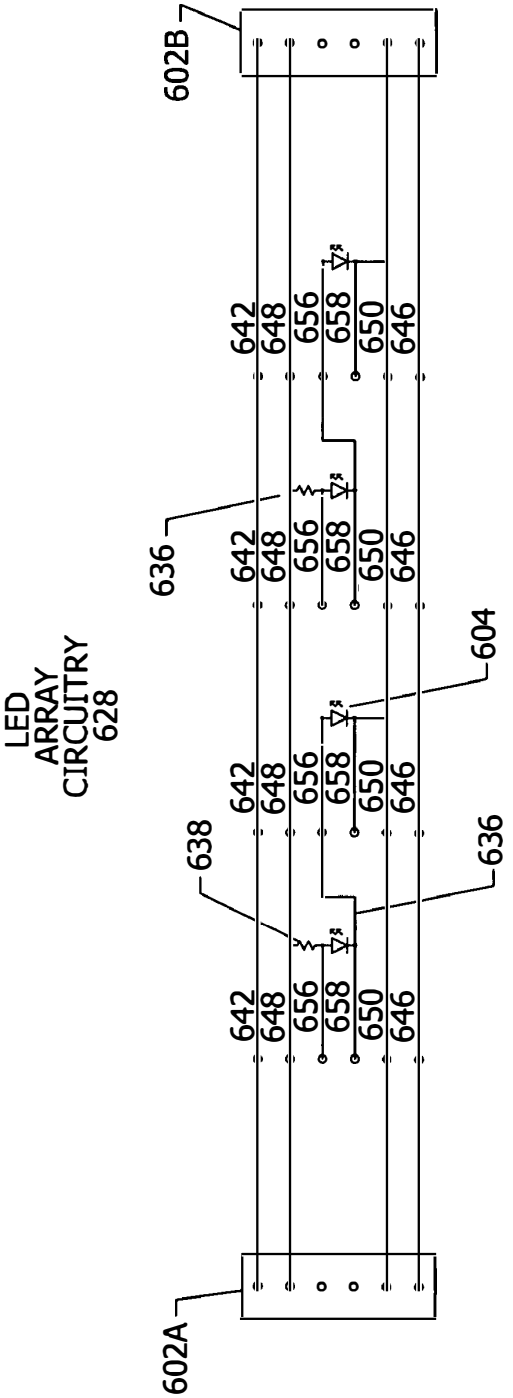

602B
642
648
656
658
650
646
636
604
638
602A
LED
ARRAY
CIRCUITRY
628

FIG. 53D

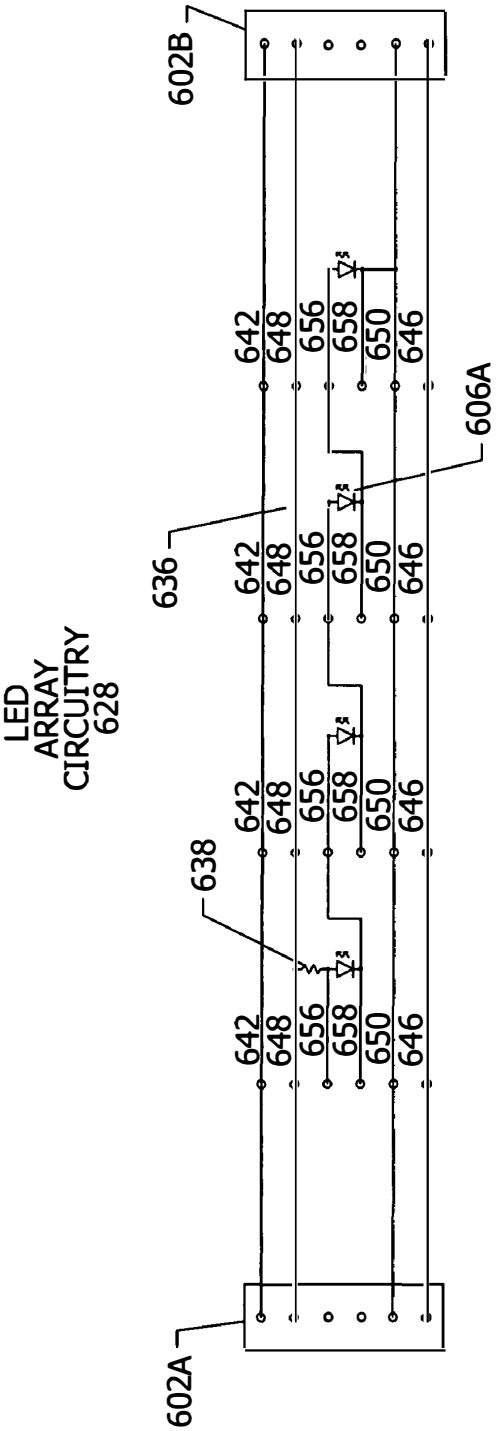

602B
642
648
656
658
650
646
606A
636
638
602A
LED
ARRAY
CIRCUITRY
628

FIG. 53E

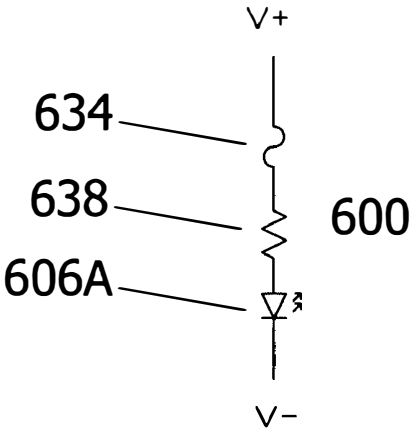


FIG. 53F

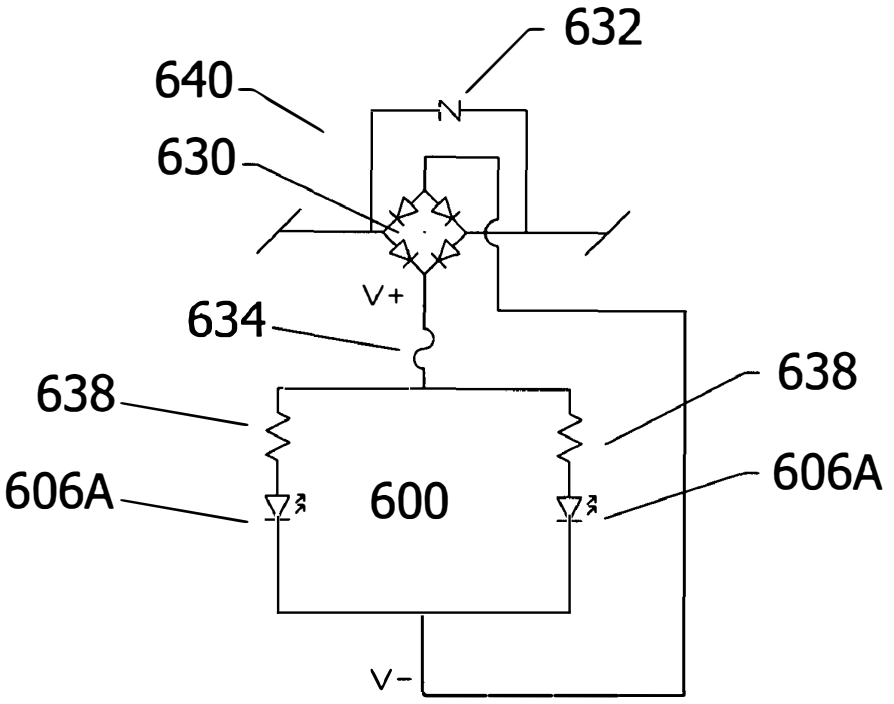


FIG. 53G

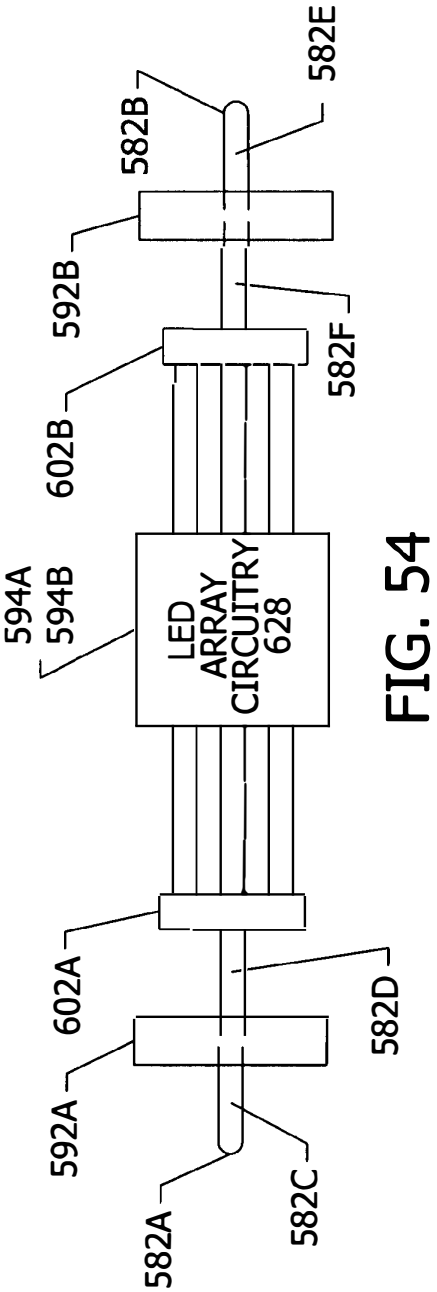


FIG. 54

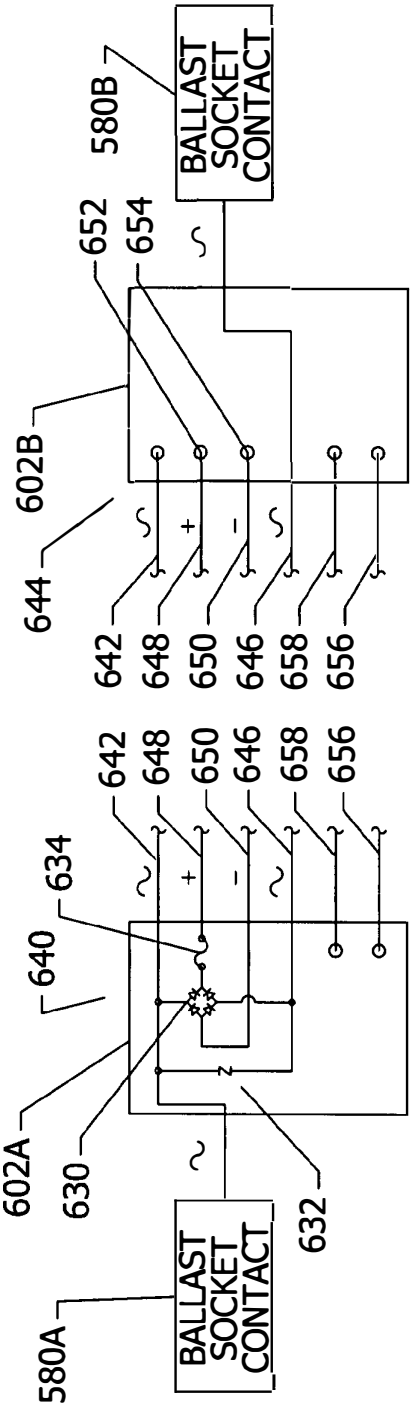


FIG. 56

FIG. 55

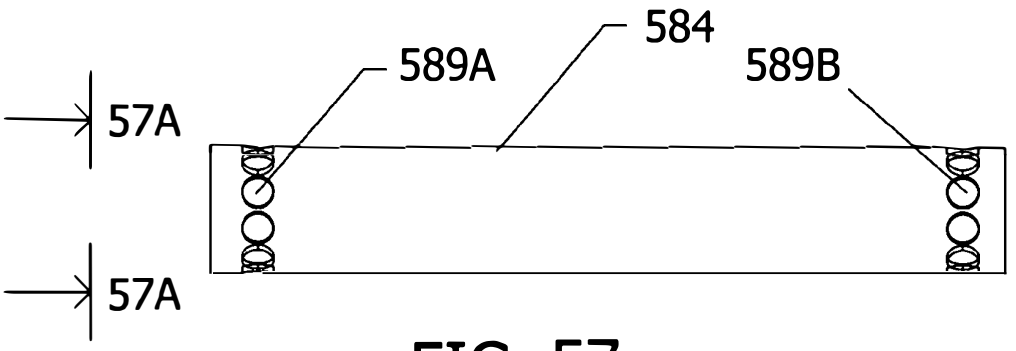


FIG. 57

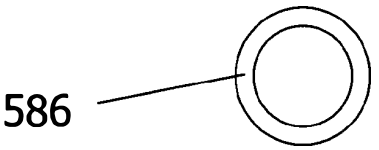


FIG. 57A

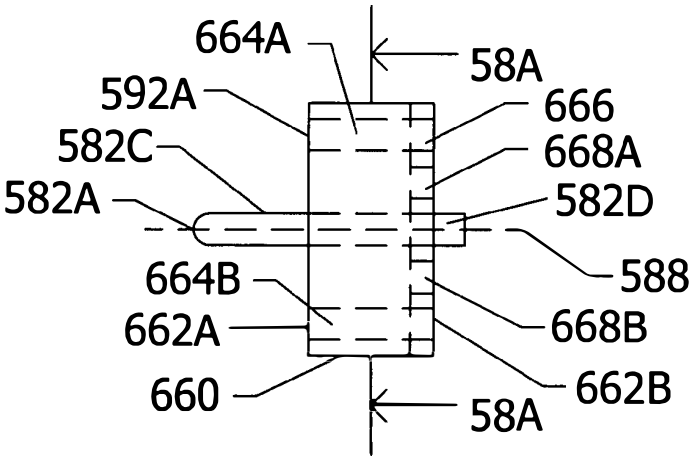


FIG. 58

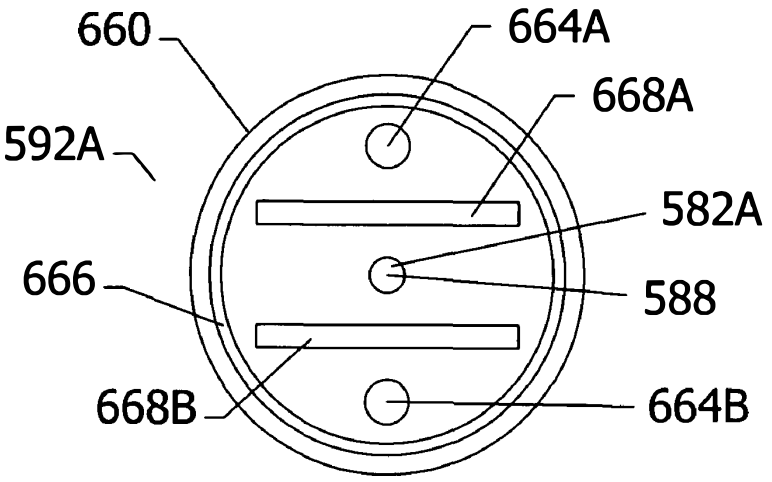


FIG. 58A

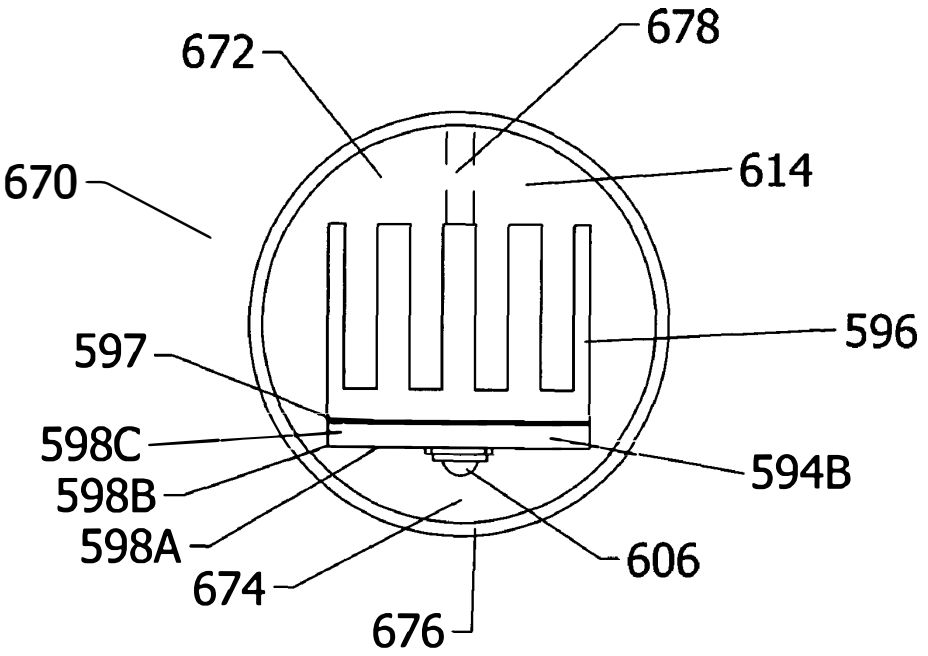


FIG. 59

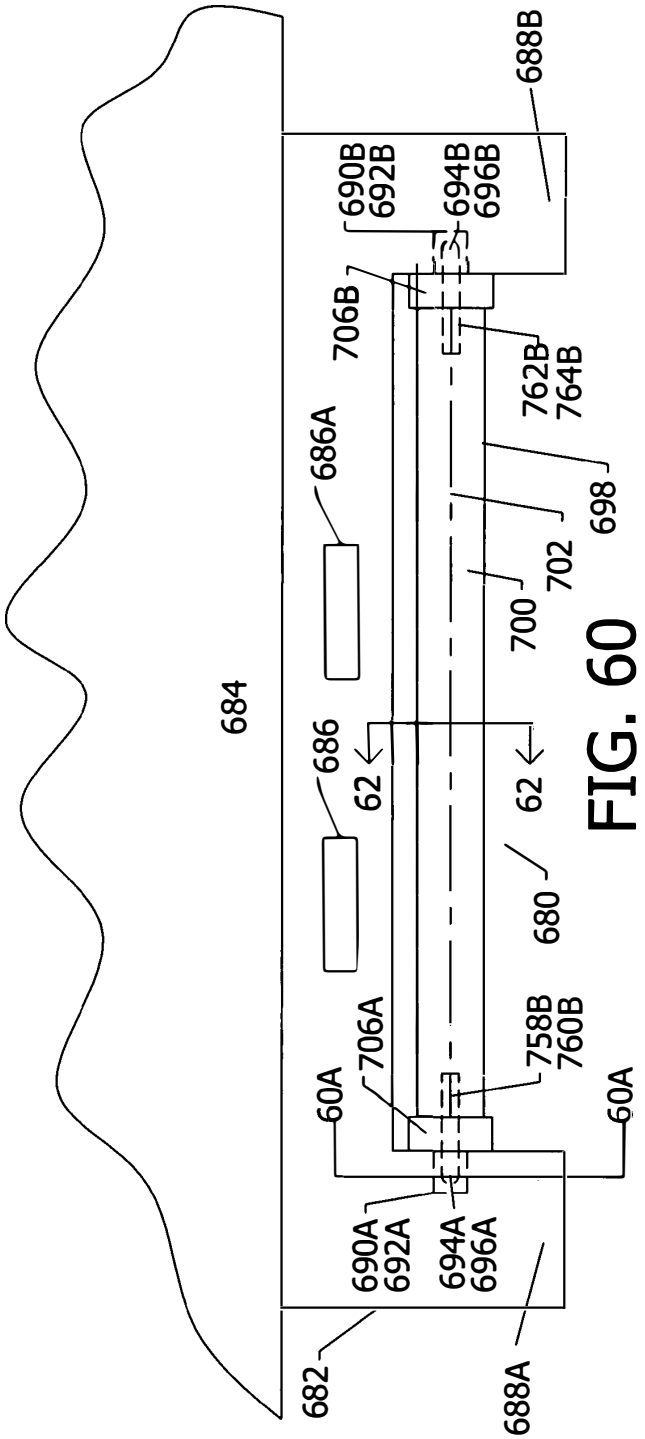


FIG. 60

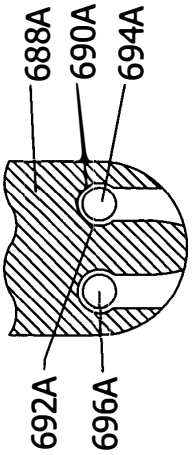


FIG. 60A

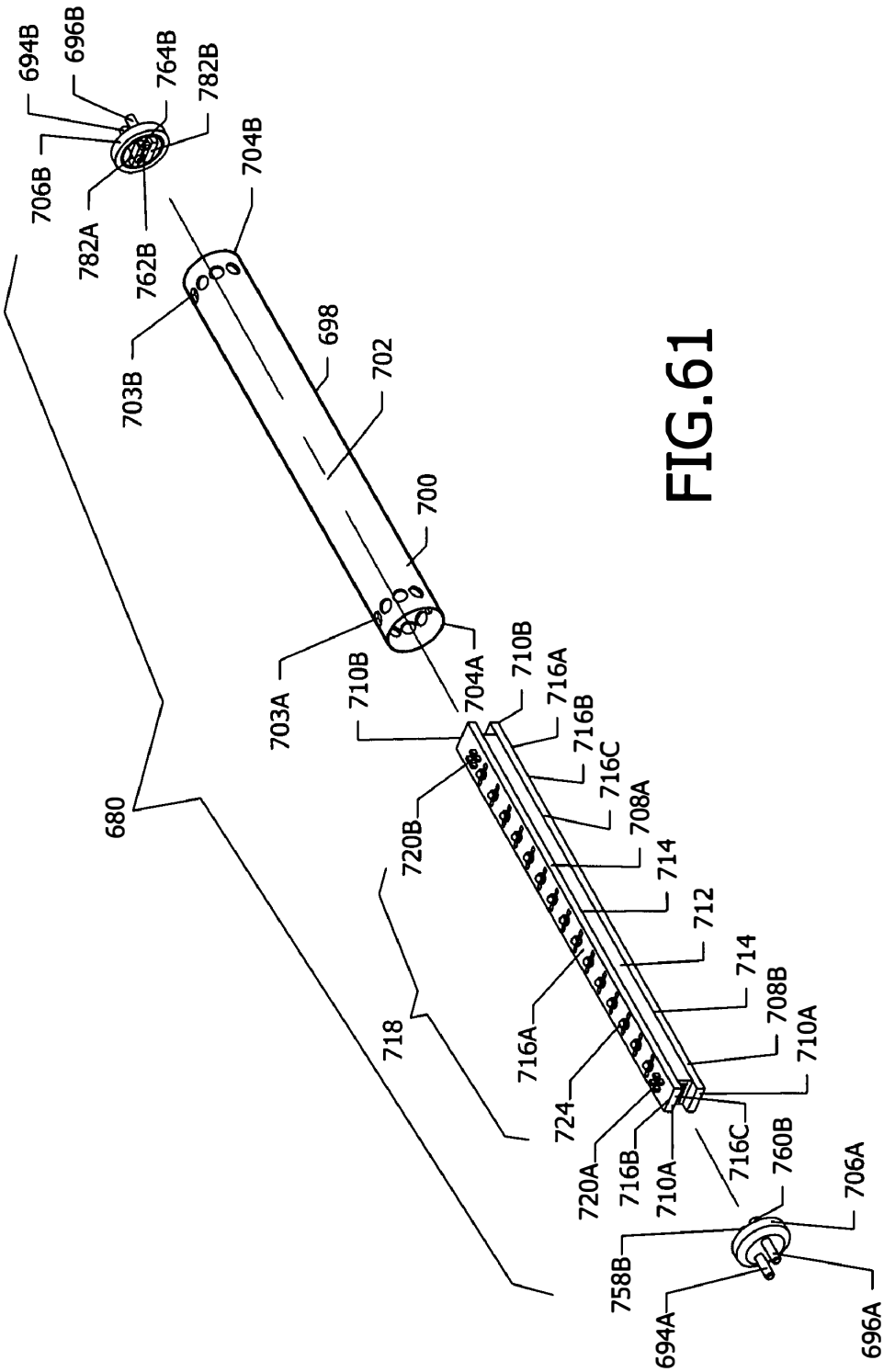

694B
696B
764B
782B
704B
706B
782A
762B
703B
698
702
700
703A
710B
704A
710B
716A
716B
716C
708A
680
720B
714
712
714
708B
710A
718
716A
724
720A
716B
710A
716C
760B
706A
758B
694A
696A

FIG.61

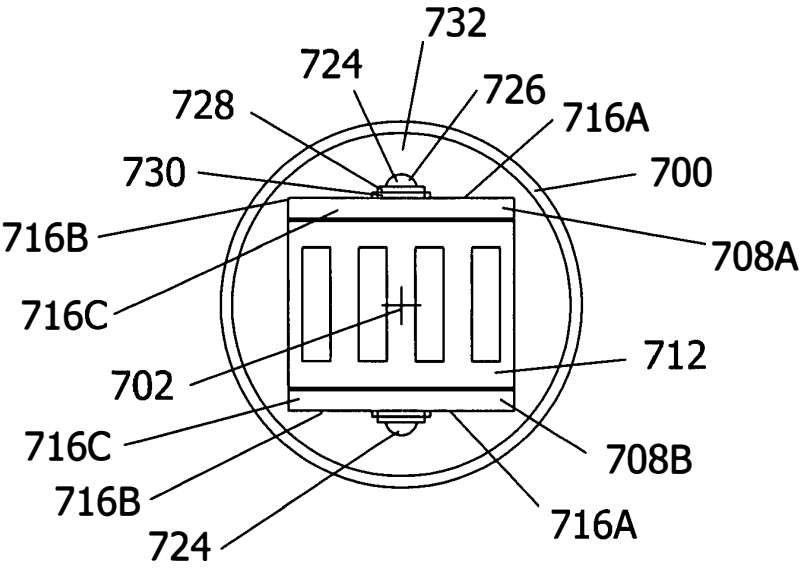


FIG. 62

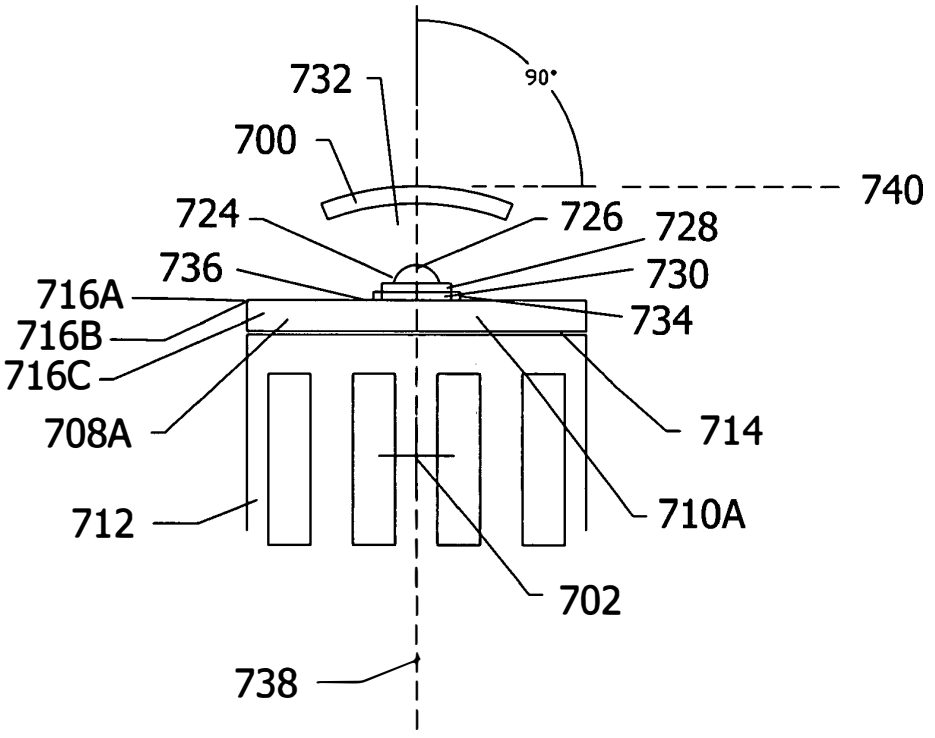


FIG. 62A

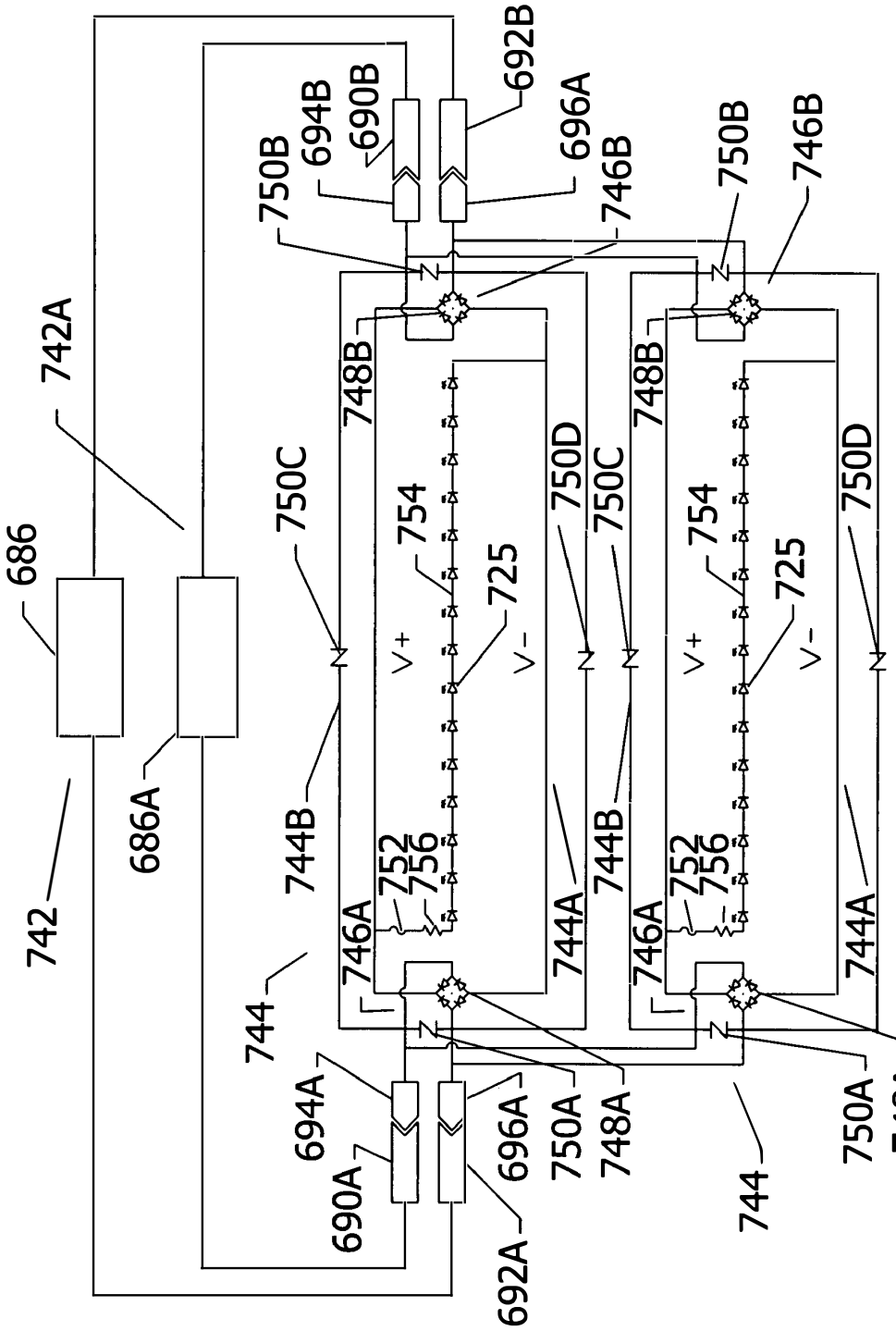

692B
694B
690B
696A
750B
746B
742A
748B
750C
754
750D
686
725
V+
V-
744B
752
756
746A
744A
742
686A
744
694A
696A
750A
748A
690A
692A

FIG. 63

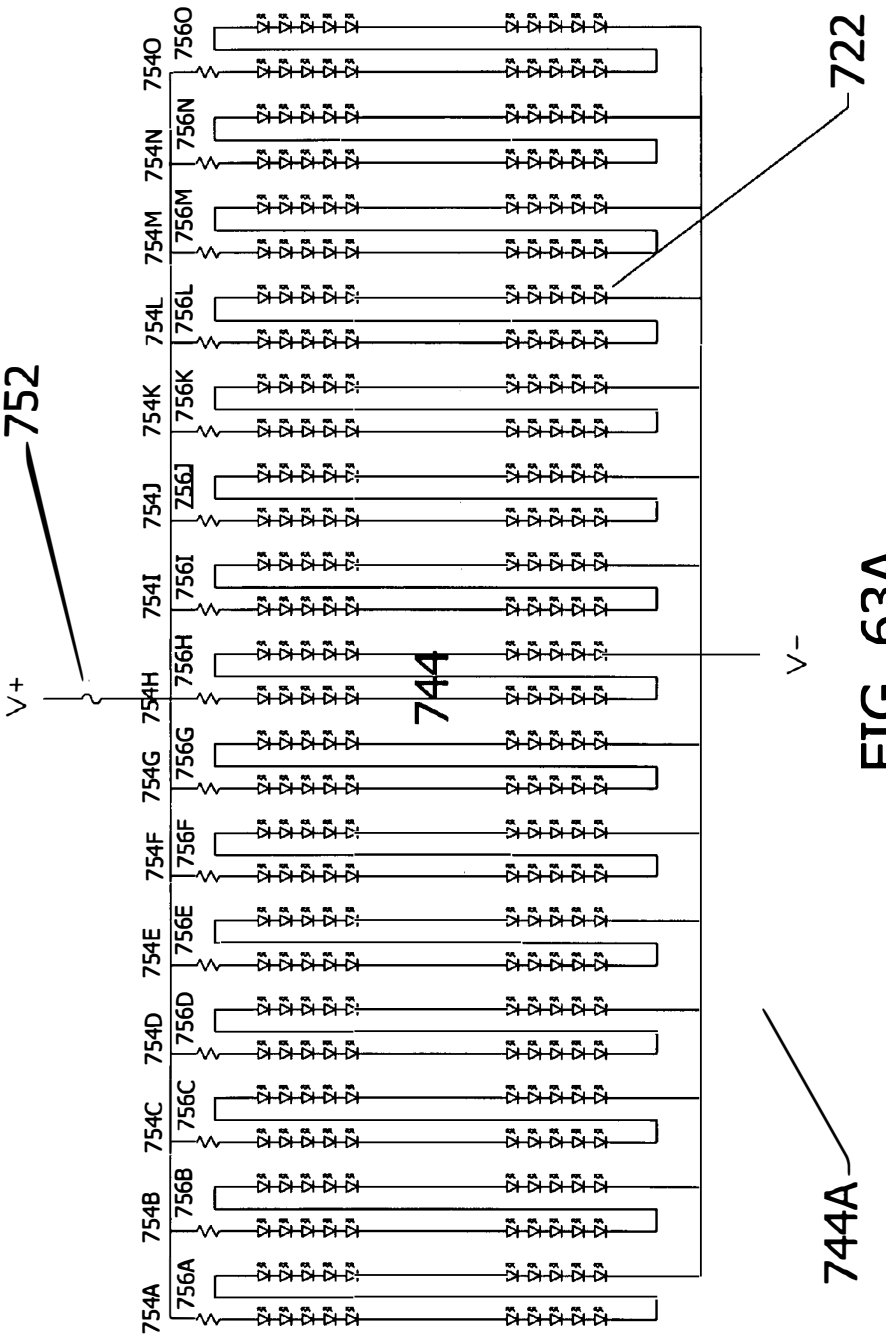

752
722
744
744A
V+
V-
754O
754N
754M
754L
754K
754J
754I
754H
754G
754F
754E
754D
754C
754B
754A
756O
756N
756M
756L
756K
756J
756I
756H
756G
756F
756E
756D
756C
756B
756A

FIG. 63A

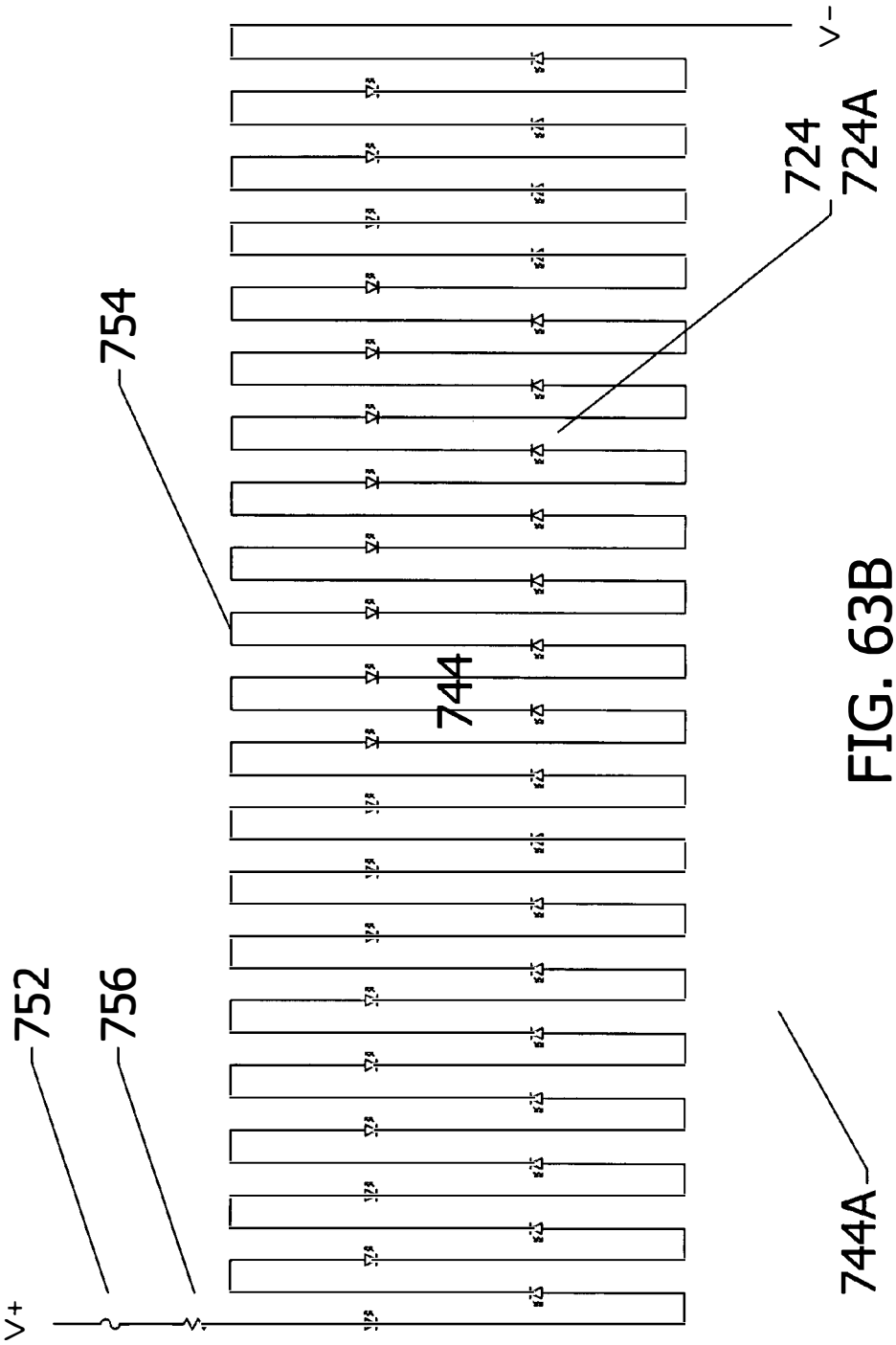


FIG. 63B

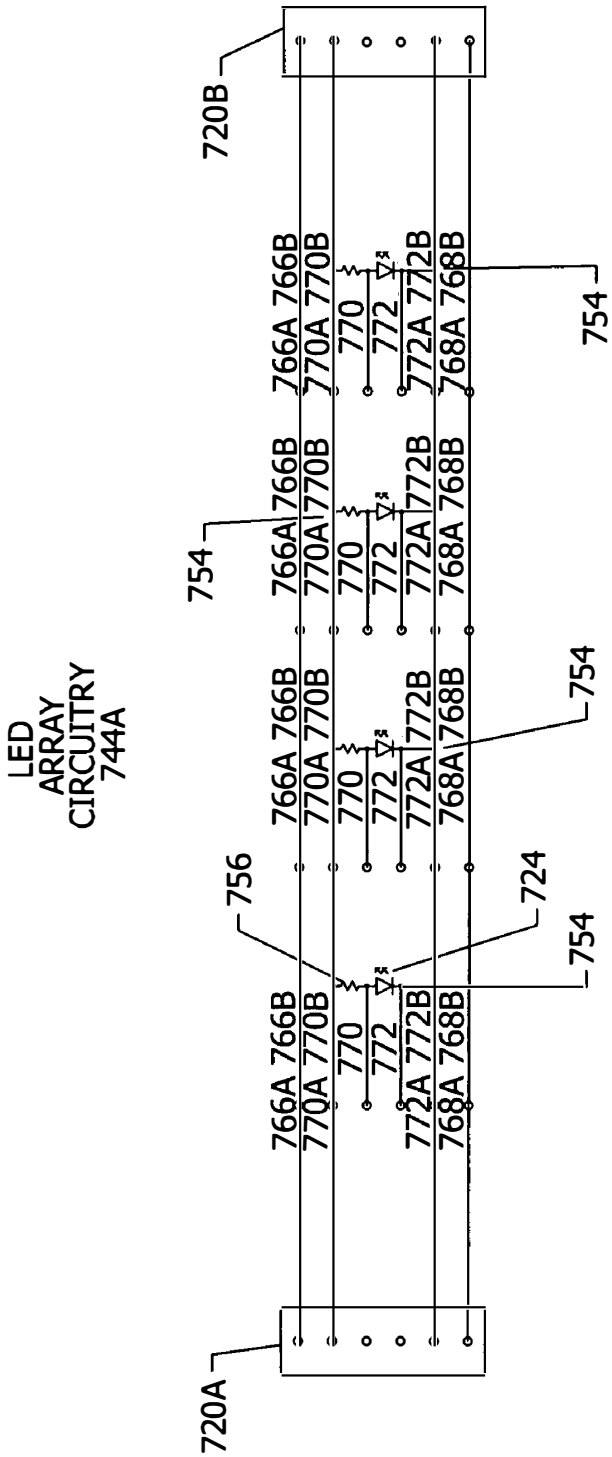

LED
ARRAY
CIRCUITRY
744A
720B
720A
754
756
724
766A 766B
770A 770B
770
772
772A 772B
768A 768B

FIG. 63C

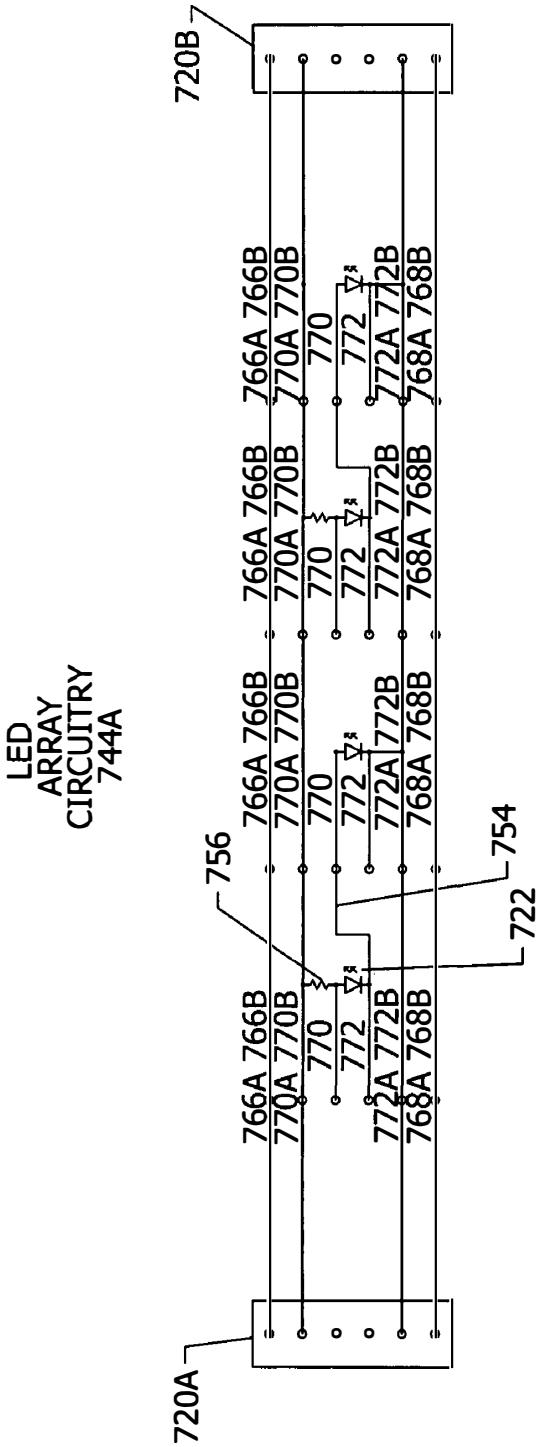

720B
720A
LED ARRAY CIRCUITRY 744A
756
754
722
766A 766B
770A 770B
770
772
772A 772B
768A 768B

FIG. 63D

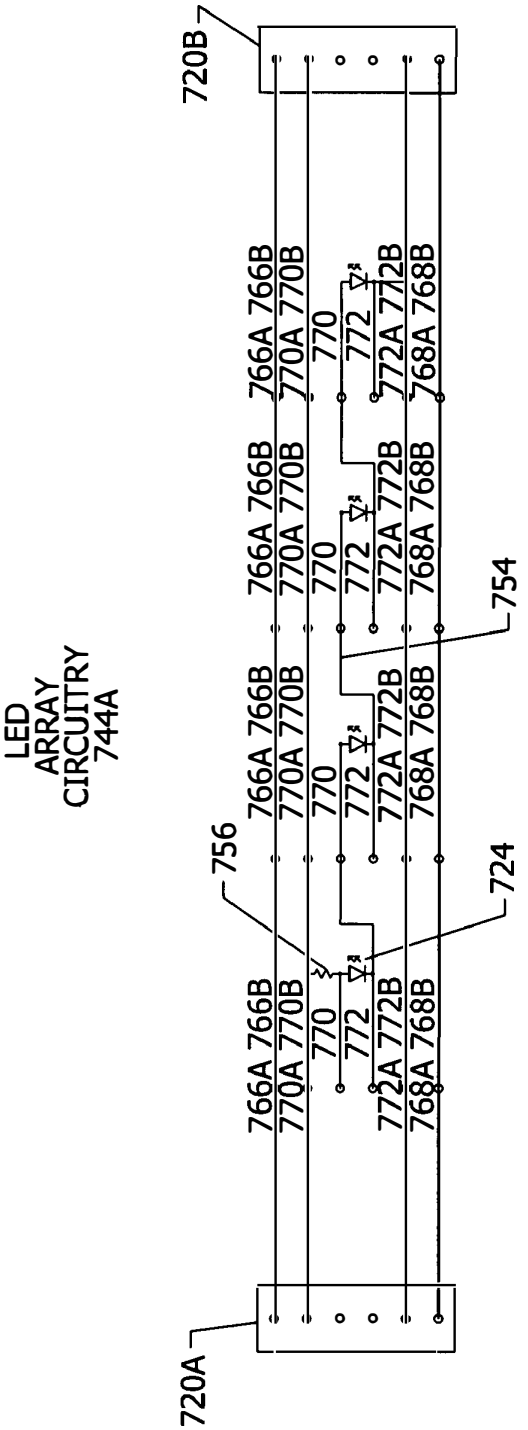

LED
ARRAY
CIRCUITRY
744A
720B
720A
754
724
756
766A 766B
770A 770B
770
772
772A 772B
768A 768B

FIG. 63E

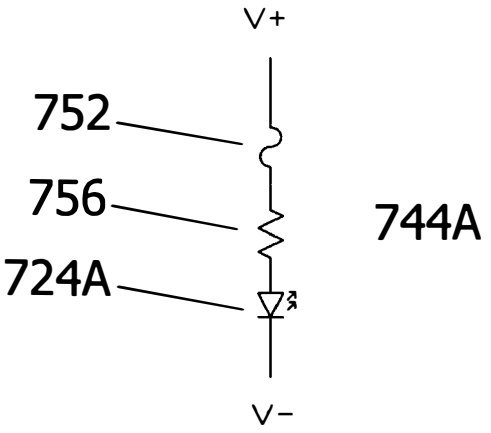


FIG. 63F

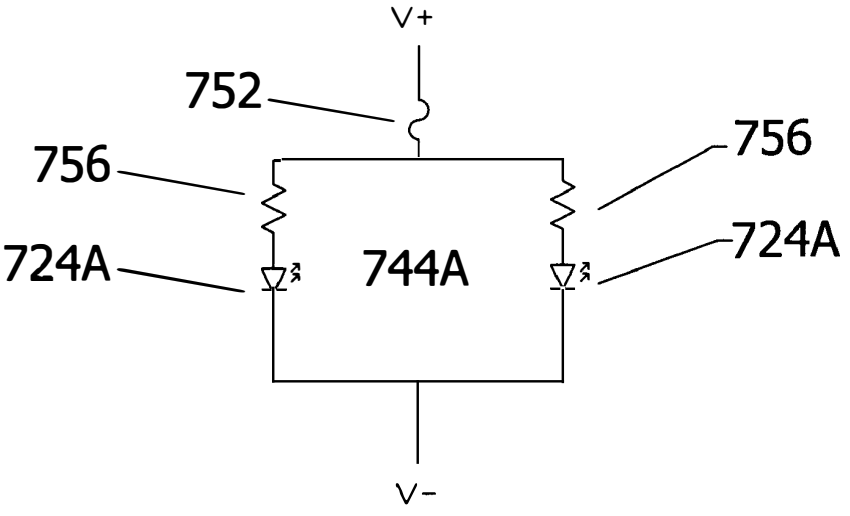


FIG. 63G

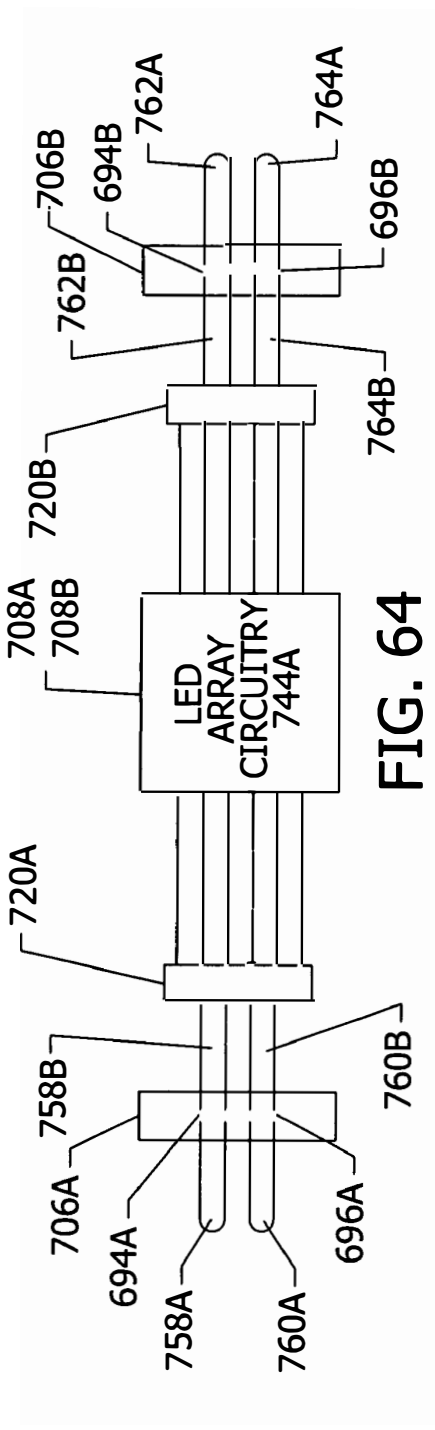


FIG. 64

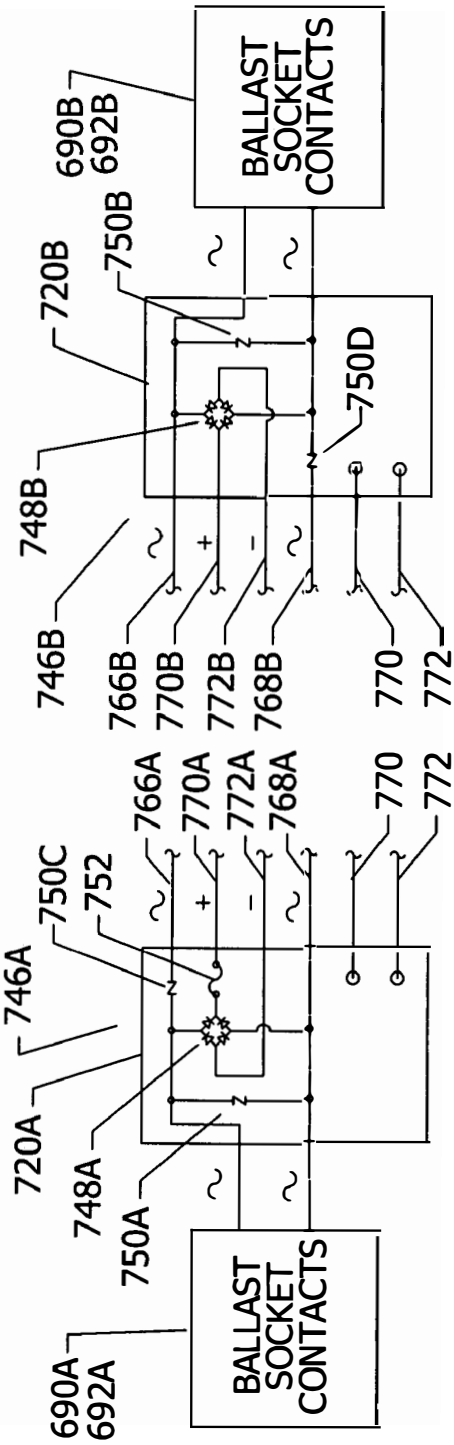


FIG. 66

FIG. 65

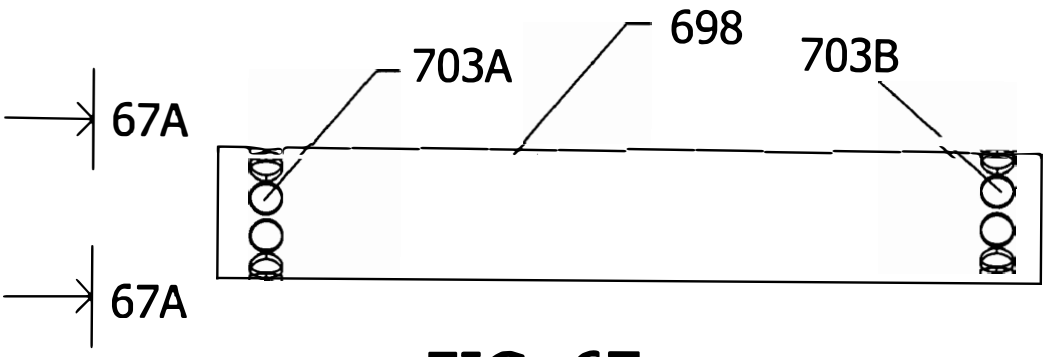


FIG. 67

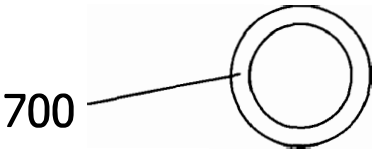


FIG. 67A

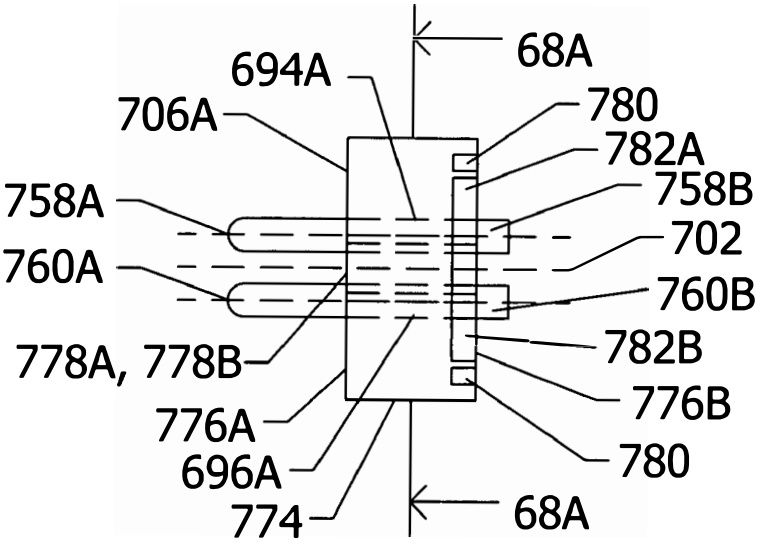


FIG. 68

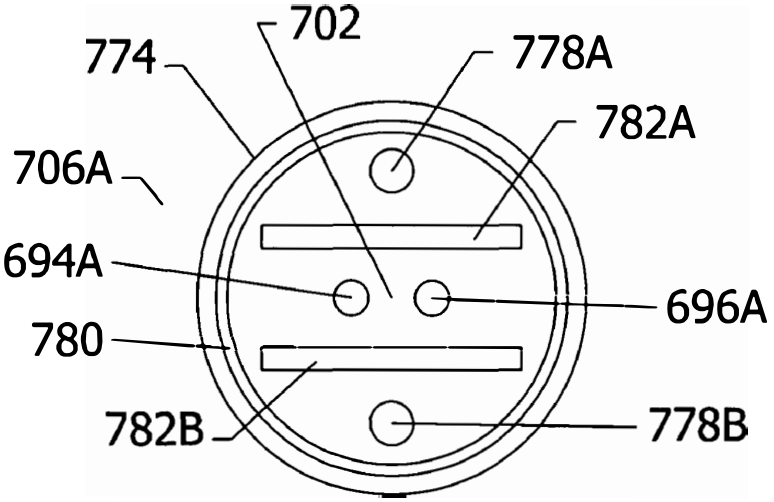


FIG. 68A

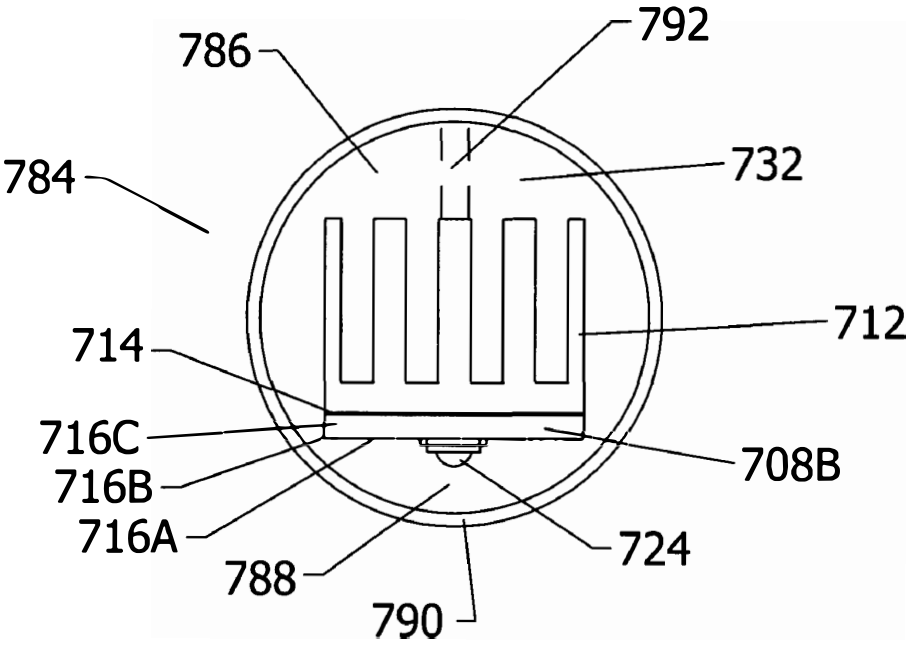


FIG. 69

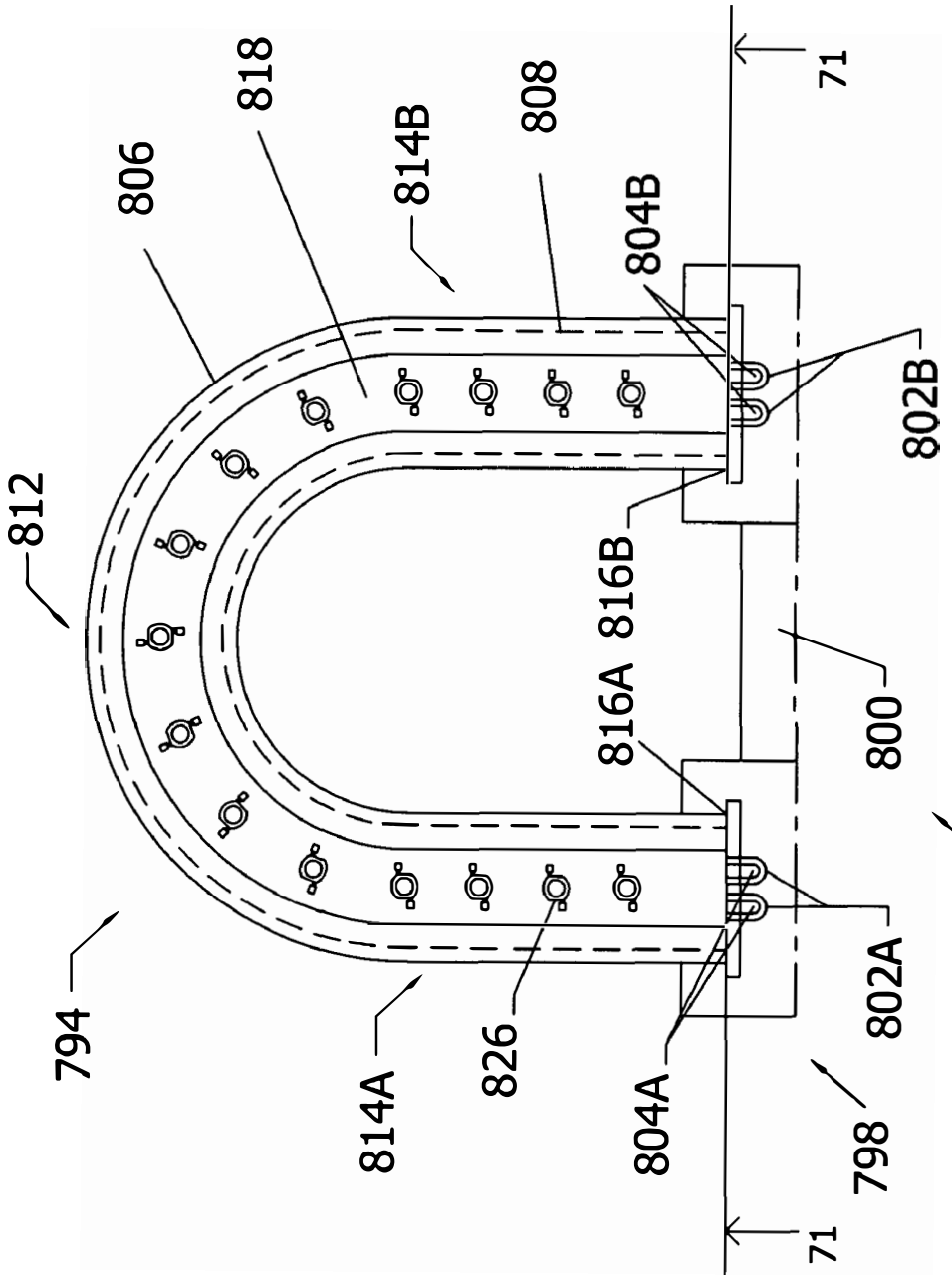

71
818
808
806
814B
804B
802B
812
816B
816A
800
796
794
802A
826
814A
804A
798
71

FIG. 70

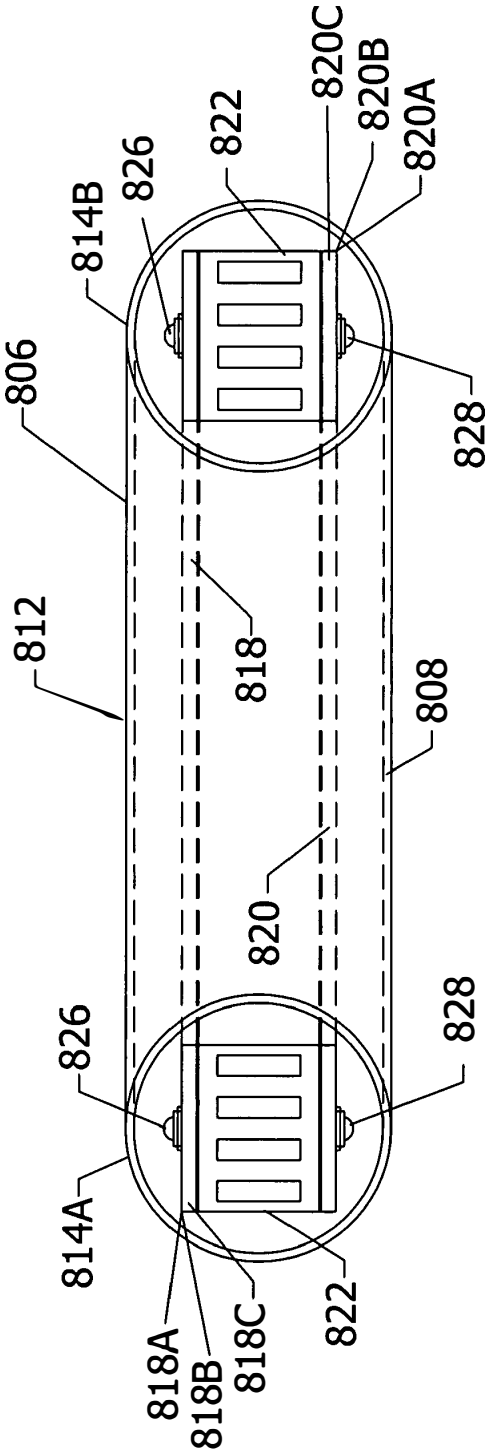

820C
820B
820A
822
826
814B
806
828
812
818
808
820
826
828
814A
818A
818B
818C
822

FIG. 71

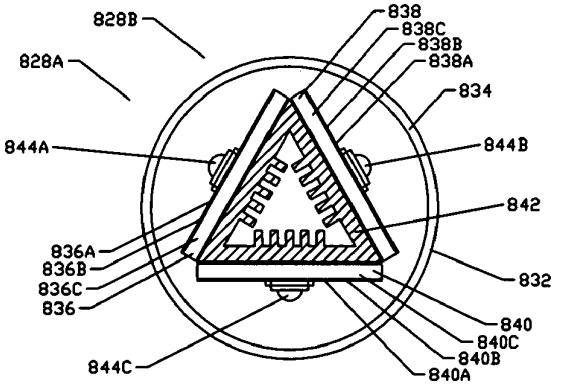


FIG.72

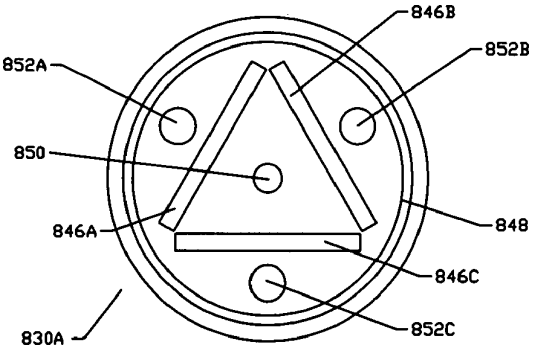


FIG. 72A

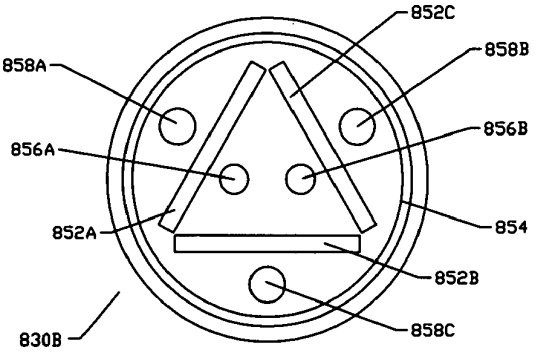


FIG.72B

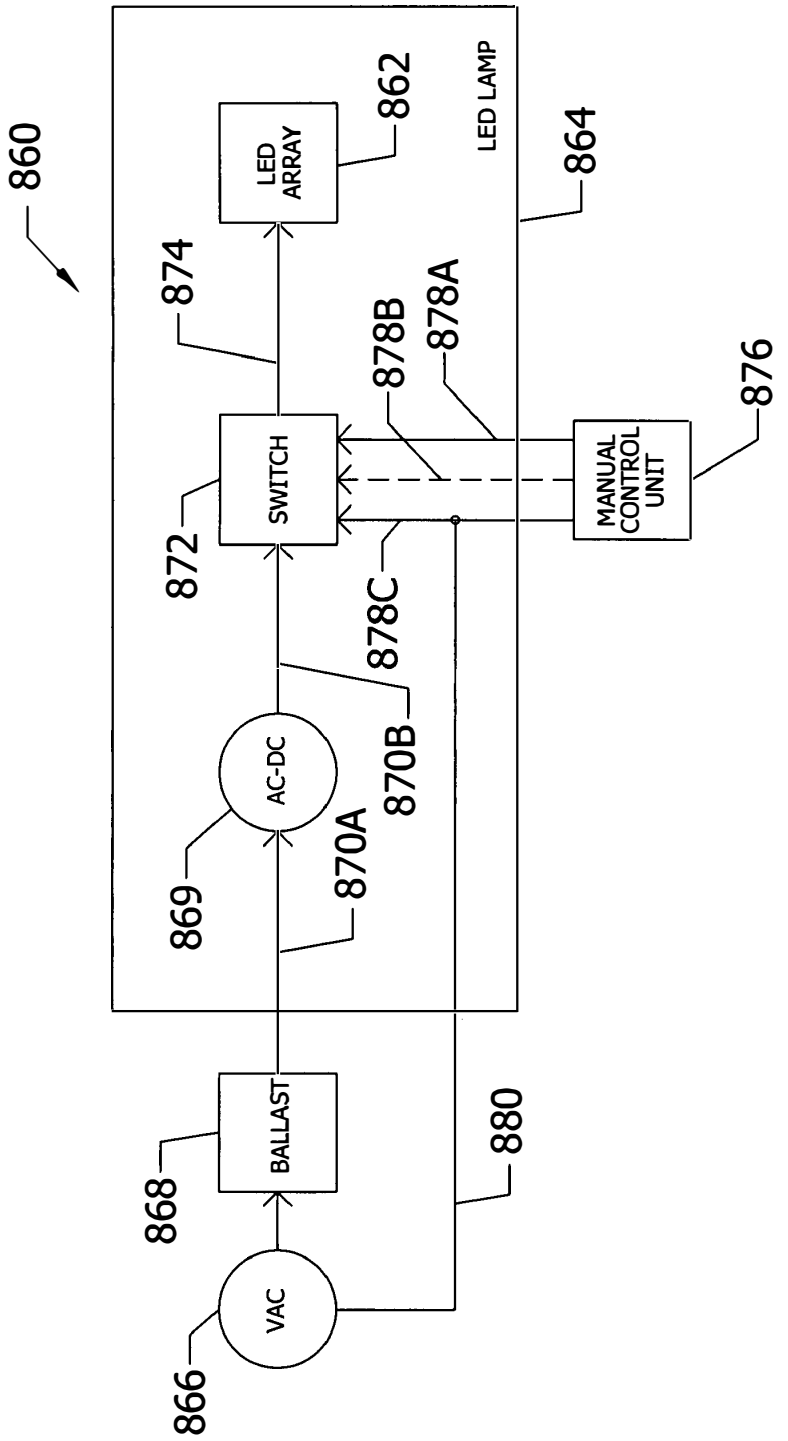

860
LED LAMP
864
LED ARRAY
862
874
878A
878B
876
SWITCH
MANUAL CONTROL UNIT
872
878C
870B
AC-DC
870A
869
BALLAST
868
880
VAC
866

FIG. 73

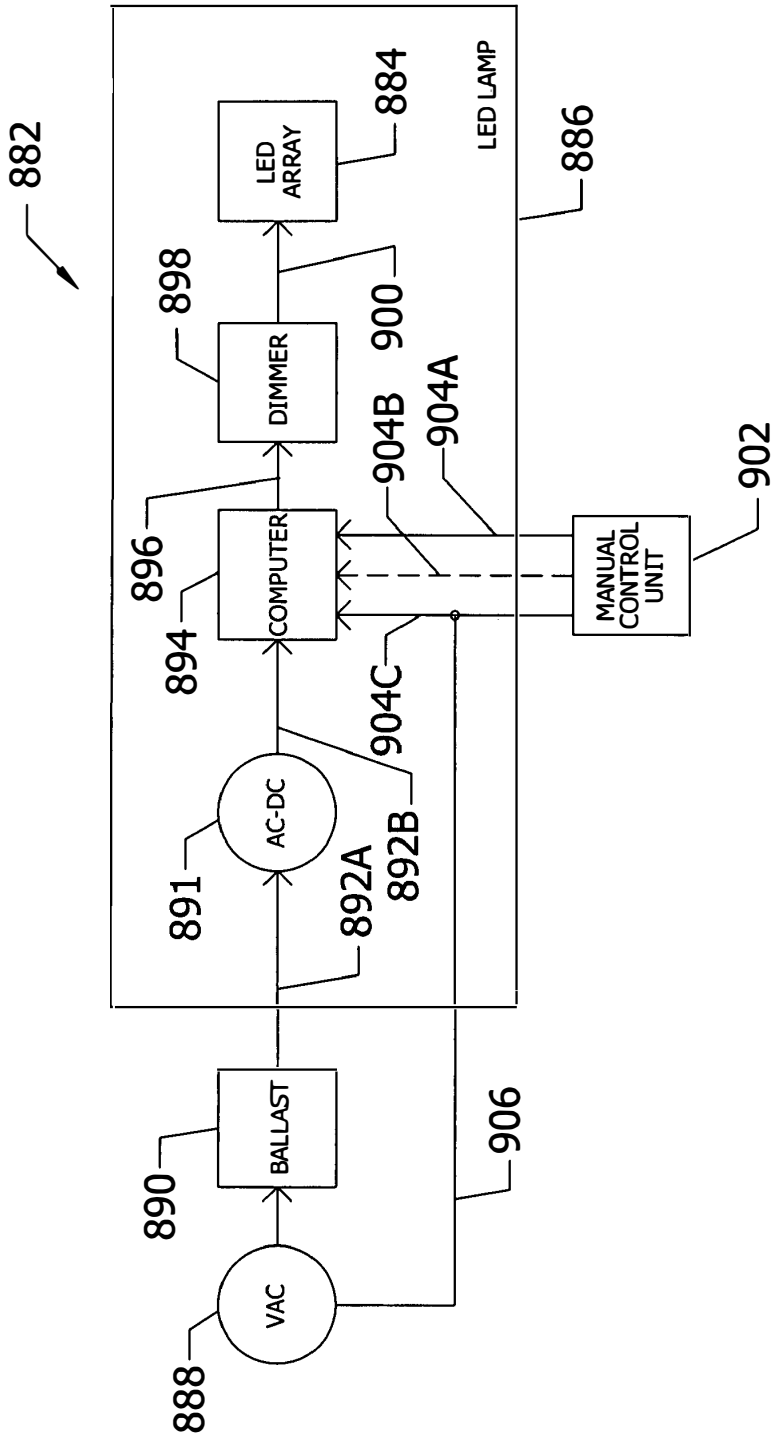

882
LED LAMP
886
LED ARRAY
884
DIMMER
898
900
904B
904A
902
COMPUTER
896
894
MANUAL CONTROL UNIT
904C
AC-DC
891
892A
892B
BALLAST
890
906
VAC
888

FIG. 73A

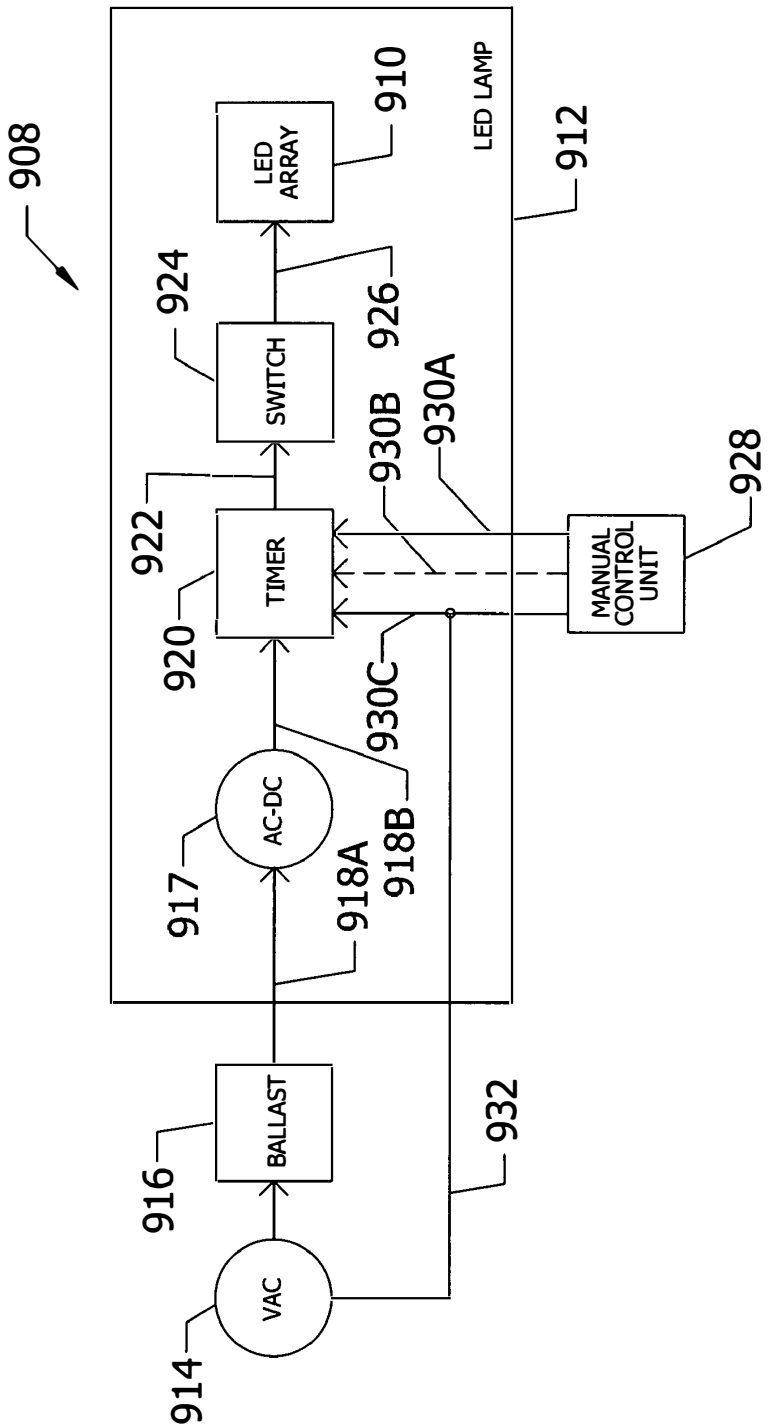

908
LED LAMP
912
LED ARRAY
910
SWITCH
924
926
930A
930B
928
MANUAL CONTROL UNIT
TIMER
922
920
930C
AC-DC
917
918A
918B
BALLAST
916
VAC
914
932

FIG. 74

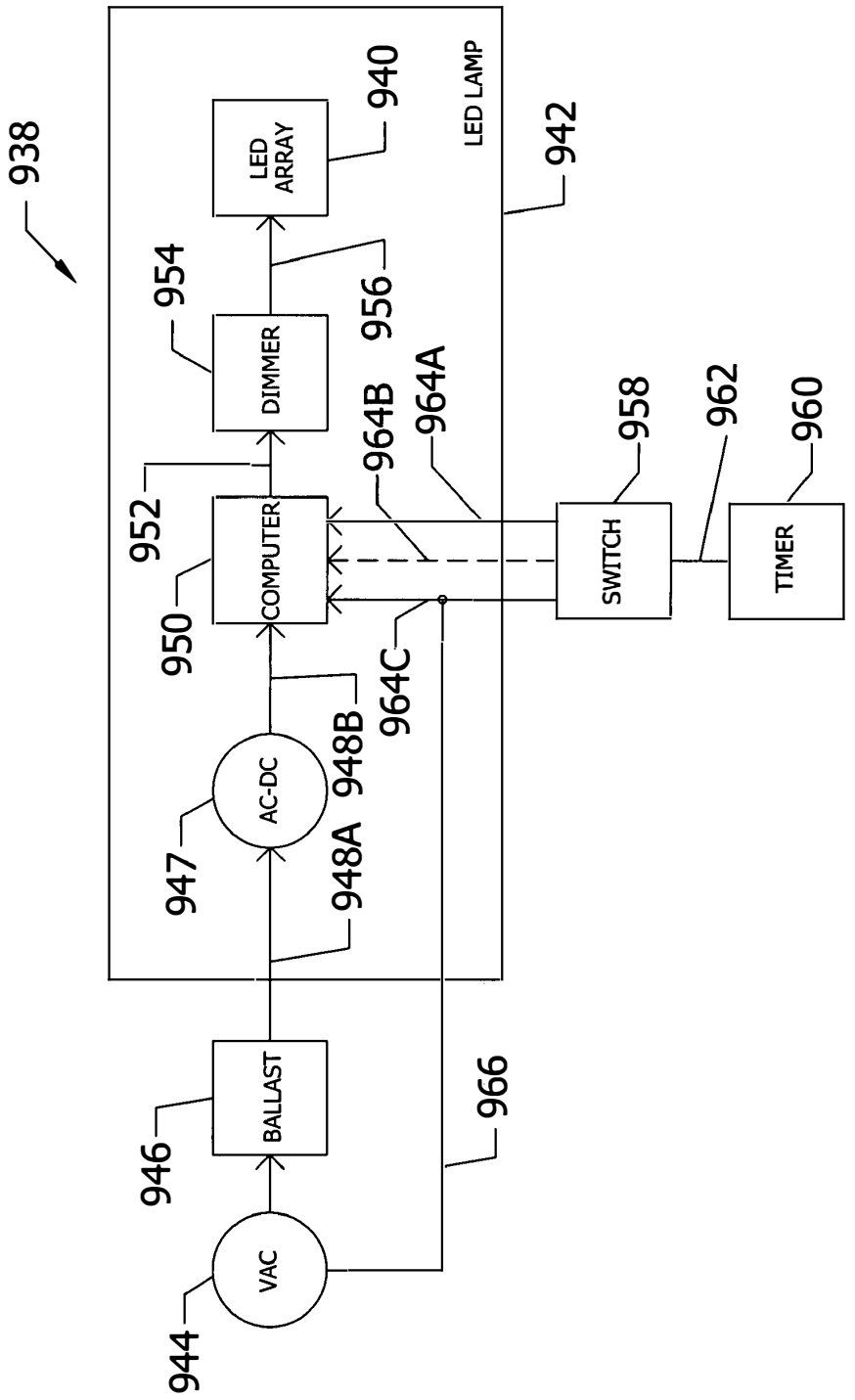

938
LED LAMP
942
LED ARRAY
940
DIMMER
954
956
964A
964B
COMPUTER
952
950
SWITCH
958
962
TIMER
960
964C
AC-DC
947
948A
948B
BALLAST
946
966
VAC
944

FIG. 74A

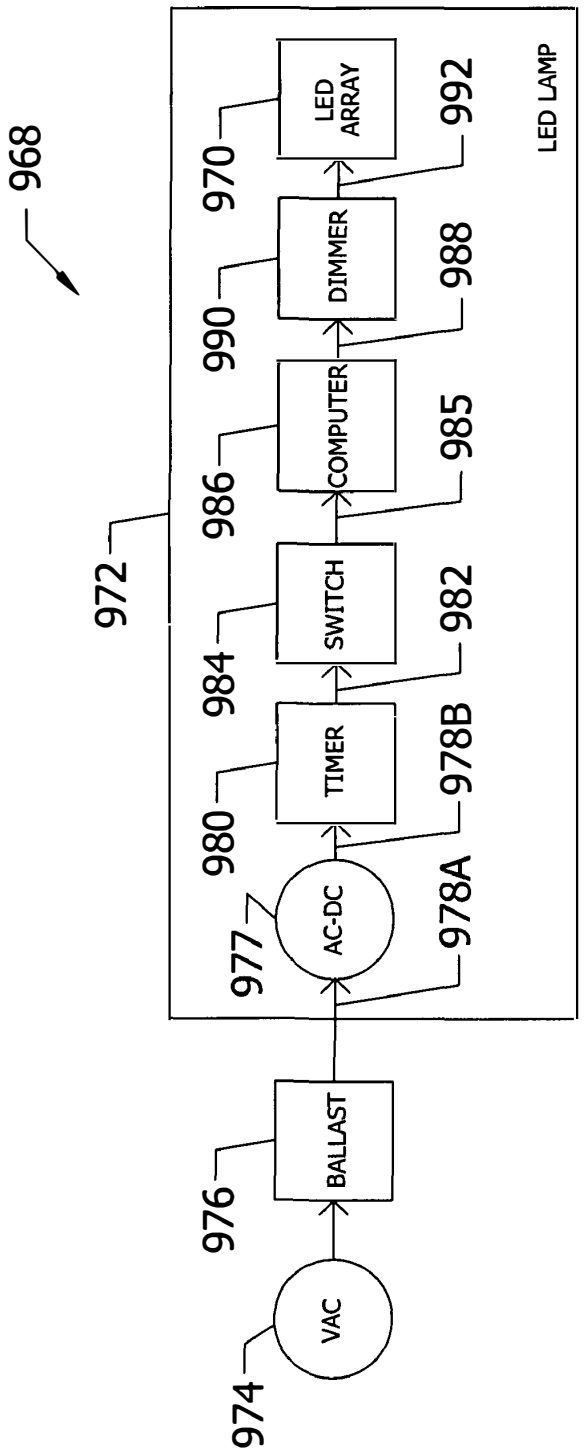

968
LED LAMP
LED ARRAY
DIMMER
COMPUTER
SWITCH
TIMER
AC-DC
BALLAST
VAC
970
990
986
984
980
977
976
974
992
988
985
982
978B
978A
972

FIG. 74B

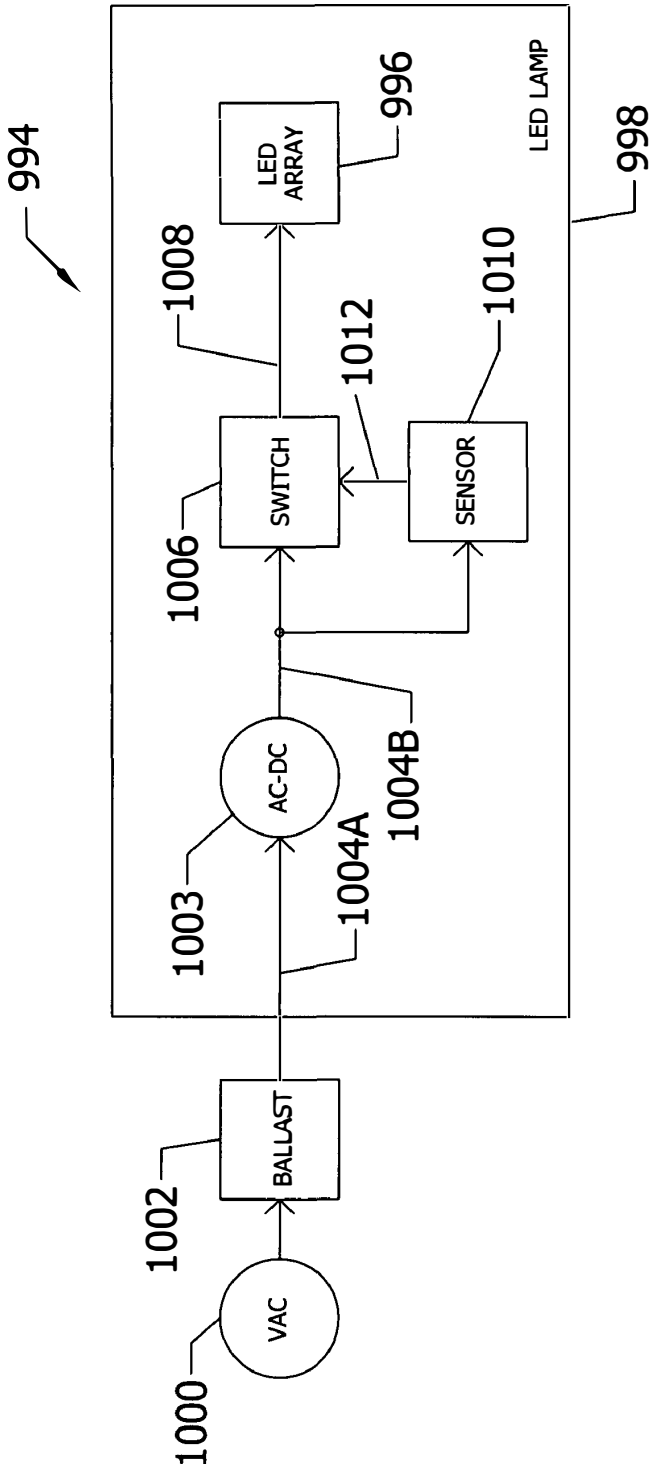

994
LED LAMP
998
LED ARRAY
996
1008
1012
1010
SWITCH
SENSOR
1006
AC-DC
1004B
1003
1004A
BALLAST
1002
VAC
1000

FIG. 75

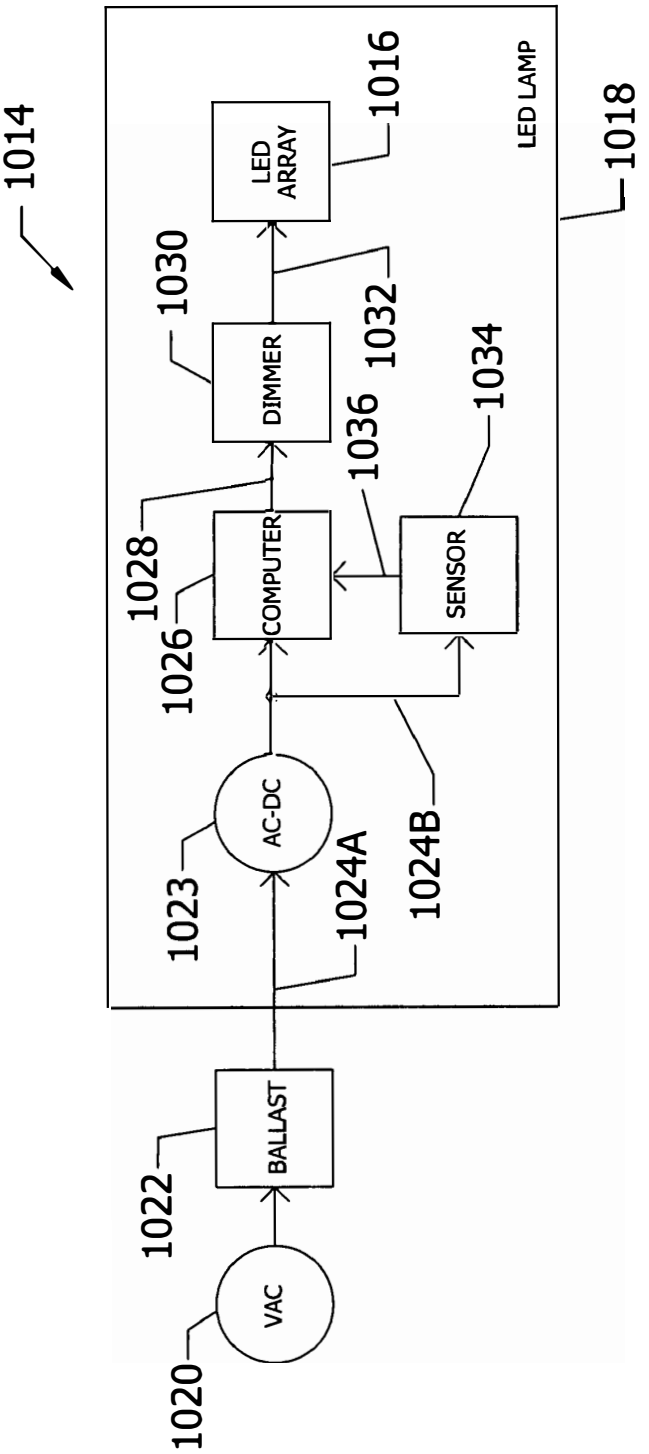

1014
LED LAMP
1018
LED ARRAY
1016
DIMMER
1030
1032
1034
1036
COMPUTER
SENSOR
1028
1026
AC-DC
1023
1024A
1024B
BALLAST
1022
VAC
1020

FIG. 75A

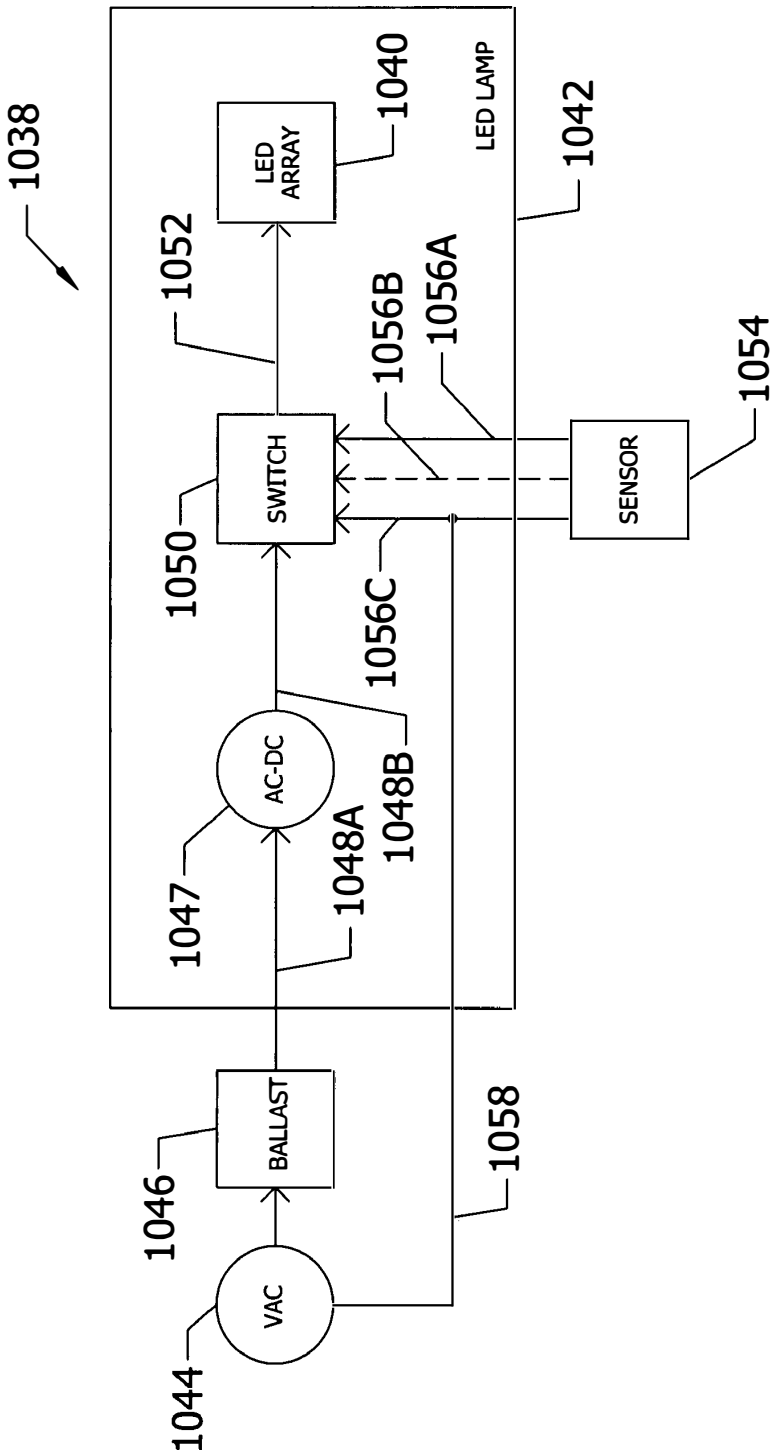

1038
LED LAMP
1042
LED ARRAY
1040
1052
1056B
1056A
1054
SWITCH
SENSOR
1050
1056C
AC-DC
1048B
1047
1048A
BALLAST
1046
1058
VAC
1044

FIG. 75B

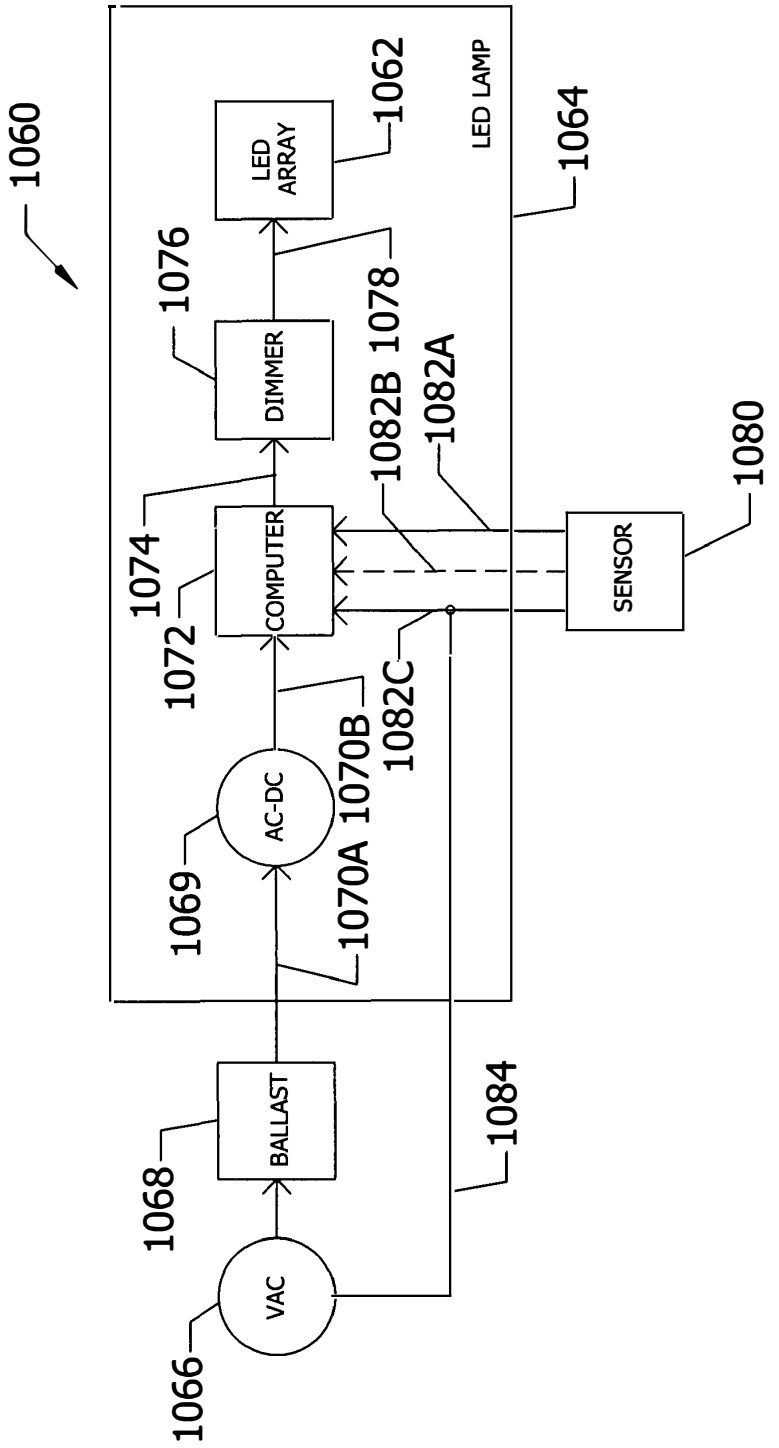

1060
LED LAMP
1064
LED ARRAY
1062
DIMMER
1076
1078
1082B
1082A
1080
SENSOR
COMPUTER
1074
1072
1082C
1070B
AC-DC
1069
1070A
BALLAST
1068
1084
VAC
1066

FIG. 75C

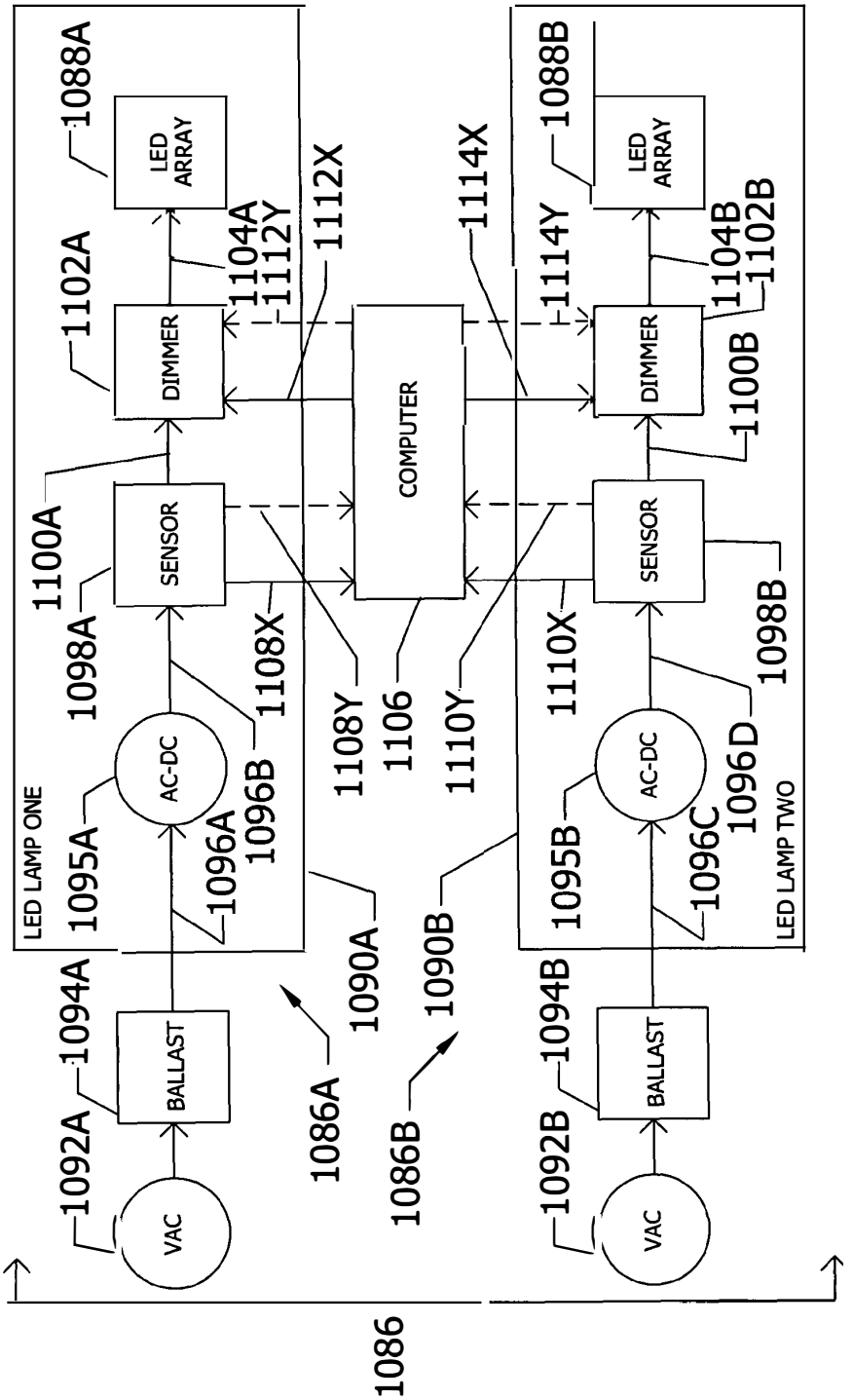

LED LAMP ONE
LED LAMP TWO
VAC
BALLAST
AC-DC
SENSOR
DIMMER
LED ARRAY
COMPUTER
1086
1086A
1086B
1088A
1088B
1090A
1090B
1092A
1092B
1094A
1094B
1095A
1095B
1096A
1096B
1096C
1096D
1098A
1098B
1100A
1100B
1102A
1102B
1104A
1104B
1106
1108X
1108Y
1110X
1110Y
1112X
1112Y
1114X
1114Y

FIG. 76

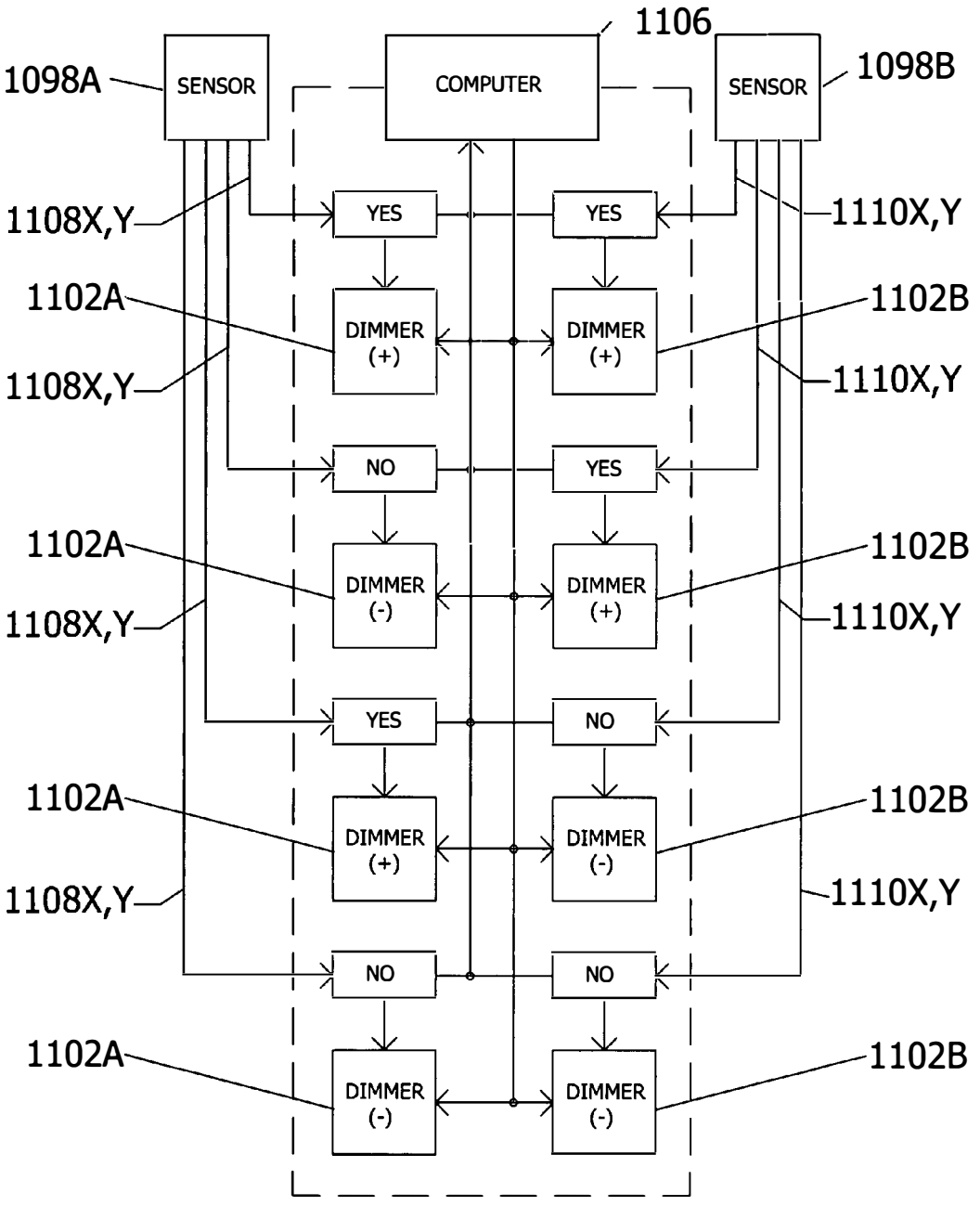

1106
1098A
SENSOR
COMPUTER
SENSOR
1098B
1108X,Y
YES
YES
1110X,Y
1102A
DIMMER (+)
DIMMER (+)
1102B
1108X,Y
1110X,Y
NO
YES
1102A
DIMMER (-)
DIMMER (+)
1102B
1108X,Y
1110X,Y
YES
NO
1102A
DIMMER (+)
DIMMER (-)
1102B
1108X,Y
1110X,Y
NO
NO
1102A
DIMMER (-)
DIMMER (-)
1102B

FIG. 76A

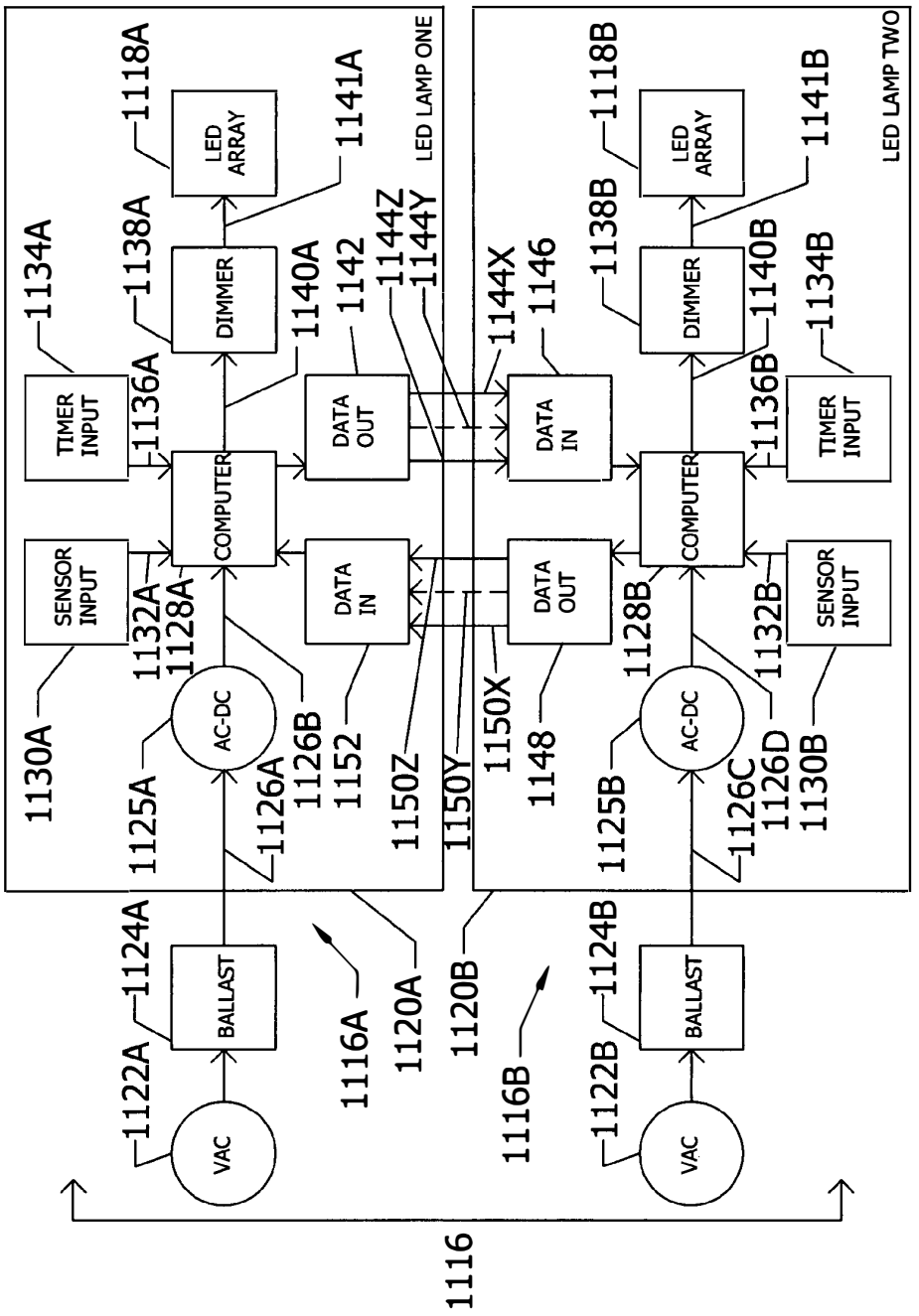

LED LAMP ONE
LED LAMP TWO
VAC
BALLAST
AC-DC
SENSOR INPUT
TIMER INPUT
COMPUTER
DIMMER
LED ARRAY
DATA IN
DATA OUT
1116
1116A
1116B
1120A
1120B
1122A
1122B
1124A
1124B
1125A
1125B
1126A
1126B
1126C
1126D
1128A
1128B
1130A
1130B
1132A
1132B
1134A
1134B
1136A
1136B
1138A
1138B
1140A
1140B
1141A
1141B
1142
1144X
1144Y
1144Z
1146
1148
1150X
1150Y
1150Z
1152

FIG. 77

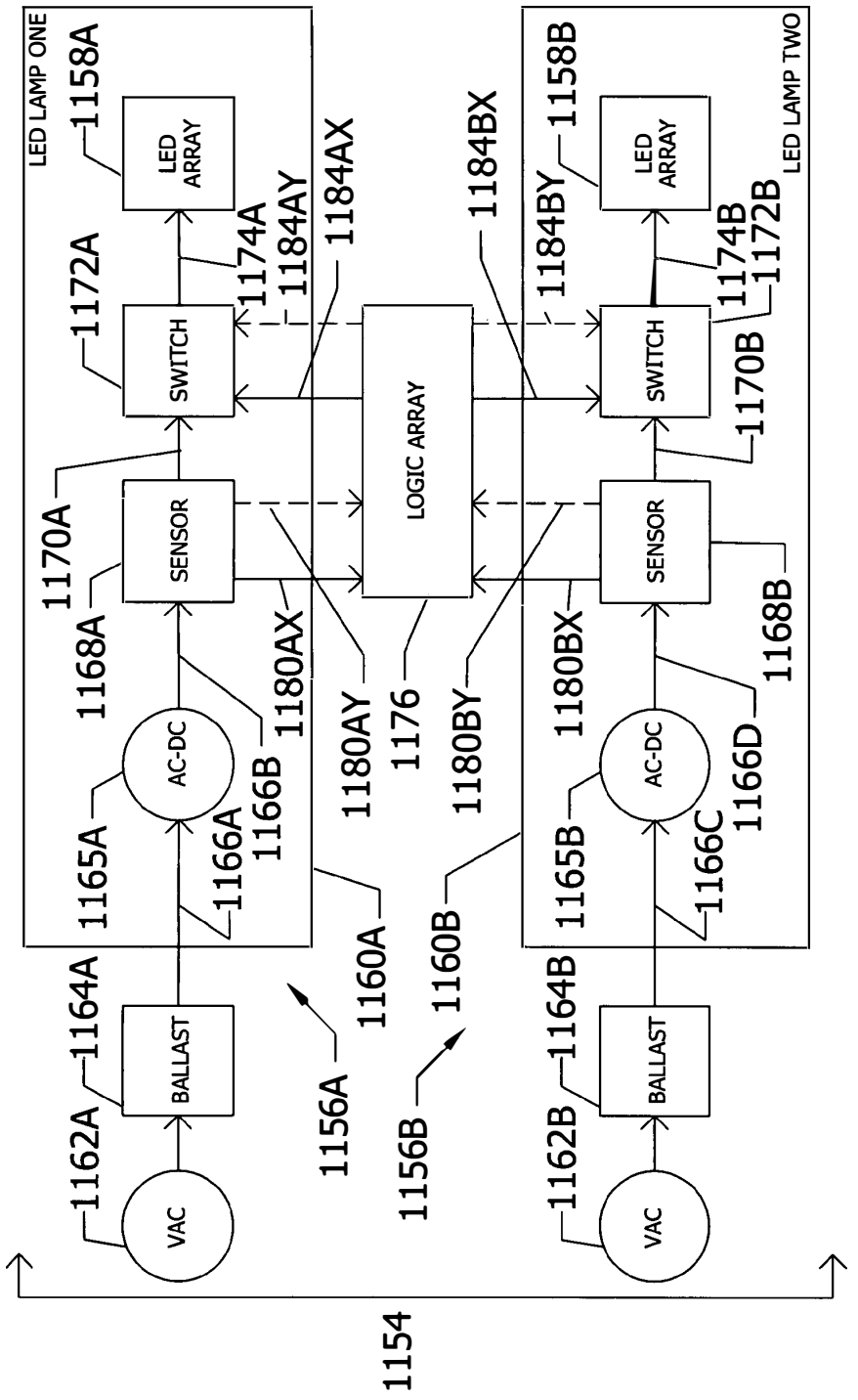

LED LAMP ONE
LED LAMP TWO
LED ARRAY
SWITCH
SENSOR
AC-DC
BALLAST
VAC
LOGIC ARRAY
1154
1156A
1156B
1158A
1158B
1160A
1160B
1162A
1162B
1164A
1164B
1165A
1165B
1166A
1166B
1166C
1166D
1168A
1168B
1170A
1170B
1172A
1172B
1174A
1174B
1176
1180AX
1180AY
1180BX
1180BY
1184AX
1184AY
1184BX
1184BY

FIG. 78

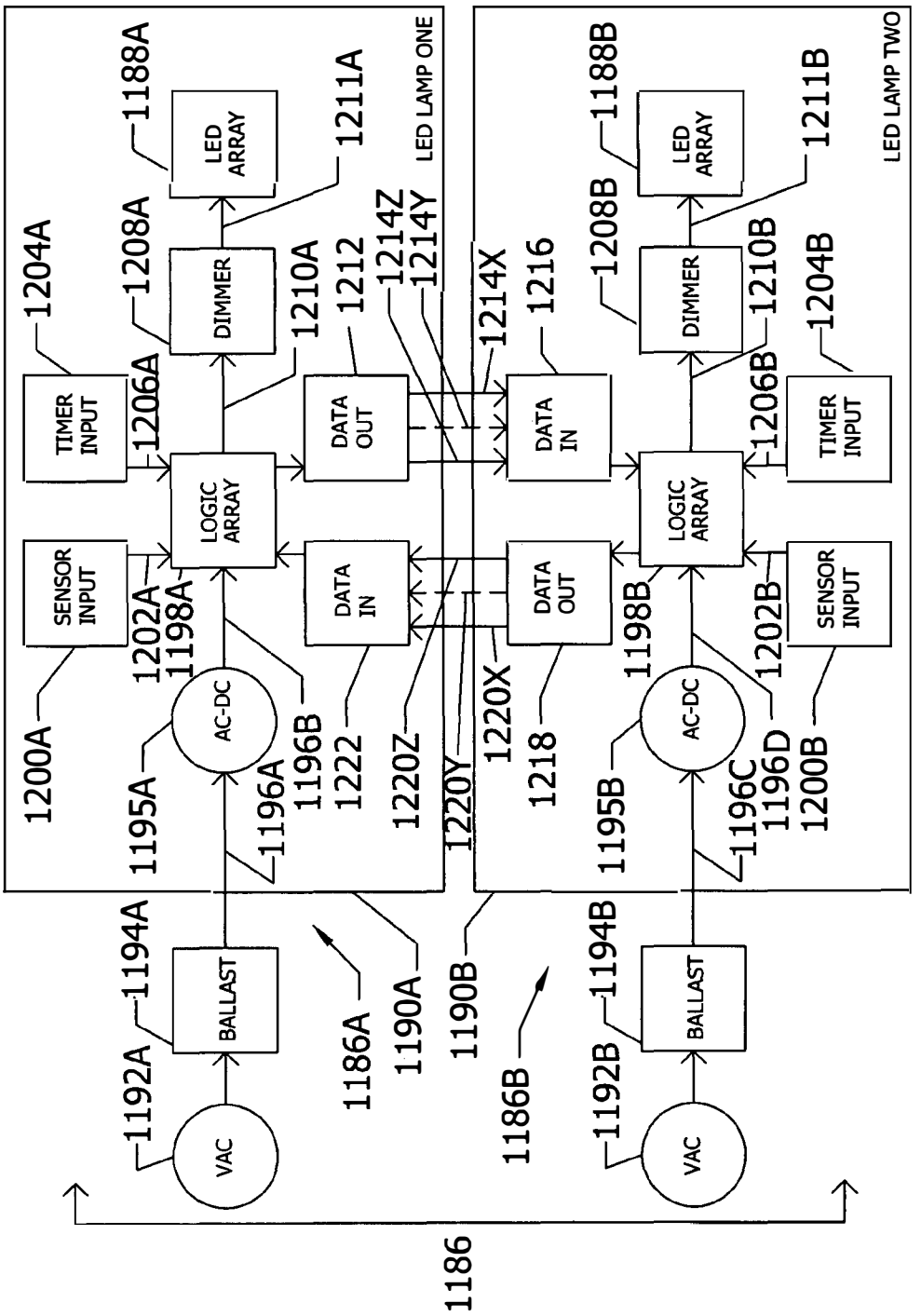

LED LAMP ONE
LED LAMP TWO
LED ARRAY
DIMMER
TIMER INPUT
SENSOR INPUT
LOGIC ARRAY
DATA OUT
DATA IN
AC-DC
BALLAST
VAC
1186
1186A
1186B
1188A
1188B
1190A
1190B
1192A
1192B
1194A
1194B
1195A
1195B
1196A
1196B
1196C
1196D
1198A
1198B
1200A
1200B
1202A
1202B
1204A
1204B
1206A
1206B
1208A
1208B
1210A
1210B
1211A
1211B
1212
1214X
1214Y
1214Z
1216
1218
1220X
1220Y
1220Z
1222

FIG. 78A

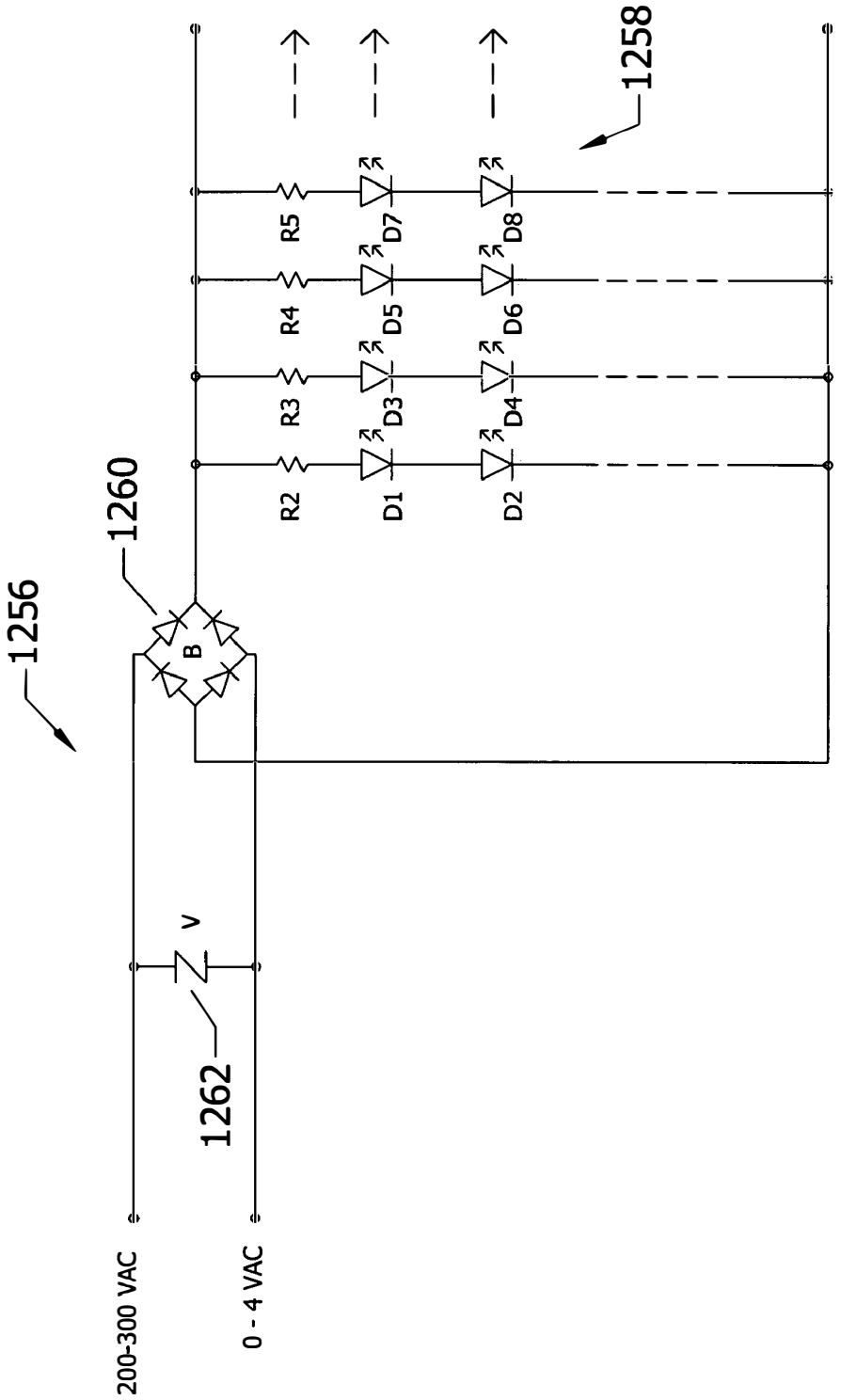

1256
1260
B
1258
R2
R3
R4
R5
D1
D2
D3
D4
D5
D6
D7
D8
V
1262
200-300 VAC
0 - 4 VAC

FIG. 79A

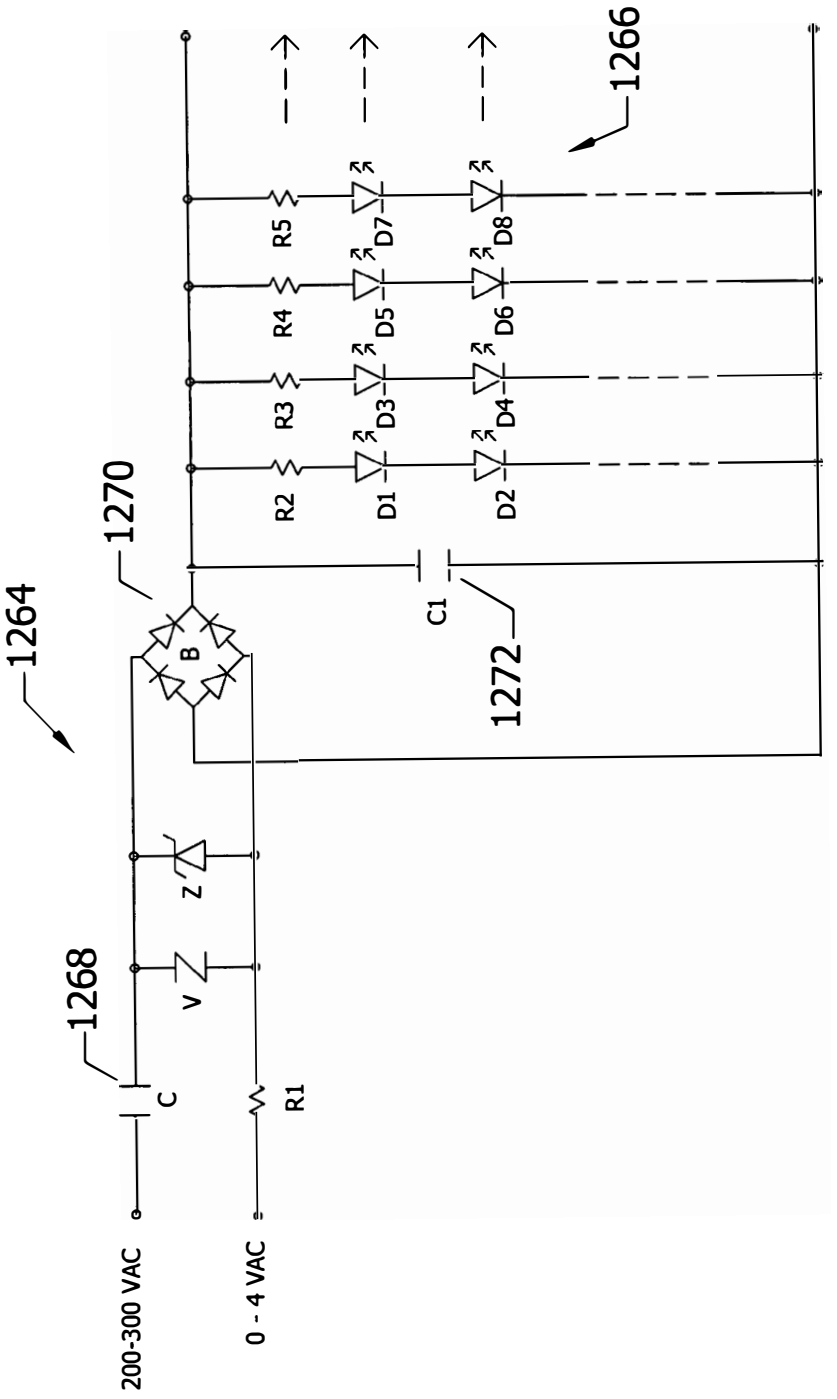

1266
1270
1264
1272
1268
R5
R4
R3
R2
D7
D8
D5
D6
D3
D4
D1
D2
C1
B
Z
V
C
R1
200-300 VAC
0 - 4 VAC

FIG. 79B

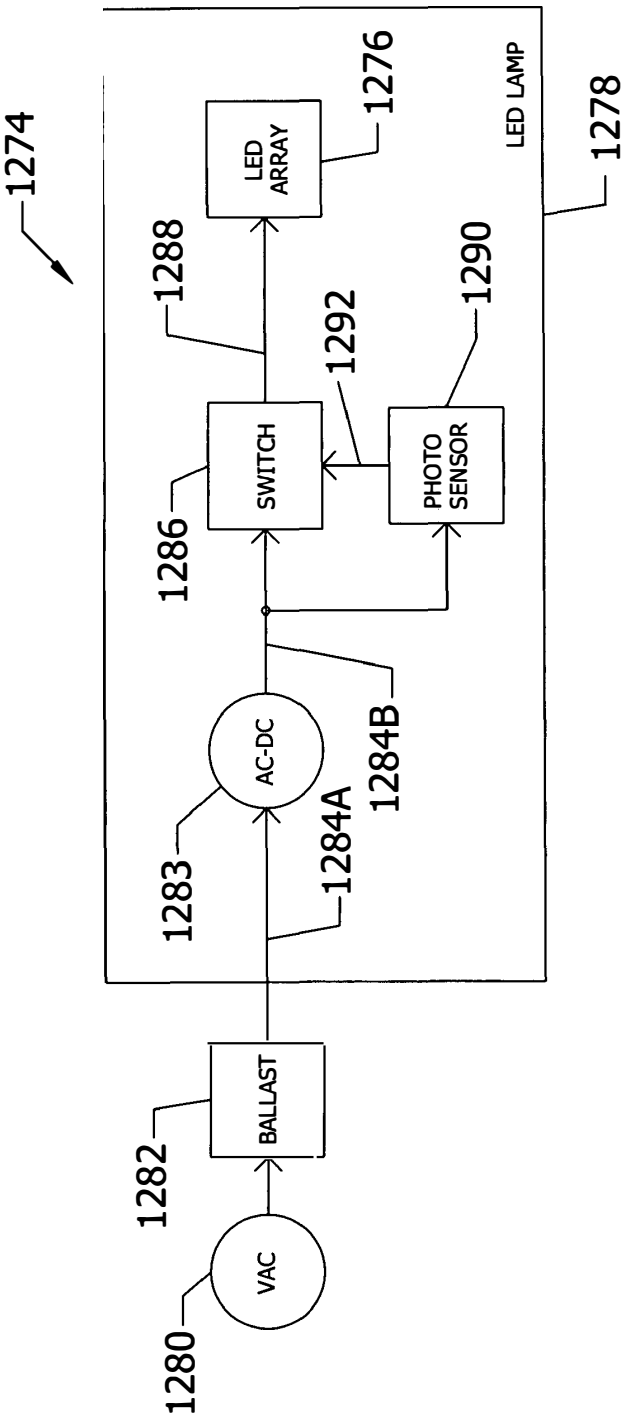

1274
LED LAMP
1278
LED ARRAY
1276
1288
1290
1292
SWITCH
PHOTO SENSOR
1286
AC-DC
1284B
1284A
1283
BALLAST
1282
VAC
1280

FIG. 80A

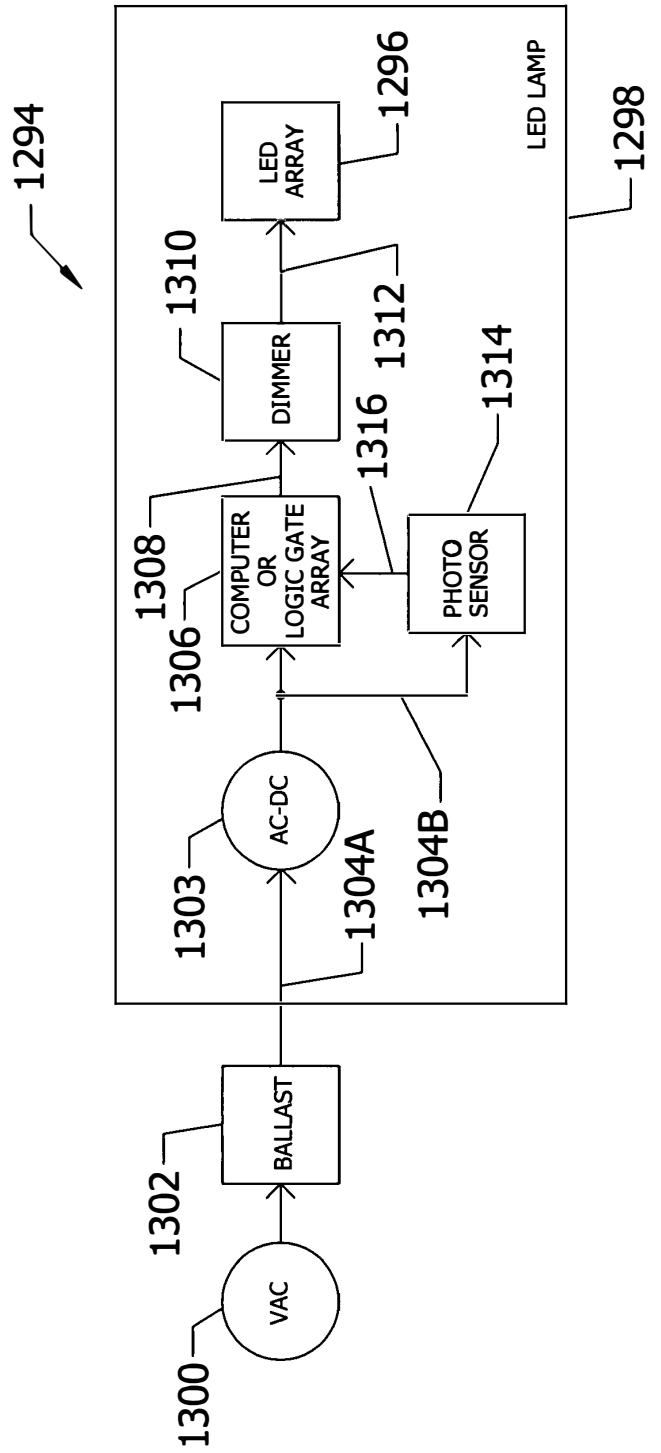

1294
LED LAMP
1298
LED ARRAY
1296
DIMMER
1310
1312
1314
1316
COMPUTER OR LOGIC GATE ARRAY
PHOTO SENSOR
1308
1306
AC-DC
1303
1304A
1304B
BALLAST
1302
VAC
1300

FIG. 80B

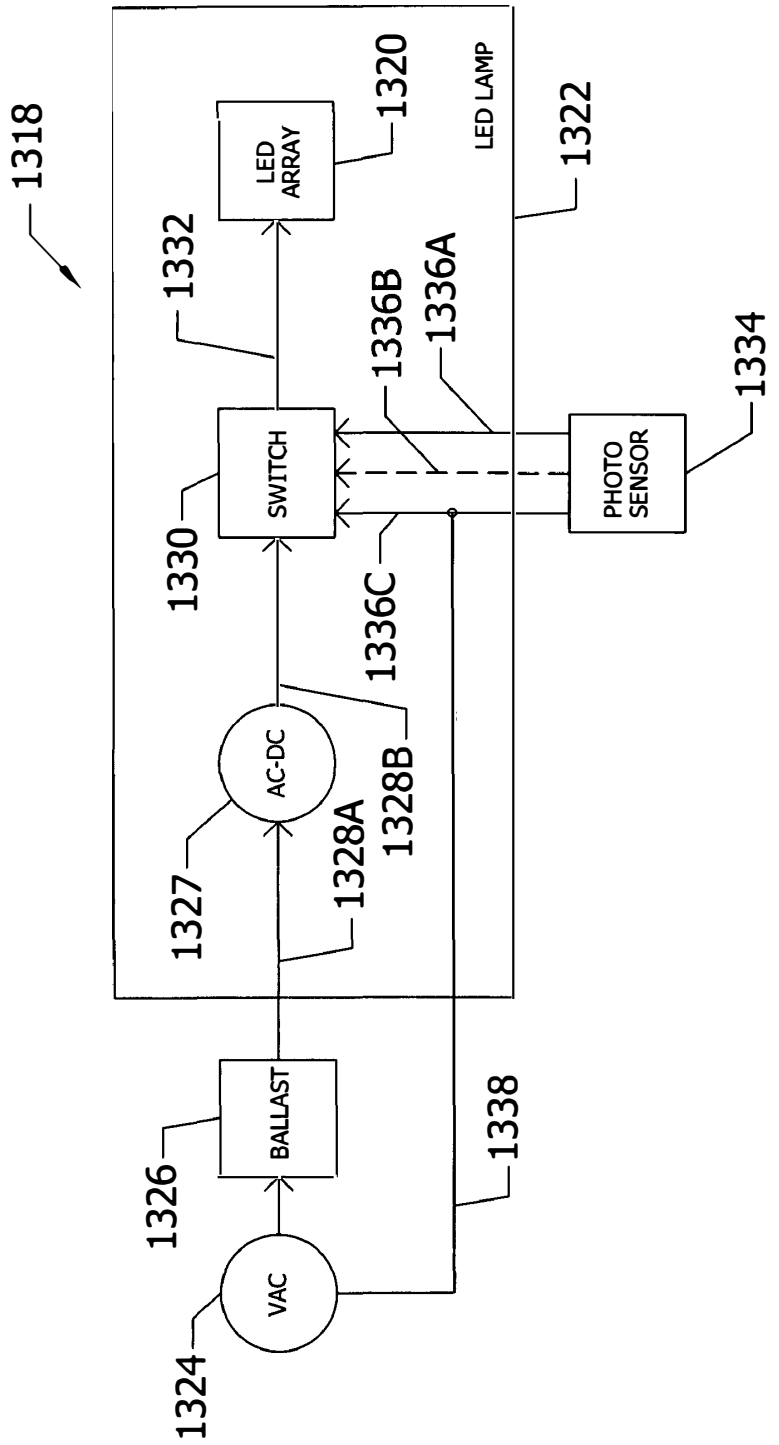

1318
LED LAMP
1322
LED ARRAY
1320
1332
1336B
1336A
1334
SWITCH
PHOTO SENSOR
1330
1336C
AC-DC
1328B
1327
1328A
BALLAST
1326
1338
VAC
1324

FIG. 80C

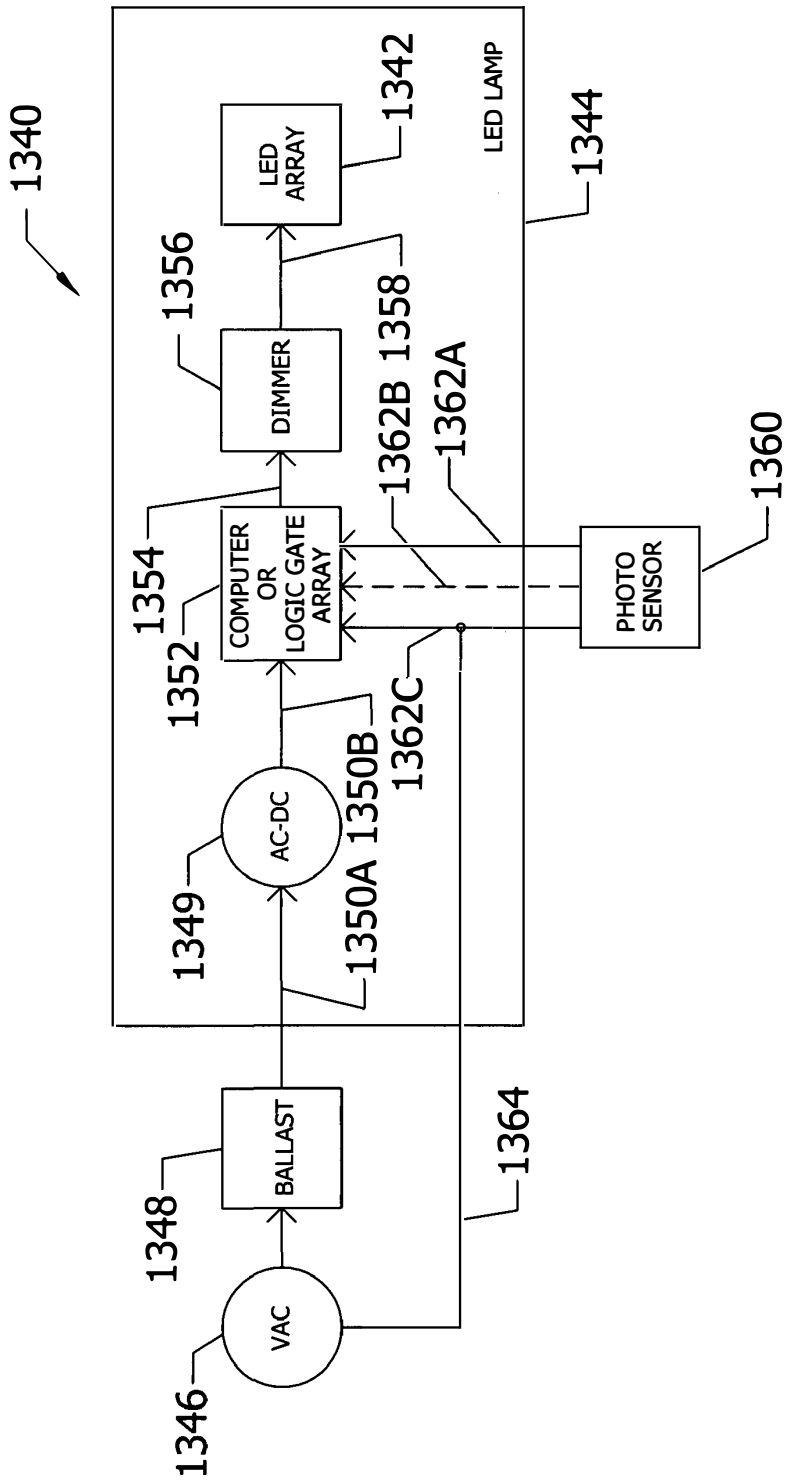

1340
LED LAMP
1344
LED ARRAY
1342
DIMMER
1356
1358
1362B
1362A
1360
PHOTO SENSOR
1354
COMPUTER OR LOGIC GATE ARRAY
1352
1362C
1350B
AC-DC
1349
1350A
BALLAST
1348
1364
VAC
1346

FIG. 80D

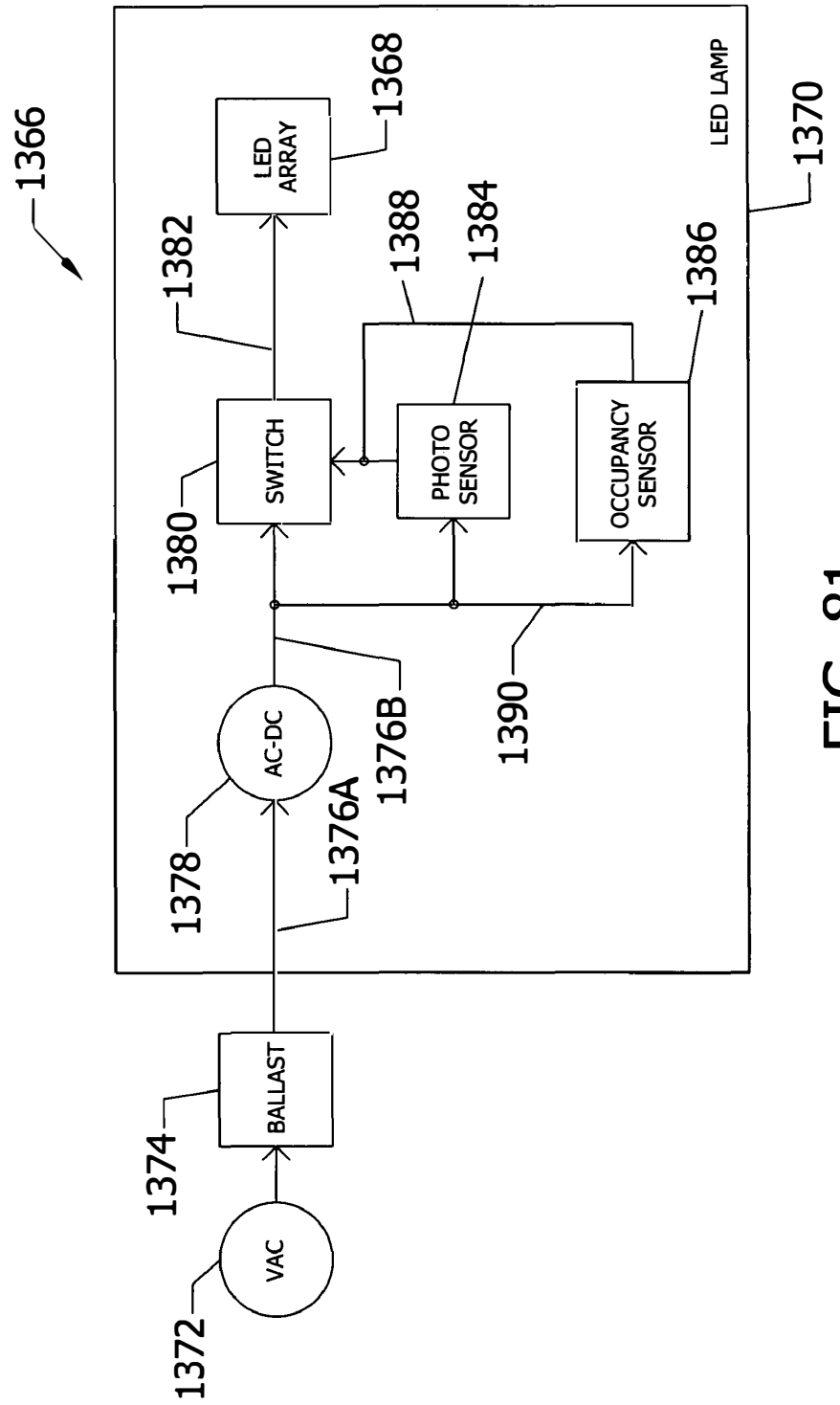

1366
LED LAMP
1370
LED ARRAY
1368
1382
1388
1384
1386
SWITCH
PHOTO SENSOR
OCCUPANCY SENSOR
1380
AC-DC
1376B
1390
1378
1376A
BALLAST
1374
VAC
1372

FIG. 81

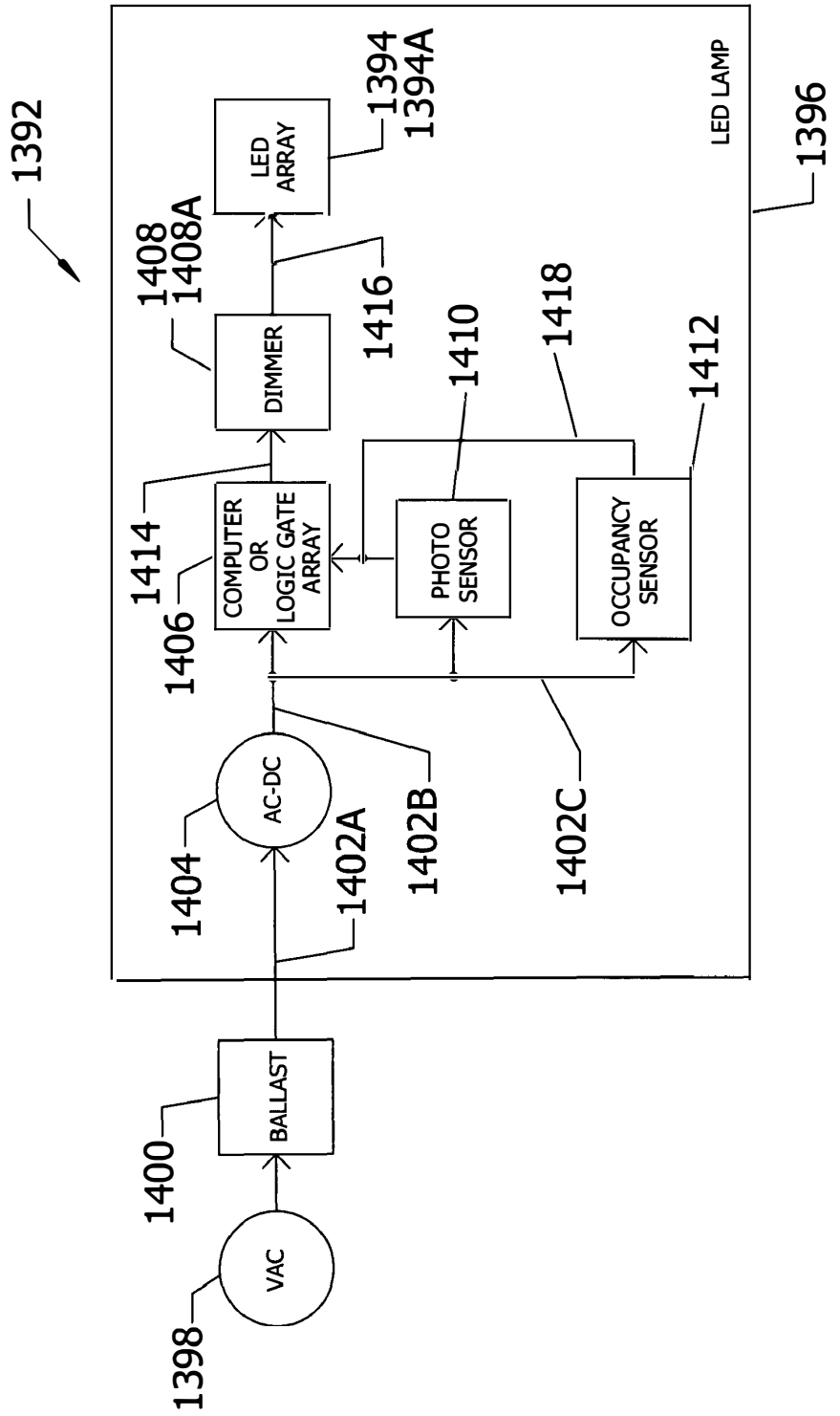

1392
LED LAMP
1396
LED ARRAY
1394
1394A
DIMMER
1408
1408A
1416
1410
1418
1412
COMPUTER OR LOGIC GATE ARRAY
1414
1406
PHOTO SENSOR
OCCUPANCY SENSOR
AC-DC
1404
1402A
1402B
1402C
BALLAST
1400
VAC
1398

FIG. 82

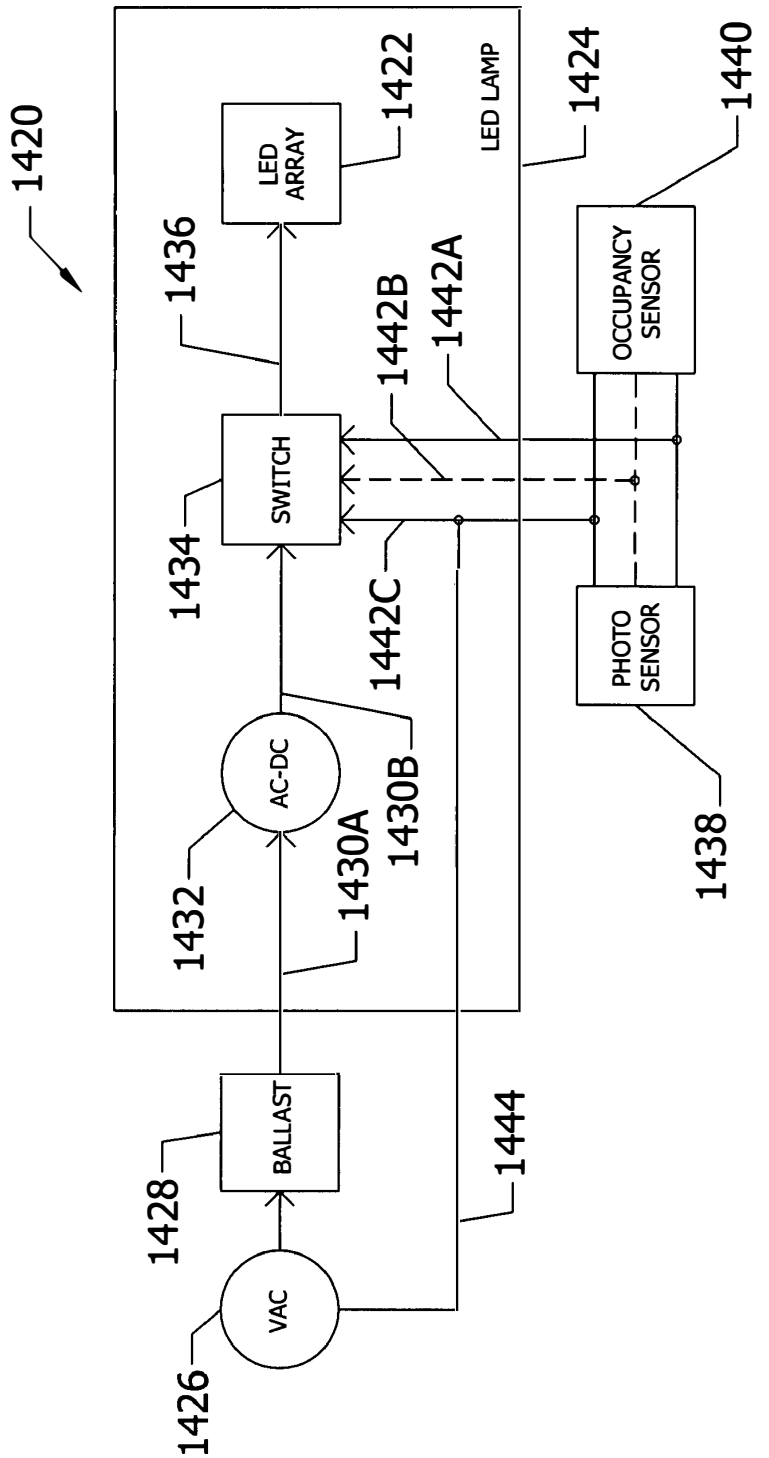

1420
LED LAMP
1424
LED ARRAY
1422
1440
OCCUPANCY SENSOR
1436
1442B
1442A
SWITCH
1434
1442C
PHOTO SENSOR
1438
AC-DC
1430B
1430A
1432
BALLAST
1428
1444
VAC
1426

FIG. 83

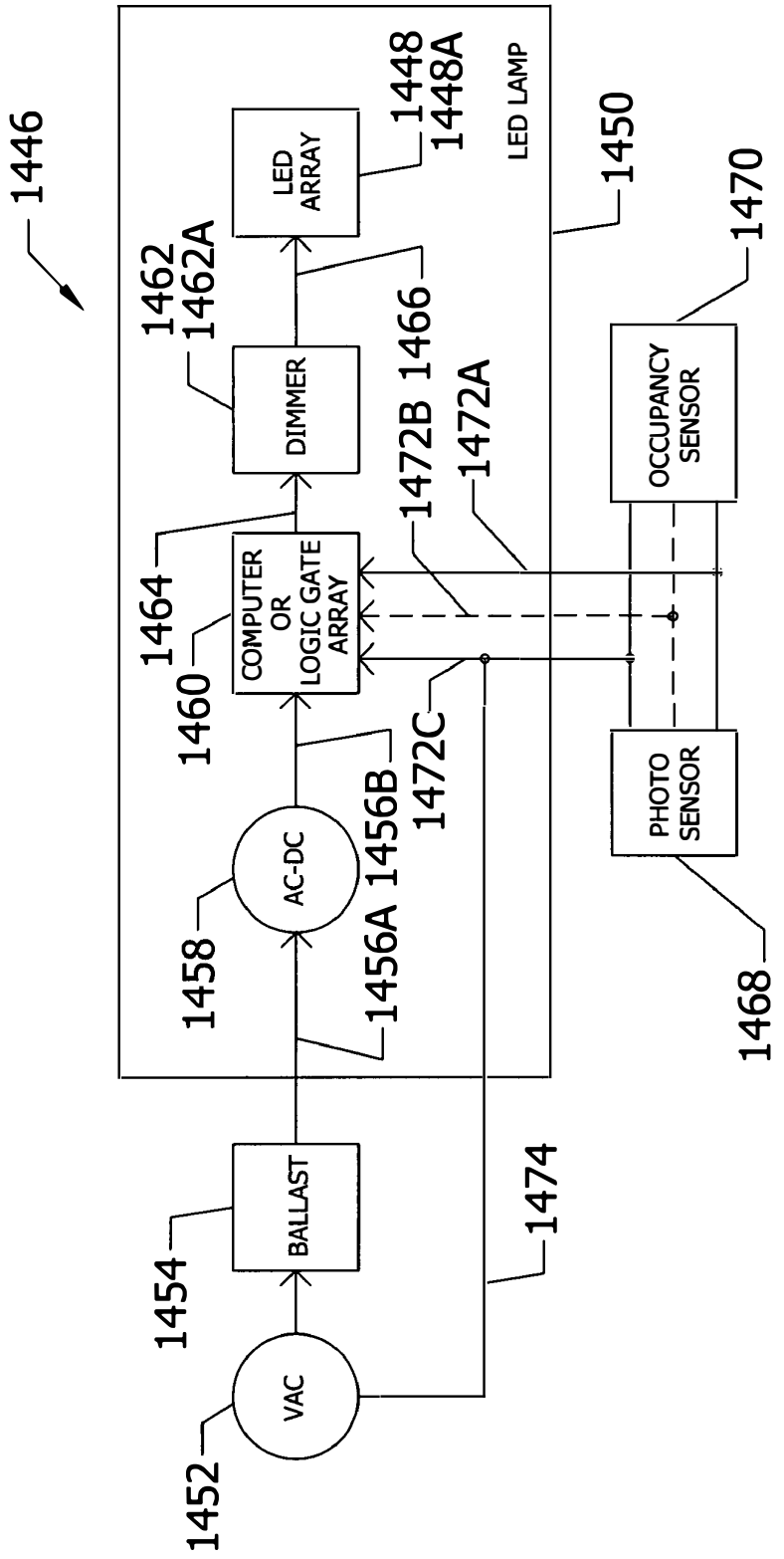

1446
LED LAMP
1450
LED ARRAY
1448
1448A
DIMMER
1462
1462A
1466
1472B
1472A
OCCUPANCY SENSOR
1470
COMPUTER OR LOGIC GATE ARRAY
1464
1460
1472C
AC-DC
1458
1456A
1456B
PHOTO SENSOR
1468
BALLAST
1454
1474
VAC
1452

FIG. 84

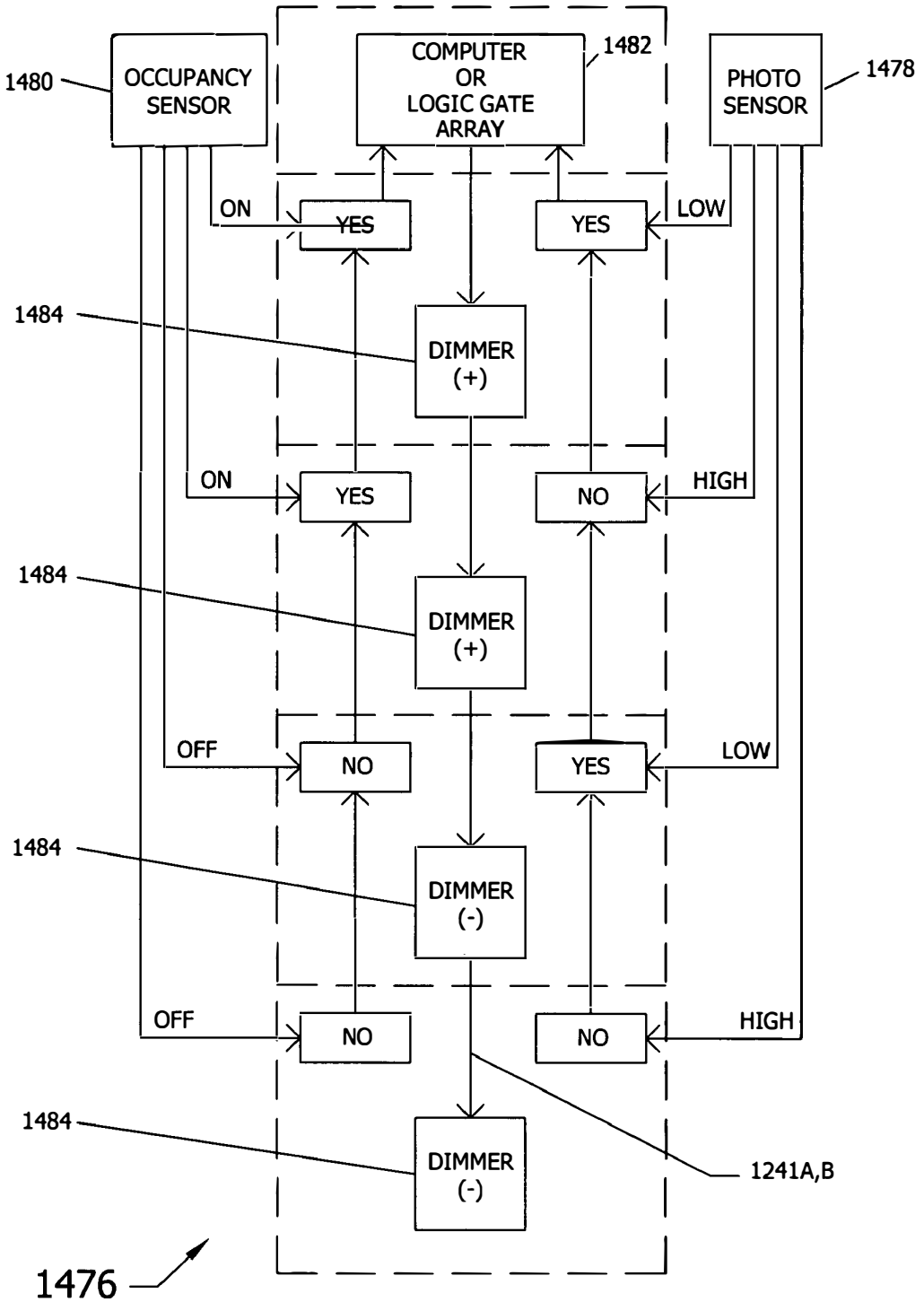

1480
OCCUPANCY SENSOR
COMPUTER OR LOGIC GATE ARRAY
1482
PHOTO SENSOR
1478
ON
YES
YES
LOW
1484
DIMMER (+)
ON
YES
NO
HIGH
1484
DIMMER (+)
OFF
NO
YES
LOW
1484
DIMMER (-)
OFF
NO
NO
HIGH
1484
DIMMER (-)
1241A,B
1476

FIG. 85

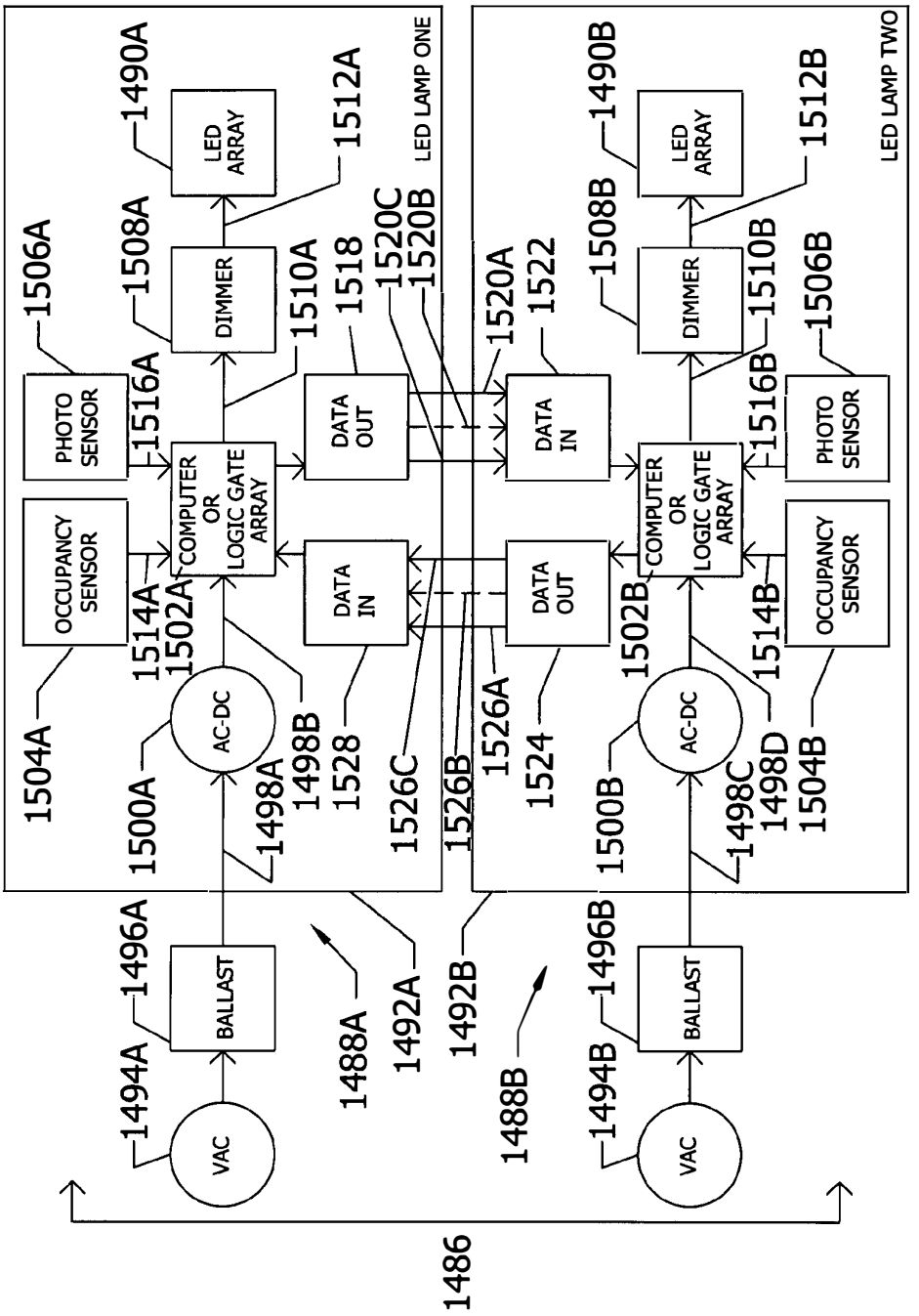

LED LAMP ONE
LED LAMP TWO
LED ARRAY
DIMMER
PHOTO SENSOR
OCCUPANCY SENSOR
COMPUTER OR LOGIC GATE ARRAY
DATA OUT
DATA IN
AC-DC
BALLAST
VAC
1486
1488A
1488B
1490A
1490B
1492A
1492B
1494A
1494B
1496A
1496B
1498A
1498B
1498C
1498D
1500A
1500B
1502A
1502B
1504A
1504B
1506A
1506B
1508A
1508B
1510A
1510B
1512A
1512B
1514A
1514B
1516A
1516B
1518
1520A
1520B
1520C
1522
1524
1526A
1526B
1526C
1528

FIG. 86

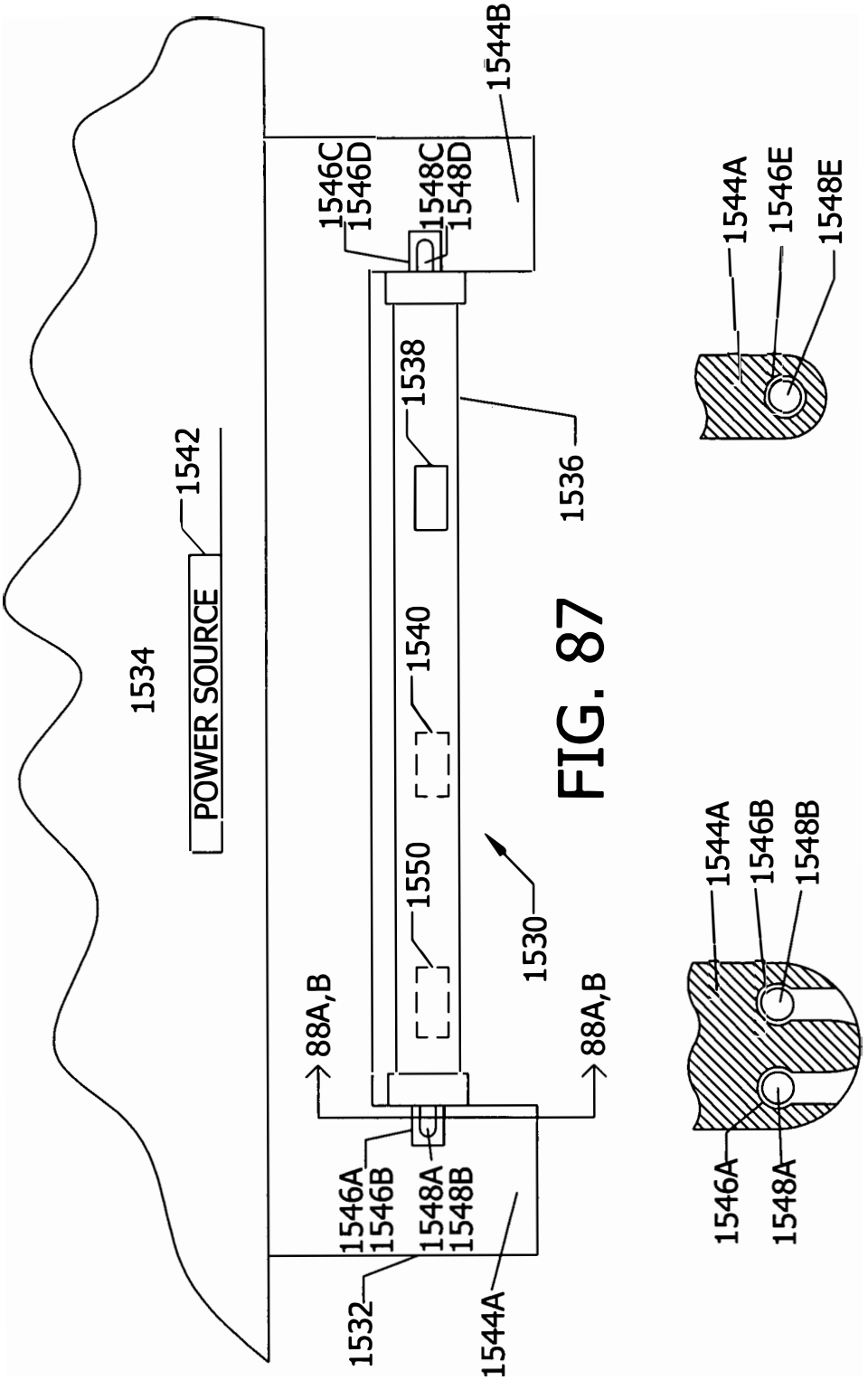


FIG. 87

FIG. 88B

FIG. 88A

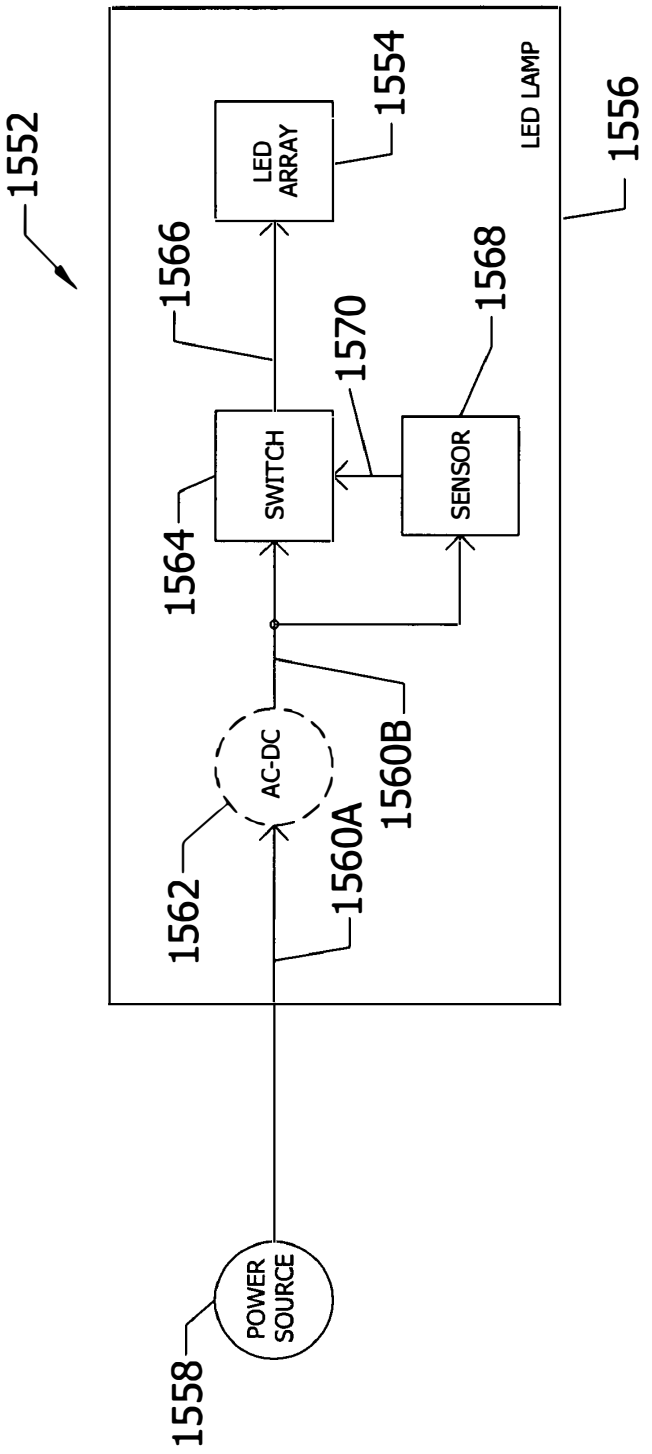

1552
LED LAMP
1556
LED ARRAY
1554
1566
1568
1570
SWITCH
SENSOR
1564
AC-DC
1560B
1562
1560A
POWER SOURCE
1558

FIG. 89A

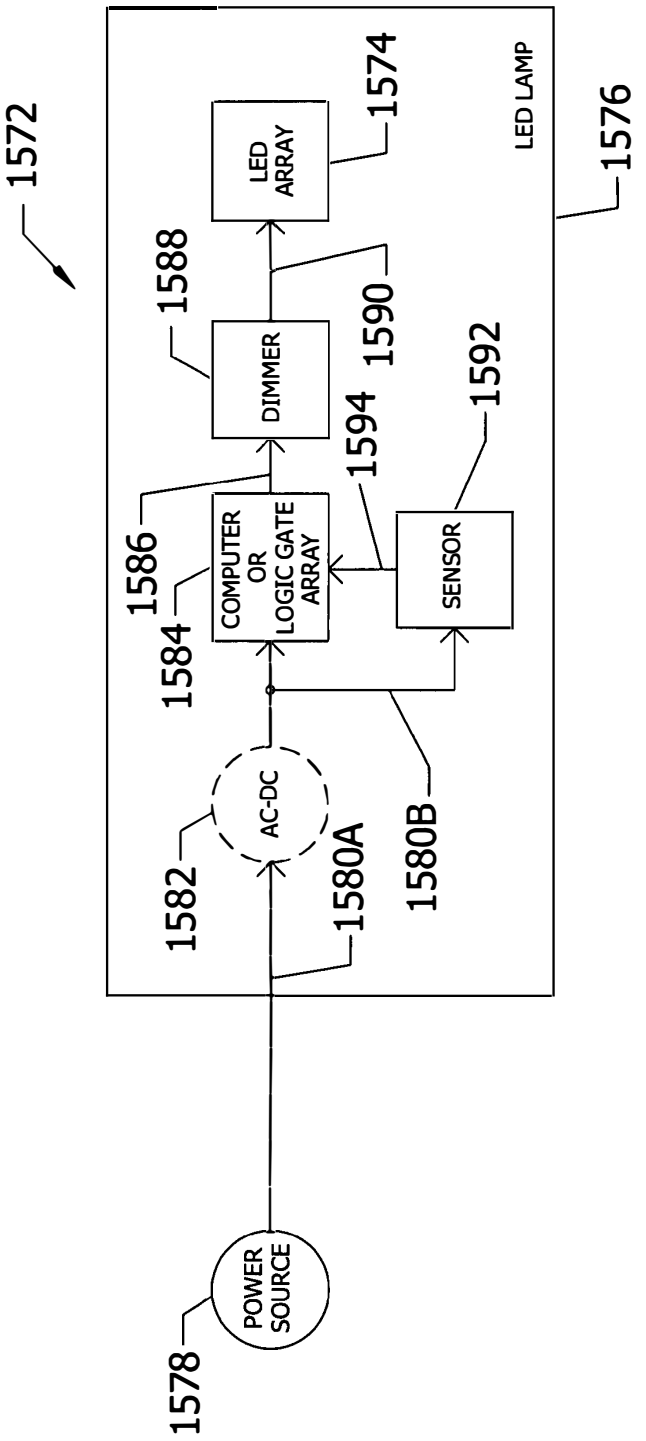

1572
LED LAMP
1576
LED ARRAY
1574
DIMMER
1588
1590
1592
1594
COMPUTER OR LOGIC GATE ARRAY
1586
1584
SENSOR
AC-DC
1582
1580A
1580B
POWER SOURCE
1578

FIG. 89B

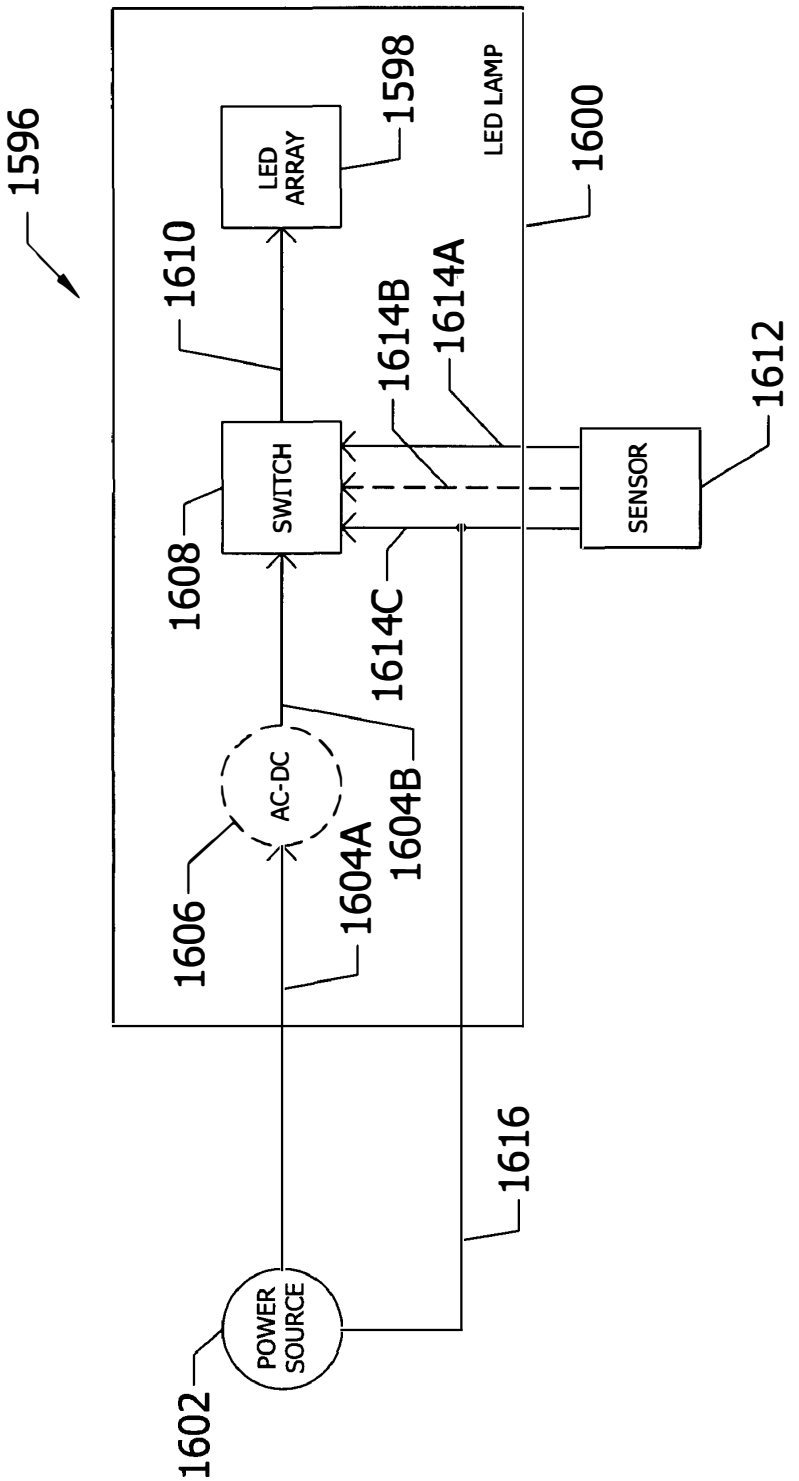

1596
LED LAMP
1600
LED ARRAY
1598
1610
1614B
1614A
1612
SWITCH
SENSOR
1608
1614C
AC-DC
1604B
1606
1604A
1616
POWER SOURCE
1602

FIG. 89C

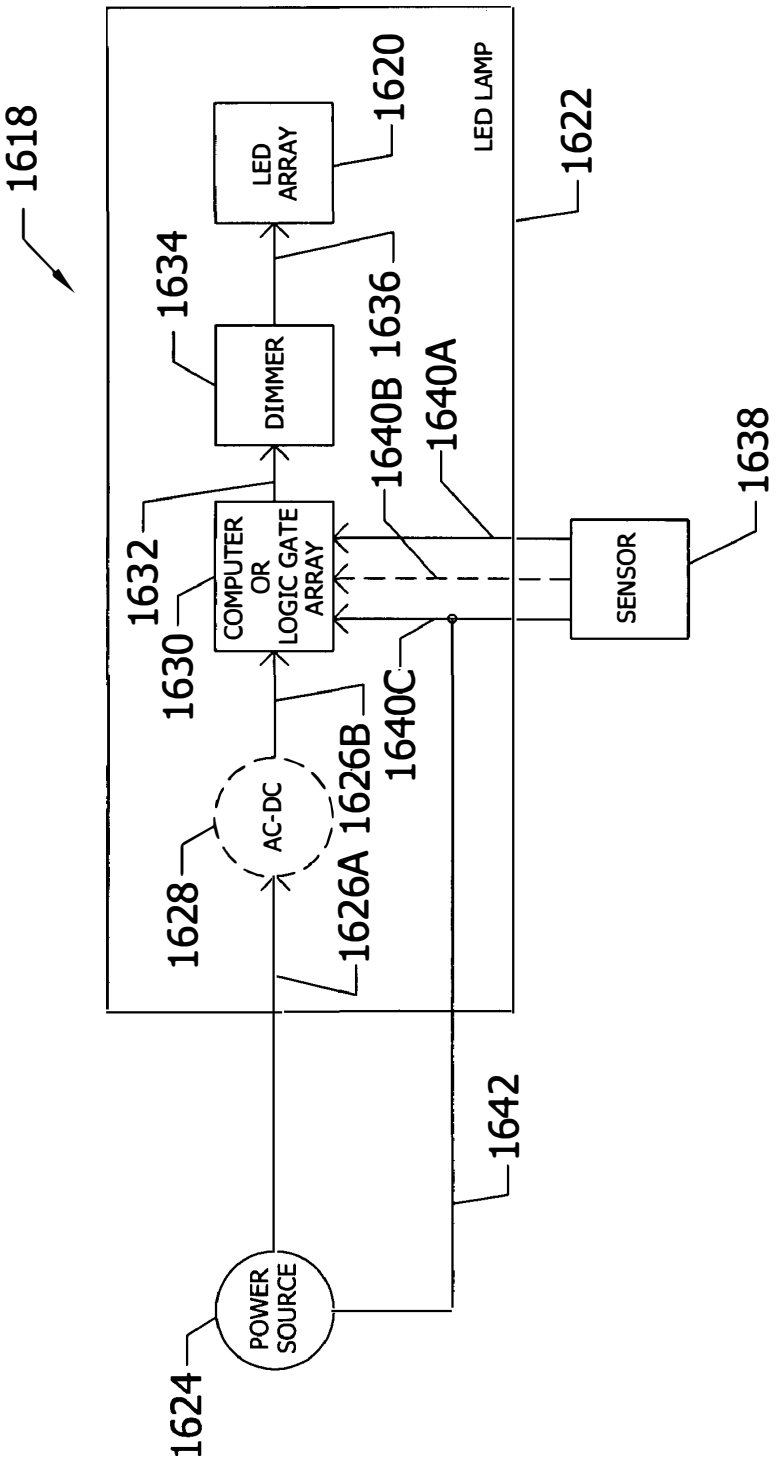

1618
LED LAMP
1622
LED ARRAY
1620
DIMMER
1634
1636
1640B
1640A
1638
SENSOR
COMPUTER OR LOGIC GATE ARRAY
1632
1630
1640C
AC-DC
1626B
1626A
1628
1642
POWER SOURCE
1624

FIG. 89D

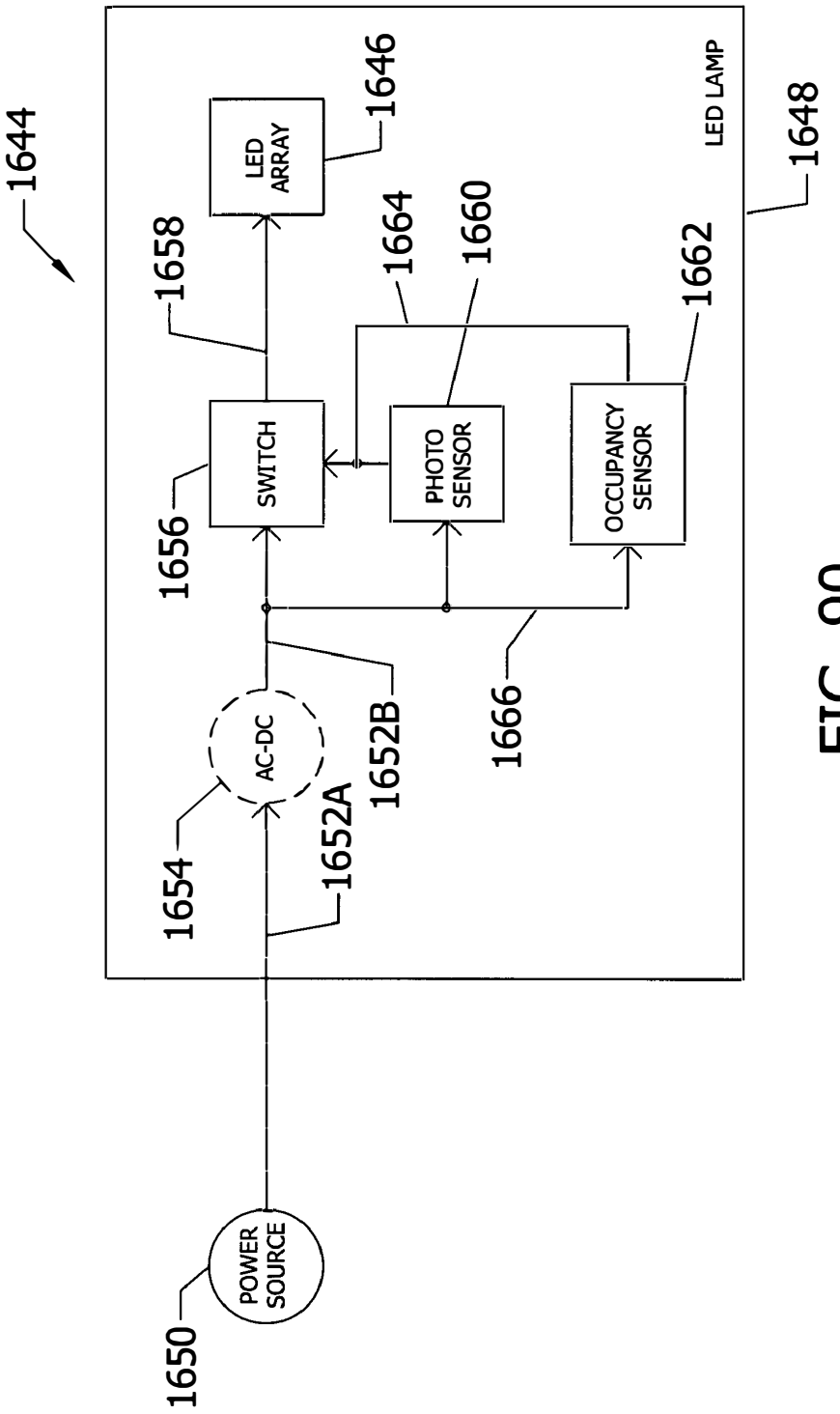

1644
LED LAMP
1648
LED ARRAY
1646
1658
1664
1660
1662
SWITCH
PHOTO SENSOR
OCCUPANCY SENSOR
1656
AC-DC
1652B
1666
1654
1652A
POWER SOURCE
1650

FIG. 90

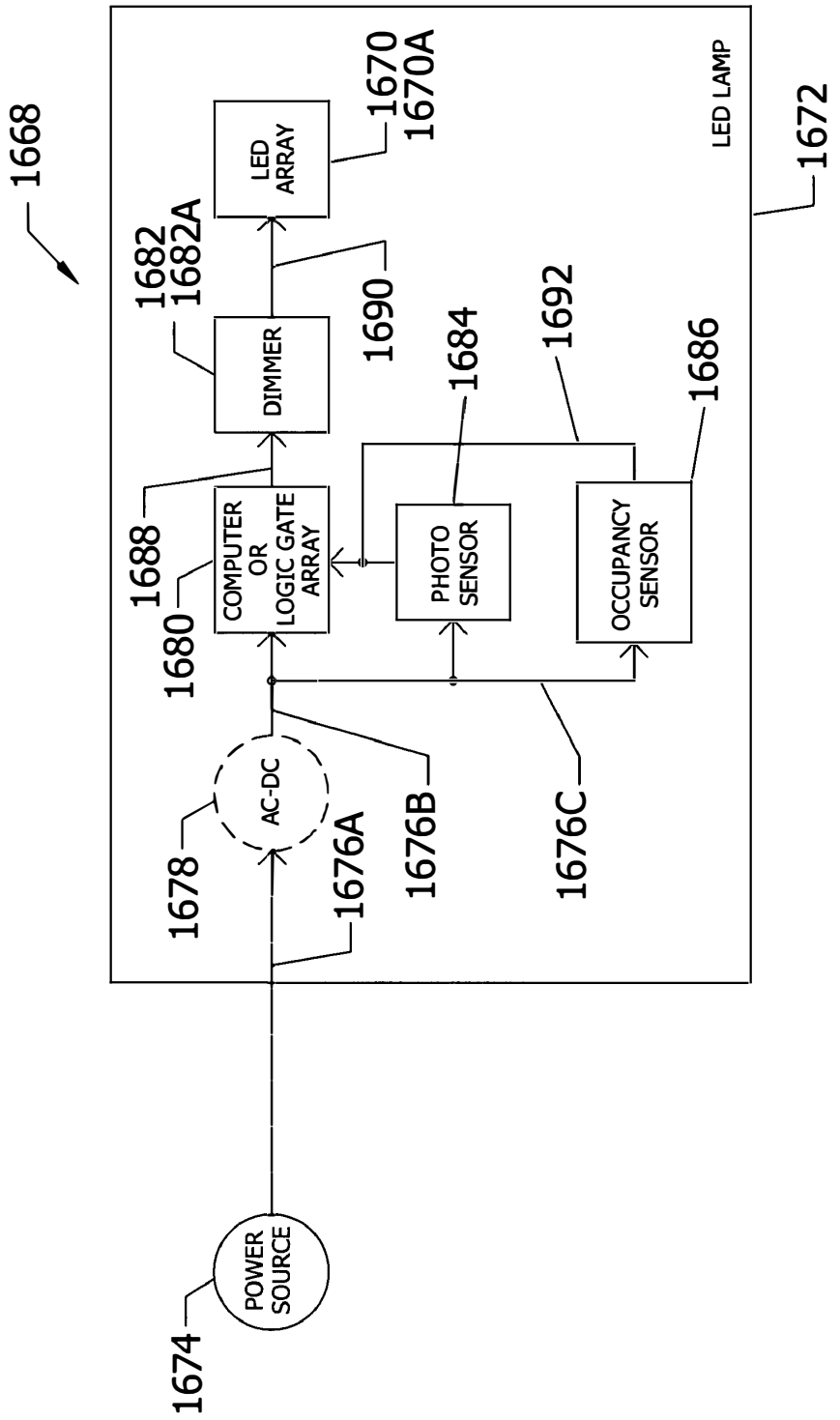

1668
LED LAMP
1672
LED ARRAY
1670
1670A
DIMMER
1682
1682A
1690
1684
1692
1686
COMPUTER OR LOGIC GATE ARRAY
PHOTO SENSOR
OCCUPANCY SENSOR
1688
1680
AC-DC
1678
1676A
1676B
1676C
POWER SOURCE
1674

FIG. 91

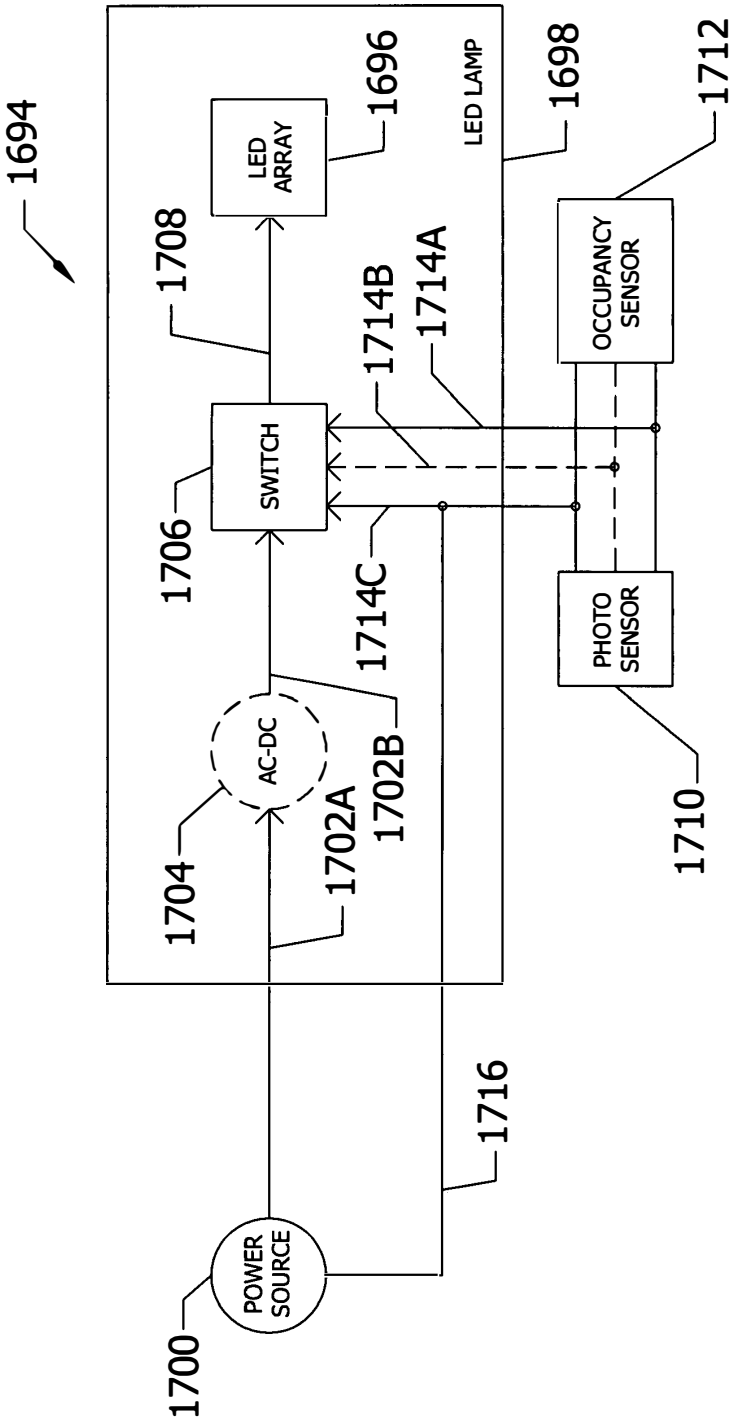

1694
LED LAMP
1698
LED ARRAY
1696
1708
1714B
1714A
OCCUPANCY SENSOR
1712
SWITCH
1706
1714C
PHOTO SENSOR
1710
AC-DC
1702B
1702A
1704
1716
POWER SOURCE
1700

FIG. 92

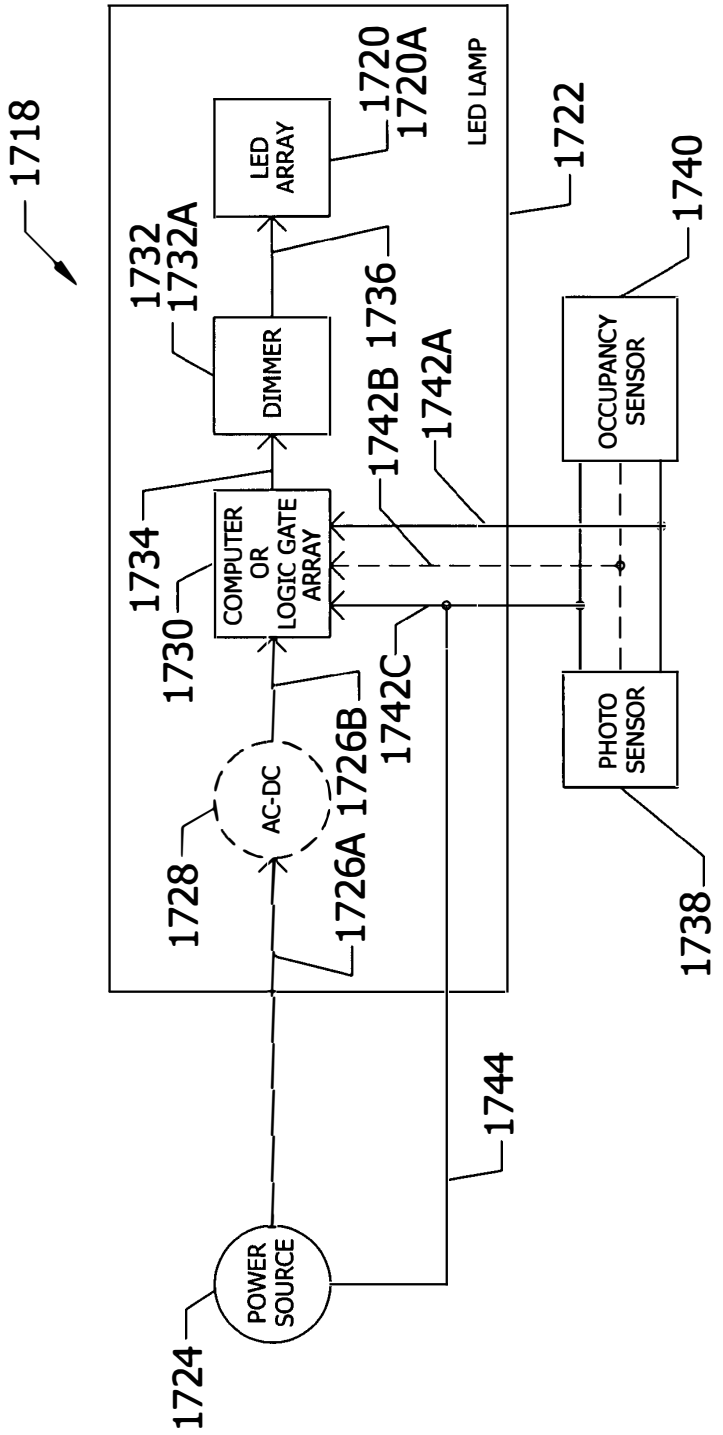

1718
LED LAMP
1722
LED ARRAY
1720
1720A
DIMMER
1732
1732A
1736
1742B
1742A
OCCUPANCY SENSOR
1740
1734
COMPUTER OR LOGIC GATE ARRAY
1730
1742C
1726B
AC-DC
1728
1726A
PHOTO SENSOR
1738
1744
POWER SOURCE
1724

FIG. 93

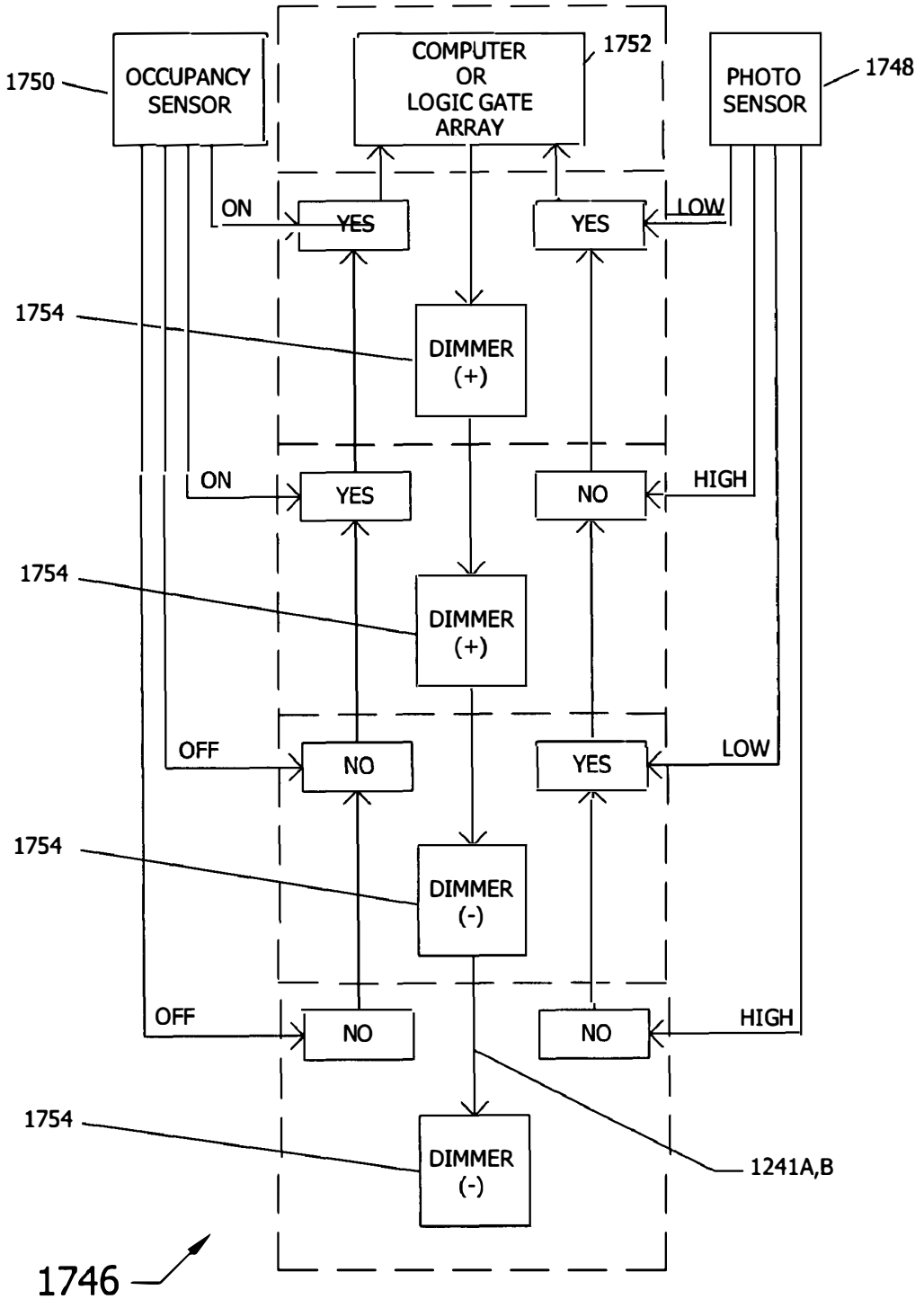

1750
OCCUPANCY SENSOR
COMPUTER OR LOGIC GATE ARRAY
1752
PHOTO SENSOR
1748
ON
YES
YES
LOW
1754
DIMMER (+)
ON
YES
NO
HIGH
1754
DIMMER (+)
OFF
NO
YES
LOW
1754
DIMMER (-)
OFF
NO
NO
HIGH
1754
DIMMER (-)
1241A,B
1746

FIG. 94

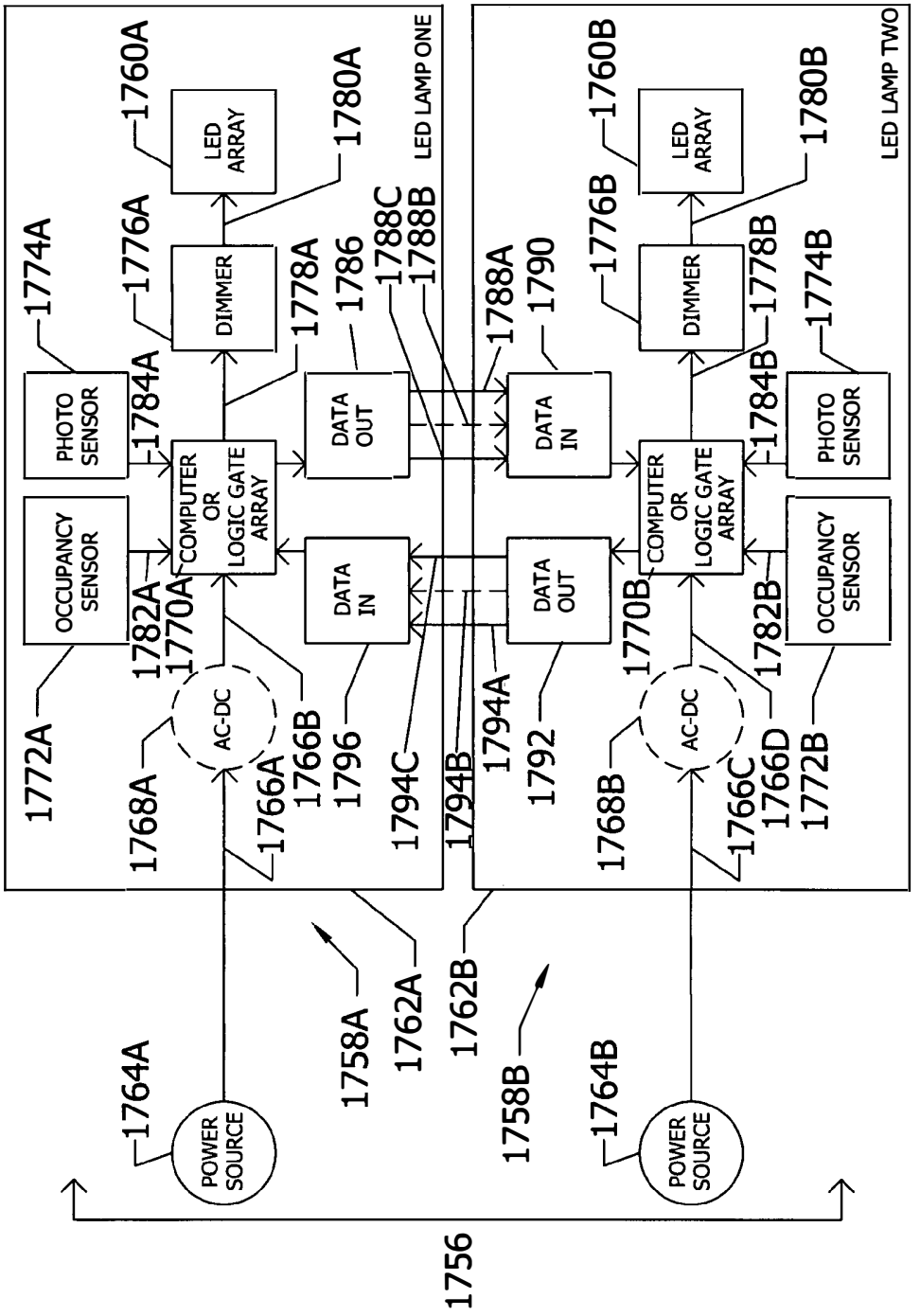

LED LAMP ONE
LED LAMP TWO
LED ARRAY
DIMMER
PHOTO SENSOR
OCCUPANCY SENSOR
COMPUTER OR LOGIC GATE ARRAY
DATA OUT
DATA IN
AC-DC
POWER SOURCE
1760A
1776A
1774A
1772A
1780A
1778A
1786
1788C
1788B
1784A
1782A
1770A
1768A
1766A
1766B
1796
1794C
1794B
1788A
1790
1792
1794A
1760B
1776B
1774B
1778B
1780B
1784B
1782B
1770B
1768B
1766C
1766D
1772B
1764A
1764B
1758A
1758B
1762A
1762B
1756

FIG. 95

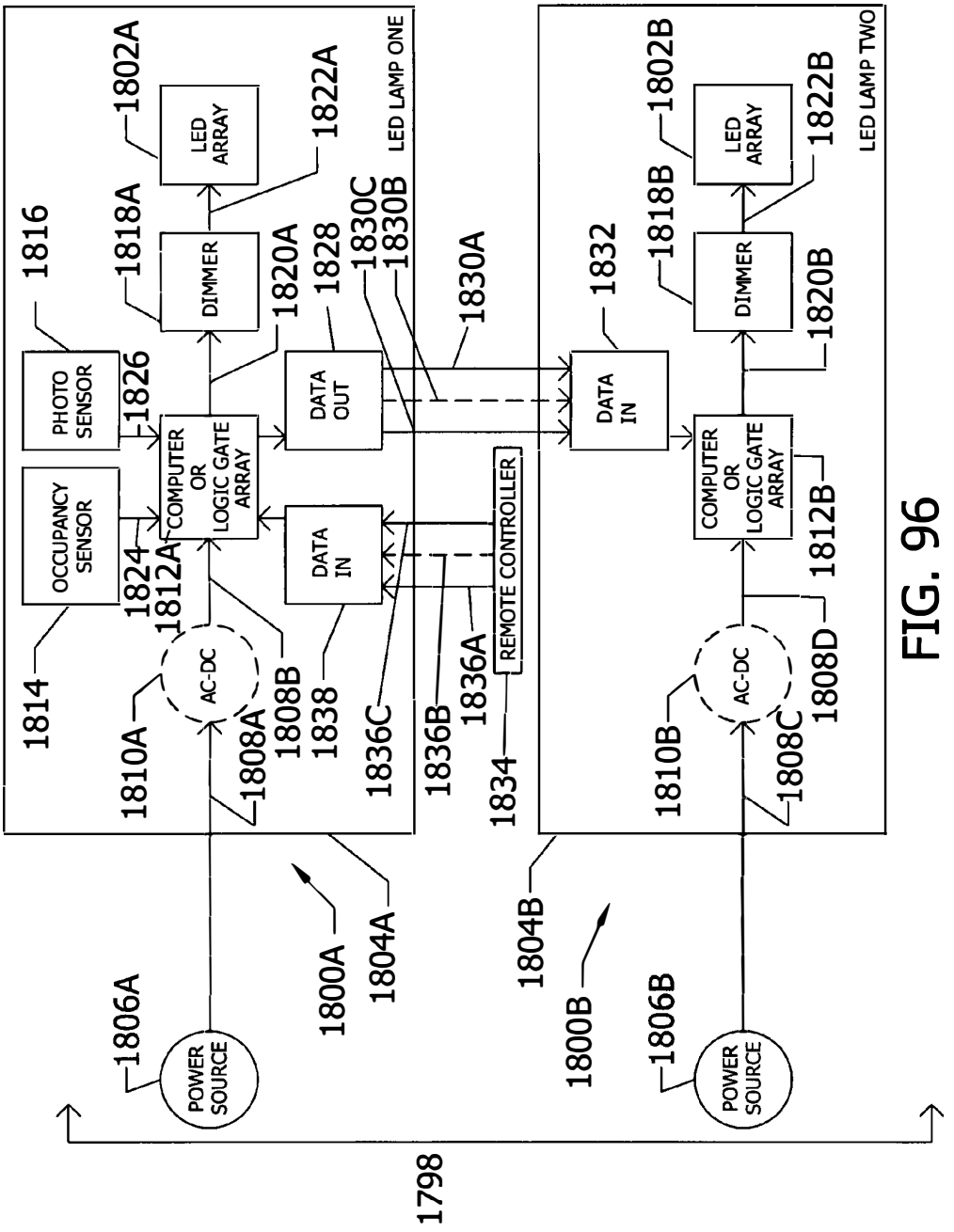

LED LAMP ONE
LED LAMP TWO
LED ARRAY
DIMMER
PHOTO SENSOR
OCCUPANCY SENSOR
COMPUTER OR LOGIC GATE ARRAY
DATA OUT
DATA IN
REMOTE CONTROLLER
AC-DC
POWER SOURCE
1798
1800A
1800B
1802A
1802B
1804A
1804B
1806A
1806B
1808A
1808B
1808C
1808D
1810A
1810B
1812A
1812B
1814
1816
1818A
1818B
1820A
1820B
1822A
1822B
1824
1826
1828
1830A
1830B
1830C
1832
1834
1836A
1836B
1836C
1838

FIG. 96

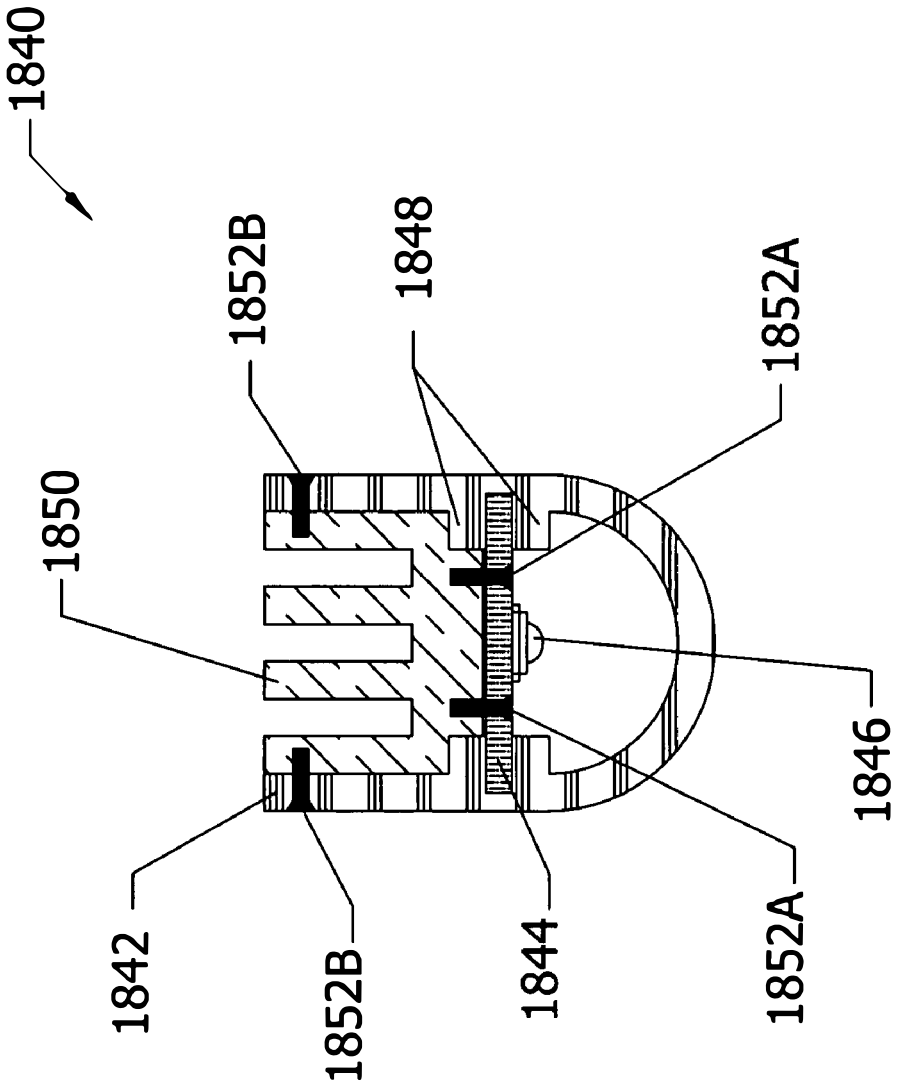


FIG. 97

RETROFIT LED LAMP FOR FLUORESCENT FIXTURES WITHOUT BALLAST

HISTORY OF THE INVENTION

This application is a continuation-in-part of U.S. application Ser. No. 11/198,633, filed on Aug. 5, 2005, which is a continuation-in-part of U.S. Pat. No. 7,067,992, issued on Jun. 27, 2006, which is a continuation-in-part of U.S. Pat. No. 6,853,151, issued on Feb. 8, 2005, which is a continuation-in-part of U.S. Pat. No. 6,762,562, issued on Jul. 13, 2004.

FIELD OF THE INVENTION

The present invention relates to a fluorescent replacement LED lamp powered directly by a power source with power control devices.

BACKGROUND OF THE INVENTION

U.S. Pat. Nos. 6,762,562; 6,853,151; 7,067,992; and U.S. patent application Ser. No. 11/198,633 set forth LED arrays positioned in tubes that are powered by reduced voltage from a ballast. This reduced voltage can be provided with various controls positioned inside or outside of the tubes, so that the illumination from the LED arrays can be varied, or switched to an on or off mode in accordance with illumination requirements that are independent of the main AC voltage lines in the area of the LED lamp as long as the main AC voltage lines are constantly on.

The present invention uses alternate power sources in lieu of the existing ballast as the main source of power to the LED lamp. The present invention discloses new retrofit LED lamps that are powered directly from line voltage alternating current (e.g., 120 Volts RMS at 60 Hz, 220 Volts RMS at 50 Hz), or other input power means where the ballast is removed or bypassed. The line voltage AC can be rectified to DC voltage that is then provided with various controls positioned internal or external to the tubes, so that the illumination from the LED arrays can be varied, or switched to an on or off mode in accordance with the illumination requirements.

Although the present LED lamp invention uses various power control devices to maximize energy savings for replacing fluorescent lamps, the same power control devices, systems, and techniques as disclosed in this specification can also be used for other lamp types including, but not limited to incandescent, halogen, HID, MH, MSR, HPS, phosphorescent, lasers, electro-luminescent, and other types of luminescent lamps for added energy efficiency and savings. In particular, the use of the power control devices can be use in tubular devices that are powered by external power sources including line voltage AC and DC drivers and supplies for the direct replacement of existing fluorescent lamps and devices.

The present invention is shown in FIGS. **87**, **88**A, **88**B, **89**A, **89**B, **89**C, **89**D, **90**, **91**, **92**, **93**, **94**, **95**, **96**, and **97**, and is described in detail later. Before proceeding to such detailed description of FIGS. **87-97**, some preliminary comments are now made in relation to the present invention as follows.

A ballast by definition is a device used to provide a starting voltage, and to stabilize and regulate the current in a circuit including fluorescent and discharge lamps. A power supply by definition is a separate unit or a device that supplies power or electrical energy to another device or a group of devices in a system. Since the starting voltage from a ballast is reduced to a lower voltage with the use of a voltage-reducing device, the ballast essentially operates like a current limiting power supply. The LED lamp of the present invention is then designed to work with all types of power supplies and ballasts interchangeably or with direct line voltage alternating current or VAC and even VDC power.

In the present invention, direct line voltage alternating current (VAC) provides the main electrical power to the LED retrofit lamp. For direct line VAC connection, the ballast is removed or bypassed, and the line voltage electrical power may go straight into a rectifying circuit that converts the VAC to VDC to power the various electrical components in the LED lamp. Direct connection to AC power without using a rectifying circuit is now possible. This is the case, for example, when the LEDs used are of the Acriche variety that are specially designed and manufactured by Seoul Semiconductor for direct AC connection. These LEDs can operate off 100, 110, 220, or 230 VAC. An alternate arrangement would be to connect a series of LEDs together to receive the line voltage AC, break down the input voltage evenly across each LED, and then use current limiting means to power the LEDs directly. Ultimately, DC voltage is supplied to other electrical components, including, but not limited to, a computer with its related hardware and software, logic gates, switches, sensors, dimmers, timers, and LED arrays, and other such associated electrical units known in the art.

There can be high transient voltage spikes in any AC or DC system. The sources of the transient voltage spikes can be from lightning, nuclear electromagnetic pulse, high energy switching, high voltage sparks, or electrostatic discharge. They may be found wherever the energy stored in inductors, capacitors, or electromechanical devices such as motors and generators are returned to a circuit. Because these LED lamps are designed for external AC and DC input voltages, there could be the need for voltage surge suppressors, movistors, varistors, inductors, and the like to reduce unwanted electrical voltage spikes and to protect the LED lamps. But these voltage suppression devices are optional. The LED lamp will still operate without these voltage suppression devices. However, without them, the LED lamps become unreliable and not protected from external voltage spikes that may permanently damage the internal electronic components within the LED lamp.

Dimmers as described herein can be conventional SCR or triac type dimmers, duty cycle modulated dimmers, amplitude modulated dimmers, frequency modulated dimmers, direct current voltage dimmers, current drivers, voltage drivers, autotransformers, rheostats, power op-amps, linear amplifiers, transistors, switches, and other types of dimmers can be use in the LED lamp.

Likewise, straight VDC power sources can be connected directly to the LED lamp of the present invention. Some DC power sources that can be used include, but are not limited to batteries, automotive and marine DC systems, AC to DC converters, DC to DC converters, linear and switched DC power supplies, current regulating LED drivers, buck converters, boost converters, buck-boost converters, and other such electrical systems known in the art.

Presently, in the area of fluorescent lighting, the latest energy savings involve the retrofit of existing fluorescent fixtures with new longer-life super T8 or T5 fluorescent lamps in use with new electronic ballasts. In many cases, fully functional electronics and mercury harmful lamps are likewise discarded. In addition, the cost involved for the labor to retrofit and re-wire all the existing fluorescent lighting in a commercial or industrial building can be quite expensive.

A different approach to energy efficient lighting is herewith proposed by disclosing new tubular LED fluorescent retrofit lamps for use with existing or new fluorescent housings where the ballasts are removed or bypassed. The use of

energy efficient and environmentally friendly tubular LED retrofit lamps will help eliminate harmful and hazardous mercury waste as produced by present fluorescent lamps. The tubular LED retrofit lamps of the present invention are designed to fit into existing fluorescent sockets to provide direct compatibility and ease of installation. Some benefits of using LEDs as a lighting alternative compared to fluorescent lamps include no mercury, longer life, better energy efficiency, better CRI, no flickering, full dimming capability, and operation in extreme cold conditions.

When Nichia Corporation first introduced the first white LED back in 1996; there were some problems with the new technology. Some of these obstacles included wide manufacturing tolerances for color temperature and intensity, low light output per unit, low efficacy (under 15 to 24 lumens per watt (LPW)), poor lumen maintenance, and lastly, high expense. These drawbacks prevented wide acceptance, promotion, sale, and implementation of LED lamps in the beginning.

Today, high brightness white LEDs are becoming much more popular as large companies like GE, Philips, and Sylvania/Osram have invested billions of dollars towards research and development to improve the performance of the new high brightness and power white LEDs to overcome the initial barriers and bring more usable white LED products to market. For example, Lumileds Lighting, a partnership between Philips Lighting and Hewlett Packard, introduced a new line of Luxeon white LEDs at Lightfair 2005. The solution to the wide manufacturing tolerances for achieving a consistent color temperature and intensity was to introduce color-matched white Luxeon Lamps, each containing multiple white Luxeon LEDs that are selected by advanced binning algorithms. By correctly combining an appropriate mix of LEDs, the Luxeon Lamps themselves have well-controlled and consistent color temperatures of 3200K (warm white), 4100K (commercial white) or 5500K (cool white). Lumileds Lighting intends to release their new Luxeon Rebel high-brightness LEDs in 2007.

The low light output per unit barrier can be overcome by using more LEDs in an array or using more LED dies in a package like the Luxeon K2 and BL Series of LED light engines available from Lumileds and Lamina Ceramics, respectively. Enfis Limited in the United Kingdom also offers a very dense LED die array available in Red, Green, Blue, and Amber colors besides White. Special optics and light gathering reflectors and other optical techniques can be used with the new high brightness and high power LEDs to provide comparable light outputs to conventional light sources.

The new Luxeon white LEDs mentioned before when used in linear lamps, have twice the efficacy of conventional halogen and incandescent lamps. When incorporated into a system, they can exceed the efficacy of fluorescent lighting. For example, a 3200K linear lamp has an efficacy of 32 LPW; a 4100K linear lamp has an efficacy of 40 LPW; a 5500K linear lamp has an efficacy of 50 LPW; and a new and improved 5500K lamp will offer an efficacy of 72 LPW.

Lumen maintenance for white LEDs has also improved with a minimum expected lifetime of 50,000 hours at 70% lumen maintenance. The life would increase with lower drive current and better heat management systems. Lumileds Lighting also publishes a one-year payback period when using the Luxeon white LED linear lamps when compared with a T5 or T8 fluorescent lamp with equal lumen output.

Prices for white LEDs have dropped significantly since their first introduction and particularly with the original discrete 5 mm white LEDs. For example, at introduction, a 5 mm white LED cost about $3-$5 each. Today, they cost about 80 cents in small quantities, and around 35 cents each in larger quantities of up to one million pieces. The cost of the new high power LED die array packages are now the premium, but they too will drop down in price as technology increases, and more LED manufacturers are producing similar white LEDs and lighting fixture manufacturers are using them in new LED products available to the public. Present day white LEDs when used in an array are a viable substitute for fluorescent lamps.

The following paragraphs will compare the differences between a typical new long-life 32-watt T8 fluorescent lamp versus the new tubular LED replacement lamp.

The cost for a typical long-life 32-watt T8 fluorescent lamp is around $5.00 with a life of 20,000 hours including installation. Since LED replacement lamps for fluorescents are unknown in the present market, we can use a comparable linear LED lamp as a base model. Ledtronics, Inc. located in California, presently sells a warm white LED lamp Part Number LED25T10-21W-120AM at a retail price of $79.99. Based on their published data, in an approximate 4-inch space, there are (64) 5 mm white LEDs mounted to a flat FR4 type circuit board. The lamp puts out 134 lumens or 136 foot-candles with a 40-degree beam spread, and consumes 1.86-watts. Obviously, the final cost for a similar tubular LED linear lamp will vary depending on the type and quantity of LEDs used.

Many LED manufacturers are now offering white LEDs with high luminosity flux outputs at relatively lower prices. Based on pricing obtained most recently during the write-up of this application from LED manufacturers like Lumileds, Nichia, and Cree Lighting, the Cree XLamp 7090 white LED is presently the industry's brightest 350 mA packaged LED. A single Cree XLamp 7090 white LED has a typical luminous or radiant flux of 52 lumens at 350 mA with a color temperature of between 4500K and 8000K. The new Cree XLamp 7090 white LED each consumes a power of 1.4-watts and has a 100 degrees viewing angle. In quantities of one million pieces, the price of each Cree XLamp 7090 white LED is $1.95 USD.

When the Cree XLamp 7090 white LED is used in place of standard 5 mm high brightness white Nichia LEDs, for example, the following calculations result.

Using the standard 32-watt rating of a typical T8 fluorescent lamp as a starting point and dividing by 1.4-watts gives approximately 22.857 Cree XLamp 7090 white LEDs being used in one 4-foot LED lamp of the present invention. Rounding off to a factor of four arrives at a total of 20 Cree XLamp 7090 white LEDs to be used in the new LED replacement lamps. This arrives at an LED acquisition cost of $39.00 or (20×$1.95). With the circuit board, electronics, mechanical parts, and including markup and mass production in very high volume quantities, one can possibly see the basic tubular 4-foot LED retrofit lamp selling for at least $50.00 versus the $5.00 for the T8 fluorescent lamp. The use of the new tubular LED lamp system may cost more initially, but the savings realized over a number of years will justify the initial expense along with the other benefits to follow.

The expected life of the tubular 4-foot LED linear lamp is at least 50,000 hours as compared to the life of a T8 fluorescent lamp of 20,000 hours. Therefore, the tubular LED linear lamp can last 2.5 times longer than the T8 retrofit fluorescent lamp.

A T8 has an overall 360-degree output rating of about 2,700 lumens with a color rendering index or CRI of 82. The tubular 4-foot LED lamp model should produce 1040 (20×52) lumens in a vertical direction beam output distribution over 100-degrees. When compared to the same portion of beam

output distribution of 750 lumens (2,700/3.6) over a comparable beam spread of 100-degrees from the T8 fluorescent lamp model, the tubular 4-foot LED lamp produces more light output with a CRI of 90.

Based on the labor required to maintain, repair, and replace a large number of lamps, the average cost including labor and material for retrofitting an existing fluorescent fixture with a T8 20,000-hour fluorescent lamp and a non-dimming electronic ballast is about $25.00, at $5.00 for the lamp, $15.00 for the non-dimming ballast, and $5 for the initial installation. The average cost including labor and material for the same T8 lamp and a dimming electronic ballast is about $50.00, at $5.00 for the lamp, $40 for the dimming ballast, and $5 for the installation. Based on these numbers and the values determined by earlier calculations, we can have the following possible fluorescent fixture retrofit options:

Ballast Type	Lamp	Cost	Relamping Cost	Total
Magnetic	T12	$ 0.00	$ 0.00	$ 0.00
Magnetic	T8	$10.00	$10.00	$20.00
Electronic – Dim	T8	$25.00	$10.00	$35.00
Electronic + Dim	T8	$50.00	$10.00	$60.00
Line Voltage VAC	T8/T12	N/A	N/A	N/A
Magnetic	LED	$55.00	$ 0.00	$55.00
Electronic – Dim	LED	$70.00	$ 0.00	$70.00
Electronic + Dim	LED	$95.00	$ 0.00	$95.00
External VAC Source	LED	$55.00	$ 0.00	$55.00
External VDC source	LED	$95.00	$ 0.00	$95.00

In the first row, we have an existing fluorescent fixture using an old magnetic ballast and an old T12 type lamp. This serves as the base model with no upgrade done here. In the second row, the old T12 lamp is replaced with a T8 lamp, but the magnetic ballast is left in place. The initial cost of the lamp including labor to install it would be $10.00. The T8 lamp will need to be replaced twice, once at 20,000 hours and a second time at 40,000 hours. With the assumption that the cost of the new lamp including labor to install it is still $5.00, this will add $10.00 giving a final overall cost of $20.00. In the third row, an existing fluorescent fixture is replaced with a new T8 lamp and a new non-dimming electronic ballast. The initial cost of the lamp and ballast including labor is $25.00 added to $10.00 for two lamp changes comes to a final overall cost of $35.00 for this arrangement. In the fourth row the fixture is replaced with an electronic dimming ballast and a new T8 lamp giving a final overall cost of $60.00 for this configuration. A line voltage version of a fluorescent lamp is not applicable.

In the seventh row, the old T12 is retrofitted with a new tubular LED linear lamp, and the old magnetic ballast is kept giving a total cost of $55.00, which includes the cost of the LED lamp estimated at $50.00 and an initial installation labor cost of $5.00. In the eighth row, a new tubular LED linear lamp with a new non-dimming electronic ballast is retrofitted at a total cost of $70.00. In the ninth row, a the fixture is retrofitted with a new tubular LED linear lamp and a new dimming electronic ballast for a total cost of $95.00. In the tenth row, the ballast is removed or bypassed, and a new retrofit tubular LED linear lamp is wired directly to line voltage alternating current or an external VAC source for a total cost of $55.00. In the last row is shown an entry for the use of an external direct-current voltage source for use with a new tubular LED linear lamp. A standard rule for a DC power supply is usually $1 per watt. A 40-watt DC power source priced at $40 along with the basic LED replacement lamp cost of $50 plus $5 for labor creates a total cost of $95.00.

As seen in the table above, two retrofit options give the same final cost. They include replacing the old lamp with a new LED retrofit lamp only, or using the new tubular LED linear retrofit lamp in the existing fixture and removing or bypassing the old ballast, and using direct line voltage AC to power the new LED retrofit lamp. The use of the new LED linear retrofit lamps show a cost savings over replacing the old ballast and T12 lamp with a new dimming electronic ballast and long life T8 lamp if the price of the new basic LED retrofit lamp is priced at $50.00 each, up to a cost of not more than $60.00 each to be competitive.

The new basic LED retrofit lamp is inherently dimmable using standard SCR or triac type wall dimmers and autotransformers or other automatic external energy saving devices. This being the case, the new basic LED retrofit lamps are more comparable to a replacement situation of a T8 lamp with a new dimming ballast than with a T8 lamp and a non-dimming ballast. Obviously, the final decision will be up to the end user's preference and budget cost concerns. The new LED retrofit lamp offers even more advantages over the use of a fluorescent lamp when we look at the energy savings involved when the two lamps are compared in the following paragraph.

Consumption and cost comparisons follow. A typical T8 fluorescent lamp consumes 32-watts. The new basic 4-foot LED retrofit lamp model should consume about 28-watts (20×1.4) based on the published data from Cree Lighting. A 28-watt LED lamp running 12 hours per day at 10 cents per kilowatt-hour uses a total energy cost per year of $12.26 per LED lamp. The total BTU used by the 28-watt LED lamp in one year equates to 122.6 kW or 418,437 BTUs. By comparison, the T8 fluorescent lamp also running 12 hours per day at 10 cents per kilowatt-hour uses a total energy cost per year of $14.02 per T8 fluorescent lamp. The total BTU used by the 32-watt T8 fluorescent lamp in one year equates to 140.16 kW or 478,506 BTUs. Therefore, by using the tubular 4-foot retrofit LED lamp instead of the T8 fluorescent lamp, an end user can see a possible additional savings of $1.76 per year with a difference of 60,069 BTUs saved per retrofit LED lamp used instead of a 32-watt T8 fluorescent lamp.

It becomes evident that the best cost savings with the best overall energy savings option is to use the new tubular LED retrofit lamp powered by direct line voltage AC with the ballast removed or bypassed in existing fluorescent fixtures. The design of the new tubular LED retrofit lamps offers the flexibility for an end user to use it with or without the ballast. As the cost for new high-brightness white LEDs continues to drop, the LED retrofit lamp option running off direct line voltage alternating current will become an even better option for overall cost savings, energy efficiency, and environmental friendliness.

With the addition of power control devices like timers, sensors, and switches being used with the basic LED retrofit lamps of the present invention, additional energy and cost savings can be gained. The use of power control devices is a more intelligent and efficient way to save money on energy bills without sacrificing lighting levels, safety, and lamp life.

According to LaMar Lighting Company located in Farmingdale, N.Y., the average stairwell is occupied less than 5% per 24-hour day or only 1.2 hours a day. During the time of non-occupancy, the LED retrofit lamps with power control devices provide the best energy savings by reducing the power to LED arrays. Other areas of intermittent or limited use including hallways, restrooms, cafeterias, conference rooms and some offices, etc. can also contribute to additional energy savings when using the basic LED replacement lamps with power controlling devices.

The present continuation-in-part application will be set forth in detail in relation to previously mentioned FIGS. **87-97** immediately after the following relevant material from the ancestor patents and applications.

With the present energy crisis, it becomes evident that the need for more energy efficient lamps of all configurations needs to be developed and implemented as soon as possible for energy conservation.

The most effective of all trends in energy-efficient lighting is not a product at all, but complex systems that blend the best of new lighting technologies with intelligent design strategies and ties them both to building automation schemes.

One of these systems, known as "Daylight Harvesting," employs light level sensors or photosensors to detect available daylight, and then to adjust the output of electric lights to compensate for light coming into an architectural space from the outside.

Daylight harvesting is beneficial from two standpoints: sunlight is good for people, and electricity is expensive, both financially and environmentally. Yet most lighting systems in schools, offices, and retail spaces operate at full output during all hours of operation regardless of how much sunlight is available. The amount of natural light available to any given building differs by geography and the building's design, but on average, the sunlight available to interiors through windows and skylights can provide sufficient light for most educational and business activities.

The financial costs of not turning off or dimming electric lights include unnecessarily high electric bills for lighting and for the air conditioning required to remove heat created by lights. But the total costs go far beyond economics to include eyestrain, because of excessive brightness and even a lessening of emotional and intellectual well-being. Combining good building design with automation to create the process know as daylight harvesting is the preferable way to deal with these problems because, as any facilities manager will say, counting on occupants to manually turn off or dim lights is highly unreliable.

Daylight harvesting in commercial buildings is experiencing renewed interest in the United States, particularly in light of the environmental consequences of power generation, the desire for sustainable design, and current strains on the nation's power grid. The United States Department of Energy estimates that US commercial businesses use one-quarter of their total energy consumption for lighting. Daylight harvesting and its associated systems, therefore, offer the opportunity to reduce energy consumption and costs.

Commercial buildings in the United States house more than 64 billion square feet of lit floor space. Most of these buildings are lit by fluorescent lighting systems. Estimates show between 30% and 50% of the spaces in these buildings has access to daylight either through windows or skylights. The installation of technologies designed to take advantage of available daylight would be an appropriate energy-saving strategy that could potentially turn off millions of light fixtures for some portion of each day.

A building's windows and skylights, or "fenestration," affect both the daylight available and the energy requirements of a building's heating, cooling, and lighting systems. The definition of fenestration as defined by the Merriam Webster's Collegiate Dictionary 12th edition is the arrangement, proportioning, and design of windows and doors in a building or room. The best way to capitalize on available daylight is to use integrated lighting controls that allow customized light levels and time of day control in use with proper fenestration to reduce energy use and lower power demand.

Daylight harvesting is a system, and all the elements of that system must be considered. Whether dealing with an existing building or a new design, the system begins with fenestration. Next, light compensation must be achieved with gradations of illumination, produced either through switching, or through dimming or brightening to maintain balanced light levels that illuminate without generating unwanted glare.

Lighting controls that respond to daylight distribution via windows, their orientation, location and glazing materials, will complement the abundant natural light available and greatly reduce lighting costs. Efficient lighting systems will also reduce wasted heat, decreasing the cooling load of the entire HVAC system and reducing overall electric usage.

Automatic controls can include the following:

- Centralized, web-based control to provide intuitive control that integrates with building automation systems including HVAC and security.
- Time of Day control to turn off certain lights according to a schedule.
- Timers that automatically switch off lights after a predetermined period.
- Occupancy sensors that detect your presence and provide light or turn it off when you leave a room.
- Light level photosensors that detect available daylight and modulate output of light accordingly.

Many current energy codes now require lights to be automatically turned off at the end of the day. Time of Day control provides the capability to schedule lighting based on the day of week and time of day in increments as small as one minute. This type of control ensures that lights are on or off in designated areas at user-specified times.

Another form of scheduling is based on an astronomical clock, which can control outdoor lighting using true on dawn and dusk settings. For example, lights can be turned on thirty minutes before dusk or turned off fifteen minutes after dawn. A building's longitude and latitude settings are used by the lighting control system to calculate dawn and dusk. Typically, an astronomical clock eliminates the need to use outdoor light level sensors.

Maximum energy savings up to 75% can be achieved through control and sensing means where the lighting system is controlled by both daylighting and occupancy sensors. A typical daylight harvesting system using the LED retrofit lamp of the present invention includes at least one light level photosensor paired with dimming controls, and dimming the lights proportionally to the amount of daylight entering the work space. The use of a light level sensor or photosensor will sense the amount of daylight available in a room and adjust the LED retrofit lamp output accordingly. Power control of the LED retrofit lamp can come from at least one occupancy sensor by itself or from at least one photosensor by itself. The use of at least one occupancy sensor in solo or with at least one light level photosensor in an LED retrofit lamp of the present invention will provide for maximum energy savings and conservation.

Many private, public, commercial and office buildings including transportation vehicles like trains and buses use fluorescent lamps installed in lighting fixtures. Fluorescent lamps are presently much more efficient than incandescent lamps in using energy to create light. Rather than applying current to a wire filament to produce light, fluorescent lamps rely upon an electrical arc passing between two electrodes, one located at ends of the lamp. The arc is conducted by mixing vaporized mercury with purified gases, mainly Neon and Krypton or Argon gas inside a tube lined with phosphor. The mercury vapor arc generates ultraviolet energy, which causes the phosphor coating to glow or fluoresce and emit

light. Standard electrical lamp sockets are positioned inside the lighting fixtures for securing and powering the fluorescent lamps to provide general lighting.

Unlike incandescent lamps, fluorescent lamps cannot be directly connected to alternating current power lines. Unless the flow of current is somehow stabilized, more and more current will flow through the lamp until it overheats and eventually destroys itself. The length and diameter of an incandescent lamp filament wire limits the amount of electrical current passing through the lamp and therefore regulates its light output. The fluorescent lamp, however using primarily an electrical arc instead of a wire filament, needs an additional device called a ballast to regulate and limit the current to stabilize the fluorescent lamp's light output.

Fluorescent lamps sold in the United States today are available in a wide variety of shapes and sizes. They run from miniature versions rated at 4 watts and 6 inches in length with a diameter of ⅝ inches, up to 215 watts extending eight feet in length with diameters exceeding 2 inches. The voltage required to start the lamp is dependent on the length and diameter of the lamp. Larger lamps require higher voltages. Ballast must be specifically designed to provide the proper starting and operating voltages required by the particular fluorescent lamp.

In all fluorescent lighting systems today, the ballast performs two basic functions. The first is to provide the proper voltage to establish an arc between the two electrodes, and the second is to provide a controlled amount of electrical energy to heat the lamp electrodes. These are to limit the amount of current to the lamp using a controlled voltage that prevents the lamp from destroying itself.

Fluorescent ballasts are available in magnetic, hybrid, and the more popular electronic ballasts. Of the electronic ballasts available, there are rapid start and instant start versions. A hybrid ballast combines both electronic and magnetic components in the same package.

In rapid start ballasts, the ballast applies a low voltage of about four volts across the two pins at either end of the fluorescent lamp. After this voltage is applied for at least one half of a second, an arc is struck across the lamp by the ballast starting voltage. After the lamp is ignited, the arc voltage is reduced to the proper operating voltage so that the current is limited through the fluorescent lamp.

Instant start ballasts on the other hand, provide light within 1/10 of a second after voltage is applied to the fluorescent lamp. Since there is no filament heating voltage used in instant start ballasts, these ballasts require about two watts less per lamp to operate than do rapid start ballasts. The electronic ballast operates the lamp at a frequency of 20,000 Hz or greater, versus the 60 Hz operation of magnetic and hybrid type ballasts. The higher frequency allows users to take advantage of increased fluorescent lamp efficiencies, resulting in smaller, lighter, and quieter ballast designs over the standard electromagnetic ballast.

Existing fluorescent lamps today use small amounts of mercury in their manufacturing process. The United States Environmental Protection Agency's (EPA) Toxicity Characteristic Leaching Procedure (TCLP) is used by the Federal Government and most states to determine whether or not used fluorescent lamps should be characterized as hazardous waste. It is a test developed by the EPA in 1990 to measure hazardous substances that might dissolve into the ecosystem. Some states use additional tests or criteria and a few have legislated or regulated that all fluorescent lamps are hazardous whether or not they pass the various tests. For those states that use TCLP to determine the status of linear fluorescent lamps, the mercury content is the critical factor. In order to minimize variability in the test, the National Electrical Manufacturers Association (NEMA) developed a standard on how to perform TCLP testing on linear fluorescent lamps (NEMA Standards Publication LL1-1997).

The TCLP attempts to simulate the effect of disposal in a conventional landfill under the complex conditions of acid rain. Briefly, TCLP testing of fluorescent lamps consists of the following steps:

1. All lamp parts are crushed or cut into small pieces to ensure all potential hazardous materials will leach out in the test.

2. The lamp parts are put into a container and an acetic acid buffer with a pH of 5 is added. A slightly acidic extraction fluid is used to represent typical landfill extraction conditions.

3. The closed container is tumbled end-over-end for 18 hours at 30 revolutions per minute.

4. The extraction fluid is then filtered and the mercury that is dissolved in the extraction fluid is measured per liter of liquid.

The average test result must be lower than 0.2 milligrams of mercury per liter of extraction fluid for the lamp to be qualified as non-hazardous waste. Items that pass the TCLP described above are TCLP-compliant, are considered non-hazardous by the EPA, and are exempt from the Universal Waste Ruling (UWR). Four-foot long fluorescent lamps with more than 6 milligrams of mercury, for example, fail the TCLP without an additive. The UWR is the part of the EPA's Resource Conservation and Recovery Act (RCRA), which governs the handling of hazardous waste. The UWR was established in May 1995 to simplify procedures for the handling, disposal, and recycling of batteries, pesticides, and thermostats, all considered widespread sources of low-level toxic waste. The purpose was to reduce the cost of complying with the more stringent hazardous waste regulations while maintaining environmental safeguards. Lamps containing mercury and lead were not included in the UWR. Originally, in most states, users disposing more than 350 lamps a month were required to comply with the more stringent government regulations. In Jul. 6, 1999 the EPA added non-TCLP-compliant lamps like those containing lead and mercury to the UWR. This addition went into effect in Jan. 6, 2000. So lamps that pass the TCLP are exempt from the UWR.

Not all states comply with the UWR after Jan. 6, 2000. Individual states have a choice of adopting the UWR for lamps or keeping the original RCRA full hazardous waste regulation. States can elect to impose stricter requirements than the federal government, which is what California has done with its TTLC or Total Threshold Limit Concentration test. In addition to a leaching test, the state of California has a total threshold limit concentration (TTLC) for mercury for hazardous waste qualification. Other states are considering implementing a total mercury threshold as well. California has a more rigorous testing procedure for non-hazardous waste classification. The Total Threshold Limit Concentration (TTLC) also needs to be passed in order for a fluorescent lamp to be classified as non-hazardous waste. The TTLC requires a total mercury concentration of less than 20 weight ppm (parts per million): for example, a F32 T8 lamp with a typical weight of 180 grams must contain less than 3.6 milligrams of mercury. Philips' ALTO lamps were the first fluorescent lamps to pass the Environmental Protection Agency's (EPA) TCLP (Toxic Characteristic Leaching Procedure) test for non-hazardous waste. Philips offers a linear fluorescent lamp range that complies with TTLC and is not hazardous waste in California with other lamp manufacturers following close behind.

Certain fluorescent lamp manufacturers like General Electric (GE) and Osram-Sylvania (OSI) use additives to legally influence the TCLP test. Different additives can be used. GE puts ascorbic acid and a strong reducing agent into the cement used to fix the lamp caps to the fluorescent lamp ends. OSI mixes copper-carbonate to the cement or applies zinc plated iron lamp end caps. The copper, iron, and zinc ions reduce soluble mercury. These additives are found in fluorescent lamps produced in 1999 and 2000. The use of additives reduces the soluble mercury measured by the TCLP test in laboratories and is a legitimate way to produce TCLP compliant fluorescent lamps.

Unfortunately, the additive approach does not reduce or eliminate the amount of hazardous mercury in the environment. More importantly, the additives may not work as effectively in the real world as they do in the laboratory TCLP test. In real world disposal, the lamp end caps are not cut to pass a 0.95 cm sieve, are not tumbled intensively with all other lamp parts for 18 hours, and so forth. Therefore, the additives that become available during the TCLP test to reduce mercury leaching may not or only partly, do their job in real world disposal. As a consequence, lamps that rely on additives pass TCLP, but may still have relatively high amounts of mercury leaching out into the environment.

The TCLP test is a controlled laboratory test meant to represent typical landfill conditions. The EPA developed this test in order to reduce leaching of hazardous materials in the environment. Of course, such a test is a compromise between the practicality of testing a large variety of landfill materials and actual landfill conditions. Not every landfill has a pH of 5 and metal parts are not normally cut into small pieces.

The amount of mercury that leaches out in real life will depend strongly on the type of additive used and the exact disposal conditions. However, the "additive" approach is not a guarantee that only small amounts of mercury will leach into the environment upon disposal.

Several states including New Jersey, Delaware, and Arkansas have addressed the additive issue. They have indicated that if lamps with additives were thrown away as non-hazardous waste and are later found to behave differently in the landfill, then the generators and those who dispose of such lamps could potentially face the possibility of having violated the hazardous waste disposal regulation known as RCRA.

The best fluorescent lamps in production at this time include GE's ECOLUX reduced mercury long-life XL and Philips' ALTO Advantage T8 lamps. They both have a rated lamp life of 24,000 hours, produce 2,950 lumens, and have a Color Rendering Index (CRI) of 85. Rated life for fluorescent lamps is based on a cycle of 3 hours on and 20 minutes off.

Besides the emission of ultra-violet (UV) rays and the described use of mercury in the manufacture of fluorescent lamps, there are other disadvantages to existing conventional fluorescent lamps that include flickering and limited usage in cold weather environments.

In conclusion, a particularly useful approach to a safer environment is to have a new lamp that contains no harmful traces of mercury that can leach out in the environment, no matter what the exact disposal conditions are. No mercury lamps are the best option for the environment and for the end-user that desires non-hazardous lamps. Also, no mercury LED retrofitting lamps will free many users from the regulatory burdens such as required paperwork and record keeping, training, and regulated shipping of otherwise hazardous materials. In addition, numerous industrial and commercial facility managers will no longer be burdened with the costs and hassles of disposing large numbers of spent fluorescent lamps considered as hazardous waste. The need for a safer, energy efficient, reliable, versatile, and less maintenance light source is needed.

Light emitting diode (LED) lamps and organic light emitting diode (OLED) lamps that retrofit fluorescent lighting fixtures using existing ballasts, or other power supplies can help to relieve some of the above power and environmental problems.

An organic light emitting diode or OLED is an electronic device made by placing a series of extremely thin layers of organic film material between two conductors. The conductors can be glass substrate or flexible plastic material. When electrical current is applied, these organic film materials emit bright light. This process is called electro-phosphorescence. Even with the layered configuration, OLEDs are very thin, usually less than 500 nm or 0.5 thousandths of a millimeter. OLED displays offer up to 165 degrees viewing and require only 2-10 volts to operate while OLED panels may also be used as lighting devices. An alternative name for OLED technology is OEL or Organic Electro-Luminescence.

Recent advances made by GE Lighting in the first quarter of 2004 have produced a very bright 24 square inch OLED panel producing well over 1200 lumens of light with an efficacy of 15 lumens per watt and a power consumption of about 80-watts. This latest breakthrough demonstrates that the light quality, output, and efficiency of OLED technology can meet the needs of general illumination on par with todays incandescent and possibly fluorescent lamp technologies. Because OLED panels are thinner, lighter, and flexible by nature, it serves as a possible light source for the present invention.

In the present application, the use of "LED" covers both conventional high-brightness semiconductor light emitting diodes (LEDs) and organic light emitting diodes (OLEDs); semiconductor dies that produce light in response to current, light emitting polymers, electro-luminescent strips (EL), etc. Furthermore, the use of "LED" may refer to a single light-emitting device having multiple semiconductor dies that are individually controlled. It should also be understood that the use of "LED" does not restrict the package type of an LED. The use of "LED" may refer to packaged LEDs, non-packaged LEDs, surface mount LEDs, chip-on-board (COB) LEDs, and LEDs of all other configurations. The use of "LED" also includes LEDs packaged or associated with phosphor, wherein the phosphor may convert radiant energy emitted from the LED to a different wavelength of light. The use of "LED" will also include high-brightness white LEDs as well as high-brightness color LEDs in different packages. An LED array can consist of at least one LED or a plurality of LEDs, and at least one LED array can also consist of a plurality of LED arrays.

These new LED lamps can be used with magnetic, hybrid, and electronic instant and rapid start ballasts, and will plug directly into the present sockets thereby replacing the fluorescent lamps in existing lighting fixtures or with other AC or DC power supplies. The new LED retrofit lamps are adapted to be inserted into the housing of existing fluorescent lighting fixtures acting as a direct replacement light unit for the fluorescent lamps of the original equipment. The major advantage is that the new LED retrofit lamps with integral electronic circuitry are able to replace existing fluorescent lamps without any need to remove the installed ballasts or make modifications to the internal wiring of the already installed fluorescent lighting fixtures. The new LED retrofit lamps include replacing linear cylindrical tube T8 and T12 lamps, U-shape curved lamps, circular T5 lamps, helical CFL compact type

fluorescent and PL lamps, and other tubular shaped fluorescent lamps with two or more electrical contacts that mate with existing sockets.

The use of light emitting diodes and organic light emitting diodes as alternate light sources to replace existing lamp designs is a viable option. Light Emitting Diodes (LEDs) are compound semiconductor devices that convert electricity to light when biased in the forward direction. In 1969, General Electric invented the first LED, SSL1 (Solid State Lamp). The SSL1 was a gallium phosphide device that had transistor-like properties i.e. high shock, vibration resistance and long life. Because of its small size, ruggedness, fast switching, low power and compatibility with integrated circuitry, the SSL1 was developed for many indicator-type applications. It was these unique advantages over existing light sources that made the SSL1 find its way into many future applications.

Today advanced high-brightness LEDs and OLEDs are the next generation of lighting technology that is currently being installed in a variety of lighting applications. As a result of breakthroughs in material efficiencies and optoelectronic packaging design, LEDs are no longer used as just indicator lamps. They are now used as a light source for the illumination of monochromatic applications such as traffic signals, vehicle brake lights, and commercial signs.

In addition, white light LED technology will change the lighting industry, as we know it. Even with further improvements in color quality and performance, white light LED technology has the potential to be a dominant force in the general illumination market. LED benefits include: energy efficiency, compact size, low wattage, low heat, long life, extreme robustness and durability, little or no UV emission, no harmful mercury, and full compatibility with the use of integrated circuits.

To reduce electrical cost and to increase reliability, LED lamps have been developed to replace the conventional incandescent lamps typically used in existing general lighting fixtures. LED lamps consume less energy than conventional lamps and give much longer lamp life.

Unfortunately, the prior art LED lamp designs used thus far still do not provide sufficiently bright and uniform illumination for general lighting applications, nor can they be used strictly as direct and simple LED retrofit lamps for existing fluorescent lighting fixtures and ballast configurations.

U.S. Pat. No. D366,506 issued to Lodhie on Jan. 19, 1999, and U.S. Pat. No. D405,201 issued to Lodhie on Feb. 2, 1999, both disclose an ornamental design for a bulb. One has a bayonet base and the other a medium screw base, but neither was designed exclusively for use as a retrofit lamp for a fluorescent lighting fixture using the existing fluorescent sockets and ballast electronics. Power to the circuit boards and light emitting diodes are provided on one end only. Fluorescent ballasts can provide power on at least one end, but normally power to the lamp is supplied into two ends. Likewise, U.S. Pat. No. 5,463,280 issued to Johnson, U.S. Pat. No. 5,655,830 issued to Ruskouski, and U.S. Pat. No. 5,726,535 issued to Yan, all disclose LED Retrofit lamps exclusively for exit signs and the like. But as mentioned before, none of the disclosed retrofit lamps are designed for use as a retrofit lamp for a fluorescent lighting fixture using the existing fluorescent sockets and ballast electronics. Power to the circuit boards and light emitting diodes are provided on one end only while existing fluorescent ballasts can provide power on two ends of a lamp.

U.S. Pat. No. 5,577,832 issued to Lodhie on Nov. 26, 1996, teaches a multilayer LED assembly that is used as a replacement light for equipment used in manufacturing environments. Although the multiple LEDs, which are mounted perpendicular to a base provides better light distribution, this invention was not exclusively designed for use as a retrofit lamp for fluorescent lighting fixtures using the existing fluorescent sockets and ballast electronics. In addition, this invention was designed with a single base for powering and supporting the LED array with a knob coupled to an axle attached to the base on the opposite end. The LED array of the present invention is not supported by the lamp base, but is supported by the tubular housing itself. The present invention provides power on both ends of the retrofit LED lamp serving as a true replacement lamp for existing fluorescent lighting fixtures.

U.S. Pat. No. 5,688,042 issued to Madadi on Nov. 18, 1997, discloses LED lamps for use in lighted sign assemblies. The invention uses three flat elongated circuit boards arranged in a triangular formation with light emitting diodes mounted and facing outward from the center. This configuration has its limitation, because the light output is not evenly distributed away from the center. This LED lamp projects the light of the LEDs in three general zonal directions. Likewise, power to the LEDs is provided on one end only. In addition, the disclosed configuration of the LEDs limits its use in non-linear and curved housings.

U.S. Pat. No. 5,949,347 issued to Wu on Sep. 7, 1999, also discloses a retrofit lamp for illuminated signs. In this example, the LEDs are arranged on a shaped frame, so that they are aimed in a desired direction to provide bright and uniform illumination. But similar to Madadi et al, this invention does not provide for an omni-directional and even distribution of light as will be disclosed by the present invention. Again, power to the LEDs is provided on one end of the lamp only and cannot be used in either non-linear or curved housings.

U.S. Pat. No. 5,575,459 issued to Anderson on Nov. 19, 1996, U.S. Pat. No. 6,471,388 BI issued to Marsh on Oct. 29, 2002, and U.S. Pat. No. 6,520,655 B2 issued to Ohuchi on Feb. 18, 2003 all contain information that relate to replacement LED lamps, but do not disclose the detailed specifics of the original invention.

The following list of U.S. patents and patent publications is made of record and presented for background reference as being related to the present invention disclosure.

Relevant References

1) U.S. Pat. No. 6,739,734 issued to Hulgan on May 25, 2004;

2) U.S. Pat. No. 6,860,628 issued to Robertson et al. on Mar. 1, 2005;

3) U.S. Pat. No. 6,936,968 issued to Cross et al. on Aug. 30, 2005;

4) U.S. Pat. No. 7,049,761 issued to Timmermans et al. on May 23, 2006;

5) U.S. Pat. No. 7,053,557 issued to Cross et al. on May 30, 2006; and

6) U.S. Pat. No. 7,114,830 issued to Robertson et al. on Oct. 3, 2006.

The Timmermans et al. reference is particularly relevant to the present invention for the reason that Timmermans et al. describes a retrofit LED lamp for an existing fluorescent lamp. Timmermans et al., however, does not show, discuss, or suggest any power saving devices associated with the basic retrofit LED lamp as is particularly set forth herein as shown and discussed in FIGS. **87-96** herein, nor does Timmermans et al. utilize voltage suppression devices.

The present invention has been made in order to solve the problems that have arisen in the course of an attempt to develop energy efficient lamps. This invention is designed to replace the existing hazardous fluorescent lamps that contain harmful mercury and emit dangerous ultra-violet rays. They

can be used directly in existing fluorescent sockets and lighting fixtures powered directly by line voltage AC where the ballast is removed or bypassed and the tubular LED retrofit lamp of the present invention is connected directly to the line voltage alternating current or direct current voltage.

A primary object of the present invention is to provide a tubular LED retrofit lamp that will bring about better energy conservation and savings.

SUMMARY OF THE INVENTION

In the present invention, the use of a ballast assembly to provide power to the light emitting diode (LED) lamp is optional. Instead, the ballast assembly can be removed or bypassed, so that the LED lamp is then powered directly from an external power source. The external power source can be the same line voltage AC input to the present lighting fixture or a DC voltage input from an external DC power device.

The present continuation-in-part invention may include a power saving device for a light emitting diode (LED) lamp mounted to an existing fixture for a fluorescent lamp having LEDs positioned within a tube and electrical power delivered from an external power source to the LEDs. The LED lamp includes means for controlling the delivery of the electrical power from the external power source to the LEDs, wherein the use of electrical power can be reduced or eliminated automatically during periods of non-use. Such means for controlling can include an on-off switch mounted inside or outside of the tube, and can also include a current driver dimmer mounted in the tube that regulates the amount of power delivered to the LEDs. A computer or logic gate array controls the dimmer or power switch. A sensor such as a light level photosensor and/or an occupancy sensor mounted external to the tube or internal to the tube can send signals to the computer or logic gate array to trigger a switch or control a dimmer. Two or more such LED lamps with one or more computers or logic gate arrays in network communication with sensors can be controlled, so as to reduce flickering between lamps when illumination areas are being alternately occupied. Preset or manually set timers can control switches or be used in combination with the computer, logic gate array, and dimmer. A combination of at least one occupancy detection sensor and/or at least one light level photosensor used together to provide input signals to the computer, logic gate arrays, or switches, will provide the best savings in energy and conservation.

A prior inventive embodiment disclosed a power saving device that includes a fluorescent luminaire having a ballast assembly and LEDs positioned within a tube and electrical power delivered from the ballast assembly to the LEDs. The LED lamp includes means for controlling the delivery of the electrical power from the ballast assembly to the LEDs wherein the use of electrical power can be reduced or eliminated automatically during periods of non-use. Such means for controlling can include an on-off switch mounted in the tube or can also include a current driver dimmer mounted in the tube that regulates the amount of power delivered to the LEDs. A computer or an array of logic gates can control the dimmer or switches to the LED arrays. A sensor such as an occupancy motion detection sensor mounted external to the tube or within the tube can send signals to the computer, logic gate arrays, or switches. Two or more such LED lamps with one or more computers in network communication with the sensors can be controlled so as to reduce flickering between lamps when illumination areas are being alternately occupied. Preset or manually set timers can control the switch or be used in combination with the computer, logic gate arrays, switch, and dimmer.

The aforementioned problems were met by providing an LED lamp that has a main, generally tubular housing terminating at both ends in a lamp base that inserts directly into the lamp socket of existing fluorescent lighting fixtures used for general lighting in public, private, commercial, industrial, residential buildings, and even in transportation vehicles. The new LED lamps include replacing linear cylindrical tube T8 and T12 lamps, U-shape curved lamps, circular T5 lamps, and CFL compact type fluorescent and PL lamps, etc. The main outer tubular housing of the new LED lamps can be linear, U-shaped, circular, or helical in configuration. It can be manufactured as a single hollow housing or as two halves that can be combined to form a single hollow housing. The two halves can be designed to snap together, or can be held together with glue, or by other means like ultrasonic welding, etc. The main outer tubular housing can be made of a light transmitting material like glass or acrylic plastic for example. The surface of the main outer tubular housing can be diffused or can be coated with a white translucent film to create a more dispersed light output similar to present fluorescent lamps. Power to the LED lamps in the various shapes and configurations is provided at the two ends by existing fluorescent ballasts. Integral electronic circuitry converts the power from the fluorescent ballasts necessary to power the LEDs mounted to the circuit boards that are inserted within the main outer tubular housing. Desirably, the two base end caps of the LED lamp have apertures therein to allow air to pass through into and out from the interior of the main outer tubular housing and integral electronic circuitry.

In one embodiment of the present invention, the discrete or surface mount LEDs are compactly arranged and fixedly mounted with lead-free solder onto a flat rectangular flexible circuit board made of a high-temperature polyimide or equivalent material. There are long slits between each column and row of LEDs. The entire flexible circuit board with the attached LEDs is rolled to form a hollow and generally cylindrical frame, with the LEDs facing radially outward from a central axis. Although this embodiment describes a generally cylindrical frame, it can be appreciated by someone skilled in the art to form the flexible circuit board into shapes other than a cylinder, such as an elongated oval, triangle, rectangle, hexagon, octagon, and so on among many other possible configurations. Accordingly, the shape of the tubular housing holding the individual flexible circuit board can be made in a similar shape to match the shape of the formed flexible circuit board. The entire frame is then inserted inside the main outer tubular housing. It can also be said that the shape of the flexible circuit board can be made into the same shape as the tubular housing. The length of the frame is always within the length of the linear main outer tubular housing. AC power generated by the external fluorescent ballast is converted to DC power by additional integral electronics. Electrical connector means are used to connect the integral electronics to the light emitting diode array and to provide current to the LEDs at one or both ends of the flexible circuit board. Since present linear fluorescent lamps are available in one, two, four, six, and eight feet lengths, the flexible circuit board can be designed in increments of one-foot lengths. Individual flexible circuit boards can be cascaded and connected in series to achieve the desired lengths. Likewise, the main outer tubular housing in linear form will be available in the desired lengths, i.e. one, two, four, six, and eight feet lengths. The main outer tubular housing can also be provided in a U-shape, circular, spiral shape, or other curved configuration. The slits

provided on the flat flexible circuit board located between each linear array of LEDs allows for the rolled frame to contour and adapt its shape to fit into the curvature of the main outer tubular housing. Such a design allows for the versatile use in almost any shape that the main outer tubular housing can be manufactured in. There is an optional flexible center support that can isolate the integral electronics from the flexible circuit board containing the compact LED array, which may serve as a heat sink to draw heat away from the circuit board and LEDs to the center of the main outer tubular housing and thereby dissipating the heat at the two lamp base ends. There may be cooling holes or air holes on either lamp base end caps of the LED retrofit lamp, in the isolating flexible center support, and in the flexible circuit board containing the compact LED array to allow for proper cooling and airflow. In addition, the main outer tubular housing may contain small holes or other perforations to provide additional cooling of the power electronics, LEDs, and circuit board components. Each end cap of the LED lamp can terminate in single-pin or bi-pin or quad-pin contacts.

In another embodiment of the present invention, the array of discrete or surface mount LEDs are compactly arranged in a continuously long and thin LED array, and is fixedly mounted with lead-free solder onto a very long and thin flexible circuit board strip made of a high-temperature polyimide or equivalent material. The entire flexible circuit board with the attached LEDs is then spirally wrapped around an optional interior flexible center support. Because the center support is also made of a flexible material like rubber, etc. it can be formed into the shape of a U, a circle, or even into a helical spiral similar to existing CFL or compact fluorescent lamp shapes. The entire generally cylindrical assembly consisting of the compact strip of flexible circuit board spiraling around the center support is then inserted into the main outer tubular housing. Although this embodiment describes a generally cylindrical assembly, it can be appreciated by someone skilled in the art to form the flexible circuit board strip into shapes other than a cylinder, such as an elongated oval, triangle, rectangle, hexagon, octagon, etc. Accordingly, the shape of the tubular housing holding the individual flexible circuit board strip can be made in a similar shape to match the shape of the formed flexible circuit board strip assembly. The lengthof the entire assembly is always within the length of the main outer tubular housing. AC power generated by the external fluorescent ballasts is converted to DC power by additional integral electronics. Electrical connector means are used to connect the integral electronics to the light emitting diode arrays to provide current to the LEDs at one or both ends of the flexible circuit board. Since present linear fluorescent lamps are available in one, two, four, six, and eight feet lengths, the flexible circuit board can be designed in increments of one-foot lengths. Individual flexible circuit boards can be cascaded and connected in series to achieve the desired lengths. Likewise, the main outer tubular housing in linear form will be available in the desired lengths, i.e. one, two, four, six, and eight feet lengths. Although this embodiment can be used for linear lamps, it can be appreciated by someone skilled in the art for use with curved tubular housings as well. Here, the flexible and hollow center support isolates the integral electronics from the flexible circuit board containing the compact LED array. It can be made of heat conducting material that can also serve as a heat sink to draw heat away from the circuit board and LEDs to the center of the main outer tubular housing and thereby dissipating the heat at the two lamp base ends. There may be cooling holes or air holes on either lamp base end caps of the LED retrofit lamp, in the isolating flexible center support, and in the flexible circuit board containing the compact LED array to allow for proper cooling and airflow. In addition, the main outer tubular housing may contain small holes or other perforations to provide additional cooling of the power electronics, LEDs, and circuit board components. Each end cap of the LED retrofit lamp can terminate in single-pin or bi-pin contacts.

In yet another embodiment of the present invention, the leads of each discrete LED is bent at a right angle and then compactly arranged and fixedly mounted with lead-free solder along the periphery of a generally round, flat, and rigid circuit board disk. Although this embodiment describes a generally round circular circuit board disk, it can be appreciated by someone skilled in the art to use circuit boards or support structures made in shapes other than a circle, such as an oval, triangle, rectangle, hexagon, octagon, etc. Accordingly, the shape of the tubular housing holding the individual circuit boards can be made in a similar shape to match the shape of the circuit boards. The circuit board disks are manufactured out of G10 epoxy material, FR4, or other equivalent rigid material. The LEDs in each rigid circuit board disk can be mounted in a direction perpendicular to the rigid circuit board disk, which results in light emanating in a direction perpendicular to the rigid circuit board disk instead of in a direction parallel to the circuit board as described in the previous embodiments. It can also be appreciated by someone skilled in the art to use one or more side emitting LEDs mounted directly to one side of the rigid circuit board disks with adequate heat sinking applied to the LEDs on the same or opposite sides of the rigid circuit board disks. The side emitting LEDs will be mounted in a direction parallel to the rigid circuit board disk, which also results in light emanating in a direction perpendicular to the rigid circuit board disk instead of in a direction parallel to the circuit board as described in the previous embodiments. Each individual rigid circuit board disk is then arranged one adjacent another at preset spacing by grooves provided on the inside surface of the main outer tubular housing that hold the outer rim of the individual circuit boards. The individual circuit boards are connected by electrical transfer means including headers, connectors, and/or discrete wiring that interconnect all the individual LED arrays to two lamp base caps at both ends of the tubular housing. The entire assembly consisting of the rigid circuit board disks with each LED array is inserted into one half of the main outer tubular housing. The main outer tubular housing here can be linear, U-shaped, or round circular halves. Once all the individual rigid circuit board disks and LED arrays are inserted into the grooves provided on the one half of the main outer tubular housing and are electrically interconnected to each other and to the two lamp base ends, the other mating half of the main outer tubular housing is snapped over the first half to complete the entire LED lamp assembly. The length of the entire assembly is always within the length of the main outer tubular housing. AC power generated by the external fluorescent ballasts is converted to DC power by additional integral electronics. Electrical connector means are used to connect the integral electronics to the light emitting diode arrays to provide current to the LEDs at both ends of the complete arrangement of rigid circuit board disks. Since present linear fluorescent lamps are available in one, two, four, six, and eight feet lengths, the rigid circuit board disks can be stacked to form increments of one-foot lengths. Individual rigid circuit board disks can be cascaded and connected in series to achieve the desired lengths. Likewise, the main outer tubular housing in linear form will be available in the desired lengths, i.e. one, two, four, six, and eight feet lengths. Again, this last described embodiment has cooling holes or air holes on either base end caps of the improved LED

lamp, and in the individual rigid circuit board disks containing the compact LED array to allow for proper cooling and airflow. In addition, the main outer tubular housing may contain small holes or other perforations to provide additional cooling of the power electronics, LEDs, and circuit board components. Each end cap of the LED lamp can terminate in single-pin or bi-pin or quad-pin contacts.

It can be appreciated by someone skilled in the art to use a lesser amount of LEDs in the circuit board configurations to project light from an existing fluorescent fixture in the general direction out of the fixture only without any light projected back into the fixture itself. This will allow for lower power consumption, material costs, and will offer greater fixture efficiencies with reduced light losses.

Ballasts are usually connected to an AC (alternating current) power line operating at 50 Hz or 60 Hz (hertz or cycles per second) depending on the local power company. Most ballasts are designed for one of these frequencies, but not both. Some electronic ballast, however, can operate on both frequencies. Also, some ballasts are designed to operate on DC (direct current) power. These are considered specialty ballasts for applications like transportation vehicle bus lighting.

Electromagnetic and hybrid ballasts operate the lamp at the same low frequency as the power line at 50 Hz or 60 Hz. Electronic ballasts operate the lamp at a higher frequency at or above 20,000 Hz to take advantage of the increased lamp efficiency. The fluorescent lamp provides roughly 10% more light when operating at high frequency versus low frequency for the same amount of input power. The typical application, however involves operating the fluorescent lamp at lower input power and high frequency while matching the light output of the lamp at rated power and low frequency. The result is a substantial savings in energy conservation.

Ballasts can be connected or wired between the input power line and the lamp in a number of configurations. Multiple lamp ballasts for rapid start or instant start lamps can operate lamps connected in series or parallel depending on the ballast design. When lamps are connected in series to a ballast and one lamp fails, or is removed from the fixture, the other lamp(s) connected to that ballast would not light. When the lamps are connected in parallel to a ballast and one lamp fails, or are removed, the other lamp(s) will continue to light.

As discussed earlier, electronic rapid start fluorescent lamp ballasts apply a low voltage of about 4 volts across the two contact pins at each end of the lamp. After this voltage is applied for at least one half of a second, a high voltage arc is struck across the lamp by the ballast starting voltage. After the lamp ignites, the arc voltage is reduced down to a proper operating voltage and the current is limited through the lamp by the ballast. In the case of electronic instant start fluorescent lamp ballasts, an initial high-voltage arc is struck between the two lamp base ends to ignite the lamp. After the lamp ignites, the arc voltage is again reduced down to a proper operating voltage and the current is limited through the lamp by the ballast. For magnetic type lamp ballasts, a constant voltage is applied to the two lamp base ends to energize and maintain the electrical arc within the fluorescent lamp.

For standard fluorescent lamps with a filament voltage of about 3.4 volts to 4.5 volts, the minimum starting voltage to ignite the lamp can range from about 108 volts to about 230 volts. For HO or high output fluorescent lamps, the minimum starting voltage is higher from about 110 volts to about 500 volts.

Given these various voltage considerations, the present invention is designed to work with existing ballast output configurations. The improved LED lamp does not require the pre-heating of a filament like a fluorescent lamp and does not need the ignition voltage to function. The circuit is designed so that the electrical contact pins of the two lamp base end caps of the LED lamp may be reversed, or the entire lamp assembly can be swapped end for end and still function correctly similar to a fluorescent lamp. In the preferred electrical design, a single LED circuit board array can be powered by two separate power electronics at either end of the improved LED lamp consisting of bridge rectifiers to convert the AC voltage to DC voltage. Voltage surge absorbers are used to limit the high voltage to a workable voltage, and optional resistor(s) may be used to limit the current seen by the LEDs. The current limiting resistor(s) is purely optional, because the existing fluorescent ballast is already a current limiting device. The resistor(s) then serve as a secondary protection device. In a normal fluorescent lamp and ballast configuration, the ignition voltage travels from one end of the lamp to the other end. In the new and improved LED retrofit lamp, the common or lower potential of both circuits are tied together, and the difference in potential between the two ends will serve as the main direct current or DC voltage potential to drive the LED circuit board array. That is the anode will be the positive potential and the cathode will be the negative potential to provide power to the LEDs. The individual LEDs within the LED circuit board array can be electrically connected in series, in parallel, or in a combination of series and/or parallel configurations.

In an alternate electrical design for electronic rapid start ballasts; the LED lamp can be electronically designed to work with the initial filament voltage of four volts present on one end of the LED lamp while leaving the other end untouched. The filament voltage is converted through a rectifier circuit or an ac-to-dc converter circuit to provide a DC or direct current voltage to power the LED array. In-line series resistor(s) and/or transistors can be used to limit the current as seen by the LEDs. In addition, a voltage surge absorber or transient voltage suppresser device can be used on the AC input side of the circuit to limit the AC voltage driving the power converter circuit. This electrical design can be used for other types of ballasts as well.

In yet another alternate electrical design for existing fluorescent ballasts, both ends of the improved LED lamp will have a separate rectifier circuit or ac-to-dc converter circuit as described above. Again, the series resistor(s) and voltage surge absorber(s) can be used. In this arrangement, either end of the improved LED lamp will drive its own independent and separate LED circuit board array. This will allow the improved LED lamp to remain lit if one LED array tends to go out leaving the other on.

LEDs are now available in colors like Red, Blue, Green, Yellow, Amber, Orange, and many other colors including White. Although any type and color of LED can be used in the LED arrays used on the circuit boards of the present invention, an LED with a wide beam angle will provide a better blending of the light beams from each LED thereby producing an overall generally evener distribution of light output omni-directionally and in every position. The use of color LEDs eliminates the need to wrap the fluorescent lamp body in colored gel medium to achieve color dispersions. Color LEDs give the end user more flexibility on output power distribution and color mixing control. The color mixing controls are necessary to achieve the desired warn tone color temperature and output.

As an option, the use of a compact array of LEDs strategically arranged in an alternating hexagonal pattern provides the necessary increased number of LEDs resulting in a more even distribution and a brighter output. The minimum number

of LEDs used in the array is determined by the total light output required to be at least equivalent to an existing fluorescent lamp that is to be replaced by the improved LED lamp of the present invention.

Besides using discrete radial mounted 5 mm or 10 mm LEDs, which are readily available from LED manufacturers including Nichia, Lumileds, Gelcore, etc. just to name a few, surface mounted device (SMD) light emitting diodes can be used in some of the embodiments of the present invention mentioned above.

SMD LEDs are semiconductor devices that have pins or leads that are soldered on the same side that the components sit on. As a result there is no need for feed-through hole passages where solder is applied on both sides of the circuit boards. Therefore, SMD LEDs can be used on single sided boards. They are usually smaller in package size than standard discrete component devices. The beam spread of SMD LEDs is somewhat wider than discrete axial LEDs, yet well less than 360-degree beam spread devices.

In particular, the Luxeon brand of white SMD (surface mounted device) LEDs can also be used. Luxeon is a product from Lumileds Lighting, LLC a joint venture between Philips Lighting and Hewlett Packard's Agilent Technologies. Luxeon power light source solutions offer huge advantages over conventional lighting and huge advantages over other LED solutions and providers. Lumileds Luxeon technology offers a 17 lumens 1-Watt white LED in an SMD package that operates at 350 mA and 3.2 volts DC, as well as a high flux 120 lumens 5-Watt white LED in a lambertian or a side emitting radiation pattern SMD package that operates at 700 mA and 6.8 volts. Nichia Corporation offers a similarly packaged white output LED with 23 lumens also operating at 350 mA and 3.2 volts. LEDs will continue to increase in brightness within a relatively short period of time.

In addition, Luxeon now markets a new Luxeon Emitter SMD high-brightness LED that has a special lens in front that bends the light emitted by the LED at right angles and projects the light beam radially perpendicular to the LED center line so as to achieve a light beam having a 360 degree radial coverage. In addition, such a side-emitting radial beam SMD LED has what is designated herein as a high-brightness LED capacity.

In the past, rigid circuit boards consisted of fiberglass composition called G10 epoxy or FR4 type circuit boards. They did not contain a layer of rigid metal until recently and primarily with the invention of the new high brightness LEDs that needed more heat dissipation. The metal substrate circuit boards or metal core printed circuit boards (MCPCB) were developed and are meant to be attached to a heat sink to further extract heat away from the LEDs. They comprise a circuit layer, a dielectric layer, and a metal base layer.

The Berquist Co. of Prescott, WI offers metal substrate printed circuit boards known by the trade name of Metal Clad that are made of printed circuit foil having a thickness of 1 oz. to 10 oz. (35-350 m) offering electrical isolation with minimal thermal resistance. These metal substrate circuit boards have a multiple-layer dielectric that bond with the base metal and circuit material. As such, metal substrate circuit boards conduct heat more effectively and efficiently than standard circuit boards. The dielectric layer offers electrical isolation with minimal thermal resistance. As such a heat sink, a cooling fan, or other cooling devices may not be required in certain instances. A multiple-layer dielectric bonds the base metal and circuit metal together. Metal substrate circuit boards are very rigid and can be formed in various shapes such as thin elongated rectangles, circular, and curved configurations.

There are also ceramic substrate circuit boards, and also a ceramic on metal circuit board called LTCC-M. This new MCPCB technology combines ceramic on metal and is pioneered by Lamina Ceramics located in Westampton, N.J. The ceramic on metal technology in combination with compact arrays of LED dies including Chip on Board or COB technology provides for brighter and more superior thermal performance than some standard MCPCB designs.

More recently, Lumileds Lighting, LLC now offers a Luxeon warm white LED with a 90 CRI (Color Rendering Index) and 3200 degrees Kelvin CCT (Correlated Color Temperature). Lumileds Luxeon warm white is the first generally available low CCT and high CRI warm white solid-state light source. This new Luxeon LED opens the door for significantly greater use of solid-state illumination in interior and task lighting applications by replicating the soothing, warm feel typically associated with incandescent and halogen lamps. The additional benefit here being the availability of true LED retrofit lamps for existing and new fluorescent lamp fixtures that offer a softer and warmer light output similar to the output produced by incandescent and halogen lamps. An alternate arrangement to get similar CRI and CCT would be to use existing high CCT white color LEDs with a combination of yellow or amber color LEDs to achieve the desired color tone. This lower CCT break through was never available before to the end user with conventional fluorescent lamps unless they used a color film wrap or similar product to "color" the fluorescent lamp light output.

The described LED retrofit lamp invention can be manufactured in variety of different fluorescent lamp bases, including, but not limited to medium bi-pin base, single-pin base, recessed double contact (DC) base, circline quad-pin base, and PL (bi-pin) base and medium screw base used with compact fluorescents

This invention can be summarized as follows: A retrofit light emitting diode (LED) lamp for mounting to an existing fixture for a fluorescent lamp having a ballast assembly including ballast opposed electrical contacts, comprising a tubular wall generally circular in cross-section having tubular wall ends, one or more LEDs positioned within the tubular wall between the tubular wall ends. An electrical circuit provides electrical power from the ballast assembly to the LED or LEDs. The electrical circuit includes one or more metal substrate circuit boards and electrically connects the electrical circuit with the ballast assembly. Each supports and holds the LEDs and the LED electrical circuit. The electrical circuit includes an LED electrical circuit including opposed electrical contacts. At least one electrical string is positioned within the tubular wall and generally extends between the tubular wall ends. The one or more LEDs are in electrical connection with the at least one electrical string, and are positioned to emit light through the tubular wall. Means for suppressing ballast voltage is delivered from the ballast assembly to an LED operating voltage within the voltage design capacity of the at least one LED. The metal substrate circuit board includes opposed means for connecting the metal substrate circuit board to the tubular wall ends, which include means for mounting the means for connecting and the one or more metal substrate circuit boards. The opposed means for connecting the one or more metal substrate circuit boards to the tubular wall ends includes each metal substrate circuit board having opposed tenon connecting ends, and the means for mounting includes each of the tubular wall ends defining a mounting slot, the opposed tenon connecting ends being positioned in the mounting slots. Two or more opposed metal substrate boards each mounting LEDs can be mounted in the tubular wall. It should be noted that the opposed tenon con-

necting ends can be located not just on each end of the metal substrate circuit board, but can be located just on the opposed ends of the metal base layer of each metal substrate circuit board.

With the need for energy conservation and savings, smart lighting controls and sensors are used to turn off or dim lighting when there is no one presently occupying a space lit by the lighting. For this reason, one improvement to the present invention allow for added energy conservation and savings by incorporating the smart lighting control and sensors in the LED lamp of the present invention.

The advantage of each LED retrofit lamp having its own sensor ensures each LED lamp operates independent of or together with other LED retrofit lamps. For example, there presently exists a problem with occupancy sensors. There is usually only one occupancy sensor used to control a bank of lights. Depending on the location of the occupancy sensor, when someone is in the room, but is not noticed by the occupancy sensor either because he or she is out of range or has not moved for a while will either turn the entire bank of lights off, or to cause the bank of lights to dim down to an unusable light level.

The on board occupancy sensor located in each LED retrofit lamp of the present invention will trigger the lamp to remain full on when it senses the presence of someone near the LED lamp of the present invention and will turn off or dim the LED retrofit lamp when the person exits the room. A timer can be built-in to the electronics or can be pre-programmed for a delay for false trigger conditions.

Power control modules and other components can be incorporated into the electrical circuits used in the LED retrofit lamp of the present invention. The first circuit module may be a dimming module placed in between the DC voltage input to the LED array. This dimming module can take a control input either from a hard-wired sensor like an occupancy sensor, a timer, a computer or from a hand-held or wall mounted remote control box that sends the dimming signal to the dimming module located within the LED retrofit lamp. The dimming current driver module will contain the necessary electronics to decipher data input control signals and provide the current driver power to operate the LED arrays. LED current control can be accomplished by time and amplitude domain control or other means well known in the arts. The occupancy sensor can be preset to dim the LED retrofit lamp to perhaps 50% brightness to conserve energy when no one is in a room, for example while a light level photosensor can switch on and off the power to the ballast or LED array. The LED retrofit lamp would be programmed to turn the LED arrays on when luminance on the photocell drops below a certain value, and turn the LED arrays off when the luminance due to sunlight reaches a higher cut-off value. This value could be adjustable depending on the user's needs. Instead of turning on and off the LED arrays, the LED arrays can likewise be dimmed.

Electrical compensation of daylight can be controlled either by dimming (varying the light output to provide the desired brightness) or by switching (turning individual lamps or fixtures in different areas of a building or room on or off as necessary). Just as a typical two-lamp fixture containing the LED retrofit lamps of the present invention can be switched to illuminate both LED retrofit lamps, one LED retrofit lamp, or neither LED retrofit lamp, multiple fixtures all containing the LED retrofit lamps of the present invention can be turned on or off individually to illuminate each part of a room in just the needed amount of light. In addition, the internal dimming function located in each LED retrofit lamp of the present invention can adjust the output of the individual LED retrofit lamps to achieve greater control.

The dimming controller can be used to program presets during the day or have a manual adjustment to dim the LED lamp down to full off or anywhere between 0% and 100% brightness. This dimming controller will send the control signal directly to the LED lamp itself and not change the AC voltage to the light fixture like conventional dimmers do. A data control signal to a computer based control system driving the dimming controller can be wireless, including using IR (Infra-Red), RF (Radio-Frequency), WiFi/802.11, FHSS (Frequency Hopping Spread Spectrum, Bluetooth technology, and ZigBee. The data control signal can also be a direct hard-wire connection including DMX512, RS232, Ethernet, DALI, Lonworks, RDM, TCPIP, CEBus Standard EIA-600, X10, and other Power Line Carrier Communication (PLC) protocols.

Note that existing fluorescent lamps cannot be dimmed to 0% or they will simply go out, while LED lamps can be dimmed down to 0%. The bottom line is energy and cost saving. The cost savings comes into play, because the cost of dimmable fluorescent ballasts is usually more than twice the cost of a standard non-dimmable fluorescent ballast, and these dimmable ballasts require a special dimming switch at an additional cost. In addition, savings in lower electrical bills can be significant.

Another circuit module can be a color effects module for use with color LEDs instead of white LEDs used in the LED lamps. This module allows the LED lamp to change colors. The controllers used for the dimming modules can be modified to achieve the color changing function required here. There will be a minimum of RGB color LEDs, but Amber or A can also be used. The dimming module described hereinbefore used a single channel to dim the entire array of white LEDs, but this circuit module will require 3 or 4 channels of dimming control to achieve different color combinations. Presently, fluorescent lamps use a plastic color wrap to get a colored light. The color changing LED lamp will give a user the ability to achieve more colors without having to stock and change different color wraps to get different desired color light outputs.

Another circuit module would be a by-pass or feed-thru module that simply bridges the power from the ballast or other power source straight to the LEDs. The lamp would then function as the LED lamp disclosed in the original parent application and previous CIP application.

It should be noted that each one or all of the circuit modules mentioned above could be permanently or temporarily mounted for versatility. The use of a microprocessor, processor, CPU, computer, microcontroller, or controller and related components including memory RAM and ROM, programming, input and output means, and addressing means need not be required to make the various functions work. The same functions can be accomplished with integrated circuits transistors, switches, and logic gate arrays etc.

The terms "programming" or "data program" are used herein in a generic sense to refer to any type of computer code (i.e., software or microcode) that can be employed to program one or more microprocessors, processors, CPUs, computers, microcontrollers, or controllers.

The term "addressing means" is used herein to refer to a device (i.e., a light source in general, a lighting unit or fixture or luminaire, a microprocessor, processor, CPU, computer, microcontroller, or controller associated with one or more light sources or lighting units, other non-lighting related devices, etc.) that is configured to receive information or data

intended for multiple devices, including itself, and to selectively respond to particular information intended for it.

The term "addressing means" is often used in connection with a networked environment or a "network" in which multiple devices are coupled together by way of some communications medium or media including direct hard wire, wireless, or power line carrier (PLC) methods.

The term "network" as used herein refers to any interconnection of two or more devices including computers that facilitates the transport of information (i.e., for device control, data storage, data exchange, etc.) between any two or more devices and/or among multiple devices coupled to the network. As should be readily appreciated, various implementations of networks suitable for interconnecting multiple devices may include any of a variety of network topologies and employ any of a variety of communications protocols. Additionally, in various networks according to the present invention, any one connection between two devices may represent a dedicated connection between the two systems, or alternatively a non-dedicated connection. In addition to carrying information intended for the two devices, such a non-dedicated connection may carry information not necessarily intended for either of the two devices (i.e., an open network connection). Furthermore, it should be readily appreciated that various networks of devices as discussed herein may employ one or more wireless, wire/cable, signals on a power line carrier, and/or fiber optic links to facilitate information transport throughout the network.

In one network implementation, one or more devices coupled to a network may serve as a controller for one or more other devices coupled to the network (i.e., in a Master and Slave relationship). In another implementation, a networked environment may include one or more dedicated controllers that are configured to control one or more of the devices coupled to the network (i.e., in a Master and Master relationship). Generally, multiple devices coupled to the network each may have access to data that is present on the communications medium or media, however, a given device may have "addressing means" in that it is only configured to selectively transmit and receive data on the network based on one or more address identifiers assigned to it.

The present invention will be better understood and the objects and important features, other than those specifically set forth above, will become apparent when consideration is given to the following details and description, which when taken in conjunction with the annexed drawings, describes, illustrates, and shows preferred embodiments or modifications of the present invention, and what is presently considered and believed to be the best mode of practice in the principles thereof.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is an elevational side view of a retrofitted single-pin LED lamp mounted to an existing fluorescent fixture having an electronic instant start, hybrid, or magnetic ballast having a pair of single contact electrical socket connectors;

FIG. **1**A is a detailed end view of the LED retrofit lamp taken through line **1**A-**1**A of FIG. **1** showing a single-pin;

FIG. **2** is an exploded perspective view of the LED retrofit lamp shown in FIG. **1** taken in isolation;

FIG. **3** is a cross-sectional view of the LED retrofit lamp through a single row of LEDs taken through line **3**-**3** of FIG. **1**;

FIG. **3**A is a detailed mid-sectional cross-sectional view of a single LED of the LEDs shown in FIG. **3** with portions of the tubular wall and LED circuit board but devoid of the optional linear housing;

FIG. **4** is an overall electrical circuit for the retrofitted LED lamp shown in FIG. **1** wherein the array of LEDs are arranged in an electrical parallel relationship and shown for purposes of exposition in a flat position;

FIG. **4**A is an alternate arrangement of the array of LEDs arranged in an electrical parallel relationship shown for purposes of exposition in a flat position for the overall electrical circuit analogous to the overall electrical circuit shown in FIG. **4** for the LED retrofit lamp;

FIG. **4**B is another alternate arrangement of an array of LEDs arranged in an electrical series relationship shown for purposes of exposition in a flat compressed position for an overall electrical circuit analogous to the electrical circuit shown in FIG. **4** for the LED retrofit lamp;

FIG. **4**C is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **4** including lead lines and pin headers and connectors for the LED retrofit lamp;

FIG. **4**D is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **4**A including lead lines and pin headers and connectors for the LED retrofit lamp;

FIG. **4**E is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **4**B including lead lines and pin headers and connectors for the LED retrofit lamp;

FIG. **4**F shows a single high-brightness LED positioned on a single string in electrical series arrangement shown for purposes of exposition in a flat compressed mode for the overall electrical circuit shown in FIG. **4** for the retrofit lamp;

FIG. **4**G shows two high-brightness LEDs in an electrical parallel arrangement of two parallel strings with one high-brightness LED positioned on each of the two parallel strings shown for purposes of exposition in a flat compressed mode for the overall electrical circuit shown in FIG. **4** for the retrofit lamp;

FIG. **5** is a schematic view showing the LED arrays in FIGS. **4** and **4**A electrically connected by pin headers and connectors to two opposed integral electronics circuit boards that are electrically connected to base end caps each having a single-pin connection;

FIG. **6** is a schematic circuit of one of the two integral electronics circuit boards shown in FIG. **5** positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. **4** and **4**A;

FIG. **7** is a schematic circuit of the other of the two integral electronics circuit boards shown in FIG. **5** positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. **4** and **4**A;

FIG. **8** is an isolated side view of the cylindrical internal support shown in FIGS. **2** and **3**;

FIG. **8**A is an end view taken through line **8**A-**8**A in FIG. **8**;

FIG. **9** is a side view of an isolated single-pin end cap shown in FIGS. **1** and **5**;

FIG. **9**A is a sectional view taken through line **9**A-**9**A of the end cap shown in FIG. **9**;

FIG. **10** is an alternate sectional view to the sectional view of the LED retrofit lamp taken through a single row of LEDs shown in FIG. **3**;

FIG. **11** is an elevational side view of a retrofitted LED lamp mounted to an existing fluorescent fixture having an electronic rapid start, hybrid, or magnetic ballast having a pair of double contact electrical socket connectors;

FIG. **11**A is a detailed end view of the LED retrofit lamp taken through line **11**A-**11**A of FIG. **11** showing a bi-pin electrical connector;

FIG. **12** is an exploded perspective view of the LED retrofit lamp shown in FIG. **11** taken in isolation;

FIG. **13** is a cross-sectional view of the LED retrofit lamp through a single row of LEDs taken through line **13**-**13** of FIG. **11**;

FIG. **13**A is a detailed mid-sectional cross-sectional view of a single LED of the LEDs shown in FIG. **13** with portions of the tubular wall and LED circuit board but devoid of the optional linear housing;

FIG. **14** is an overall electrical circuit for the retrofitted LED lamp shown in FIG. **11** wherein the array of LEDs are arranged in an electrical parallel relationship and shown for purposes of exposition in a flat position;

FIG. **14**A is an alternate arrangement of the array of LEDs arranged in an electrically parallel relationship shown for purposes of exposition in a flat position for the overall electrical circuit shown in FIG. **14** for the LED retrofit lamp;

FIG. **14**B is another alternate arrangement of the array of LEDs arranged in an electrically parallel relationship shown for purposes of exposition in a flat compressed position for an overall electrical circuit analogous to the overall electrical circuit shown in FIG. **14** for the LED retrofit lamp;

FIG. **14**C is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **14** including lead lines and pin headers and connectors for the LED retrofit lamp;

FIG. **14**D is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **14**A including lead lines and pin headers and connectors for the LED retrofit lamp;

FIG. **14**E is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **14**B including lead lines and pin headers and connectors for the LED retrofit lamp;

FIG. **14**F shows a single high-brightness LED positioned on a single string in electrical series arrangement shown for purposes of exposition in a flat compressed mode for the overall electrical circuit shown in FIG. **14** for the retrofit lamp;

FIG. **14**G shows two high-brightness LEDs in an electrical parallel arrangement of two parallel strings with one high-brightness LED positioned on each of the two parallel strings shown for purposes of exposition in a flat compressed mode for the overall electrical circuit shown in FIG. **14** for the retrofit lamp;

FIG. **15** is a schematic view showing the LED array in FIGS. **14** and **14**A electrically connected by pin headers and connectors to two opposed integral electronics circuit boards that are electrically connected to base end caps each having a bi-pin connections;

FIG. **16** is a schematic circuit of one of the two integral electronics circuit boards shown in FIG. **15** positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. **14** and **14**A;

FIG. **17** is a schematic circuit of the other of the two integral electronics circuit boards shown in FIG. **15** positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. **14** and **14**A;

FIG. **18** is an isolated side view of the cylindrical internal support shown in FIGS. **12** and **13**;

FIG. **18**A is an end view taken through line **18**A-**18**A in FIG. **18**;

FIG. **19** is a side view of an isolated bi-pin end cap shown in FIGS. **11** and **15**;

FIG. **19**A is a sectional view taken through line **19**A-**19**A of the end cap shown in FIG. **19**;

FIG. **20** is an alternate sectional view to the sectional view of the LED retrofit lamp taken through a single row of LEDs shown in FIG. **13**;

FIG. **21** is top view of a retrofitted semi-circular LED lamp mounted to an existing fluorescent fixture having an electronic rapid start, hybrid, or magnetic ballast;

FIG. **21**A is a view taken through line **21**A-**21**A in FIG. **21**;

FIG. **22** is a top view taken in isolation of the semi-circular circuit board with slits shown in FIG. **21**;

FIG. **23** is a perspective top view taken in isolation of a circuit board in a flat pre-assembly mode with LEDs mounted thereon in a staggered pattern;

FIG. **24** is a perspective view of the circuit board shown in FIG. **23** in a cylindrically assembled configuration in preparation for mounting into a linear tubular wall;

FIG. **25** is a partial fragmentary end view of a layered circuit board for a retrofitted LED lamp for a fluorescent lamp showing a typical LED mounted thereto proximate a tubular wall;

FIG. **26** is an elevational side view of another embodiment of a retrofitted single-pin type LED lamp mounted to an existing fluorescent fixture;

FIG. **26**A is a view taken through line **26**A-**26**A of FIG. **26** showing a single-pin type LED retrofit lamp wherein the existing fluorescent fixture has an electronic instant start, hybrid, or magnetic ballast having a pair of single contact electrical sockets;

FIG. **27** is an exploded perspective view of the LED retrofit lamp shown in FIG. **26** including the integral electronics taken in isolation;

FIG. **28** is a sectional top view of the tubular wall taken through line **28**-**28** in FIG. **26** of a single row of LEDs;

FIG. **29** is an elongated sectional view of that shown in FIG. **27** taken through plane **29**-**29** bisecting the cylindrical tube and the disks therein with LEDs mounted thereto;

FIG. **29**A is an alternate elongated sectional view of that shown in FIG. **27** taken through plane **29**-**29** bisecting the cylindrical tube and the disks therein with a single LED mounted in the center of each disk wherein ten LEDs are arranged in an electrically series relationship;

FIG. **29**B is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **29** including lead lines and pin headers for the LED retrofit lamp;

FIG. **29**C is another simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **29** including lead lines and pin headers for the LED retrofit lamp;

FIG. **29**D is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **29**A including lead lines and pin headers for the LED retrofit lamp;

FIG. **30** shows a fragmented sectional side view of a portion of two cylindrical support disks and of two LEDs taken from adjoining LED rows as indicated in FIG. **29** and further

showing electrical connections between the LEDs as related to the LED retrofit lamp of FIG. **26**;

FIG. **30**A shows an alternate fragmented sectional side view of a portion of two cylindrical support disks and of a single LED centrally mounted to each cylindrical support disks taken from adjoining LED rows as indicated in FIG. **29** and further showing electrical connections between the LEDs as related to the LED retrofit lamp of FIG. **26**;

FIG. **30**B is an isolated top view of the 6-wire electrical connectors and headers shown in side view in FIG. **30**;

FIG. **31** is a schematic view showing the LED array in FIGS. **26** and **27** electrically connected by pin connectors to two opposed integral electronics circuit boards that are electrically connected to base end caps each having a single-pin connection;

FIG. **32** is a schematic circuit of one of the two integral electronics circuit boards shown in FIG. **31** positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIG. **31**;

FIG. **33** is a schematic circuit of the other of the two integral electronics circuit boards shown in FIG. **31** positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIG. **31**;

FIG. **34** shows a full frontal view of a single support disk as related to the LED retrofit lamp shown in FIG. **26** taken in isolation with an electrical schematic rendering showing a single row of ten LEDs connected in series within an electrical string as a part of the total parallel electrical structure for the LEDs;

FIG. **34**A shows a full frontal view of a single support disk as related to the LED retrofit lamp shown in FIG. **26** taken in isolation with an electrical schematic rendering showing a single LED to be connected in series within an electrical string as a part of the total parallel electrical structure for the LEDs;

FIG. **35** is a side view of an isolated single-pin end cap of those shown in FIGS. **26** and **27**;

FIG. **35**A is a sectional view taken through line **35**A-**35**A of the end cap shown in FIG. **35**;

FIG. **36** is an elevational side view of another embodiment of a retrofitted bi-pin LED lamp mounted to an existing fluorescent fixture;

FIG. **36**A is a view taken through line **36**A-**36**A of FIG. **36** showing a bi-pin type LED retrofit lamp wherein the existing fluorescent fixture has an electronic rapid start, hybrid, or magnetic ballast having a pair of double contact electrical sockets;

FIG. **37** is an exploded perspective view of the LED retrofit lamp shown in FIG. **36** including the integral electronics taken in isolation;

FIG. **38** is a sectional top view of the tubular wall taken through line **38**-**38** in FIG. **36** of a single row of LEDs;

FIG. **39** is an elongated sectional view of the LED retrofit lamp shown in FIG. **37** taken through plane **39**-**39** bisecting the cylindrical tube and the disks therein with LEDs mounted thereto;

FIG. **39**A is an alternate elongated sectional view of that shown in FIG. **37** taken through plane **39**-**39** bisecting the cylindrical tube and the disks therein with a single LED mounted in the center thereto;

FIG. **39**B is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **39** including lead lines and pin headers for the LED retrofit lamp;

FIG. **39**C is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **39** including lead lines and pin headers for the LED retrofit lamp;

FIG. **39**D is a simplified arrangement of the array of LEDs shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **39**A including lead lines and pin headers for the LED retrofit lamp;

FIG. **40** shows a fragmented sectional side view of a portion of two cylindrical support disks and of two LEDs taken from adjoining LED rows as indicated in FIG. **39**, and further showing electrical connections between the LEDs as related to the LED retrofit lamp of FIG. **36**;

FIG. **40**A shows an alternate fragmented sectional side view of a portion of two cylindrical support disks and of a single LED centrally mounted to each cylindrical support disks taken from adjoining LED rows as indicated in FIG. **39**, and further showing electrical connections between the LEDs as related to the LED retrofit lamp of FIG. **36**;

FIG. **40**B is an isolated top view of the 6-wire electrical connectors and headers shown in side view in FIG. **40**;

FIG. **41** is a schematic view showing the LED array in FIGS. **36** and **37** electrically connected by pin connectors to two opposed integral electronics circuit boards that are electrically connected to base end caps each having a bi-pin connections;

FIG. **42** is a schematic circuit of one of the two integral electronics circuit boards shown in FIG. **41** positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIG. **41**;

FIG. **43** is a schematic circuit of the other of the two integral electronics circuit boards shown in FIG. **41** positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIG. **41**;

FIG. **44** shows a full frontal view of a single support disk as related to the LED retrofit lamp shown in FIG. **36** taken in isolation with an electrical schematic rendering showing a single row of ten LEDs connected in series within an electrical string as a part of the total parallel electrical structure for the LEDs;

FIG. **44**A shows a full frontal view of a single support disk as related to the LED retrofit lamp shown in FIG. **36** taken in isolation with an electrical schematic rendering showing a single LED to be connected in series within an electrical string as a part of the total parallel electrical structure for the LEDs;

FIG. **45** is a side view of an isolated bi-pin end cap shown in FIGS. **36** and **37**;

FIG. **45**A is a sectional view taken through line **45**A-**45**A of the end cap shown in FIG. **45**;

FIG. **46** is a fragment of a curved portion of an LED retrofit lamp showing disks in the curved portion;

FIG. **47** is a simplified cross-section of a tubular housing as related to FIG. **1** devoid of light emitting diodes with a self-biased circuit board mounted therein with both the tubular housing and circuit board being oval in cross-section;

FIG. **47**A is a simplified cross-section of a tubular housing as related to FIG. **1** devoid of light emitting diodes with a self-biased circuit board mounted therein with both the tubular housing and circuit board being triangular in cross-section;

FIG. **47**B is a simplified cross-section of a tubular housing as related to FIG. **1** devoid of light emitting diodes with a self-biased circuit board mounted therein with both the tubular housing and circuit board being rectangular in cross-section;

FIG. **47**C is a simplified cross-section of a tubular housing as related to FIG. **1** devoid of light emitting diodes with a

self-biased circuit board mounted therein with both the tubular housing and circuit board being hexagonal in cross-section;

FIG. **47**D is a simplified cross-section of a tubular housing as related to FIG. **1** devoid of light emitting diodes with a self-biased circuit board mounted therein with both the tubular housing and circuit board being octagonal in cross-section;

FIG. **48** is a simplified cross-section of a tubular housing as related to FIG. **26** devoid of light emitting diodes with a support structure mounted therein with both the tubular housing and support structure being oval in cross-section;

FIG. **48**A is a simplified cross-section of a tubular housing as related to FIG. **26** devoid of light emitting diodes with a support structure mounted therein with both the tubular housing and support structure being triangular in cross-section;

FIG. **48**B is a simplified cross-section of a tubular housing as related to FIG. **26** devoid of light emitting diodes with a support structure mounted therein with both the tubular housing and support structure being rectangular in cross-section;

FIG. **48**C is a simplified cross-section of a tubular housing as related to FIG. **26** devoid of light emitting diodes with a support structure mounted therein with both the tubular housing and support structure being hexagonal in cross-section;

FIG. **48**D is a simplified cross-section of a tubular housing as related to FIG. **26** devoid of light emitting diodes with a support structure mounted therein with both the tubular housing and support structure being octagonal in cross-section;

FIG. **49** is a simplified cross-view of a support structure positioned in a tubular housing with a single high-brightness SMD LED mounted to the center of the support;

FIG. **50** is a side view of the alternate retrofitted single-pin LED lamp mounted to an existing fluorescent fixture having an electronic instant start, hybrid, or magnetic ballast having a pair of single contact electrical socket connectors;

FIG. **50**A is a detailed end view of the alternate LED retrofit lamp taken through line **50**A-**50**A of FIG. **50** showing a single-pin;

FIG. **51** is an exploded perspective view of the alternate LED retrofit lamp shown in FIG. **50** taken in isolation;

FIG. **52** is a cross-sectional view of the alternate LED retrofit lamp through a single row of LEDs taken through line **52**-**52** of FIG. **50**;

FIG. **52**A is a detailed mid-sectional cross-sectional view of a single LED of the LEDs shown in FIG. **52** with portions of the tubular wall and LED circuit board;

FIG. **53** is an overall electrical circuit for the alternate retrofitted LED lamp shown in FIG. **50** wherein the array of LEDs are arranged in an electrical parallel relationship;

FIG. **53**A is an alternate arrangement of the array of LEDs arranged in an electrical parallel relationship for the overall electrical circuit analogous to the overall electrical circuit shown in FIG. **53** for the alternate LED retrofit lamp;

FIG. **53**B is another alternate arrangement of an array of LEDs arranged in an electrical series relationship for an overall electrical circuit analogous to the electrical circuit shown in FIG. **53** for the alternate LED retrofit lamp;

FIG. **53**C is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. **53** for the alternate LED retrofit lamp;

FIG. **53**D is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. **53**A for the alternate LED retrofit lamp;

FIG. **53**E is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. **53**B for the alternate LED retrofit lamp;

FIG. **53**F shows a single high-brightness LED positioned on a single string in electrical series arrangement for the overall electrical circuit shown in FIG. **53** for the alternate retrofit lamp;

FIG. **53**G shows two high-brightness LEDs in an electrical parallel arrangement of two parallel strings with one high-brightness LED positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. **53** for the alternate retrofit lamp;

FIG. **54** is a schematic view showing the LED arrays in FIGS. **53** and **53**A electrically connected to two opposed integral electronics circuitry that are electrically connected to base end caps each having a single-pin connection;

FIG. **55** is a schematic circuit of one of the two integral electronics circuitry shown in FIG. **54** positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. **53** and **53**A;

FIG. **56** is a schematic circuit of the other of the two integral electronics circuitry shown in FIG. **54** positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. **53** and **53**A;

FIG. **57** is an isolated side view of the elongated cylindrical housing shown in FIGS. **50** and **51** detailing the cooling vent holes located at opposite ends;

FIG. **57**A is an end view taken through line **57**A-**57**A in FIG. **57**;

FIG. **58** is a side view of an isolated single-pin end cap shown in FIGS. **50** and **54**;

FIG. **58**A is a sectional view taken through line **58**A-**58**A of the end cap shown in FIG. **58**;

FIG. **59** is an alternate sectional view to the sectional view of the alternate LED retrofit lamp taken through a single row of LEDs shown in FIG. **52**;

FIG. **60** is a side view of the alternate retrofitted LED lamp mounted to an existing fluorescent fixture having an electronic rapid start, hybrid, or magnetic ballast having a pair of double contact electrical socket connectors;

FIG. **60**A is a detailed end view of the alternate LED retrofit lamp taken through line **60**A-**60**A of FIG. **60** showing a bi-pin electrical connector;

FIG. **61** is an exploded perspective view of the alternate LED retrofit lamp shown in FIG. **60** taken in isolation;

FIG. **62** is a cross-sectional view of the alternate LED retrofit lamp through a single row of LEDs taken through line **62**-**62** of FIG. **60**;

FIG. **62**A is a detailed mid-sectional cross-sectional view of a single LED of the LEDs shown in FIG. **62** with portions of the tubular wall and LED circuit board;

FIG. **63** is an overall electrical circuit for the alternate retrofitted LED lamp shown in FIG. **60** wherein the array of LEDs are arranged in an electrical parallel relationship;

FIG. **63**A is an alternate arrangement of the array of LEDs arranged in an electrically parallel relationship for the overall electrical circuit shown in FIG. **63** for the alternate LED retrofit lamp;

FIG. **63**B is another alternate arrangement of the array of LEDs arranged in an electrically parallel relationship for an overall electrical circuit analogous to the overall electrical circuit shown in FIG. **63** for the alternate LED retrofit lamp;

FIG. **63**C is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. **63** for the alternate LED retrofit lamp;

FIG. **63**D is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. **63**A for the alternate LED retrofit lamp;

FIG. **63**E is a simplified arrangement of the array of LEDs for the overall electrical circuit shown in FIG. **63**B for the alternate LED retrofit lamp;

FIG. **63**F shows a single high-brightness LED positioned on a single string in electrical series arrangement for the overall electrical circuit shown in FIG. **63** for the alternate retrofit lamp;

FIG. **63**G shows two high-brightness LEDs in an electrical parallel arrangement of two parallel strings with one high-brightness LED positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. **63** for the alternate retrofit lamp;

FIG. **64** is a schematic view showing the LED array in FIGS. **63** and **63**A electrically connected to two opposed integral electronics circuitry that are electrically connected to base end caps each having a bi-pin connections;

FIG. **65** is a schematic circuit of one of the two integral electronics circuitry in FIG. **64** positioned at one side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. **63** and **63**A;

FIG. **66** is a schematic circuit of the other of the two integral electronics circuitry shown in FIG. **64** positioned at the other side of the alternating current voltage emanating from the ballast for the LED array shown in FIGS. **63** and **63**A;

FIG. **67** is an isolated side view of the elongated cylindrical housing shown in FIGS. **60** and **61** detailing the cooling vent holes located at opposite ends;

FIG. **67**A is an end view taken through line **67**A-**67**A in FIG. **67**;

FIG. **68** is a side view of an isolated bi-pin end cap shown in FIGS. **60** and **64**;

FIG. **68**A is a sectional view taken through line **68**A-**68**A of the end cap shown in FIG. **68**;

FIG. **69** is an alternate sectional view to the sectional view of the alternate LED retrofit lamp taken through a single row of LEDs shown in FIG. **62**;

FIG. **70** is a top view of an alternate LED retrofit lamp that is partly curved;

FIG. **71** is a sectional view of FIG. **70** taken through line **71**-**71**;

FIG. **72** is a section view of an LED lamp **828**A and **828**B that is for mounting either to an instant start ballast assembly with opposed single pin contacts or to a rapid start ballast assembly with opposed bi-pin contacts;

FIG. **72**A is an interior view of one circular single pin base end cap **830**A taken in isolation representing both opposed base end caps of LED lamp **828**A;

FIG. **72**B is an interior view of one circular bi-pin base end cap **830**B taken in isolation representing both opposed base end caps of LED lamp **828**B;

FIG. **73** is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a switch on the DC power line also positioned therein and in operational power contact with an external manual control unit having three alternative data input signal lines to the switch;

FIG. **73**A is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer and a dimmer on the DC power line also positioned therein and in operational power contact with an external manual control unit having three alternative data input signal lines to the computer;

FIG. **74** is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a timer and a switch on the DC power line also positioned therein and in operational contact with an external manual timer control unit having three alternative data input signal lines to the timer;

FIG. **74**A is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer and a dimmer on the DC power line also positioned therein and in operational contact with an external manually operated timer and switch having three alternative data input signal lines to the computer;

FIG. **74**B is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a timer, a switch, a computer, and a dimmer also positioned therein;

FIG. **75** is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a sensor in operational contact with a switch on the DC power line also positioned therein;

FIG. **75**A is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer in operational communication with a sensor and a dimmer on the DC power line also positioned therein;

FIG. **75**B is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube and a switch also positioned in the tube on the DC power line and in operational contact with a sensor positioned external to the tube having three alternative signal lines to the switch;

FIG. **75**C is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer and a dimmer on the DC power line also positioned therein and a sensor positioned external to the tube having three alternative signal lines to the computer;

FIG. **76** is a schematic block diagram showing two LED lamps in network communication each including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a sensor and a dimmer on the DC power line also positioned therein, and a computer in operational communication with both sensors and dimmers each using two alternative signal lines to and from the computer respectively;

FIG. **76**A is a logic diagram related to the schematic block diagram shown in FIG. **76** that sets forth the four operational possibilities between the two LED lamps;

FIG. **77** is a schematic block diagram showing two LED lamps in network communication each including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer in operational contact with a sensor, a timer, and a dimmer also positioned therein in each LED lamp, and both computers being in operational signal communications with each other using two alternative signal lines;

FIG. **78** is a schematic block diagram showing two LED lamps in network communication each including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a sensor and switch on the DC power line and in operational contact also positioned therein, and logic gate arrays in operational communication with the both sensors and switches each using two alternative signal lines to and from the logic gate arrays respectively;

FIG. **78**A is a schematic block diagram showing two LED lamps in network communication each including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with logic gate arrays in operational contact with a sensor, a timer, and a switch also positioned therein in each LED lamp, and both sets of logic gate arrays being in operational signal communications with each other using two alternative signal lines;

FIG. **79**A is an electrical circuit for providing DC power from a ballast to an LED array incorporating a voltage suppressor and a bridge rectifier on the power input side;

FIG. **79**B is an alternative electrical circuit analogous to FIG. **79**A for providing DC power from a ballast to an LED array positioned in a tube incorporating a non-polarized capacitor, a zener diode, a varistor, and a bridge rectifier on the power input side. An optional filter capacitor is also shown;

FIG. **80**A is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a light level photosensor in operational contact with a switch on the DC power line also positioned therein;

FIG. **80**B is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer in operational communication with a light level photosensor and a dimmer on the DC power line also positioned therein;

FIG. **80**C is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube and a switch also positioned in the tube on the DC power line and in operational contact with a light level photosensor positioned external to the tube having three alternative signal lines to the switch;

FIG. **80**D is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer and a dimmer on the DC power line also positioned therein and a light level photosensor positioned external to the tube having three alternative signal lines to the computer;

FIG. **81** is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a light level photosensor and an occupancy sensor both in operational contact with a switch on the DC power line also positioned therein;

FIG. **82** is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer in operational communication with a light level photosensor, an occupancy sensor, and a dimmer on the DC power line also positioned therein;

FIG. **83** is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube and a switch also positioned in the tube on the DC power line and in operational contact with a light level photosensor and an occupancy sensor both positioned external to the tube having three alternative signal lines to the switch;

FIG. **84** is a schematic block diagram showing an LED lamp including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with a computer and a dimmer on the DC power line also positioned therein and a light level photosensor and occupancy sensor both positioned external to the tube having three alternative signal lines to the computer;

FIG. **85** is a logic diagram related to the schematic block diagram shown in FIG. **84** that sets forth the four operational possibilities between the two types of sensors;

FIG. **86** is a schematic block diagram showing two LED lamps in network communication each including an AC power line from a ballast to a power converter and then to an LED array positioned in a tube with an occupancy sensor input and a photosensor input and a dimmer on the DC power line also positioned therein, and a computer in operational communication with the light level sensors, occupancy sensors, and dimmers;

FIG. **87** is a side view of a retrofit LED lamp mounted in a fluorescent fixture;

FIG. **88**A is a sectional view taken through line **88**A-**88**A of FIG. **87** showing a detailed end view of the existing double-contact sockets and bi-pin connector of the retrofit LED lamp;

FIG. **88**B is an alternative sectional view taken through line **88**B-**88**B of FIG. **87** showing a detailed end view of the existing single-contact socket and single-pin connector of the retrofit LED lamp;

FIG. **89**A is a schematic block diagram showing an LED lamp of the present invention where the ballast is removed or bypassed and including a power line from an external power source to a power converter and then to an LED array positioned in a tube with a power control sensor in operational contact with a switch on the power line to the LED array also positioned therein;

FIG. **89**B is a schematic block diagram showing an LED lamp of the present invention where the ballast is removed or bypassed and including a power line from an external power source to a power converter and then to an LED array positioned in a tube with a computer or logic gate array in operational communication with a power control sensor and a dimmer on the power line to the LED array also positioned therein;

FIG. **89**C is a schematic block diagram showing an LED lamp of the present invention where the ballast is removed or bypassed and including a power line from an external power source to a power converter and then to an LED array positioned in a tube and a switch also positioned in the tube on the power line to the LED array and in operational contact with a power control sensor positioned external to the tube having three alternative signal lines to the switch;

FIG. **89**D is a schematic block diagram showing an LED lamp of the present invention where the ballast is removed or bypassed and including a power line from an external power source to a power converter and then to an LED array positioned in a tube with a computer or logic gate array and a dimmer on the power line to the LED array also positioned therein and a power control sensor positioned external to the tube having three alternative signal lines to the computer or logic gate array;

FIG. **90** is a schematic block diagram showing an LED lamp of the present invention where the ballast is removed or bypassed and including a power line from an external power source to a power converter and then to an LED array positioned in a tube with a power control light level photosensor and a power control occupancy sensor both in operational contact with a switch on the power line to the LED array also positioned therein;

FIG. **91** is a schematic block diagram showing an LED lamp of the present invention where the ballast is removed or bypassed and including a power line from an external power source to a power converter and then to an LED array positioned in a tube with a computer or logic gate array in opera-

tional communication with a power control light level photosensor, a power control occupancy sensor, and a dimmer on the power line to the LED array also positioned therein;

FIG. **92** is a schematic block diagram showing an LED lamp of the present invention where the ballast is removed or bypassed and including a power line from an external power source to a power converter and then to an LED array positioned in a tube and a switch also positioned in the tube on the power line to the LED array and in operational contact with a power control light level photosensor and a power control occupancy sensor both positioned external to the tube having three alternative signal lines to the switch;

FIG. **93** is a schematic block diagram showing an LED lamp of the present invention where the ballast is removed or bypassed and including a power line from an external power source to a power converter and then to an LED array positioned in a tube with a computer or logic gate array and a dimmer on the power line to the LED array also positioned therein and a power control light level photosensor and a power control occupancy sensor both positioned external to the tube having three alternative signal lines to the computer or logic gate array;

FIG. **94** is a logic diagram related to the schematic block diagram shown in FIG. **93** that sets forth the four operational possibilities between the two types of power control sensors;

FIG. **95** is a schematic block diagram showing two LED lamps of the present invention in a master and master network communication with each other where the ballasts are removed or bypassed and each LED lamp includes a power line from an external power source to a power converter and then to an LED array positioned in a tube with a power control photosensor input and a power control occupancy sensor input with a dimmer on the power line to the LED array also positioned therein, and a computer or logic gate array in operational communication with the power control light level sensor, power control occupancy sensor, dimmer, and other computer or logic gate array;

FIG. **96** is a schematic block diagram showing two LED lamps of the present invention in a master and slave network communication with each other where the ballasts are removed or bypassed and each LED lamp includes a power line from an external power source to a power converter and then to an LED array positioned in a tube with only the master LED lamp including a power control photosensor input and a power control occupancy sensor input positioned therein, and a master computer or logic gate array in operational communication with the one power control light level sensor, the one power control occupancy sensor, dimmer, and a slave computer or logic gate array, slave dimmer, and slave LED array; and

FIG. **97** is a profile end view of an open tubular lens housing with a heat sink attached to either to the circuit board to which LEDs or LED arrays are mounted, or directly to the open tubular lens housing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

It is noted that the immediate following disclosure relates to continuation-in-part application Ser. No. 11/198,633, the parent application of the present application. The disclosure of the present child application begins with FIG. **87** and continues through to FIG. **97**.

Reference is now made to the drawings and in particular to FIGS. **1-97** in which identical of similar parts are designated by the same reference numerals throughout.

An LED lamp **10** shown in FIGS. **1-10** is seen in FIG. **1** retrofitted to an existing elongated fluorescent fixture **12** mounted to a ceiling **14**. An instant start type ballast assembly **16** is positioned within the upper portion of fixture **12**. Fixture **12** further includes a pair of fixture mounting portions **18**A and **18**B extending downwardly from the ends of fixture **12** that include ballast electrical contacts shown as ballast end sockets **20**A and **20**B that are in electrical contact with ballast assembly **16**. Fixture sockets **20**A and **20**B are each single contact sockets in accordance with the electrical operational requirement of an instant start type ballast. As also seen in FIG. **1**A, LED lamp **10** includes opposed single-pin electrical contacts **22**A and **22**B that are positioned in ballast sockets **20**A and **20**B, respectively, so that LED lamp **10** is in electrical contact with ballast assembly **16**.

As shown in the disassembled mode of FIG. **2** and also indicated schematically in FIG. **4**, LED lamp **10** includes an elongated housing **24** particularly configured as a tubular wall **26** circular in cross-section taken transverse to a center line **28** that is made of a translucent material such as plastic or glass and preferably having a diffused coating. Tubular wall **26** has opposed tubular wall ends **30**A and **30**B. LED lamp **10** further includes a pair of opposed lamp base end caps **32**A and **32**B mounted to single electrical contact pins **22**A and **22**B, respectively for insertion in ballast electrical socket contacts **20**A and **20**B in electrical power connection to ballast assembly **16** so as to provide power to LED lamp **10**. Tubular wall **26** is mounted to opposed base end caps **32**A and **32**B at tubular wall ends **30**A and **30**B in the assembled mode as shown in FIG. **1**. LED lamp **10** also includes an electrical LED array circuit board **34** that is cylindrical in configuration. Although this embodiment describes a generally cylindrical configuration, it can be appreciated by someone skilled in the art to form the flexible circuit board **34** into shapes other than a cylinder for example, such as an elongated oval, triangle, rectangle, hexagon, octagon, etc. Accordingly, the shape of the tubular housing **24** holding the individual flexible circuit board **34** can be made in a similar shape to match the shape of the formed flexible circuit board **34** configuration. LED array circuit board **34** is positioned and held within tubular wall **26**. In particular, LED array circuit board **34** has opposed circuit board circular ends **36**A and **36**B that are slightly inwardly positioned from tubular wall ends **30**A and **30**B, respectively. LED array circuit board **34** has interior and exterior cylindrical sides **38**A and **38**B, respectively with interior side **38**A forming an elongated central passage **37** between tubular wall circular ends **30**A and **30**B and with exterior side **38**B being spaced from tubular wall **26**. LED array circuit board **34** is preferably assembled from a material that has a flat preassembled unbiased mode and an assembled self-biased mode as shown in the mounted position in FIGS. **2** and **3** wherein cylindrical sides **38**A and **38**B press outwardly towards tubular wall **26**. LED array circuit board **34** is shown in FIG. **2** and indicated schematically in FIG. **5**. LED lamp **10** further includes an LED array **40** comprising one hundred and fifty LEDs mounted to LED array circuit board **34**. An integral electronics circuit board **42**A is positioned between LED array circuit board **34** and base end cap **32**A, and an integral electronics circuit board **42**B is positioned between LED array circuit board **34** and base end cap **32**B.

As seen in FIGS. **2** and **5**, LED lamp **10** also includes a 6-pin connector **43**A connected to integral electronics circuit board **42**A, and a 6-pin header **44**A positioned between and connected to 6-pin connector **43**A and LED array circuit board **34**. LED lamp **10** also includes a 6-pin connector **43**B positioned for connection to 6-pin header **44**A and LED array circuit board **34**. Also, a 6-pin connector **43**C is positioned for

connection to LED array circuit board **34** and to a 6-pin header **44**B, which is positioned for connection to a 6-pin connector **43**D, which is connected to integral electronics circuit board **42**B.

LED lamp **10** also includes an optional elongated cylindrical support member **46** defining a central passage **47** that is positioned within elongated housing **24** positioned immediately adjacent to and radially inward relative to and in support of cylindrical LED array electrical LED array circuit board **34**. Cylindrical support member **46** is also shown in isolation in FIGS. **8** and **8**A. Optional support member **46** is made of an electrically non-conductive material such as rubber or plastic and is rigid in its position. It is preferably made of a self-biasable material and is in a biased mode in the cylindrical position, so that it presses radially outward in support of cylindrical LED array electrical LED array circuit board **34**. Optional support member **46** is longitudinally aligned with tubular center line **28** of tubular member **26**. Optional support member **46** further isolates integral electronics circuit boards **42**A and **42**B from LED array circuit board **34** containing the compact LED array **40**. Optional support member **46**, which is preferably made of a heat conducting material, may operate as a heat sink to draw heat away from LED array circuit board **34** and LED array **40** to the center of elongated housing **24** and thereby dissipating the heat out at the two ends **30**A and **30**B of tubular wall **26**. Optional support member **46** defines cooling holes or holes **48** to allow heat from LED array **40** to flow to the center area of tubular wall **26** and from there to be dissipated at tubular circular ends **30**A and **30**B.

The sectional view of FIG. **3** taken through a typical single LED row **50** comprising ten individual LEDs **52** of the fifteen rows of LED array **40** shown in FIG. **4**. LED row **50** is circular in configuration, which is representative of each of the fifteen rows of LED array **40** as shown in FIG. **4**. Each LED **52** includes a light emitting lens portion **54**, a body portion **56**, and a base portion **58**. A cylindrical space **60** is defined between interior side **38**A of LED array circuit board **34** and cylindrical tubular wall **26**. Each LED **52** is positioned in space **60** as seen in the detailed view of FIG. **3**A, which is devoid of optional linear housing **24**. Lens portion **54** is in juxtaposition with the inner surface of tubular wall **26** and base portion **58** is mounted to the outer surface of LED array circuit board **34** in electrical contact therewith. A detailed view of a single LED **52** shows a rigid LED electrical lead **62** extending from LED base portion **58** to LED array circuit board **34** for electrical connection therewith. Lead **62** is secured to LED circuit board **34** by solder **64**. An LED center line **66** is aligned transverse to center line **28** of tubular wall **26**. As shown in the sectional view of FIG. **3**, light is emitted through tubular wall **26** by the ten LEDs **52** in equal strength about the entire circumference of tubular wall **26**. Projection of this arrangement is such that all fifteen LED rows **50** are likewise arranged to emit light rays in equal strength the entire length of tubular wall **26** in equal strength about the entire 360-degree circumference of tubular wall **26**. The distance between LED center line **66** and LED array circuit board **34** is the shortest that is geometrically possible. In FIG. **3**A, LED center line **66** is perpendicular to tubular wall center line **28**. FIG. **3**A indicates a tangential plane **67** relative to the cylindrical inner surface of linear wall **26** in phantom line at the apex of LED lens portion **54** that is perpendicular to LED center line **66** so that all LEDs **52** emit light through tubular wall **26** in a direction perpendicular to tangential line **67** so that maximum illumination is obtained from all LEDs **52**.

FIG. **4** shows the total LED electrical circuitry for LED lamp **10**. The total LED circuitry is shown in a schematic format that is flat for purposes of exposition. The total LED circuitry comprises two circuit assemblies, namely, existing ballast assembly circuitry **68** and LED circuitry **70**, the latter including LED array circuitry **72**, and integral electronics circuitry **84**. LED circuitry **70** provides electrical circuits for LED lighting element array **40**. When electrical power, normally 120 VAC or 240 VAC at 50 or 60 Hz, is applied, ballast circuitry **68** as is known in the art of instant start ballasts provides either an AC or DC voltage with a fixed current limit across ballast socket electrical contacts **20**A and **20**B, which is conducted through LED circuitry **70** by way of single contact pins **22**A and **22**B to a voltage input at a bridge rectifier **74**. Bridge rectifier **74** converts AC voltage to DC voltage if ballast circuitry **68** supplies AC voltage. In such a situation wherein ballast circuitry **68** supplies DC voltage, the voltage remains DC voltage even in the presence of bridge rectifier **74**.

LEDs **52** have an LED voltage design capacity, and a voltage suppressor **76** is used to protect LED lighting element array **40** and other electronic components primarily including LEDs **52** by limiting the initial high voltage generated by ballast circuitry **68** to a safe and workable voltage.

Bridge rectifier **74** provides a positive voltage V+ to an optional resettable fuse **78** connected to the anode end and also provides current protection to LED array circuitry **72**. Fuse **78** is normally closed and will open and de-energize LED array circuitry **72** only if the current exceeds the allowable current through LED array **40**. The value for resettable fuse **78** should be equal to or be lower than the maximum current limit of ballast assembly **16**. Fuse **78** will reset automatically after a cool-down period.

Ballast circuitry **68** limits the current going into LED circuitry **70**. This limitation is ideal for the use of LEDs in general and of LED lamp **10** in particular because LEDs are basically current devices regardless of the driving voltage. The actual number of LEDs will vary in accordance with the actual ballast assembly **16** used. In the example of the embodiment herein, ballast assembly **16** provides a maximum current limit of 300 mA.

LED array circuitry **72** includes fifteen electrical strings **80** individually designated as strings **80**A, **80**B, **80**C, **80**D, **80**E, **80**F, **80**G, **80**H, **80**I, **80**J, **80**K, **80**L, **80**M, **80**N and **80**O all in parallel relationship with all LEDs **52** within each string **80**A-**80**O being electrically wired in series. Parallel strings **80** are so positioned and arranged that each of the fifteen strings **80** is equidistant from one another. LED array circuitry **72** includes ten LEDs **52** electrically mounted in series within each of the fifteen parallel strings **80**A-O for a total of one-hundred and fifty LEDs **52** that constitute LED array **40**. LEDs **52** are positioned in equidistant relationship with one another and extend generally the length of tubular wall **26**, that is, generally between tubular wall ends **30**A and **30**B. As shown in FIG. **4**, each of strings **80**A-**80**O includes an optional resistor **82** designated individually as resistors **82**A, **82**B, **82**C, **82**D, **82**E, **82**F, **82**G, **82**H, **821**, **82**J, **82**K, **82**L, **82**M, **82**N, and **82**O in respective series alignment with strings **80**A-**80**O at the current input for a total of fifteen resistors **82**. The current limiting resistors **82**A-**82**O are purely optional, because the existing fluorescent ballast used here is already a current limiting device. The resistors **82**A-**82**O then serve as secondary protection devices. A higher number of individual LEDs **52** can be connected in series within each LED string **80**. The maximum number of LEDs **52** being configured around the circumference of the 1.5-inch diameter of tubular wall **26** in the particular example herein of LED lamp **10** is ten. Each LED **52** is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When LED array circuitry

72 is energized, the positive voltage that is applied through resistors 82A-82O to the anode end circuit strings 80A-80O and the negative voltage that is applied to the cathode end of circuit strings 80A-80O will forward bias LEDs 52 connected to strings 80A-80O and cause LEDs 52 to turn on and emit light.

Ballast assembly 16 regulates the electrical current through LEDs 52 to the correct value of 20 mA for each LED 52. The fifteen LED strings 80 equally divide the total current applied to LED array circuitry 72. Those skilled in the art will appreciate that different ballasts provide different current outputs.

If the forward drive current for LEDs 52 is known, then the output current of ballast assembly 16 divided by the forward drive current gives the exact number of parallel strings of LEDs 52 in the particular LED array, here LED array 40. The total number of LEDs in series within each LED string 80 is arbitrary since each LED 52 in each LED string 80 will see the same current. Again in this example, ten LEDs 52 are shown connected in series within each LED string 80 because of the fact that only ten LEDs 52 of the 5 mm discrete type of LED will fit around the circumference of a 1.5-inch diameter lamp housing. Ballast assembly 16 provides 300 mA of current, which when divided by the fifteen LED strings 80 of ten LEDs 52 per LED string 80 gives 20 mA per LED string 80. Each of the ten LEDs 52 connected in series within each LED string 80 sees this 20 mA. In accordance with the type of ballast assembly 16 used, when ballast assembly 16 is first energized, a high voltage may be applied momentarily across ballast socket contacts 20A and 20B, which conduct to pin contacts 22A and 22B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry 72 and voltage surge absorber 76 absorbs the voltage applied by ballast circuitry 68, so that the initial high voltage supplied is limited to an acceptable level for the circuit. Optional resettable fuse 78 is also shown to provide current protection to LED array circuitry 72.

As can be seen from FIG. 4A, there can be more than ten LEDs 52 connected in series within each string 80A-80O. There are twenty LEDs 52 in this example, but there can be more LEDs 52 connected in series within each string 80A-80O. The first ten LEDs 52 of each parallel string will fill the first 1.5-inch diameter of the circumference of tubular wall 26, the second ten LEDs 52 of the same parallel string will fill the next adjacent 1.5-inch diameter of the circumference of tubular wall 26, and so on until the entire length of the tubular wall 26 is substantially filled with all LEDs 52 comprising the total LED array 40.

LED array circuitry 72 includes fifteen electrical LED strings 80 individually designated as strings 80A, 80B, 80C, 80D, 80E, 80F, 80G, 80H, 80I, 80J, 80K, 80L, 80M, 80N and 80O all in parallel relationship with all LEDs 52 within each string 80A-80O being electrically wired in series. Parallel strings 80 are so positioned and arranged that each of the fifteen strings 80 is equidistant from one another. LED array circuitry 72 includes twenty LEDs 52 electrically mounted in series within each of the fifteen parallel strings 80A-O for a total of three-hundred LEDs 52 that constitute LED array 40. LEDs 52 are positioned in equidistant relationship with one another and extend generally the length of tubular wall 26, that is, generally between tubular wall ends 30A and 30B. As shown in FIGS. 4 and 4A, each of strings 80A-80O includes an optional resistor 82 designated individually as resistors 82A, 82B, 82C, 82D, 82E, 82F, 82G, 82H, 82I, 82J, 82K, 82L, 82M, 82N, and 82O in respective series alignment with strings 80A-80O at the current input for a total of fifteen resistors 82. Again, a higher number of individual LEDs 52 can be connected in series within each LED string 80. The maximum number of LEDs 52 being configured around the circumference of the 1.5-inch diameter of tubular wall 26 in the particular example herein of LED lamp 10 is ten. Each LED 52 is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When LED array circuitry 72 is energized, the positive voltage that is applied through resistors 82A-82O to the anode end circuit strings 80A-80O and the negative voltage that is applied to the cathode end of circuit strings 80A-80O will forward bias LEDs 52 connected to strings 80A-80O and cause LEDs 52 to turn on and emit light.

Ballast assembly 16 regulates the electrical current through LEDs 52 to the correct value of 20 mA for each LED 52. The fifteen LED strings 80 equally divide the total current applied to LED array circuitry 72. Those skilled in the art will appreciate that different ballasts provide different current outputs.

If the forward drive current for LEDs 52 is known, then the output current of ballast assembly 16 divided by the forward drive current gives the exact number of parallel strings of LEDs 52 in the particular LED array, here LED array 40. The total number of LEDs in series within each LED string 80 is arbitrary since each LED 52 in each LED string 80 will see the same current. Again in this example, twenty LEDs 52 are shown connected in series within each LED string 80 because of the fact that only ten LEDs 52 of the 5 mm discrete type of LED will fit around the circumference of a 1.5-inch diameter lamp housing. Ballast assembly 16 provides 300 mA of current, which when divided by the fifteen strings 80 of ten LEDs 52 per LED string 80 gives 20 mA per LED string 80. Each of the twenty LEDs 52 connected in series within each LED string 80 sees this 20 mA. In accordance with the type of ballast assembly 16 used, when ballast assembly 16 is first energized, a high voltage may be applied momentarily across ballast socket contacts 20A and 20B, which conduct to pin contacts 22A and 22B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry 72 and voltage surge absorber 76 absorbs the voltage applied by ballast circuitry 68, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

FIG. 4B shows another alternate arrangement of LED array circuitry 72. LED array circuitry 72 consists of a single LED string 80 of LEDs 52 arranged in series relationship including for exposition purposes only forty LEDs 52 all electrically connected in series. Positive voltage V+ is connected to optional resettable fuse 78, which in turn is connected to one side of current limiting resistor 82. The anode of the first LED in the series string is then connected to the other end of resistor 82. A number other than forty LEDs 52 can be connected within the series LED string 80 to fill up the entire length of the tubular wall of the present invention. The cathode of the first LED 52 in the series LED string 80 is connected to the anode of the second LED 52; the cathode of the second LED 52 in the series LED string 80 is then connected to the anode of the third LED 52, and so forth. The cathode of the last LED 52 in the series LED string 80 is likewise connected to ground or the negative potential V−. The individual LEDs 52 in the single series LED string 80 are so positioned and arranged such that each of the forty LEDs is spaced equidistant from one another substantially filling the entire length of tubular wall 26. LEDs 52 are positioned in equidistant relationship with one another and extend substantially the length of tubular wall 26, that is, generally between tubular wall ends 30A and 30B. As shown in FIG. 4B, the single series LED string 80 includes an optional resistor 82 in respective series alignment with single series LED string 80

at the current input. Each LED **52** is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When LED array circuitry **72** is energized, the positive voltage that is applied through resistor **82** to the anode end of single series LED string **80** and the negative voltage that is applied to the cathode end of single series LED string **80** will forward bias LEDs **52** connected in series within single series LED string **80**, and cause LEDs **52** to turn on and emit light.

The single series LED string **80** of LEDs **52** as described above works ideally with the high-brightness or brighter high flux white LEDs available from Lumileds and Nichia in the SMD (surface mounted device) packages as discussed earlier herein. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The high-brightness LEDs **52**A have to be connected in series, so that each high-brightness LED **52**A within the same single LED string **80** will see the same current and therefore output the same brightness. The total voltage required by all the high-brightness LEDs **52**A within the same single LED string **80** is equal to the sum of all the individual voltage drops across each high-brightness LED **52**A and should be less than the maximum voltage output of ballast assembly **16**.

FIG. **4**C shows a simplified arrangement of the LED array circuitry **72** of LEDs **52** shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **4**. AC lead lines **86** and **90** and DC positive lead line **92** and DC negative lead line **94** are connected to integral electronics circuit boards **42**A and **42**B by way of 6-pin headers **44**A and **44**B and connectors **43**A-**43**D. Four parallel LED strings **80** each including a resistor **82** are each connected to DC positive lead line **92** on one side, and to LED positive lead line **100** or the anode side of each LED **52** and on the other side. The cathode side of each LED **52** is then connected to LED negative lead line **102** and to DC negative lead line **94** directly. AC lead lines **86** and **90** simply pass through LED array circuitry **72**.

FIG. **4**D shows a simplified arrangement of the LED array circuitry **72** of LEDs **52** shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **4**A. AC lead lines **86** and **90** and DC positive lead line **92** and DC negative lead line **94** are connected to integral electronics boards **42**A and **42**B by way of 6-pin headers **44**A and **44**B and connectors **43**A-**43**D. Two parallel LED strings **80** each including a single resistor **82** are each connected to DC positive lead line **92** on one side, and to LED positive lead line **100** or the anode side of the first LED **52** in each LED string **80** on the other side. The cathode side of the first LED **52** is connected to LED negative lead line **102** and to adjacent LED positive lead line **100** or the anode side of the second LED **52** in the same LED string **80**. The cathode side of the second LED **52** is then connected to LED negative lead line **102** and to DC negative lead line **94** directly in the same LED string **80**. AC lead lines **86** and **90** simply pass through LED array circuitry **72**.

FIG. **4**E shows a simplified arrangement of the LED array circuitry **72** of LEDs **52** shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **4**B. AC lead lines **86** and **90** and DC positive lead line **92** and DC negative lead line **94** are connected to integral electronics boards **42**A and **42**B by way of 6-pin headers **44**A and **44**B and connectors **43**A-**43**D. Single parallel LED string **80** including a single resistor **82** is connected to DC positive lead line **92** on one side, and to LED positive lead line **100** or the anode side of the first LED **52** in the LED string **80** on the other side. The cathode side of the first LED **52** is connected to LED negative lead line **102** and to adjacent LED positive lead line **100** or the anode side of the second LED **52**. The cathode side of the second LED **52** is connected to LED negative lead line **102** and to adjacent LED positive lead line **100** or the anode side of the third LED **52**. The cathode side of the third LED **52** is connected to LED negative lead line **102** and to adjacent LED positive lead line **100** or the anode side of the fourth LED **52**. The cathode side of the fourth LED **52** is then connected to LED negative lead line **102** and to DC negative lead line **94** directly. AC lead lines **86** and **90** simply pass through LED array circuitry **72**.

The term high-brightness as describing LEDs herein is a relative term. In general, for the purposes of the present application, high-brightness LEDs refer to LEDs that offer the highest luminous flux outputs. Luminous flux is defined as lumens per watt. For example, Lumileds Luxeon high-brightness LEDs produce the highest luminous flux outputs at the present time. Luxeon 5-watt high-brightness LEDs offer extreme luminous density with lumens per package that is four times the output of an earlier Luxeon 1-watt LED and up to 50 times the output of earlier discrete 5 mm LED packages. Gelcore is soon to offer an equivalent and competitive product.

With the new high-brightness LEDs in mind, FIG. **4**F shows a single high-brightness LED **52**A positioned on an electrical string in what is defined herein as an electrical series arrangement with single a high-brightness LED **52**A for the overall electrical circuit shown in FIG. **4**. The single high-brightness LED **52**A fulfills a particular lighting requirement formerly fulfilled by a fluorescent lamp.

Likewise, FIG. **4**G shows two high-brightness LEDs **52**A in electrical parallel arrangement with one high-brightness LED **52**A positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. **4**. The two high-brightness LEDs **52**A fulfill a particular lighting requirement formerly fulfilled by a fluorescent lamp.

The single LED string **80** of SMD LEDs **52** connected in series can be mounted onto a long thin strip flexible circuit board made of polyimide or equivalent material. The flexible circuit board **34** is then spirally wrapped into a generally cylindrical configuration. Although this embodiment describes a generally cylindrical configuration, it can be appreciated by someone skilled in the art to form the flexible circuit board **34** into shapes other than a cylinder, such as an elongated oval, triangle, rectangle, hexagon, and octagon, as some examples of a wide possible variation of configurations. Accordingly, the shape of the tubular housing **24** holding the single wrapped flexible circuit board **34** can be made in a similar shape to match the shape of the formed flexible circuit board **34** configuration.

LED array circuit board **34** is positioned and held within tubular wall **26**. As in FIGS. **2** and **5**, LED array circuit board **34** has opposed circuit board circular ends **36**A and **36**B that are slightly inwardly positioned from tubular wall ends **30**A and **30**B, respectively. LED array circuit board **34** has interior and exterior cylindrical sides **38**A and **38**B, respectively with interior side **38**A forming an elongated central passage **37** between tubular wall circular ends **30**A and **30**B with exterior side **38**B being spaced from tubular wall **26**. LED array circuit board **34** is preferably assembled from a material that has a flat preassembled unbiased mode and an assembled self-biased mode wherein cylindrical sides **38**A and **38**B press outwardly towards tubular wall **26**. The SMD LEDs **52** are mounted on exterior cylindrical side **38**B with the lens **54** of

each LED **52** held in juxtaposition with tubular wall **25** and pointing radially outward from center line **28**. As shown in the sectional view of FIG. **3**, LEDs **52** emits light through tubular wall **26** in equal strength about the entire 360-degree circumference of tubular wall **26**.

As described earlier in FIGS. **2** and **5**, an optional support member **46** is made of an electrically non-conductive material such as rubber or plastic and is held rigid in its position. It is preferably made of a self-biasable material and is in a biased mode in the cylindrical position, so that it presses radially outward in holding support of cylindrical LED array electrical LED array circuit board **34**. Optional support member **46** is longitudinally aligned with tubular center line **28** of tubular member **26**. Optional support member **46** further isolates integral electronics circuit boards **42**A and **42**B from LED array circuit board **34** containing the compact LED array **40**. Optional support member **46**, which is preferably made of a heat conducting material, may operate as a heat sink to draw heat away from LED array circuit board **34** and LED array **40** to the center of elongated housing **24** and thereby dissipating the heat out at the two ends **30**A and **30**B of tubular wall **26**. Optional support member **46** defines cooling holes or holes **48** to allow heat from LED array **40** to flow to the center area of tubular wall **26** and from there to be dissipated at tubular circular ends **30**A and **30**B.

Ballast assembly **16** regulates the electrical current through LEDs **52** to the correct value of 300 mA or other ballast assembly **16** rated lamp current output for each LED **52**. The total current is applied to both the single LED string **80** and to LED array circuitry **72**. Again, those skilled in the art will appreciate that different ballasts provide different rated lamp current outputs.

If the forward drive current for LEDs **52** is known, then the output current of ballast assembly **16** divided by the forward drive current gives the exact number of parallel strings **80** of LEDs **52** in the particular LED array, here LED array **40** shown in electrically parallel configuration in FIG. **4** and in electrically series configurations in FIGS. **4**A and **4**B. Since the forward drive current for LEDs **52** is equal to the output current of ballast assembly **16**, then the result is a single series LED string **80** of LEDs **52**. The total number of LEDs in series within each series LED string **80** is arbitrary since each LED **52** in each series LED string **80** will see the same current. Again in this example shown in FIG. **4**B, forty LEDs **52** are shown connected within series LED string **80**. Ballast assembly **16** provides 300 mA of current, which when divided by the single series LED string **80** of forty LEDs **52** gives 300 mA for single series LED string **80**. Each of the forty LEDs **52** connected in series within single series LED string **80** sees this 300 mA. In accordance with the type of ballast assembly **16** used, when ballast assembly **16** is first energized, a high voltage may be applied momentarily across ballast socket contacts **20**A and **20**B, which conduct to pin contacts **22**A and **22**B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry **72** and voltage surge absorber **76** absorbs the voltage applied by ballast circuitry **68**, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

It can be seen from someone skilled in the art from FIGS. **4**, **4**A, and **4**B that the LED array **40** can consist of at least one parallel electrical LED string **80** containing at least one LED **52** connected in series within each parallel electrical LED string **80**. Therefore, the LED array **40** can consist of any number of parallel electrical strings **80** combined with any number of LEDs **52** connected in series within electrical strings **80**, or any combination thereof.

FIGS. **4**C, **4**D, and **4**E show simplified electrical arrangements of the array **40** of LEDs **52** shown with at least one LED **52** in a series parallel configuration. Each LED string **80** has an optional resistor **82** in series with each LED **52**.

As shown in the schematic electrical and structural representations of FIG. **5**, LED array circuit board **34** of LED array **40** is positioned between integral electronics circuit board **42**A and **42**B that in turn are electrically connected to ballast circuitry **68** by single contact pins **22**A and **22**B, respectively. Single contact pins **22**A and **22**B are mounted to and protrude out from base end caps **32**A and **32**B, respectively, for electrical connection to integral electronics circuit boards **42**A and **42**B. Contact pins **22**A and **22**B are soldered directly to integral electronics circuit boards **42**A and **42**B, respectively. In particular, pin inner extension **22**D of connecting pin **22**A is electrically connected by being soldered directly to the integral electronics circuit board **42**A. Similarly, being soldered directly to integral electronics circuit board **42**B electrically connects pin inner extension **22**F of connecting pin **22**B. 6-pin connector **44**A is shown positioned between and in electrical connection with integral electronics circuit board **42**A and LED array circuit board **34** and LED circuitry **70** shown in FIG. **4** mounted thereon. 6-pin connector **44**B is shown positioned between and in electrical connection with integral electronics circuit board **42**B and LED array circuit board **34** and LED circuitry **70** mounted thereon.

As seen in FIG. **6**, a schematic of integral electronics circuitry **84** is mounted on integral electronics circuit board **42**A. Integral electronics circuit **84** is also shown in FIG. **4** as part of the schematically shown LED circuitry **70**. Integral electronics circuitry **84** is in electrical contact with ballast socket contact **20**A, which is shown as providing AC voltage. Integral electronics circuitry **84** includes bridge rectifier **74**, voltage surge absorber **76**, and fuse **78**. Bridge rectifier **74** converts AC voltage to DC voltage. Voltage surge absorber **76** limits the high voltage to a workable voltage within the design voltage capacity of LEDs **52**. The DC voltage circuits indicated as plus (+) and minus (−) and indicated as DC leads **92** and **94** lead to and from LED array **40** (not shown). It is noted that FIG. **6** indicates the presence of AC voltage by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies **16** as mentioned earlier herein. In such a case DC voltage would be supplied to LED lighting element array **40** even in the presence of bridge rectifier **74**. It is particularly noted that in such a case, voltage surge absorber **76** would remain operative.

FIG. **7** shows a further schematic of integral electronics circuit **42**B that includes integral electronics circuitry **88** mounted on integral electronics board **42**B with voltage protected AC lead line **90** extending from LED array **40** (not shown) and by extension from integral electronics circuitry **84**. The AC lead line **90** having passed through voltage surge absorber **76** is a voltage protected circuit and is in electrical contact with ballast socket contact **20**B. Integral circuitry **88** includes DC positive and DC negative lead lines **92** and **94**, respectively, from LED array circuitry **72** to positive and negative DC terminals **96** and **98**, respectively, mounted on integral electronics board **42**B. Integral circuitry **88** further includes AC lead line **90** from LED array circuitry **72** to ballast socket contact **20**B.

FIGS. **6** and **7** show the lead lines going into and out of LED circuitry **70** respectively. The lead lines include AC lead lines **86** and **90**, positive DC voltage **92**, DC negative voltage **94**, LED positive lead line **100**, and LED negative lead line **102**. The AC lead lines **86** and **90** are basically feeding through LED circuitry **70**, while the positive DC voltage lead line **92** and negative DC voltage lead line **94** are used prima-

rily to power the LED array **40**. DC positive lead line **92** is the same as LED positive lead line **100** and DC negative lead line **94** is the same as LED negative lead line **102**. LED array circuitry **72** therefore consists of all electrical components and internal wiring and connections required to provide proper operating voltages and currents to LEDs **52** connected in parallel, series, or any combinations of the two.

FIGS. **8** and **8**A show the optional support member **46** with cooling holes **48** in both side and cross-sectional views respectively.

FIG. **9** shows an isolated view of one of the base end caps, namely, base end cap **32**A, which is the same as base end cap **32**B, mutatis mutandis. Single-pin contact **22**A extends directly through the center of base end cap **32**A in the longitudinal direction in alignment with center line **28** of tubular wall **26** relative to tubular wall **26**. Single-pin **22**A as also shown in FIG. **1** where single-pin contact **22**A is mounted into ballast socket contact **20**A. Single-pin contact **22**A also includes pin extension **22**D that is outwardly positioned from base end cap **32**A in the direction towards tubular wall **26**. Base end cap **32**A is a solid cylinder in configuration as seen in FIGS. **9** and **9**A and forms an outer cylindrical wall **104** that is concentric with center line **28** of tubular wall **26** and has opposed flat end walls **106**A and **106**B that are perpendicular to center line **28**. Two cylindrical parallel vent holes **108**A and **108**B are defined between flat end walls **106**A and **106**B spaced directly above and below and lateral to single-pin contact **22**A. Single-pin contact **22**A includes external side pin extension **22**C and internal side pin extension **22**D that each extend outwardly positioned from opposed flat end walls **106**A and **106**B, respectively, for electrical connection with ballast socket contact **20**A and with integral electronics board **42**A. Analogous external and internal pin extensions for contact pin **22**B likewise exist for electrical connections with ballast socket contact **20**B and with integral electronics board **42**B.

As also seen in FIG. **9**A, base end cap **32**A defines an outer circular slot **110** that is concentric with center line **28** of tubular wall **26** and concentric with and aligned proximate to circular wall **104**. Circular slot **110** is spaced from cylindrical wall **104** at a convenient distance. Circular slot **110** is of such a width and circular end **30**A of tubular wall **26** is of such a thickness that circular end **30**A is fitted into circular slot **110** and is thus supported by circular slot **110**. Base end cap **32**B (not shown in detail) defines another circular slot (not shown) analogous to circular slot **110** that is likewise concentric with center line **28** of tubular wall **26** so that circular end **30**B of tubular wall **26** can be fitted into the analogous circular slot of base end cap **32**B wherein circular end **30**B is also supported. In this manner tubular wall **26** is mounted to end caps **32**A and **32**B.

As also seen in FIG. **9**A, base end cap **32**A defines another inner circular slot **112** that is concentric with center line **28** of tubular wall **26** and concentric with and spaced radially inward from circular slot **110**. Circular slot **112** is spaced from circular slot **110** at such a distance that would be occupied by LEDs **52** mounted to LED array circuit board **34** within tubular wall **26**. Circular slot **112** is of such a width and circular end **36**A of LED array circuit board **34** is of such a thickness that circular end **36**A is fitted into circular slot **112** and is thus supported by circular slot **112**. Base end cap **32**B (not shown) defines another circular slot analogous to circular slot **112** that is likewise concentric with center line **28** of tubular wall **26** so that circular end **36**B of LED array circuit board **34** can be fitted into the analogous circular slot of base end cap **32**B wherein circular end **36**B is also supported. In this manner LED array circuit board **34** is mounted to end caps **32**A and **32**B.

Circular ends **30**A and **30**B of tubular wall **26** and also circular ends **36**A and **36**B of LED array circuit board **34** are secured to base end caps **32**A and **32**B preferably by gluing in a manner known in the art. Other securing methods known in the art of attaching such as cross-pins or snaps can be used.

An analogous circular slot (not shown) concentric with center line **28** is optionally formed in flat end walls **106**A and **106**B of base end cap **32**A and analogous circular slot in the flat end walls of base end cap **32**B radially inward from LED circuit board circular slot **112** for insertion of the opposed ends of optional support member **46**.

Circular ends **30**A and **30**B of tubular wall **26** are optionally press fitted to circular slot **110** of base end cap **32**A and the analogous circular slot of base end cap **32**B.

FIG. **10** is a sectional view of an alternate LED lamp **114** mounted to tubular wall **26** that is a version to LED lamp **10** as shown in FIG. **3**. The sectional view of LED lamp **114** shows a single row **50**A of the LEDs of LED lamp **114** and includes a total of six LEDs **52**, with four LEDs **52**X being positioned at equal intervals at the bottom area **116** of tubular wall **26** and with two LEDs **52**Y positioned at opposed side areas **118** of tubular wall **26**A. LED array circuitry **72** previously described with reference to LED lamp **10** would be the same for LED lamp **114**. That is, all fifteen strings **80** of the LED array of LED lamp **10** would be the same for LED lamp **114**, except that a total of ninety LEDs **52** would comprise LED lamp **114** with the ninety LEDs **52** positioned at strings **80** at such electrical connectors that would correspond with LEDs **52**X and **52**Y throughout. The reduction to ninety LEDs **52** of LED lamp **114** from the one hundred and fifty LEDs **52** of LED lamp **10** would result in a forty percent reduction of power demand with an illumination result that would be satisfactory under certain circumstances. Additional stiffening of LED array circuit board **34** for LED lamp **114** is accomplished by circular slot **112** for tubular wall **26** or optionally by the additional placement of LEDs **52** at the top vertical position in space **60** (not shown) or optionally a vertical stiffening member **122** shown in phantom line that is positioned at the upper area of space **60** between LED array circuit board **34** and the inner side of tubular wall **26** and extends the length of tubular wall **26** and LED array circuit board **34**.

LED lamp **10** as described above will work for both AC and DC voltage outputs from an existing fluorescent ballast assembly **16**. In summary, LED array **40** will ultimately be powered by DC voltage. If existing fluorescent ballast **16** operates with an AC output, bridge rectifier **74** converts the AC voltage to DC voltage. Likewise, if existing fluorescent ballast **16** operates with a DC voltage, the DC voltage remains a DC voltage even after passing through bridge rectifier **26**.

Another embodiment of a retrofitted LED lamp is shown in FIGS. **11**-**20**. FIG. **11** shows an LED lamp **124** retrofitted to an existing elongated fluorescent fixture **126** mounted to a ceiling **128**. A rapid start type ballast assembly **130** including a starter **130**A is positioned within the upper portion of fixture **126**. Fixture **126** further includes a pair of fixture mounting portions **132**A and **132**B extending downwardly from the ends of fixture **126** that include ballast electrical contacts shown in FIG. **11**A as ballast double contact sockets **134**A and **136**A and ballast opposed double contact sockets **134**A and **136**B that are in electrical contact with ballast assembly **130**. Ballast double contact sockets **134**A, **136**A and **134**B, **136**B are each double contact sockets in accordance with the electrical operational requirement of a rapid start type ballast.

As also seen in FIG. **11**A, LED lamp **124** includes bi-pin electrical contacts **138**A and **140**A that are positioned in ballast double contact sockets **134**A and **136**A, respectively. LED lamp **124** likewise includes opposed bi-pin electrical contacts **138**B and **140**B that are positioned in ballast double contact sockets **134**B and **136**B, respectively. In this manner, LED lamp **124** is in electrical contact with ballast assembly **130**.

As shown in the disassembled mode of FIG. **12** and also indicated schematically in FIG. **14**, LED lamp **124** includes an elongated tubular housing **142** particularly configured as a tubular wall **144** circular in cross-section taken transverse to a center line **146**. Tubular wall **144** is made of a translucent material such as plastic or glass and preferably has a diffused coating. Tubular wall **144** has opposed tubular wall circular ends **148**A and **148**B. LED lamp **124** further includes a pair of opposed lamp base end caps **150**A and **150**B mounted to bi-pin electrical contacts **138**A, **140**A and **138**B, **140**B, respectively, for insertion in ballast electrical socket contacts **134**A, **136**A and **134**B, **136**B, respectively, in electrical power connection to ballast assembly **130** so as to provide power to LED lamp **124**. Tubular wall **144** is mounted to opposed base end caps **150**A and **150**B at tubular wall circular ends **148**A and **148**B, respectively, in the assembled mode as shown in FIG. **11**. LED lamp **124** also includes an LED array electrical circuit board **152** that is cylindrical in configuration and has opposed circuit board circular ends **154**A and **154**B.

It can be appreciated by someone skilled in the art to form the flexible circuit board **152** into shapes other than a cylinder, such as an elongated oval, triangle, rectangle, hexagon, octagon, among many possible configurations when the elongated tubular housing **142** has a like configuration. It can also be said that the shape of the tubular housing **142** holding the individual flexible circuit board **152** can be made in a similar shape to match the shape of the formed flexible circuit board **152** frame. Circuit board **152** is positioned and held within tubular wall **144**. In particular, circuit board **152** has opposed circuit board ends **154**A and **154**B that are slightly inwardly positioned from tubular wall ends **148**A and **148**B, respectively. Circuit board **152** has opposed interior and exterior cylindrical sides **156**A and **156**B, respectively with exterior side **156**B being spaced from tubular wall **144**. Circuit board **152** is preferably assembled from a material that has a flat preassembled unbiased mode and an assembled self-biased mode as shown in the mounted position in FIGS. **12** and **13** wherein cylindrical sides **156**A and **156**B press outwardly towards tubular wall **144**. Circuit board **152** is shown in FIG. **12** and indicated schematically in FIG. **14**. LED lamp **124** further includes an LED array **158** comprising one hundred and fifty LEDs mounted to circuit board **152**. An integral electronics circuit board **160**A is positioned between circuit board **152** and base end cap **150**A, and an integral electronics circuit board **160**B is positioned between circuit board **152** and base end cap **150**B.

As seen in FIGS. **12** and **15**, LED lamp **124** also includes a 6-pin connector **161**A connected to integral electronics circuit board **160**A, and a 6-pin header **162**A positioned between and connected to 6-pin connector **161**A and circuit board **152**. LED lamp **124** also includes a 6-pin connector **161**B positioned for connection to 6-pin header **162**A and circuit board **152**. Also, a 6-pin connector **161**C is positioned for connection to circuit board **152** and to a 6-pin header **162**B, which is positioned for connection to a 6-pin connector **161**D, which is connected to integral electronics circuit board **160**B.

LED lamp **124** also includes an optional elongated cylindrical support member **164** that is positioned within elongated housing **142** positioned immediately adjacent to and radially inward relative to and in support of LED array electrical circuit board **152**. Optional support member **164** is also shown in isolation in FIGS. **18** and **18**A. Optional support member **164** is made of an electrically non-conductive material such as rubber or plastic and is rigid in its position. It is preferably made of a self-biasable material and is in a biased mode in the cylindrical position, so that it presses radially outward in support of cylindrical LED array electrical circuit board **152**. Optional support member **164** is longitudinally and cylindrically aligned with tubular center line **146** of tubular wall **144**. Optional support member **164** further isolates integral electronics circuit boards **160**A and **160**B from LED array circuit board **152** containing the circuitry for LED array **158**. Optional support member **164**, which may be made of a heat conducting material, can operate as a heat sink to draw heat away from LED circuit board **152** including the circuitry for LED array **158** to the center of elongated housing **142** and thereby dissipating the heat at the two ends **148**A and **148**B of tubular wall **144**. Optional support member **164** defines cooling holes or holes **166** to allow heat from LED array **158** to flow into the center area of tubular wall **144** and from there to be dissipated at tubular circular ends **148**A and **148**B.

The sectional view of FIG. **13** taken through a typical single LED row **168** comprises ten individual LEDs **170** of the fifteen rows of LED array **158** is shown in FIG. **14**. LED row **168** is circular in configuration, which is representative of each of the fifteen rows of LED array **158** as shown in FIG. **14**. Each LED **170** includes an LED light emitting lens portion **172**, an LED body portion **174**, and an LED base portion **176**. A cylindrical space **178** is defined between exterior side **156**B of circuit board **152** and cylindrical tubular wall **144**. Each LED **170** is positioned in space **178** as seen in the detailed view of FIG. **13**A, which is devoid of optional support member **164**. LED lens portion **172** is positioned in proximity with the inner surface of tubular wall **144**, and LED base portion **176** is mounted proximate to the outer surface of LED array circuit board **152** in electrical contact with electrical elements thereon in a manner known in the art. A detailed view in FIG. **13**A of a single LED **170** shows a rigid LED electrical lead **180** extending from LED base portion **176** to LED array circuit board **152** for electrical connection therewith. Lead **180** is secured to LED array circuit board **152** by solder **182**. An LED center line **184** is aligned transverse to center line **146** of tubular wall **144** and as seen in FIG. **13**A in particular perpendicular to center line **146**. As shown in the sectional view of FIG. **13**, light is emitted through tubular wall **144** by the ten LEDs **170** in equal strength about the entire circumference of tubular wall **144**. Projection of this arrangement is such that all fifteen LED rows **168** are likewise arranged to emit light rays in equal strength the entire length of tubular wall **144** in equal strength about the entire 360-degree circumference of tubular wall **144**. The distance between LED center line **184** and LED circuit board **152** is the shortest that is geometrically possible. FIG. **13**A indicates a tangential line **186** relative to the cylindrical inner surface of tubular wall **144** in phantom line at the apex of LED lens portion **172** that is perpendicular to LED center line **184** so that all LEDs **170** emit light through tubular wall **144** in a direction perpendicular to tangential line **186** so that maximum illumination is obtained from all LEDs **170**. Each LED **170** is designed to operate within a specified LED operating voltage capacity.

FIG. **14** shows a complete electrical circuit for LED lamp **124**, which is shown in a schematic format that is flat for purposes of exposition. The complete LED circuit comprises two major circuit assemblies, namely, existing ballast circuitry **188**, which includes starter circuit **188**A, and LED circuitry **190**. LED circuitry **190** includes integral electronics

circuitry **192**A and **192**B, which are associated with integral electronics circuit boards **160**A and **160**B. LED circuitry **190** also includes an LED array circuitry **190**A and an LED array voltage protection circuit **190**B.

When electrical power, normally 120 volt VAC or 240 VAC at 50 or 60 Hz is applied to rapid start ballast assembly **130**, existing ballast circuitry **188** provides an AC or DC voltage with a fixed current limit across ballast socket electrical contacts **136**A and **136**B, which is conducted through LED circuitry **190** by way of LED circuit bi-pin electrical contacts **140**A and **140**B, respectively, (or in the event of the contacts being reversed, by way of LED circuit bi-pin contacts **138**A and **138**B) to the input of bridge rectifiers **194**A and **194**B, respectively.

Ballast assembly **130** limits the current going into LED lamp **124**. Such limitation is ideal for the present embodiment of the inventive LED lamp **124** because LEDs in general are current driven devices and are independent of the driving voltage, that is, the driving voltage does not affect LEDs. The actual number of LEDs **170** will vary in accordance with the actual ballast assembly **130** used. In the example of the embodiment of LED lamp **124**, ballast assembly **130** provides a maximum current limit of 300 mA.

Voltage surge absorbers **196**A, **196**B, **196**C and **196**D are positioned on LED voltage protection circuit **190**B for LED array circuitry **190**A in electrical association with integral electronics control circuitry **192**A and **192**B. Bridge rectifiers **194**A and **194**B are connected to the anode and cathode end buses, respectively of LED circuitry **190** and provide a positive voltage V+ and a negative voltage V−, respectively as is also shown in FIGS. **16** and **17**. FIGS. **16** and **17** also show schematic details of integral electronics circuitry **192**A and **192**B. As seen in FIGS. **16** and **17**, an optional resettable fuse **198** is integrated with integral electronics circuitry **192**A. Resettable fuse **198** provides current protection for LED array circuitry **190**A. Resettable fuse **198** is normally closed and will open and de-energize LED array circuitry **190**A in the event the current exceeds the current allowed. The value for resettable fuse **198** is equal to or is lower than the maximum current limit of ballast assembly **130**. Resettable fuse **198** will reset automatically after a cool down period.

When ballast assembly **130** is first energized, starter **130**A may close creating a low impedance path from bi-pin electrical contact **138**A to bi-pin electrical contact **138**B, which is normally used to briefly heat the filaments in a fluorescent lamp in order to help the establishment of conductive phosphor gas. Such electrical action is unnecessary for LED lamp **124**, and for that reason such electrical connection is disconnected from LED circuitry **190** by way of the biasing of bridge rectifiers **194**A and **194**B.

LED array circuitry **190**A includes fifteen electrical circuit strings **200** individually designated as strings **200**A, **200**B, **200**C, **200**D, **200**E, **200**F, **200**G, **200**H, **200**I, **200**J, **200**K, **200**L, **200**M, **200**N and **200**O all in parallel relationship with each string **200**A-**200**O being electrically wired in series. Parallel strings **200** are so positioned and arranged so that each of the fifteen strings **200**A-O is equidistant from one another. LED array circuitry **190**A provides for ten LEDs **170** electrically mounted in series to each of the fifteen parallel strings **200** for a total of one hundred and fifty LEDs **170** that constitute LED array **158**. LEDs **170** are positioned in equidistant relationship with one another and extend substantially the length of tubular wall **144**, that is, generally between tubular wall ends **148**A and **148**B. As shown in FIG. **14**, each of strings **200**A-**200**O includes a resistor **202**A-**202**O in alignment with strings **200**A-**200**O connected is series to the anode end of each LED string **200** for a total of fifteen resistors **202**. The current limiting resistors **202**A-**202**O are purely optional, because the existing fluorescent ballast used here is already a current limiting device. The resistors **202**A-**202**O then serve as secondary protection devices. A higher number of individual LEDs **170** can be connected in series at each LED string **200**. The maximum number of LEDs **170** being configured around the circumference of the 1.5-inch diameter of tubular wall **144** in the particular example herein of LED lamp **124** is ten. Each LED **170** is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When ballast **130** is energized, positive voltage that is applied through resistors **202** to the anode end of circuit strings **200** and the negative voltage that is applied to the cathode end of circuit strings **200** will forward bias LEDs **170** connected to circuit strings **200**A-**200**O and cause LEDs **170** to turn on and emit light.

Ballast assembly **130** regulates the electrical current through LEDs **170** to the correct value of 20 mA for each LED **170**. The fifteen LED strings **200** equally divide the total current applied to LED array circuitry **190**A. Those skilled in the art will appreciate that different ballasts provide different current outputs.

If the forward drive current for LEDs **170** is known, then the output current of ballast assembly **130** divided by the forward drive current gives the exact number of parallel strings of LEDs **170** in the particular LED array, here LED array **158**. The total number of LEDs in series within each LED string **200** is arbitrary since each LED **170** in each LED string **200** will see the same current. Again in this example, ten LEDs **170** are shown connected in each series LED string **200** because only ten LEDs **170** of the 5 mm discrete type of LED will fit around the circumference of a 1.5-inch diameter lamp housing. Ballast assembly **130** provides 300 mA of current, which when divided by the fifteen strings **200** of ten LEDs **170** per LED string **200** gives 20 mA per LED string **200**. Each of the ten LEDs **170** connected in series within each LED string **200** sees this 20 mA. In accordance with the type of ballast assembly **130** used, when ballast assembly **130** is first energized, a high voltage may be applied momentarily across ballast socket contacts **136**A and **136**B, which conducts to bi-pin contacts **140**A and **140**B (or **138**A and **138**B). This is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but is unnecessary for this circuit and is absorbed by voltage surge absorbers **196**A, **196**B, **196**C, and **196**D to limit the high voltage to an acceptable level for the circuit.

As can be seen from FIG. **14**A, there can be more than ten LEDs **170** connected in series within each string **200**A-**200**O. There are twenty LEDs **170** in this example, but there can be more LEDs **170** connected in series within each string **200**A-**200**O. The first ten LEDs **170** of each parallel string will fill the first 1.5-inch diameter of the circumference of tubular wall **144**, the second ten LEDs **170** of the same parallel string will fill the next adjacent 1.5-inch diameter of the circumference of tubular wall **144**, and so on until the entire length of the tubular wall **144** is substantially filled with all LEDs **170** comprising the total LED array **158**.

LED array circuitry **190**A includes fifteen electrical strings **200** individually designated as strings **200**A, **200**B, **200**C, **200**D, **200**E, **200**F, **200**G, **200**H, **200**I, **200**J, **200**K, **200**L, **200**M, **200**N and **200**O all in parallel relationship with all LEDs **170** within each string **200**A-**200**O being electrically wired in series. Parallel strings **200** are so positioned and arranged that each of the fifteen strings **200** is equidistant from one another. LED array circuitry **190**A includes twenty LEDs **170** electrically mounted in series within each of the fifteen parallel strings of LEDS **200**A-O for a total of three-

hundred LEDs **170** that constitute LED array **158**. LEDs **170** are positioned in equidistant relationship with one another and extend generally the length of tubular wall **144**, that is, generally between tubular wall ends **148**A and **148**B. As shown in FIG. **14**A, each of strings **200**A-**200**O includes an optional resistor **202** designated individually as resistors **202**A, **202**B, **202**C, **202**D, **202**E, **202**F, **202**G, **202**H, **202**I, **202**J, **202** K, **202**L, **202**M, **202**N, and **202**O in respective series alignment with strings **200**A-**200**O at the current input for a total of fifteen resistors **202**. Again, a higher number of individual LEDs **170** can be connected in series within each LED string **200**. The maximum number of LEDs **170** being configured around the circumference of the 1.5-inch diameter of tubular wall **144** in the particular example herein of LED lamp **124** is ten. Each LED **170** is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When LED array circuitry **190**A is energized, the positive voltage that is applied through resistors **202**A-**202**O to the anode end circuit strings **200**A-**200**O and the negative voltage that is applied to the cathode end of circuit strings **200**A-**200**O will forward bias LEDs **170** connected to strings **200**A-**200**O and cause LEDs **170** to turn on and emit light.

Ballast assembly **130** regulates the electrical current through LEDs **170** to the correct value of 20 mA for each LED **170**. The fifteen LED strings **200** equally divide the total current applied to LED array circuitry **190**A. Those skilled in the art will appreciate that different ballasts provide different current outputs.

If the forward drive current for LEDs **170** is known, then the output current of ballast assembly **130** divided by the forward drive current gives the exact number of parallel strings of LEDs **170** in the particular LED array, here LED array **158**. The total number of LEDs in series within each LED string **200** is arbitrary since each LED **170** in each LED string **200** will see the same current. Again in this example, twenty LEDs **170** are shown connected in series within each LED string **200** because of the fact that only ten LEDs **170** of the 5 mm discrete type of LED will fit around the circumference of a 1.5-inch diameter lamp housing. Ballast assembly **130** provides 300 mA of current, which when divided by the fifteen strings **200** of ten LEDs **170** per LED string **200** gives 20 mA per LED string **200**. Each of the twenty LEDs **170** connected in series within each LED string **200** sees this 20 mA. In accordance with the type of ballast assembly **130** used, when ballast assembly **130** is first energized, a high voltage may be applied momentarily across ballast socket contacts **134**A, **136**A and **134**B, **136**B, which conduct to pin contacts **138**A, **140**A and **138**B, **140**B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry **190**A and voltage surge absorbers **196**A, **196**B, **196**C, and **196**D suppress the voltage applied by ballast circuitry **190**, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

FIG. **14**B shows another alternate arrangement of LED array circuitry **190**A. LED array circuitry **190**A consists of a single LED string **200** of LEDs **170** including for exposition purposes only, forty LEDs **170** all electrically connected in series. Positive voltage V+ is connected to optional resettable fuse **198**, which in turn is connected to one side of current limiting resistor **202**. The anode of the first LED in the series string is then connected to the other end of resistor **202**. A number other than forty LEDs **170** can be connected within the series LED string **200** to fill up the entire length of the tubular wall of the present invention. The cathode of the first LED **170** in the series LED string **200** is connected to the anode of the second LED **170**; the cathode of the second LED **170** in the series LED string **200** is then connected to the anode of the third LED **170**, and so forth. The cathode of the last LED **170** in the series LED string **200** is likewise connected to ground or the negative potential V−. The individual LEDs **170** in the single series LED string **200** are so positioned and arranged such that each of the forty LEDs is spaced equidistant from one another substantially filling the entire length of the tubular wall **144**. LEDs **170** are positioned in equidistant relationship with one another and extend substantially the length of tubular wall **144**, that is, generally between tubular wall ends **148**A and **148**B. As shown in FIG. **14**B, the single series LED string **200** includes an optional resistor **202** in respective series alignment with single series LED string **200** at the current input. Each LED **170** is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When LED array circuitry **190**A is energized, the positive voltage that is applied through resistor **202** to the anode end of single series LED string **200** and the negative voltage that is applied to the cathode end of single series LED string **200** will forward bias LEDs **170** connected in series within single series LED string **200**, and cause LEDs **170** to turn on and emit light.

The present invention works ideally with the brighter high flux white LEDs available from Lumileds and Nichia in the SMD packages. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The LEDs **170** have to be connected in series, so that each LED **170** within the same single LED string **200** will see the same current and therefore output the same brightness. The total voltage required by all the LEDs **170** within the same single LED string **200** is equal to the sum of all the individual voltage drops across each LED **170** and should be less than the maximum voltage output of ballast assembly **130**.

The single LED string **200** of SMD LEDs **170** connected in series can be mounted onto a long thin strip flexible circuit board made of polyimide or equivalent material. The flexible circuit board **152** is then spirally wrapped into a generally cylindrical configuration. Although this embodiment describes a generally cylindrical configuration, it can be appreciated by someone skilled in the art to form the flexible circuit board **152** into shapes other than a cylinder, such as an elongated oval, triangle, rectangle, hexagon, and octagon, as examples of a wide possibility of configurations. Accordingly, the shape of the tubular housing **142** holding the single wrapped flexible circuit board **152** can be made in a similar shape to match the shape of the formed flexible circuit board **152** configuration.

LED array circuit board **152** is positioned and held within tubular wall **144**. As in FIGS. **12** and **15**, LED array circuit board **152** has opposed circuit board circular ends **154**A and **154**B that are slightly inwardly positioned from tubular wall ends **148**A and **148**B, respectively. LED array circuit board **152** has interior and exterior cylindrical sides **156**A and **156**B, respectively with interior side **156**A forming an elongated central passage **157** between tubular wall circular ends **148**A and **148**B with exterior side **156**B being spaced from tubular wall **144**. LED array circuit board **152** is preferably assembled from a material that has a flat preassembled unbiased mode and an assembled self-biased mode wherein cylindrical sides **156**A and **156**B press outwardly towards tubular wall **144**. The SMD LEDs **170** are mounted on exterior cylindrical side **156**B with the lens **54** of each LED in juxtaposition

with tubular wall **25** and pointing radially outward from center line **146**. As shown in the sectional view of FIG. **13**, light is emitted through tubular wall **144** by the LEDs **170** in equal strength about the entire 360-degree circumference of tubular wall **144**.

As described earlier in FIGS. **12** and **15**, an optional support member **164** is made of an electrically non-conductive material such as rubber or plastic and is rigid in its position. It is preferably made of a self-biasable material and is in a biased mode in the cylindrical position, so that it presses radially outward in support of cylindrical LED array electrical LED array circuit board **152**. Optional support member **164** is longitudinally aligned with tubular center line **146** of tubular member **144**. Optional support member **164** further isolates integral electronics circuit boards **42**A and **42**B from LED array circuit board **152** containing the compact LED array **158**. Optional support member **164**, which is preferably made of a heat conducting material, may operate as a heat sink to draw heat away from LED array circuit board **152** and LED array **158** to the center of elongated housing **142** and thereby dissipating the heat out at the two ends **148**A and **148**B of tubular wall **144**. Optional support member **164** defines cooling holes or holes **166** to allow heat from LED array **158** to flow to the center area of tubular wall **144** and from there to be dissipated at tubular circular ends **148**A and **148**B.

Ballast assembly **130** regulates the electrical current through LEDs **170** to the correct value of 300 mA or other ballast assembly **130** rated lamp current output for each LED **170**. The total current is applied to both the single LED string **200** and to LED array circuitry **190**A. Again, those skilled in the art will appreciate that different ballasts provide different rated lamp current outputs.

If the forward drive current for LEDs **170** is known, then the output current of ballast assembly **130** divided by the forward drive current gives the exact number of parallel strings **200** of LEDs **170** in the particular LED array, here LED array **158**. Since the forward drive current for LEDs **170** is equal to the output current of ballast assembly **130**, then the result is a single LED string **200** of LEDs **170**. The total number of LEDs in series within each LED string **200** is arbitrary since each LED **170** in each LED string **200** will see the same current. Again in this example, forty LEDs **170** are shown connected within each series LED string **200**. Ballast assembly **130** provides 300 mA of current, which when divided by the single LED string **200** of forty LEDs **170** gives 300 mA for single LED string **200**. Each of the forty LEDs **170** connected in series within single LED string **200** sees this 300 mA. In accordance with the type of ballast assembly **130** used, when ballast assembly **130** is first energized, a high voltage may be applied momentarily across ballast socket contacts **134**A, **136**A and **134**B, **136**B, which conduct to pin contacts **138**A, **140**A and **138**B, **140**B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry **190**A and voltage surge absorbers **196**A, **196**B, **196**C, and **196**D suppress the voltage applied by ballast circuitry **70**, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

It can be seen from someone skilled in the art from FIGS. **14**, **14**A, and **14**B that the LED array **158** can consist of at least one parallel electrical LED string **200** containing at least one LED **170** connected in series within the parallel electrical LED string **200**. Therefore, the LED array **158** can consist of any number of parallel electrical strings **200** combined with any number of LEDs **170** connected in series within electrical strings **200**, or any combinations thereof.

FIG. **14**C shows a simplified arrangement of the LED array circuitry **190**A of LEDs **170** shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **14**. AC lead lines **212**A, **212**B and **214**A, **214**B and DC positive lead lines **216**A, **216**B and DC negative lead lines **218**A, **218**B are connected to integral electronics circuit boards **160**A and **160**B by way of 6-pin headers **162**A and **162**B and connectors **161**A-**161**D. Four parallel LED strings **200** each including a resistor **202** are each connected to DC positive lead lines **216**A, **216**B on one side, and to LED positive lead line **216** or the anode side of each LED **170** and on the other side. The cathode side of each LED **170** is then connected to LED negative lead line **218** and to DC negative lead lines **218**A, **218**B directly. AC lead lines **212**A, **212**B and **214**A, **214**B simply pass through LED array circuitry **190**A.

FIG. **14**D shows a simplified arrangement of the LED array circuitry **190**A of LEDs **170** shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **14**A. AC lead lines **212**A, **212**B and **214**A, **214**B and DC positive lead lines **216**A, **216**B and DC negative lead lines **218**A, **218**B are connected to integral electronics boards **160**A and **160**B by way of 6-pin headers **162**A and **162**B and connectors **161**A-**161**D. Two parallel LED strings **200** each including a single resistor **202** are each connected to DC positive lead lines **216**A, **216**B on one side, and to LED positive lead line **216** or the anode side of the first LED **170** in each LED string **200** on the other side. The cathode side of the first LED **170** is connected to LED negative lead line **218** and to adjacent LED positive lead line **216** or the anode side of the second LED **107** in the same LED string **200**. The cathode side of the second LED **170** is then connected to LED negative lead line **218** and to DC negative lead lines **218**A, **218**B directly in the same LED string **200**. AC lead lines **212**A, **212**B and **214**A, **214**B simply pass through LED array circuitry **190**A.

FIG. **14**E shows a simplified arrangement of the LED array circuitry **190**A of LEDs **170** shown for purposes of exposition in a flat compressed position for the overall electrical circuit shown in FIG. **14**B. AC lead lines **212**A, **212**B and **214**A, **214**B and DC positive lead lines **216**A, **216**B and DC negative lead lines **218**A, **218**B are connected to integral electronics boards **160**A and **160**B by way of 6-pin headers **162**A and **162**B and connectors **161**A-**161**D. Single parallel LED string **200** including a single resistor **202** is connected to DC positive lead lines **216**A, **216**B on one side, and to LED positive lead line **216** or the anode side of the first LED **170** in the LED string **200** on the other side. The cathode side of the first LED **170** is connected to LED negative lead line **218** and to adjacent LED positive lead line **216** or the anode side of the second LED **170**. The cathode side of the second LED **170** is connected to LED negative lead line **218** and to adjacent LED positive lead line **216** or the anode side of the third LED **170**. The cathode side of the third LED **170** is connected to LED negative lead line **218** and to adjacent LED positive lead line **216** or the anode side of the fourth LED **170**. The cathode side of the fourth LED **170** is then connected to LED negative lead line **218** and to DC negative lead lines **218**A, **218**B directly. AC lead lines **212**A, **212**B and **214**A, **214**B simply pass through LED array circuitry **190**A.

With the new high-brightness LEDs in mind, FIG. **14**F shows a single high-brightness LED **171**Z positioned on an electrical string in what is defined herein as an electrical series arrangement for the overall electrical circuit shown in FIG. **14** and also analogous to FIG. **14**B. The single high-brightness **171**Z fulfills a particular lighting requirement formerly fulfilled by a fluorescent lamp.

Likewise, FIG. **14**G shows two high-brightness LEDs **171**Z in electrical parallel arrangement with one high-brightness LED **171**Z positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. **14** and also analogous to the electrical circuit shown in FIG. **14**A. The two high-brightness LEDs **171**Z fulfill a particular lighting requirement formerly fulfilled by a fluorescent lamp.

As shown in the schematic electrical and structural representations of FIG. **15**, circuit board **152** for LED array **158** which has mounted thereon LED array circuitry **190**A is positioned between integral electronics circuit boards **160**A and **160**B that in turn are electrically connected to ballast assembly circuitry **188** by bi-pin electrical contacts **138**A, **140**A and **138**B, **140**B, respectively, which are mounted to base end caps **150**A and **150**B, respectively. Bi-pin contact **138**A includes an external extension **204**A that protrudes externally outwardly from base end cap **150**A for electrical connection with ballast socket contact **134**A and an internal extension **204**B that protrudes inwardly from base respect **150**A for electrical connection to integral electronics circuit boards **160**A. Bi-pin contact **140**A includes an external extension **206**A that protrudes externally outwardly from base end cap **150**A for electrical connection with ballast socket contact **136**A and an internal extension **206**B that protrudes inwardly from base end cap **150**A for electrical connection to integral electronics circuit boards **160**A. Bi-pin contact **138**B includes an external extension **208**A that protrudes externally outwardly from base end cap **150**B for electrical connection with ballast socket contact **134**B and an internal extension **208**B that protrudes inwardly from base end cap **150**B for electrical connection to integral electronics circuit board **160**B. Bi-pin contact **140**B includes an external extension **210**A that protrudes externally outwardly from base end cap **150**B for electrical connection with ballast socket contact **136**B and an internal extension **210**B that protrudes inwardly from base end cap **150**B for electrical connection to integral electronics circuit board **160**B. Bi-pin contacts **138**A, **140**A, **138**B, and **140**B are soldered directly to integral electronics circuit boards **160**A and **160**B, respectively. In particular, bin-pin contact extensions **204**A and **206**A are associated with bi-pin contacts **138**A and **140**A, respectively, and bi-pin contact extensions **208**A and **210**A are associated with bi-pin contacts **138**B and **140**B, respectively. Being soldered directly to integral electronics circuit board **160**A electrically connects bi-pin contact extensions **204**B and **206**B. Similarly, being soldered directly to integral electronics circuit board **160**B electrically connects bi-pin contact extensions **208**B and **210**B. 6-pin header **162**A is shown positioned between and in electrical connection with integral electronics circuit board **160**A and LED array circuit board **152** and LED array circuitry **190**A mounted thereon as shown in FIG. **14**. 6-pin header **162**B is shown positioned between and in electrical connection with integral electronics circuit board **160**B and LED array circuit board **152** and LED array circuitry **190**A mounted thereon.

FIG. **16** shows a schematic of integral electronics circuit **192**A mounted on integral electronics circuit board **160**A. Integral electronics circuit **192**A is also indicated in part in FIG. **14** as connected to LED array circuitry **190**A. Integral electronics circuit **192**A is in electrical contact with bi-pin contacts **138**A, **140**A, which are shown as providing either AC or DC voltage. Integral electronics circuit **192**A includes bridge rectifier **194**A, voltage surge absorbers **196**A and **196**C, and resettable fuse **198**. Integral electronic circuit **192**A leads to or from LED array circuitry **190**A. It is noted that FIG. **16** indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies **188** as mentioned earlier herein. In such a case DC voltage would be supplied to LED array **158** even in the presence of bridge rectifier **194**A. It is particularly noted that in such a case, voltage surge absorbers **196**A and **196**C would remain operative. AC lead lines **212**A and **214**A are in a power connection with ballast assembly **188**. DC lead lines **216**A and **218**A are in positive and negative direct current relationship with LED array circuitry **190**A. Bridge rectifier **194**A is in electrical connection with four lead lines **212**A, **214**A, **216**A and **218**A. A voltage surge absorber **196**A is in electrical contact with lead lines **212**A and **214**A and voltage surge absorber **196**C is positioned on lead line **212**A. Lead lines **216**A and **218**A are in electrical contact with bridge rectifier **194**A and in power connection with LED array circuitry **190**A. Fuse **198** is positioned on lead line **216**A between bridge rectifier **194**A and LED array circuitry **190**A.

FIG. **17** shows a schematic of integral electronics circuit **192**B mounted on integral electronics circuit board **160**B. Integral electronics circuit **192**B is also indicated in part in FIG. **14** as connected to LED array circuitry **190**A. Integral electronics circuit **192**B is a close mirror image or electronics circuit **192**A mutatis mutandis. Integral electronics circuit **192**B is in electrical contact with bi-pin contacts **138**B, **140**B, which are shown as providing either AC or DC voltage. Integral electronics circuit **192**B includes bridge rectifier **194**B, voltage surge absorbers **196**B and **196**D. Integral electronic circuit **192**B leads to or from LED array circuitry **190**A. It is noted that FIG. **17** indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies **188** as mentioned earlier herein. In such a case DC voltage would be supplied to LED array **158** even in the presence of bridge rectifier **194**B. It is particularly noted that in such a case, voltage surge absorbers **196**B and **196**D would remain operative. AC lead lines **212**B and **214**B are in a power connection with ballast assembly **188**. DC lead lines **216**B and **218**B are in positive and negative direct current relationship with LED array circuitry **190**A. Bridge rectifier **194**B is in electrical connection with four lead lines **212**B, **214**B, **216**B and **218**B. A voltage surge absorber **196**B is in electrical contact with lead lines **212**B and **214**B and voltage surge absorber **196**D is positioned on lead line **214**B. Lead lines **216**B and **218**B are in electrical contact with bridge rectifier **194**B and in power connection with LED array circuitry **190**A.

FIGS. **16** and **17** show the lead lines going into and out of LED circuitry **190** respectively. The lead lines include AC lead lines **212**B and **214**B, positive DC voltage **216**B, and DC negative voltage **218**B. The AC lead lines **212**B and **214**B are basically feeding through LED circuitry **190**, while the positive DC voltage lead line **216**B and negative DC voltage lead line **218**B are used primarily to power the LED array **158**. DC positive lead lines **216**A and **216**B are the same as LED positive lead line **216** and DC negative lead lines **218**A and **218**B are the same as LED negative lead line **218**. LED array circuitry **190**A therefore consists of all electrical components and internal wiring and connections required to provide proper operating voltages and currents to LEDs **170** connected in parallel, series, or any combinations of the two.

FIGS. **18** and **18**A show the optional support member **164** with cooling holes **166** in both side and cross-sectional views respectively.

FIG. **19** shows an isolated top view of one of the base end caps, namely, base end cap **150**A, which is analogous to base end cap **150**B, mutatis mutandis. Bi-pin electrical contacts **138**A, **140**A extend directly through base end cap **150**A in the

longitudinal direction in alignment with center line **146** of tubular wall **144** with bi-pin external extensions **204**A, **206**A and internal extensions **204**B, **206**B shown. Base end cap **150**A is a solid cylinder in configuration as seen in FIGS. **19** and **19**A and forms an outer cylindrical wall **220** that is concentric with center line **146** of tubular wall **144** and has opposed flat end walls **222**A and **222**B that are perpendicular to center line **146**. Two cylindrical parallel vent holes **224**A and **224**B are defined between end walls **222**A and **222**B in vertical alignment with center line **146**.

As also seen in FIG. **19**A, base end cap **150**A defines an outer circular slot **226** that is concentric with center line **146** of tubular wall **144** and concentric with and aligned proximate to circular wall **220**. Outer circular slot **226** is of such a width and circular end **148**A of tubular wall **144** is of such a thickness and diameter that outer circular slot **226** accepts circular end **148**A into a fitting relationship and circular end **148**A is thus supported by circular slot **226**. Base end cap **150**B defines another outer circular slot (not shown) analogous to outer circular slot **226** that is likewise concentric with center line **146** of tubular wall **144** so that circular end **148**B of tubular wall **144** can be fitted into the analogous circular slot of base end cap **150**B wherein circular end **148**B of tubular wall **144** is also supported. In this manner tubular wall **144** is mounted to end caps **150**A and **150**B.

As also seen in FIG. **19**A, base end cap **150**A defines an inner circular slot **228** that is concentric with center line **146** of tubular wall **144** and concentric with and spaced radially inward from outer circular slot **226**. Inner circular slot **228** is spaced from outer circular slot **226** at such a distance that would be occupied by LEDs **170** mounted to LED circuit board **152** within tubular wall **144**. Inner circular slot **228** is of such a width and diameter and circular end **154**A of LED circuit board **152** is of such a thickness and diameter that circular end **154**A is fitted into inner circular slot **228** and is thus supported by inner circular slot **228**. Base end cap **150**B defines another outer circular slot (not shown) analogous to outer circular slot **226** that is likewise concentric with center line **146** of tubular wall **144** so that circular end **154**B of LED circuit board **152** can be fitted into the analogous inner circular slot of base end cap **150**B wherein circular end **154**B is also supported. In this manner LED circuit board **152** is mounted to end caps **150**A and **150**B.

Circular ends **148**A and **148**B of tubular wall **144** and also circular ends **154**A and **154**B of LED circuit board **152** are secured to base end caps **150**A and **150**B preferably by gluing in a manner known in the art. Other securing methods known in the art of attaching such as cross-pins or snaps can be used.

An analogous circular slot (not shown) concentric with center line **146** is optionally formed in flat end walls **222**A and **222**B of base end cap **150**A and an analogous circular slot in the flat end walls of base end cap **150**B for insertion of the opposed ends of optional support member **164** so that optional support member **164** is likewise supported by base end caps **150**A and **150**B. Circular ends **148**A and **148**B of tubular wall **144** are optionally press fitted to circular slot **226** of base end cap **150**A and the analogous circular slot of base end cap **150**B.

FIG. **20** is a sectional view of an alternate LED lamp mounted to tubular wall **144**A that is a version of LED lamp **124** as shown in FIG. **13**. The sectional view of LED lamp **230** shows a single row **168**A of the LEDs of LED lamp **230** and includes a total of six LEDs **170**, with four LEDs **170**X being positioned at equal intervals at the bottom area **232** of tubular wall **144**A and with two LEDs **170**Y being positioned at opposed side areas **234** of tubular wall **144**A. LED circuitry **190** previously described with reference to LED lamp **124** would be the same for LED lamp **230**. That is, all fifteen strings **200** of LED array **158** of LED lamp **124** would be the same for LED lamp **230** except that a total of ninety LEDs **170** would comprise LED lamp **230** with the ninety LEDs **170** positioned at strings **200** at such electrical connectors that would correspond with LEDs **170**X and **170**Y throughout. The reduction to ninety LEDs **170** of LED lamp **230** from the one hundred and fifty LEDs **170** of LED lamp **124** would result in a forty percent reduction of power demand with an illumination result that would be satisfactory under certain circumstances. Stiffening of circuit board for LED lamp **230** is accomplished by circular slot **228** for tubular wall **144**A or optionally by the additional placement of LEDs **170** (not shown) at the top vertical position in space **178** or optionally a vertical stiffening member **236** shown in phantom line that is positioned vertically over center line **146** of tubular wall **144**A at the upper area of space **178** between LED circuit board **152** and the inner side of tubular wall **144**A and extends the length of tubular wall **144**A and LED circuit board **152**.

LED lamp **124** as described above will work for both AC and DC voltage outputs from an existing fluorescent ballast assembly **130**. In summary, LED array **158** will ultimately be powered by DC voltage. If existing fluorescent ballast assembly **130** operates with an AC output, bridge rectifiers **194**A and **194**B convert the AC voltage to DC voltage. Likewise, if existing fluorescent ballast **130** operates with a DC voltage, the DC voltage remains a DC voltage even after passing through bridge rectifiers **194**A and **194**B.

FIGS. **21** and **22** show a top view of a horizontally aligned curved LED lamp **238** that is secured to an existing fluorescent fixture **240** schematically illustrated in phantom line including existing fluorescent ballast **242** that in turn is mounted in a vertical wall **244**. Fluorescent ballast **242** can be either an electronic instant start or rapid start, a hybrid, or a magnetic ballast assembly for the purposes of illustrating the inventive curved LED lamp **238**, which is analogous to and includes mutatis mutandis the variations discussed herein relating to linear LED lamps **10** and **124**. Curved LED lamp **238** is generally hemispherical, or U-shaped, as viewed from above and is of a type of LED lamp that can be used as lighting over a mirror, for example, or for decorative purposes, or for other uses when such a shape of LED lamp would be retrofitted to an existing fluorescent lamp fixture.

LED lamp **238** as shown in FIGS. **21** and **21**A includes a curved housing **246** comprising a curved hemispherical tubular wall **248** having a center line **249** and tubular ends **250**A and **250**B. A pair of end caps **252**A and **252**B secured to tubular ends **250**A and **250**B, respectively, are provided with bi-pin electrical connectors **254**A and **254**B that are electrically connected to ballast double contact electrical sockets **256**A and **256**B in a manner previously described herein with regard to LED lamp **124**. Base end caps **252**A and **252**B are such as those described in FIGS. **9**A and **19**A regarding LED lamps **10** and **124**. Curved LED lamp **238** includes a curved circuit board **258** that supports an LED array **260** mounted thereon comprising twenty eight individual LEDs **262** positioned at equal intervals. Curved circuit board **258** is tubular and hemispherical and is positioned and held in tubular wall **248**. Curved circuit board **258** forms a curved central cylindrical passage **264** that extends between the ends of tubular wall **248** and opens at tubular wall ends **250**A and **250**B for exhaust of heat generated by LED array **260**. Curved circuit board **258** has opposed circuit board circular ends that are slightly inwardly positioned from tubular wall ends **250**A and **250**B, respectively.

Fifteen parallel electrical strings are displayed and described herein. In particular, fifteen rows **264** of four LEDs

262 are positioned in tubular wall 248. LED lamp 238 is provided with integral electronics (not shown) analogous to integral electronic circuits 192A and 192B described previously for LED lamp 124. Ballast circuitry and LED circuitry are analogous to those described with regard to LED lamp 124, namely, ballast circuitry 188, starter circuit 188A, LED circuitry 190 and LED array circuitry 190A. The LED array circuit for curved LED lamp 124 is mounted on the exterior side 270A of circuit board 258. In particular, fifteen parallel electrical strings for each one of the fifteen LED rows 266 comprising four LEDs 262 positioned within curved tubular wall 248 are mounted on curved circuit board 258. As seen in FIG. 21, curved tubular wall 248 and curved circuit board 258 forms a hemispherical configuration about an axial center 268. The electrical circuitry for curved LED lamp 238 is analogous to the electrical circuitry set forth herein for LED lamp 124 including LED array circuitry 190A and the parallel electrical circuit strings 200 therein with the necessary changes having been made. The physical alignment of parallel electrical circuit strings 200 of LED array circuitry 190A are parallel as shown in FIG. 14 and are radially extending in FIG. 21, but in both LED lamp 124 and curved LED lamp 238 the electrical structure of the parallel electrical circuit strings are both parallel in electrical relationship. The radial spreading of LED rows 266 outwardly extending relative to the axial center 268 of hemispherical shaped tubular wall 248 is coincidental with the physical radial spreading of the parallel electrical strings to which LED rows 266 are electrically connected.

Curved circuit board 258 has exterior and interior sides 270A and 270B, respectively, which are generally curved circular in cross-section as indicated in FIG. 21A. Although this embodiment describes a generally curved cylindrical configuration, it can be appreciated by someone skilled in the art to form the curved flexible circuit board 258 into shapes other than a cylinder for example, such as an elongated oval, triangle, rectangle, hexagon, octagon, etc. Accordingly, the shape of the curved tubular housing 246 holding the individual curved flexible circuit board 258 can be made in a similar shape to match the shape of the formed curved flexible circuit board 258 configuration. Exterior side 270A is spaced from tubular wall 248 so as to define a curved space 272 there between in which LEDs 262 are positioned. Curved space 270 is toroidal in cross-section as shown in FIG. 21A. Each LED 262 includes an LED lens portion 274, an LED body portion 276, and an LED base portion 278 with LED 262 having an LED center line 279. LEDs 262 are positioned in curved tubular wall 248 aligned to center line 249 of curved tubular wall 248 relative to a plane defined by each LED row 266. Lens portion 274 is in juxtaposition with curved tubular wall 248 and base portion 278 is mounted to curved circuit board 258 in a manner previously described herein with regard to LED lamp 124. LEDs 262 have LED center lines 279.

Curved circuit board 258 is preferably made of a flexible material that is unbiased in a preassembled flat, and movable to an assembled self-biased mode. The latter as shown in the mounted position in FIGS. 21, 21A, and 22 wherein the exterior and internal sides 270A and 270B of curved board 258 presses outwardly towards curved tubular wall 248 in structural support of LEDs 262.

As shown in the isolated view of curved circuit board 258 in FIG. 22 wherein curved circuit board 258 is in the biased mode as shown in FIGS. 21 and 21A, curved exterior side 270A is stretched to accommodate the greater area that exterior side 270A must encompass as compared to the area occupied by curved interior side 270B. Exterior side 270A defines a plurality of slits 280 that are formed lateral to the curved elongated orientation or direction of circuit board 258, and slits 280 are formed transverse to the axial center. After circuit board 258 is rolled from the flat, unbiased mode to the rolled cylindrical mode, circuit board 258 is further curved from the rolled mode to the curved mode as shown in FIGS. 21, 21A, and 22. By this action, exterior side 270A is stretched so that slits 280 become separated as shown in FIG. 22. Interior side 270B in turn becomes compressed as shown. Curved circuit board 258 is made of a material that is both biasable to accommodate the stretchability of exterior wall 270A and to some extent compressible to accommodate the compressed mode of interior wall 270B.

Curved LED lamp 238 as described above is a bi-pin type connector LED lamp such as bi-pin type LED lamp 124 for purposes of exposition only. The basic features of LED lamp 238 as described above would likewise apply to a single-pin type LED lamp such as single-pin lamp 10 described herein.

The description of curved LED lamp 238 as a hemispherical LED is for purposes of exposition only and the principles expounded herein would be applicable in general to any curvature of a curved LED lamp including the provision of a plurality of slits 280 that would allow the stretching of the external side of a biasable circuit board.

FIG. 23 shows in an isolated circuit board 282 in a flat mode subsequent to having an LED circuitry mounted thereon and further subsequent to having LEDs mounted thereon and connected to the LED circuitry, and prior to assembly to insertion into a tubular housing analogous tubular housings 24, 142, and 246 of LED lamps 10, 124, and 238. Circuit board 282 is a variation of LED array circuit board 34 of LED lamp 10, circuit board 152 for LED lamp 114, and circuit board 258 for LED lamp 238. Circuit board 282 has a flat top side 284 and an opposed flat bottom side 286. Circuit board 282 is rectangular in configuration having opposed linear end edges 288A and 288B and opposed linear side edges 290A and 290B. A total of twenty-five LEDs 292 are secured to top side 284 with each LED 292 being aligned perpendicular to flat top side 284. LED circuitry consisting of pads, tracks and vias, etc. (not shown) to provide electrical power to LEDs 292 can be mounted to top side 284 or to bottom side 286. Such LED circuitry is analogous to LED circuitry 70 for LED lamp 10 or LED circuitry 190 for LED lamp 124, as the case may be. Such LED circuitry can be mounted directly to top side 284 or can be mounted to a separate thin, biasable circuit board that is in turn secured by gluing to top side 284 as shown in FIG. 25. A manner of mounting twenty-five LEDs 292 into an alternate LED matrix 294 to that shown in FIGS. 3A and 13A is shown by way of exposition as shown in FIG. 23. Five columns 296A, 296B, 296C, 296D and 296E of three LEDs 292 each, and five columns 298A, 298B, 298C, 298D and 298E of two LEDs 292 each are aligned at equal intervals between columns 296A-E. Matrix 294 further includes the same 25 LEDs 292 being further arranged in three rows 300A, 300B, and 300C aligned at equal intervals, and in two rows 302A and 302B aligned at equal intervals between rows 300A-C. LEDs 292 are connected to an LED electrical series parallel circuit. The staggered pattern of LEDs 292 shown in FIG. 23 illustrates by way of exposition merely one of many possible patterns of placement of LEDs other than the LED pattern of placements shown in LED lamps 10, 124, and 238.

As shown in FIG. 24, flat circuit board 282 with LEDs 292 is shown rolled into a cylindrical configuration indicated as cylindrical circuit board 304 in preparation for assembly into a tubular wall such as tubular walls 26 and 144 of LED lamps 10 and 124 previously described and also mutatis mutandis of

LED lamp **238**. Flat top side **284** of flat circuit board **282** is shown as cylindrical exterior side **318** of cylindrical circuit board **304**; and flat bottom side **286** of flat circuit board **282** is shown as cylindrical interior side **320** of cylindrical circuit board **304**. The process of rolling flat circuit board **282** into cylindrical circuit board **304** can be done physically by hand, but is preferably done automatically by a machine.

A mating line **306** is shown at the juncture of linear side edges **290**A and **290**B shown in FIG. **23**. The material of flat circuit board **282**, that is, of cylindrical circuit board **304**, is flexible to allow the cylindrical configuration of circuit board **304** and is resilient and self-biased. That is, circuit board **304** is moveable between a flat unbiased mode and a cylindrical biased mode, wherein the cylindrical biased mode circuit board **304** self-biases to return to its flat unbiased mode. As such, in the cylindrical mode, cylindrical circuit board **304** presses outwardly and thus presses LEDs **292** against the tubular wall in which it is positioned and held, as described previously with regard to LED lamps **10** and **124** wherein the LEDs themselves are pressed outwardly against such a tubular wall shown schematically in phantom line as tubular wall **308** in FIG. **24**. Each LED **292** as previously discussed herein includes a lens portion **310**, a body portion **312**, and a base portion **314** so that lens portion **310** is pressed against tubular wall **306**.

FIG. **25** shows an end view of a layered cylindrical circuit board **316** having opposed cylindrical interior and exterior sides **320** and **318** in isolation with a typical LED **324** shown for purposes of exposition mounted thereto in juxtaposition with a partially indicated tubular wall **326** analogous to tubular walls **26** for LED lamp **10** and tubular wall **144** for LED lamp **124** as described heretofore. Circuit board **316** is in general is analogous to circuit boards **34** in FIG. **3** of LED lamp **10** and circuit board **152** in FIG. **13** of LED lamp **124** with the proviso that circuit board **316** comprises two layers of material, namely cylindrical outer layer **322**A and a cylindrical inner support layer **322**B. Outer layer **322**A is a thin flexible layer of material to which is mounted an LED circuit such as either LED array circuitry **72** for LED lamp **10** or LED array circuitry **190**A for LED lamp **124**. Outer layer **322**A is attached to inner layer **322**B by a means known in the art, for example, by gluing. Inner support layer **322**B is made of a flexible material and preferably of a biasable material, and is in the biased mode when in a cylindrical position as shown in FIG. **25**; and outer layer **322**A is at least flexible prior to assembly and preferably is also made of a biasable material that is in the biased mode as shown in FIG. **25**. Typical LED **324** is secured to outer layer **322**A in the manner shown earlier herein in FIGS. **3** and **3**A of LED lamp **10** and LED lamp **124**. An LED array circuit (not shown) such as LED array circuitry **72** of LED lamp **10** and LED array circuitry **190**A for LED lamp **124** can be mounted on cylindrical outer layer **322**A prior to assembly of outer layer **322**A to inner layer **322**B. Typical LED **324** is electrically connected to the LED array circuitry mounted on outer layer **322**A and/or inner layer **322**B. Together outer layer **322**A and inner layer **322**B comprise circuit board **316**.

FIGS. **26-35**A show another embodiment of the present invention, in particular an LED lamp **328** seen in FIG. **26** retrofitted to an existing fluorescent fixture **330** mounted to a ceiling **332**. An electronic instant start type ballast assembly **334**, which can also be a hybrid, or a magnetic ballast assembly, is positioned within the upper portion of fixture **330**. Fixture **330** further includes a pair of fixture mounting portions **336**A and **336**B extending downwardly from the ends of fixture **330** that include ballast electrical contacts shown as ballast end sockets **338**A and **338**B that are in electrical contact with ballast assembly **334**. Fixture ballast end sockets **338**A and **338**B are each single contact sockets in accordance with the electrical operational requirement of an electronic instant start ballast, hybrid ballast, or one type of magnetic ballast. As also seen in FIG. **26**A, LED lamp **328** includes opposed single-pin electrical contacts **340**A and **340**B that are positioned in ballast sockets **338**A and **338**B, respectively, so that LED lamp **328** is in electrical contact with ballast assembly **334**.

As shown in the disassembled mode of FIG. **27**, LED lamp **328** includes an elongated housing **342** particularly configured as a linear tubular wall **344** circular in cross-section taken transverse to a center line **346** that is made of a translucent material such as plastic or glass and preferably having a diffused coating. Tubular wall **344** has opposed tubular wall ends **348**A and **348**B. LED lamp **328** further includes a pair of opposed lamp base end caps **352**A and **352**B mounted to single electrical contact pins **340**A and **340**B, respectively for insertion in ballast electrical socket contacts **338**A and **338**B in electrical power connection to ballast assembly **334**, so as to provide power to LED lamp **328**. Tubular wall **344** is mounted to opposed base end caps **352**A and **352**B at tubular wall ends **348**A and **348**B in the assembled mode as shown in FIG. **26**. An integral electronics circuit board **354**A is positioned between base end cap **352**A and tubular wall end **348**A, and an integral electronics circuit board **354**B is positioned between base end cap **352**B and tubular wall end **348**B.

As seen in FIGS. **27** and **28**, LED lamp **328** also includes a 6-pin connector **356**A connected to integral electronics circuit board **354**A and to a 6-pin header **358** on first disk **368**. LED lamp **328** also includes a 6-pin connector **356**B connected to integral electronics circuit board **354**B and to a 6-pin header **358** on last disk **368**.

For the purposes of exposition, only ten of the original fifteen parallel electrical strings are displayed and each LED electrical string **408** is herein described as containing LED row **360**. In particular, FIG. **28** shows a typical single LED row **360** that includes ten individual LEDs **362**. LED lamp **328** includes ten LED rows **360** that comprise LED array **366**. FIG. **29** shows a partial view of six LEDs **362** of each of the ten LED rows **360**. Each LED row **360** is circular in configuration, which is representative of each of the ten rows **360** of LED array **366** as shown in FIG. **29** with all LED rows **360** being aligned in parallel relationship.

In FIG. **29**, ten circular disks **368** each having central circular apertures **372** and having opposed flat disk walls **370**A and **370**B and disk circular rims **370**C are positioned and held in tubular wall **344** between tubular end walls **348**A and **348**B. Each disk **368** that is centrally aligned with center line **346** of tubular wall **344** defines a central circular aperture **372**. Apertures **372** are provided for the passage of heat out of tubular wall **344** generated by LED array **366**. Disks **368** are spaced apart at equal distances and are in parallel alignment. The inner side of tubular wall **344** defines ten equally spaced circular grooves **374** defining parallel circular configurations in which are positioned and held disk rims **370**C.

Similar to FIG. **29**, FIG. **29**A now shows a single LED row **360** that includes one individual LED **362**. LED lamp **328** includes ten LED rows **360** that can comprise LED array **366**. FIG. **29**A shows a single LED **362** of each of the ten LED rows **360** mounted in the center of each disk **368**. A heat sink **396** is attached to each LED **362** to extract heat away from LED **362**. Ten circular disks **368** each having opposed flat disk walls **370**A and **370**B and disk circular rims **370**C are positioned and held in tubular wall **344** between tubular end walls **348**A and **348**B. Apertures **372**A are provided for the passage of heat out of tubular wall **344** generated by LED

array **366**. Disks **368** are spaced apart at equal distances and are in parallel alignment. The inner side of tubular wall **344** defines ten equally spaced circular grooves **374** defining parallel circular configurations in which are positioned and held disk rims **370**C.

Although FIGS. **28**, **29**, and **29**A show round circular circuit board disks **368**, it can be appreciated by someone skilled in the art to use circuit boards **368** made in shapes other than a circle. Likewise, the shape of the tubular housing **342** holding the individual circuit boards **368** can be made in a similar shape to match the shape of the circuit boards **368**. FIGS. **29**B, **29**C, and **29**D show simplified electrical arrangements of the array of LEDs shown with at least one LED in a series parallel configuration. Each LED string has an optional resistor in series with the LED.

In FIG. **30**, each LED **362** includes lens portion **376**, body portion **378**, and base portion **380**. Each lens portion **376** is in juxtaposition with the inner surface of tubular wall **344**. LED leads **382** and **384** extend out from the base portion **380** of LED **362**. LED lead **382** is bent at a 90-degree angle to form LED lead portions **382**A and **382**B. Likewise, LED lead **384** is also bent at a 90-degree right angle to form LED lead portions **384**A and **384**B. In FIG. **30**, a detailed isolated view of two typically spaced single LEDs **362** shows each LED **362** mounted to disk **368** with LED lead portions **382**A and **384**A lateral to disk **368** and LED lead portions **382**B and **384**B transverse to disk **368**. Disks **368** are preferably made of rigid G10 epoxy fiberglass circuit board material, but can be made of other circuit board material known in the art. LED lead portions **382**B and **384**B extend through disk wall **370**A of disk **368** to disk wall **370**B of disk **368** by means known in the art as plated through hole pads. The LED leads **382** and **384** support LED **362** so that the center line **386** of each LED **362** is perpendicular to center line **346** of tubular wall **344**. The pair of LED leads **382** and **384** connected to each LED **362** of LED array **366** extend through each disk **368** from disk wall **370**A to disk wall **370**B and then to DC positive lead line **404**, or to DC negative lead line **406**, or to another LED **362** (not shown) in the same LED string **408** by means known in the art as electrical tracks or traces located on the surface of disk wall **370**A and/or disk wall **370**B of disk **368**.

In FIG. **30**A, a special single SMD LED is mounted to the center of disk **368**. Each LED **362** includes lens portion **376**, body portion **378**, and base portion **380**. Lens portion **376** allows the light from LED **362** to be emitted in a direction perpendicular to center line **386** of LED **362** and center line **346** of tubular wall **344** with the majority of light from LED **362** passing straight through tubular wall **344**. LED leads **382** and **384** extend out from the base portion **380** of LED **362**. LED lead **382** is bent at a 90-degree angle to form LED lead portions **382**A and **382**B. Likewise, LED lead **384** is also bent at a 90-degree right angle to form LED lead portions **384**A and **384**B. In FIG. **30**A, a detailed isolated view of two typically spaced single LEDs **362** shows each LED **362** mounted to disk **368** with LED lead portions **382**A and **384**A transverse to disk **368** and LED lead portions **382**B and **384**B lateral to disk **368**. Disks **368** are preferably made of rigid G10 epoxy fiberglass circuit board material, but can be made of other circuit board material known in the art. LED lead portions **382**B and **384**B rest on and are attached to disk wall **370**A of disk **368** with solder to means known in the art as solder pads. The LED leads **382** and **384** support LED **362** so that the center line **386** of each LED **362** is parallel to center line **346** of tubular wall **344**. The pair of LED leads **382** and **384** connected to each LED **362** of LED array **366** is then connected to DC positive lead line **404**, or to DC negative lead line **406**, or to another LED **362** (not shown) in the same LED string **408** by means known in the art as electrical tracks, plated through holes, vias, or traces located on the surface of disk wall **370**A and/or disk wall **370**B of disk **368**. A heat sink **396** is attached to the base portion **380** of each LED **362** to sufficiently extract the heat generated by each LED **362**.

As further indicated in FIGS. **30**, **30**A, and **30**B, six electrical lead lines comprising AC lead line **400**, AC lead line **402**, DC positive lead line **404**, DC negative lead line **406**, LED positive lead line **404**A, and LED negative lead line **406**A are representative of lead lines that extend the entire length of tubular wall **344**, in particular extending between and joined to each of the ten disks **368** so as to connect electrically each LED string **408** of each disk **368** as shown in FIG. **34**. Each of the lead lines **400**, **402**, **404**, **406**, **404**A, and **406**A are held in position at each of disks **368** by six pins **388**A, **388**B, **388**C, **388**D, **388**E, and **388**F that extend through disks **368** and are in turn held in position by 6-pin connector **356**C mounted to disks **368** shown as disk wall **370**B for purposes of exposition. 6-pin connector **356**C is mounted to each 6-pin header **358**, and another 6-pin connector **356**D is mounted to disk wall **370**A.

As shown in the schematic electrical and structural representations of FIG. **31**, disks **368** and LED array **366** are positioned between integral electronics circuit board **354**A and **354**B that in turn are electrically connected to ballast assembly **334** by single contact pins **340**A and **340**B, respectively. Single contact pins **340**A and **340**B are mounted to and protrude out from base end caps **352**A and **352**B, respectively, for electrical connection to LED array **366**. Contact pins **340**A and **340**B are soldered directly to integral electronics circuit boards **354**A and **354**B, respectively. In particular, being soldered directly to the integral electronics circuit board **354**A electrically connects pin inner extension **340**C of single-pin contact **340**A. Similarly, being soldered directly to integral electronics circuit board **354**B electrically connects pin inner extension **340**D of connecting pin **340**B. 6-pin connector **356**A is shown positioned between and in electrical connection with integral electronics circuit board **356**A and LED array **366**. 6-pin connector **356**B is shown positioned between and in electrical connection with integral electronics circuit board **354**B and LED array **366**.

As seen in FIG. **32**, a schematic of an integral electronics circuit **390**A is mounted on integral electronics circuit board **354**A. Integral electronics circuit **390**A is in electrical contact with ballast socket contact **338**A, which is shown as providing AC voltage. Integral electronics circuit **390**A includes bridge rectifier **394**, voltage surge absorber **496**, and resettable fuse **498**. Bridge rectifier **394** converts AC voltage to DC voltage. Voltage surge absorber **496** limits the high voltage to a workable voltage within the design voltage capacity of LEDs **362**. The DC voltage circuits indicated as plus (+) and minus (−) lead to and from LED array **366** and are indicated as DC lead line **404** and **406**, respectively. The presence of AC voltage in indicated by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies **334**. In such a case DC voltage would be supplied to LED array **366** even in the presence of bridge rectifier **394**. It is particularly noted that in such a case, voltage surge absorber **496** would remain operative.

FIG. **33** shows an integral electronics circuit **390**B printed on integral electronics board **354**B with voltage protected AC lead line **400** by extension from integral electronics circuit **390**A. The AC lead line **400** having passed through voltage surge absorber **496** is a voltage protected circuit and is in electrical contact with ballast socket contact **338**B. Integral circuit **390**B includes DC positive and DC negative lead lines **404** and **406**, respectively, from LED array **366** to positive and

negative DC terminals **438** and **440**, respectively, printed on integral electronics board **354**B. Integral circuit **390**B further includes bypass AC lead line **402** from integral electronics circuit **390**A to ballast socket contact **338**B.

Circuitry for LED array **366** with integral electronics circuits **390**A and **390**B as connected to the ballast circuitry of ballast assembly **334** is analogous to that shown previously herein in FIG. **4**. As seen therein and as indicated in FIG. **29**, the circuitry for LED array **366** includes ten electrical strings in electrical parallel relationship. The ten electrical strings are typified and represented in FIG. **34** by LED electrical string **408** mounted to disk **368** at one of the disk walls **370**A or **370**B, shown as disk wall **370**A in FIG. **30** for purposes of exposition only. A single LED row **360** comprises ten LEDs **362** that are electrically connected at equal intervals along each string **408** that is configured in a circular pattern spaced from and concentric with disk rim **370**C. A typical LED string **408** is shown in FIG. **34** as including an LED row **360** comprising ten LEDs **364**A, **364**B, **364**C, **364**D, **364**E, **364**F, **364**G, **364**H, **364**I, and **364**J. First and last LEDs **364**A and **364**J, respectively, of LED string **408** generally terminate at the 6-pin connectors shown in FIG. **30** as typical 6-pin connectors **356**C and **356**D and in FIG. **34** as typical 6-pin connector **356**D. In particular, the anode side of typical LED **364**A is connected to DC positive lead line **404** by way of LED positive lead line **404**A with optional resistor **392** connected in series between the anode side of LED **364**A connected to LED positive lead line **404**A and DC positive lead line **404**. The cathode side of typical LED **364**J is connected to DC negative lead line **406** by way of LED negative lead line **406**A. Both AC lead line **400** and AC lead line **402** are shown in FIGS. **32-34**. FIG. **30**B shows an isolated top view of AC leads **400** and **402**, of positive and negative DC leads **404** and **406**, and of positive and negative LED leads **404**A and **406**A, respectively, extending between disks **368**.

Analogous to the circuit shown previously herein in FIG. **4**A, for more than ten LEDs **362** connected in series within each LED electrical string **408**, the LEDs **362** from one disk **368** will extend to the adjacent disk **368**, etc. until all twenty LEDs **362** in LED electrical string **408** spread over two disks **368** are electrically connected into one single series connection. Circuitry for LED array **366** with integral electronics circuits **390**A and **390**B as connected to the ballast circuitry of ballast assembly **334** is also analogous to that shown previously herein in FIG. **4**. As seen therein and as indicated in FIG. **29**, the circuitry for LED array **366** includes ten electrical strings in electrical parallel relationship. The ten electrical strings are typified and represented in FIG. **34** by LED electrical string **408** mounted to disk **368** at one of the disk walls **370**A or **370**B, shown as disk wall **370**A in FIG. **30** for purposes of exposition only. Each LED row **360** comprises ten LEDs **362** that are electrically connected at equal intervals along each string **408** that is configured in a circular pattern spaced from and concentric with disk rim **370**C. A typical LED string **408** is shown in FIG. **34** as including an LED row **360** comprising ten LEDs **364**A, **364**B, **364**C, **364**D, **364**E, **364**F, **364**G, **364**H, **364**I, and **364**J. First and last LEDs **364**A and **364**J, respectively, of LED string **408** generally terminate at the 6-pin connectors shown in FIG. **30** as typical 6-pin connectors **356**C and **356**D and in FIG. **34** as typical 6-pin connector **356**D. In particular, the anode side of typical LED **364**A is connected to DC positive lead line **404** by way of LED positive lead line **404**A with an optional resistor **392** connected in series between the anode side of LED **364**A connected to LED positive lead line **404**A and DC positive lead line **404**. The cathode side of typical LED **364**J is now connected to anode side of typical LED **364**A of the adjacent LED string **408** of the adjacent disk **368**. The cathode side of typical LED **364**J of the adjacent LED string **408** of the adjacent disk **368** is connected to DC negative lead line **406** by way of LED negative lead line **406**A. This completes the connection of the first twenty LEDs **362** in LED array **366**. The next twenty LEDs **362** and so forth, continue to be connected in a similar manner as described. Both AC lead line **400** and AC lead line **402** are shown in FIGS. **32-34**. FIG. **30**B shows an isolated top view of AC leads **400** and **402**, of positive and negative DC leads **404** and **406**, and of positive and negative LED leads **404**A and **406**A, respectively, extending between disks **368**.

Now analogous to the circuit shown previously herein in FIG. **4**B, for forty LEDs **362** all connected in series within one LED electrical string **408**, a single LED **362** from one disk **368** will extend to the adjacent single LED **362** in adjacent disk **368**, etc. until all forty LEDs **362** in LED electrical string **408** are electrically connected to form one single series connection. Circuitry for LED array **366** with integral electronics circuits **390**A and **390**B as connected to the ballast circuitry of ballast assembly **334** is also analogous to that shown previously herein in FIG. **4**. As seen therein and as indicated in FIG. **29**A, the circuitry for LED array **366** includes forty electrical strings in electrical parallel relationship. The forty electrical strings are typified and represented in FIG. **34**A by LED electrical string **408** mounted to disk **368** at one of the disk walls **370**A or **370**B, shown as disk wall **370**A in FIG. **30**A for purposes of exposition only. Each LED row **360** comprises a single LED **362** that is centrally mounted and concentric with disk rim **370**C. Central circular aperture **372** is no longer needed. Instead, vent holes **372**A are provided around the periphery of disk **368** for proper cooling of entire LED array **366** and LED retrofit lamp **328**. A typical LED string **408** is shown in FIG. **34**A as including a single LED row **360** comprising single LED **364**A. Each LED **364**A of LED string **408** in each disk **368**, generally terminate at the 6-pin connectors shown in FIG. **30** as typical 6-pin connectors **356**C and **356**D and in FIG. **34**A as typical 6-pin connector **356**D. In particular, the anode side of typical LED **364**A is connected to DC positive lead line **404** by way of LED positive lead line **404**A with an optional resistor **392** connected in series between the anode side of LED **364**A connected to LED positive lead line **404**A and DC positive lead line **404**. The cathode side of typical LED **364**A, which is connected to LED negative lead line **406**A, is now connected to the anode side of typical LED **364**A of the adjacent LED string **408** of the adjacent disk **368**. The cathode side of typical LED **364**A of the adjacent LED string **408** of the adjacent disk **368** is likewise connected to LED negative lead line **406**A of the adjacent disk **368** and to the anode side of the next typical LED **364**A of the adjacent LED string **408** of the adjacent disk **368** and so forth. The next thirty-eight LEDs **364**A continue to be connected in a similar manner as described with the cathode of the last and fortieth LED **364**A connected to DC negative lead line **406** by way of LED negative lead line **406**A. This completes the connection of all forty LEDs **362** in LED array **366**. Both AC lead line **400** and AC lead line **402** are shown in FIGS. **32-34**. FIG. **30**B shows an isolated top view of AC leads **400** and **402**, of positive and negative DC leads **404** and **406**, and of positive and negative LED leads **404**A and **406**A, respectively, extending between disks **368**.

The single series string **408** of LEDs **362** as described works ideally with the high-brightness high flux white LEDs available from Lumileds and Nichia in the SMD (surface mounted device) packages discussed previously. Since these new devices require more current to drive them and run on

low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The LEDs **362** have to be connected in series, so that each LED **362** within the same single string **408** will see the same current and therefore output the same brightness. The total voltage required by all the LEDs **362** within the same single string **408** is equal to the sum of all the individual voltage drops across each LED **362** and should be less than the maximum voltage output of ballast assembly **334**.

FIG. **35** shows an isolated view of one of the base end caps shown for purposes of exposition as base end cap **352**A, which is the same as base end cap **352**B, mutatis mutandis. Single-pin contact **340**A extends directly through the center of base end cap **352**A in the longitudinal direction in alignment with center line **346** of tubular wall **344**. Single-pin **340**A as also shown in FIG. **26** where single-pin contact **340**A is mounted into ballast socket **338**A. Single-pin contact **340**A also includes pin extension **340**D that is outwardly positioned from base end cap **352**A in the direction towards tubular wall **344**. Base end cap **352**A is a solid cylinder in configuration as seen in FIGS. **35** and **35**A and forms an outer cylindrical wall **410** that is concentric with center line **346** of tubular wall **344** and has opposed flat end walls **412**A and **412**B that are perpendicular to center line **346**. Two cylindrical parallel vent holes **414**A and **414**B are defined between end walls **412**A and **412**B spaced directly above and below and lateral to single-pin contact **340**A. Single-pin contact **340**A includes external side pin extension **340**C and internal side pin extension **340**D that each extend outwardly positioned from opposed flat end walls **412**A and **412**B, respectively, for electrical connection with ballast socket contact **338**A and with integral electronics circuit board **354**A. Analogous external and internal pin extensions **340**E and **340**F for contact pin **340**B likewise exist for electrical connections with ballast socket contact **338**B and with integral electronics circuit board **354**B.

As also seen in FIG. **35**A, base end cap **352**A defines a circular slot **416** that is concentric with center line **346** of tubular wall **344** and concentric with and aligned proximate to circular wall **410**. Circular slot **416** is spaced from cylindrical wall **410** at a convenient distance. Circular slot **416** is of such a width and circular end **348**A of tubular wall **344** is of such a thickness that circular end **348**A is fitted into circular slot **416** and is thus supported by circular slot **416**. Base end cap **352**B (not shown in detail) defines another circular slot (not shown) analogous to circular slot **416** that is likewise concentric with center line **346** of tubular wall **344** so that circular end **348**B of tubular wall **344** can be fitted into the analogous circular slot of base end cap **352**B wherein circular end **348**B is also supported. In this manner tubular wall **344** is mounted to end caps **3**.**52**A and **352**B. Circular ends **348**A and **348**B of tubular wall **344** are optionally glued to circular slot **416** of base end cap **352**A and the analogous circular slot of base end cap **352**B.

FIGS. **36**-**45**A show another embodiment of the present invention, in particular an LED lamp **418** seen in FIG. **36** retrofitted to an existing fluorescent fixture **420** mounted to a ceiling **422**. An electronic instant start type ballast assembly **424**, which can also be a hybrid or a magnetic ballast assembly, is positioned within the upper portion of fixture **420**. Fixture **420** further includes a pair of fixture mounting portions **426**A and **426**B extending downwardly from the ends of fixture **420** that include ballast electrical contacts shown as ballast end sockets **428**A and **428**B that are in electrical contact with ballast assembly **424**. Fixture sockets **428**A and **428**B are each double contact sockets in accordance with the electrical operational requirement of an electronic instant start, hybrid, or magnetic ballast. As also seen in FIG. **36**A, LED lamp **418** includes opposed bi-pin electrical contacts **430**A and **430**B that are positioned in ballast sockets **428**A and **428**B, respectively, so that LED lamp **418** is in electrical contact with ballast assembly **424**.

As shown in the disassembled mode of FIG. **37**, LED lamp **418** includes an elongated housing **432** particularly configured as a linear tubular wall **434** circular in cross-section taken transverse to a center line **436** that is made of a translucent material such as plastic or glass and preferably having a diffused coating. Tubular wall **434** has opposed tubular wall ends **438**A and **438**B. LED lamp **418** further includes a pair of opposed lamp base end caps **440**A and **440**B mounted to bi-pin electrical contacts **430**A and **430**B, respectively for insertion in ballast electrical socket contacts **428**A and **428**B in electrical power connection to ballast assembly **424** so as to provide power to LED lamp **418**. Tubular wall **434** is mounted to opposed base end caps **440**A and **440**B at tubular wall ends **438**A and **438**B in the assembled mode as shown in FIG. **36**. An integral electronics circuit board **442**A is positioned between base end cap **440**A and tubular wall end **438**A and an integral electronics circuit board **442**B is positioned between base end cap **440**B and tubular wall end **438**B.

As seen in FIGS. **37** and **38**, LED lamp **418** also includes a 6-pin connector **444**A connected to integral electronics circuit board **442**A and to a 6-pin header **446** on first disk **454**. LED lamp **418** also includes a 6-pin connector **444**B connected to integral electronics circuit board **442**B and to a 6-pin header **446** on last disk **454**.

For the purposes of exposition, only ten of the original fifteen parallel electrical strings are displayed and described herein. In particular, a sectional view taken through FIG. **37** is shown in FIG. **38** showing a typical single LED row **448** that include ten individual LEDs **450**. LED lamp **418** includes ten LED rows **448** that comprise an LED array **452**. FIG. **39** shows a partial view that includes each of the ten LED rows **448**. LED row **448** includes ten LEDs **450** and is circular in configuration, which is representative of each of the ten LED rows **448** of LED array **452** with all LED rows **448** being aligned in parallel relationship.

In FIGS. **39** and **40**, ten circular disks **454** having opposed flat disk walls **454**A and **454**B and disk circular rims **454**C are positioned and held in tubular wall **434** between tubular end walls **438**A and **438**B. Each disk **454** that is centrally aligned with center line **436** of tubular wall **434** defines a central circular aperture **456**. Apertures **456** are provided for the passage of heat out of tubular wall **434** generated by LED array **452**. Disks **454** are spaced apart at equal distances and are in parallel alignment. The inner side of tubular wall **434** defines ten equally spaced circular grooves **458** defining parallel circular configurations in which are positioned and held disk rims **454**C.

Similar to FIG. **39**, FIG. **39**A now shows a single LED row **448** that includes one individual LED **450**. LED lamp **418** includes ten LED rows **448** that can comprise LED array **452**. FIG. **39**A shows a single LED **450** of each of the ten LED rows **448** mounted in the center of each disk **454**. A heat sink **479** is attached to each LED **450** to extract heat away from LED **450**. Ten circular disks **454** each having opposed flat disk walls **454**A and **454**B and disk circular rims **454**C are positioned and held in tubular wall **434** between tubular end walls **438**A and **438**B. Apertures **457** are provided for the passage of heat out of tubular wall **434** generated by LED array **452**. Disks **454** are spaced apart at equal distances and are in parallel alignment. The inner side of tubular wall **434**

defines ten equally spaced circular grooves **458** defining parallel circular configurations in which are positioned and held disk rims **454**C.

Although FIGS. **39**, **39**A, and **40** show round circuit board disks **454**, it can be appreciated by someone skilled in the art to use circuit boards **454** made in shapes other than a circle. Likewise the shape of the tubular housing **432** holding the individual circuit boards **454** can be made in a similar shape to match the shape of the circuit boards **454**.

FIGS. **39**B, **39**C, and **39**D show simplified electrical arrangements of the array of LEDs shown with at least one LED in a series parallel configuration. Each LED string has an optional resistor in series with the LED.

In FIG. **40**, each LED **450** includes lens portion **460**, body portion **462**, and base portion **464**. Each lens portion **460** is in juxtaposition with the inner surface of tubular wall **434**. LED leads **466** and **470** extend out from the base portion **464** of LED **450**. LED lead **466** is bent at a 90-degree angle to form LED lead portions **466**A and **466**B. Likewise, LED lead **470** is also bent at a 90-degree right angle to form LED lead portions **470**A and **470**B. In FIG. **40**, a detailed isolated view of two typically spaced single LEDs shows each LED **450** mounted to disk **454** with LED lead portions **466**A and **470**A lateral to disk **454** and LED lead portions **466**B and **470**B transverse to disk **454**. Disks **454** are preferably made of rigid G10 epoxy fiberglass circuit board material, but can be made of other circuit board material known in the art. LED lead portions **466**B and **470**B extend through disk wall **454**A of disk **454** to disk wall **454**B of disk **454** by means known in the art as plated through hole pads. The LED leads **466** and **470** are secured to disk **454** with solder or other means known in the art. The LED leads **466** and **470** support LED **450** so that the center line **468** of each LED **450** is perpendicular to center line **436** of tubular wall **434**. The pair of LED leads **466** and **470** connected to each LED **450** of LED array **452** extend through each disk **454** from disk wall **454**A to disk wall **454**B and then to DC positive lead line **486**A, or to DC negative lead line **486**B, or to another LED **450** (not shown) in the same LED string **488** by means known in the art as electrical tracks or traces located on the surface of disk wall **454**A and/or disk wall. **454**B of disk **454**.

In FIG. **40**A, a special single SMD LED **450** is mounted to the center of disk **454**. Each LED **450** includes lens portion **460**, body portion **462**, and base portion **464**. Lens portion **460** allows the light from LED **450** to be emitted in a direction perpendicular to center line **468** of LED **450** and center line **436** of tubular wall **434** with the majority of light from LED **450** passing straight through tubular wall **434**. LED leads **466** and **470** extend out from the base portion **464** of LED **450**. LED lead **466** is bent at a 90-degree angle to form LED lead portions **466**A and **466**B. Likewise, LED lead **470** is also bent at a 90-degree right angle to form LED lead portions **470**A and **470**B. In FIG. **40**A, a detailed isolated view of two typically spaced single LEDs **450** shows each LED **450** mounted to disk **454** with LED lead portions **466**A and **470**A transverse to disk **454** and LED lead portions **466**B and **470**B lateral to disk **454**. Disks **454** are preferably made of rigid G10 epoxy fiberglass circuit board material, but can be made of other circuit board material known in the art. LED lead portions **466**B and **470**B rest on and are attached to disk wall **454**A of disk **454** with solder to means known in the art as plated through hole pads. The LED leads **466** and **470** support LED **450** so that the center line **468** of each LED **450** is parallel to center line **436** of tubular wall **434**. The pair of LED leads **466** and **470** connected to each LED **450** of LED array **452** is then connected to DC positive lead line **486**A, or to DC negative lead line **486**B, or to another LED **450** (not shown) in the same LED string **488** by means known in the art as electrical tracks or traces located on the surface of disk wall **454**A and/or disk wall **454**B of disk **454**. A heat sink **479** is attached to the base portion **464** of each LED **450** to sufficiently extract the heat generated by each LED **450**.

As further indicated in FIGS. **40**, **40**A, and **40**B, six electrical lead lines comprising AC lead line **484**A, AC lead line **484**B, DC positive lead line **486**A, DC negative lead line **486**B, LED positive lead line **486**C, and LED negative lead line **486**D are representative of lead lines that extend the entire length of tubular wall **434**, in particular extending between and joined to each of the ten disks **454** so as to connect electrically each LED string **488** of each disk **454** as shown in FIG. **44**. Each of the lead lines **484**A, **484**B, **486**A, **486**B, **486**C, and **486**D are held in position at each of disks **454** by six pins **474**A, **474**B, **474**C, **474**D, **474**E, and **474**F that extend through disks **454** and are in turn held in position by 6-pin headers **446** mounted to disks **454** shown as disk wall **454**B for purposes of exposition. A 6-pin connector **444**C is mounted to each 6-pin header **446** and another 6-pin connector **444**D is mounted to disk wall **454**A.

As shown in the schematic electrical and structural representations of FIG. **41**, disks **454** and LED array **452** are positioned between integral electronics circuit boards **442**A and **442**B that in turn are electrically connected to ballast assembly **424** by bi-pin contacts **430**A and **430**B, respectively. Bi-pin contacts **430**A and **430**B are mounted to and protrude out from base end caps **440**A and **440**B, respectively, for electrical connection to ballast assembly **424**. Bi-pin contacts **430**A and **430**B are soldered directly to integral electronics circuit boards **442**A and **442**B, respectively. In particular, bi-pin inner extensions **430**C of bi-pin contacts being soldered directly to the integral electronics circuit board **442**A electrically connects **430**A. Also, being soldered directly to integral electronics circuit board **442**B electrically connects bi-pin inner extensions **430**D of bi-pins **430**B. 6-pin connector **444**A is shown positioned between and in electrical connection with integral electronics circuit board **442**A and LED array **452** and disks **454**. 6-pin connector **444**B is shown positioned between and in electrical connection with integral electronics circuit board **442**B and LED array **452** and disks **454**.

FIG. **42** shows a schematic of integral electronics circuit **476**A mounted on integral electronics circuit board **442**A. Integral electronics circuit **476**A is also indicated in part in FIG. **41** as connected to LED array **452**. Integral electronics circuit **476**A is in electrical contact with bi-pin contacts **430**A, which are shown as providing either AC or DC voltage. Integral electronics circuit **476**A includes a bridge rectifier **478**A, voltage surge absorbers **480**A and **480**B, and a resettable fuse **482**. Integral electronic circuit **476**A leads to or from LED array **452**. FIG. **42** indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. The AC voltage could be DC voltage supplied by certain ballast assemblies **424** as mentioned earlier herein. In such a case DC voltage would be supplied to LED array **452** even in the presence of bridge rectifier **478**A. It is particularly noted that in such a case, voltage surge absorbers **480**A and **480**B would remain operative. AC lead lines **484**A and **484**B are in a power connection with ballast assembly **424**. DC lead lines **486**A and **486**B are in positive and negative, respectively, direct current voltage relationship with LED array **452**. Bridge rectifier **478**A is in electrical connection with four lead lines **484**A, **484**B, **486**A and **486**B. Voltage surge absorber **480**B is in electrical contact with AC lead line **484**A. DC lead lines **486**A and **486**B are in electrical contact with bridge rectifier **478**A and in power connection

with LED array **452**. Fuse **482** is positioned on DC lead line **486**A between bridge rectifier **478**A and LED array **452**.

FIG. **43** shows a schematic of integral electronics circuit **476**B mounted on integral electronics circuit board **442**B. Integral electronics circuit **476**B is also indicated in part in FIG. **41** as connected to LED array **452**. Integral electronics circuit **476**B is a close mirror image of electronics circuit **476**A mutatis mutandis. Integral electronics circuit **476**B is in electrical contact with bi-pin contacts **430**B, which provide either AC or DC voltage. Integral electronics circuit **476**B includes bridge rectifier **478**B and voltage surge absorbers **480**C and **480**D. Integral electronic circuit **476**B leads to or from LED array **452**. FIG. **43** indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. The AC voltage could be DC voltage supplied by certain ballast assemblies **424** as mentioned earlier herein. In such a case DC voltage would be supplied to LED array **452** even in the presence of bridge rectifier **478**B. It is particularly noted that in such a case, voltage surge absorbers **480**C and **480**D would remain operative. AC lead lines **484**A and **484**B are in a power connection with ballast assembly **424**. DC lead lines **486**A and **486**B are in positive and negative direct current voltage relationship with LED array **452**. Bridge rectifier **478**B is in electrical connection with the four lead lines **484**A, **484**B, **486**A and **486**B. Lead lines **484**A, **484**B, **486**A, and **486**B are in electrical contact with bridge rectifier **478**B and in power connection with LED array **452**.

Circuitry for LED array **452** with integral electronics circuits **442**A and **442**B as connected to the ballast circuitry of ballast assembly **424** is analogous to that shown previously herein in FIG. **4**. As seen therein and as indicated in FIG. **39**, the circuitry for LED array **452** includes ten electrical strings in electrical parallel relationship. The ten electrical strings are typified and represented in FIG. **44** by LED electrical string **488** mounted to disk **454** at one of the disk walls **454**A or **454**B, shown as disk wall **454**A in FIG. **40** for purposes of exposition only. A single LED row **448** comprises ten LEDs **450** that are electrically connected at equal intervals along each string **488** that is configured in a circular pattern spaced from and concentric with disk rim **454**C. A typical LED string **488** is shown in FIG. **44** as including an LED row **448** comprising ten LEDs **450**A, **450**B, **450**C, **450**D, **450**E, **450**F, **450**G, **450**H, **450**I, and **450**J. First and last LEDs **450**A and **450**J, respectively, of LED string **488** generally terminate at the 6-pin connectors shown in FIG. **40** as typical 6-pin connectors **444**C and **444**D and in FIG. **44** as typical 6-pin connector **444**D. In particular, the anode side of typical LED **450**A is connected to DC positive lead line **486**A by way of LED positive lead line **486**C with optional resistor **490** connected in series between the anode side of LED **450**A connected to LED positive lead line **486**C and DC positive lead line **486**A. The cathode side of typical LED **450**J is connected to DC negative lead line **486**B by way of LED negative lead line **486**D. Both AC lead line **484**A and AC lead line **484**B are shown in FIGS. **42-44**. FIG. **40**B shows an isolated top view of AC leads **484**A and **484**B, of positive and negative DC leads **486**A and **486**B, and of positive and negative LED leads **486**C and **486**D, respectively, extending between disks **454**.

Analogous to the circuit shown previously herein in FIG. **4**A, for more than ten LEDs **450** connected in series within each LED electrical string **488**, the LEDs **450** from one disk **454** will extend to the adjacent disk **454**, etc. until all twenty LEDs **450** in LED electrical string **488** spread over two disks **454** are electrically connected into one single series connection. Circuitry for LED array **452** with integral electronics circuits **442**A and **442**B as connected to the ballast circuitry of ballast assembly **424** is also analogous to that shown previously herein in FIG. **4**. As seen therein and as indicated in FIG. **39**, the circuitry for LED array **452** includes ten electrical strings in electrical parallel relationship. The ten electrical strings are typified and represented in FIG. **44** by LED electrical string **488** mounted to disk **454** at one of the disk walls **454**A or **454**B, shown as disk wall **454**A in FIG. **40** for purposes of exposition only. Each LED row **448** comprises ten LEDs **450** that are electrically connected at equal intervals along each string **488** that is configured in a circular pattern spaced from and concentric with disk rim **454**C. A typical LED string **488** is shown in FIG. **44** as including an LED row **448** comprising ten LEDs **450**A, **450**B, **450**C, **450**D, **450**E, **450**F, **450**G, **450**H, **450**I, and **450**J. First and last LEDs **450**A and **450**J, respectively, of LED string **488** generally terminate at the 6-pin connectors shown in FIG. **40** as typical 6-pin connectors **444**C and **444**D and in FIG. **44** as typical 6-pin connector **444**D. In particular, the anode side of typical LED **450**A is connected to DC positive lead line **486**A by way of LED positive lead line **486**C with an optional resistor **490** connected in series between the anode side of LED **450**A connected to LED positive lead line **486**C and DC positive lead line **486**A. The cathode side of typical LED **450**J is now connected to anode side of typical LED **450**A of the adjacent LED string **488** of the adjacent disk **454**. The cathode side of typical LED **450**J of the adjacent LED string **488** of the adjacent disk **454** is connected to DC negative lead line **486**B by way of LED negative lead line **486**D. This completes the connection of the first twenty LEDs **450** in LED array **452**. The next twenty LEDs **450** and so forth, continue to be connected in a similar manner as described. Both AC lead line **484**A and AC lead line **484**B are shown in FIGS. **42-44**. FIG. **40**B shows an isolated top view of AC leads **484**A and **484**B, of positive and negative DC leads **486**A and **486**B, and of positive and negative LED leads **486**C and **486**D, respectively, extending between disks **454**.

Now analogous to the circuit shown previously herein in FIG. **4**B, for forty LEDs **450** all connected in series within one LED electrical string **488**, a single LED **450** from one disk **454** will extend to the adjacent single LED **450** in adjacent disk **454**, etc. until all forty LEDs **450** in LED electrical string **488** are electrically connected to form one single series connection. Circuitry for LED array **452** with integral electronics circuits **442**A and **442**B as connected to the ballast circuitry of ballast assembly **424** is also analogous to that shown previously herein in FIG. **4**. As seen therein and as indicated in FIG. **39**A, the circuitry for LED array **452** includes forty electrical strings in electrical parallel relationship. The forty electrical strings are typified and represented in FIG. **44**A by LED electrical string **488** mounted to disk **454** at one of the disk walls **454**A or **454**B, shown as disk wall **454**A in FIG. **40**A for purposes of exposition only. Each LED row **448** comprises a single LED **450** that is centrally mounted and concentric with disk rim **454**C. Central circular aperture **456** is no longer needed. Instead, vent holes **457** are provided around the periphery of disk **454** for proper cooling of entire LED array **452** and LED retrofit lamp **418**. A typical LED string **488** is shown in FIG. **44**A as including a single LED row **448** comprising single LED **450**A. Each LED **450**A of LED string **488** in each disk **454**, generally terminate at the 6-pin connectors shown in FIG. **40** as typical 6-pin connectors **444**C and **444**D and in FIG. **44**A as typical 6-pin connector **444**D. In particular, the anode side of typical LED **450**A is connected to DC positive lead line **486**A by way of LED positive lead line **486**C with an optional resistor **490** connected in series between the anode side of LED **450**A connected to LED positive lead line **486**C and DC positive lead line **486**A. The cathode side of typical LED **450**A, which

is connected to LED negative lead line **486**D, is now connected to the anode side of typical LED **450**A of the adjacent LED string **488** of the adjacent disk **454**. The cathode side of typical LED **450**A of the adjacent LED string **488** of the adjacent disk **454** is likewise connected to LED negative lead line **486**D of the adjacent disk **454** and to the anode side of the next typical LED **450**A of the adjacent LED string **488** of the adjacent disk **454** and so forth. The next thirty-eight LEDs **450**A continue to be connected in a similar manner as described with the cathode of the last and fortieth LED **450**A connected to DC negative lead line **486**B by way of LED negative lead line **486**D. This completes the connection of all forty LEDs **450** in LED array **452**. Both AC lead line **484**A and AC lead line **484**B are shown in FIGS. **42-44**. FIG. **40**B shows an isolated top view of AC leads **484**A and **484**B, of positive and negative DC leads **486**A and **486**B, and of positive and negative LED leads **486**C and **486**D, respectively, extending between disks **454**.

The single series string **488** of LEDs **450** as described works ideally with the high-brightness high flux white LEDs available from Lumileds and Nichia in the SMD packages. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The LEDs **450** have to be connected in series, so that each LED **450** within the same single string **488** will see the same current and therefore output the same brightness. The total voltage required by all the LEDs **450** within the same single string **488** is equal to the sum of all the individual voltage drops across each LED **450** and should be less than the maximum voltage output of ballast assembly **424**.

FIG. **45** shows an isolated top view of one of the base end caps, namely, base end cap **440**A, which is analogous to base end cap **440**B, mutatis mutandis. Bi-pin electrical contacts **430**A extend directly through base end cap **440**A in the longitudinal direction in alignment with center line **436** of tubular wall **434** with bi-pin internal extensions **430**C shown. Base end cap **440**A is a solid cylinder in configuration as seen in FIGS. **45** and **45**A and forms an outer cylindrical wall **492** that is concentric with center line **436** of tubular wall **434** and has opposed flat end walls **494**A and **494**B that are perpendicular to center line **436**. Two cylindrical vent holes **496**A and **496**B are defined between end walls **494**A and **494**B in vertical alignment with center line **436**.

As also seen in FIG. **45**A, base end cap **440**A defines a circular slot **498** that is concentric with center line **436** of tubular wall **434** and concentric with and aligned proximate to circular wall **492**. Outer circular slot **498** is of such a width and circular end **438**A of tubular wall **434** is of such a thickness and diameter that outer circular slot **498** accepts circular end **438**A into a fitting relationship and circular end **438**A is thus supported by circular slot **498**. In this similar manner tubular wall **434** is mounted to both end caps **440**A and **440**B. Circular ends **438**A and **438**B of tubular wall **434** are optionally glued to circular slot **498** of base end cap **440**A and the analogous circular slot of base end cap **440**B.

A portion of a curved tubular wall **500** shown in FIG. **46** includes an inner curved portion **502** and an outer curved portion **504**. Disks **506** are shown as six in number for purposes of exposition only and each having six LEDs **508** mounted thereto having rims **510** mounted in slots **512** defined by tubular wall **500**. Disks **506** are positioned and held in tubular wall **500** at curved inner portion **502** at first equal intervals and at curved outer portion **504** at second equal intervals with the second equal intervals being greater than the first equal intervals. Curved tubular wall **500** has a curved center line **514**. Each LED **508** has an LED center line **516** (seen from top view) such as LED center line **468** seen in FIG. **40** that is aligned with curved center line **514** of curved tubular wall **500** relative to a plane defined by any LED row **528** indicated by arrows in FIG. **46**, or relative to a parallel plane defined by disks **506**.

FIG. **47** shows a simplified cross-section of an oval tubular housing **530** as related to FIG. **1** with a self-biased oval circuit board **532** mounted therein.

FIG. **47**A shows a simplified cross-section of a triangular tubular housing **534** as related to FIG. **1** with a self-biased triangular circuit board **536** mounted therein.

FIG. **47**B shows a simplified cross-section of a rectangular tubular housing **538** as related to FIG. **1** with a self-biased rectangular circuit board **540** mounted therein.

FIG. **47**C shows a simplified cross-section of a hexagonal tubular housing **542** as related to FIG. **1** with a self-biased hexagonal circuit board **544** mounted therein.

FIG. **47**D shows a simplified cross-section of an octagonal tubular housing **546** as related to FIG. **1** with a self-biased octagonal circuit board **548** mounted therein. FIG. **48** shows a simplified cross-section of an oval tubular housing **550** as related to FIG. **26** with an oval support structure **550**A mounted therein.

FIG. **48**A shows a simplified cross-section of a triangular tubular housing **552** as related to FIG. **26** with a triangular support structure **552**A mounted therein.

FIG. **48**B shows a simplified cross-section of a rectangular tubular housing **554** as related to FIG. **26** with a rectangular support structure **554**A mounted therein.

FIG. **48**C shows a simplified cross-section of a hexagonal tubular housing **556** as related to FIG. **26** with a hexagonal support structure **556**A mounted therein.

FIG. **48**D shows a simplified cross-section of an octagonal tubular housing **558** as related to FIG. **26** with an octagonal support structure **558**A mounted therein.

FIG. **49** shows a high-brightness SMD LED **560** having an SMD LED center line **562** mounted to a typical support structure **564** mounted within a tubular housing (not shown) such as tubular housings **550**, **552**, **554**, **556**, and **558** and in addition analogous to disks **368** mounted in tubular housing **342** and disks **454** mounted in tubular housing **432**. Typical support structure **564** and the tubular housing in which it is mounted have a tubular housing center line **566** that is in alignment with SMD LED center line **562**. A light beam **568** shown in phantom line is emitted from high-brightness SMD LED **560** perpendicular to SMD LED center line **562** and tubular housing center line **566** at a 360-degree angle. Light beam **568** is generated in a radial light beam plane that is lateral to and slightly spaced from support structure **564**, which is generally flat in configuration in side view. Thus, light beam **568** passes through the particular tubular wall to which support structure **564** is mounted in a 360-degree coverage. High-brightness SMD LED **560** shown can be, for example, a Luxeon Emitter high-brightness LED, but other analogous high-brightness side-emitting radial beam SMD LEDs that emit high flux side-emitting radial light beams can be used.

Reference is now made to the drawings and in particular to FIGS. **1-10** in which identical of similar parts are designated by the same reference numerals throughout.

An LED lamp **570** shown in FIGS. **50-59** is seen in FIG. **50** retrofitted to an existing elongated fluorescent fixture **572** mounted to a ceiling **574**. An instant start type ballast assembly **576** is positioned within the upper portion of fixture **572**. Fixture **572** further includes a pair of fixture mounting por-

tions **578**A and **578**B extending downwardly from the ends of fixture **572** that include ballast electrical contacts shown as ballast sockets **580**A and **580**B that are in electrical contact with ballast assembly **576**. Fixture sockets **580**A and **580**B are each single contact sockets in accordance with the electrical operational requirement of an instant start type ballast. As also seen in FIG. **50**A, LED lamp **570** includes opposed single-pin electrical contacts **582**A and **582**B that are positioned in ballast sockets **580**A and **580**B respectively, so that LED lamp **570** is in electrical contact with ballast assembly **576**.

As shown in the disassembled mode of FIG. **51** and also indicated schematically in FIG. **53**, LED lamp **570** includes an elongated housing **584** particularly configured as a tubular wall **586** circular in cross-section taken transverse to a center line **588** that is made of a translucent material such as plastic or glass and preferably having a diffused coating. Tubular wall **586** has opposed tubular wall ends **590**A and **590**B with cooling vent holes **589**A and **589**B juxtaposed to tubular wall ends **590**A and **590**B. Optional electric micro fans (not shown) can be used to provide forced air-cooling across the electronic components contained within elongated housing **584**. The optional cooling micro fans can be arranged in a push or pull configuration. LED lamp **570** further includes a pair of opposed lamp base end caps **592**A and **592**B mounted to single electrical contact pins **582**A and **582**B, respectively for insertion in ballast electrical sockets **580**A and **580**B in electrical power connection to ballast assembly **576** so as to provide power to LED lamp **570**. Tubular wall **586** is mounted to opposed base end caps **592**A and **592**B at tubular wall ends **590**A and **590**B in the assembled mode as shown in FIG. **50**. LED lamp **570** also includes electrical LED array circuit boards **594**A and **594**B that are rectangular in configuration. Circuit board **594**A is preferably manufactured from a Metal Core Printed Circuit Board (MCPCB) consisting of a circuit layer **598**A, a dielectric layer **598**B, and a metal base layer **598**C. Likewise, circuit board **594**B comprises a circuit layer **598**A, a dielectric layer **598**B, and metal base layer **598**C. Each dielectric layer **598**B is an electrically non-conductive, but is a thermally conductive dielectric layer separating the top conductive circuit layer **598**A and metal base layer **598**C. Each circuit layer **598**A contains the electronic components including the LEDs, traces, vias, holes, etc. while the metal base layer **598**C is attached to heat sink **596**. Metal core printed circuit boards are designed for attachment to heat sinks using thermal epoxy, Sil-pads, or heat conductive grease **597** used between metal base layer **598**C and heat sink **596**. The metal substrate LED array circuit boards **594**A and **594**B are each screwed down to heat sink **596** with screws (not shown) or other mounting hardware.

Circuit layer **598**A is the actual printed circuit foil containing the electrical connections including pads, traces, vias, etc. Electronic integrated circuit components get mounted to circuit layer **598**A. Dielectric layer **598**B offers electrical isolation with minimum thermal resistance and bonds the circuit metal layer **598**A to the metal base layer **598**C. Metal base layer **598**C is often aluminum, but other metals such as copper may also be used. The most widely used base material thickness is 0.04" (1.0 mm) in aluminum, although other thicknesses are available. The metal base layer **598**C is further attached to heat sink **596** with thermally conductive grease **597** or other material to extract heat away from the LEDs mounted to circuit layer **598**A. The Berquist Company markets their version of a MCPCB called Thermal Clad (T-Clad). Although this embodiment describes a generally rectangular configuration for circuit boards **594**A and **594**B, it can be appreciated by someone skilled in the art to form circuit boards **594**A and **594**B into curved shapes or combinations of rectangular and curved portions.

LED array circuit boards **594**A and **594**B are positioned within tubular wall **586** and supported by opposed lamp base end caps **592**A and **592**B. In particular, LED array circuit boards **594**A and **594**B each have opposed circuit board short edge ends **595**A and **595**B that are positioned in association with tubular wall ends **590**A and **590**B, respectively. As mentioned earlier, LED array circuit boards **594**A and **594**B each have a circuit layer **598**A, a dielectric layer **598**B, and a metal base layer **598**C respectively with heat sink **596** sandwiched between metal base layers **598**C between tubular wall circular ends **590**A and **590**B, and circuit layers **598**A being spaced away from tubular wall **586**. LED array circuit boards **594**A and **594**B are shown in FIGS. **51** and **52**, and indicated schematically in FIG. **54**.

LED lamp **570** further includes an LED array **600** comprising a total of thirty Lumileds Luxeon surface mounted device (SMD) LED emitters **606** mounted to LED array circuit boards **594**A and **594**B. Integral electronics **602**A is positioned on one end of LED array circuit boards **594**A and **594**B in close proximity to base end cap **592**A, and integral electronics **602**B is positioned on the opposite end of LED array circuit boards **594**A and **594**B in close proximity to base end cap **592**B. As seen in FIGS. **51** and **54**, integral electronics **602**A is connected to LED array circuit boards **594**A and **594**B and also to integral electronics **602**B. Integral electronics **602**A and **602**B are identical in both LED array circuit boards **594**A and **594**B.

The sectional view of FIG. **52** includes a single typical SMD LED **606** from each LED array **600** in LED array circuit boards **594**A and **594**B shown in FIG. **53**. LED **606** is representative of one of the fifteen LEDs **606** connected in series in each LED array **600** as shown in FIG. **53**. Each LED **606** includes a light emitting lens portion **608**, a body portion **610**, and a base portion **612**. A cylindrical space **614** is defined between circuit layer **598**A of each LED array circuit board **594**A and **594**B and cylindrical tubular wall **586**. Each LED **606** is positioned in space **614** as seen in the detailed view of FIG. **52**A. Lens portion **608** is in juxtaposition with the inner surface of tubular wall **586** and base portion **612** is mounted to metal base layer **598**C of LED array circuit boards **594**A and **594**B. A detailed view of a single LED **606** in FIG. **52**A shows a rigid LED electrical lead **616** extending from LED base portion **612** to LED array circuit boards **594**A and **594**B for electrical connection therewith. Lead **616** is secured to LED circuit boards **594**A and **594**B by solder **618**. An LED center line **620** is aligned transverse to center line **588** of tubular wall **586**. As shown in the sectional view of FIG. **52**, light is emitted through tubular wall **586** by the two SMD LEDs **606** in substantially equal strength about the entire circumference of tubular wall **586**. Projection of this arrangement is such that all fifteen LEDs **606** are likewise arranged to emit light rays in substantially equal strength the entire length of tubular wall **586** and in substantially equal strength about the entire 360-degree circumference of tubular wall **586**. The distance between LED center line **620** and LED array circuit boards **594**A and **594**B is the shortest that is geometrically possible with heat sink **596** sandwiched between LED array circuit boards **594**A and **594**B. In FIG. **52**A, LED center line **620** is perpendicular to tubular wall center line **588**. FIG. **52**A indicates a tangential plane **622** relative to the cylindrical inner surface of linear wall **586** in phantom line at the apex of LED lens portion **608** that is perpendicular to LED center line **620** so that all LEDs **606** emit light through tubular wall **586** in a direction perpendicular to tangential plane **622**, so that maximum illumination is obtained from all SMD LEDs **606**.

FIG. **53** shows the total LED electrical circuitry for LED lamp **570**. The LED electrical circuitry for both LED array circuit boards **594**A and **594**B are identically described herein, mutatis mutandis. The total LED circuitry comprises two circuit assemblies, namely, existing ballast assembly circuitry **624** and LED circuitry **626**, the latter including LED array circuitry **628** and integral electronics circuitry **640**. LED circuitry **626** provides electrical circuits for LED lighting element array **600**. When electrical power, normally 120 VAC or 240 VAC at 50 or 60 Hz, is applied, ballast circuitry **624** as is known in the art of instant start ballasts provides either an AC or DC voltage with a fixed current limit across ballast electrical sockets **580**A and **580**B, which is conducted through LED circuitry **626** by way of single contact pins **582**A and **582**B to a voltage input at a bridge rectifier **630**. Bridge rectifier **630** converts AC voltage to DC voltage if ballast circuitry **624** supplies AC voltage. In such a situation wherein ballast circuitry **624** supplies DC voltage, the voltage remains DC voltage even in the presence of bridge rectifier **630**.

LEDs **606** have an LED voltage design capacity, and a voltage suppressor **632** is used to protect LED lighting element array **600** and other electronic components primarily including LEDs **606** by limiting the initial high voltage generated by ballast circuitry **624** to a safe and workable voltage.

Bridge rectifier **630** provides a positive voltage V+ to an optional resettable fuse **634** connected to the anode end and also provides current protection to LED array circuitry **628**. Fuse **634** is normally closed and will open and de-energize LED array circuitry **628** only if the current exceeds the allowable current through LED array **600**. The value for resettable fuse **634** should be equal to or be lower than the maximum current limit of ballast assembly **576**. Fuse **634** will reset automatically after a cool-down period.

Ballast circuitry **624** limits the current going into LED circuitry **626**. This limitation is ideal for the use of LEDs in general and of LED lamp **570** in particular because LEDs are basically current devices regardless of the driving voltage. The actual number of LEDs will vary in accordance with the actual ballast assembly **576** used. In the example of the embodiment herein, ballast assembly **576** provides a maximum current limit of 300 mA, but higher current ratings are also available.

LED array circuitry **628** includes a single LED string **636** with all SMD LEDs **606** within LED string **636** being electrically wired in series. Each SMD LED **606** is preferably positioned and arranged equidistant from one another in LED string **636**. Each LED array circuitry **628** includes fifteen SMD LEDs **606** electrically mounted in series within LED string **636** for a total of fifteen SMD LEDs **606** that constitute each LED array **600** in LED array circuit boards **594**A and **594**B. SMD LEDs **606** are positioned in equidistant relationship with one another and extend generally the length of tubular wall **586**, that is, generally between tubular wall ends **590**A and **590**B. As shown in FIG. **53**, LED string **636** includes an optional resistor **638** in respective series alignment with LED string **636** at the current input. The current limiting resistor **638** is purely optional, because the existing fluorescent ballast used here is already a current limiting device. The resistor **638** then serves as a secondary protection device. A higher number of individual SMD LEDs **606** can be connected in series within each LED string **636**. The maximum number of SMD LEDs **606** being configured around the circumference of the 1.5-inch diameter of tubular wall **586** in the particular example herein of LED lamp **570** is two. Each LED **606** is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−.

When LED array circuitry **628** is energized, the positive voltage that is applied through resistor **638** to the anode end of LED string **636**, and the negative voltage that is applied to the cathode end of LED string **636** will forward bias LEDs **604** connected within LED string **636** and cause SMD LEDs **606** to turn on and emit light.

Ballast assembly **576** regulates the electrical current through SMD LEDs **606** to the correct value of 300 mA for each SMD LED **606**. Each LED string **636** sees the total current applied to LED array circuitry **628**. Those skilled in the art will appreciate that different ballasts provide different current outputs to drive LEDs that require higher operating currents. To provide additional current to drive the newer high-flux LEDs that require higher currents to operate, the electronic ballast outputs can be tied together in parallel to "overdrive" the LED retrofit lamp of the present invention.

The total number of LEDs in series within each LED string **636** is arbitrary since each SMD LED **606** in each LED string **636** will see the same current. The maximum number of LEDs is dependent on the maximum power capacity of the ballast. Again in this example, fifteen SMD LEDs **606** are shown connected in series within each LED string **636**. Each of the fifteen SMD LEDs **606** connected in series within each LED string **636** sees this 300 mA. In accordance with the type of ballast assembly **576** used, when ballast assembly **576** is first energized, a high voltage may be applied momentarily across ballast socket contacts **580**A and **580**B, which conduct to pin contacts **582**A and **582**B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry **628** and voltage surge absorber **632** absorbs the voltage applied by ballast circuitry **624**, so that the initial high voltage supplied is limited to an acceptable level for the circuit. Optional resettable fuse **634** is also shown to provide current protection to LED array circuitry **628**.

As can be seen from FIG. **53**A, there can be more than fifteen 5 mm LEDs **604** connected in series within each string **636**A-**636**O. There are twenty 5 mm LEDs **604** in this example, but there can be more 5 mm LEDs **604** connected in series within each string **636**A-**636**O. LED array circuitry **628** includes fifteen electrical LED strings **636** individually designated as strings **636**A, **636**B, **636**C, **636**D, **636**E, **636**F, **636**G, **636**H, **636**I, **636**J, **636**K, **636**L, **636**M, **636**N and **636**O all in parallel relationship with all 5 mm LEDs **604** within each string **636**A-**636**O being electrically wired in series. Parallel strings **636**A-**636**O are so positioned and arranged that each of the fifteen strings **636** is equidistant from one another. LED array circuitry **628** includes twenty 5 mm LEDs **604** electrically mounted in series within each of the fifteen parallel strings **636**A-**636**O for a total of three-hundred 5 mm LEDs **604** that constitute each LED array **600**. 5 mm LEDs **604** are positioned in equidistant relationship with one another and extend generally the length of tubular wall **586**, that is, generally between tubular wall ends **590**A and **590**B. As shown in FIG. **53**A, each of strings **636**A-**636**O includes an optional resistor **638** designated individually as resistors **638**A, **638**B, **638**C, **638**D, **638**E, **638**F, **638**G, **638**H, **638**I, **638**J, **638**K, **638**L, **638**M, **638**N, and **638**O in respective series alignment with strings **636**A-**636**O at the current input for a total of fifteen resistors **638**. Again, a higher number of individual 5 mm LEDs **604** can be connected in series within each LED string **636**. Each 5 mm LED **604** is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When LED array circuitry **628** is energized, the positive voltage that is applied through resistors **638**A-**638**O to the anode end of LED strings **636**A-**636**O, and the negative voltage that is applied to the cathode

end of LED strings **636**A-**636**O will forward bias 5 mm LEDs **604** connected to LED strings **636**A-**636**O and cause 5 mm LEDs **604** to turn on and emit light.

Ballast assembly **576** regulates the electrical current through 5 mm LEDs **604** to the correct value of 20 mA for each 5 mm LED **604**. The fifteen LED strings **636**A-**636**O equally divide the total current applied to LED array circuitry **628**. Those skilled in the art will appreciate that different ballasts provide different current outputs.

If the forward drive current for each 5 mm LEDs **604** is known, then the output current of ballast assembly **576** divided by the forward drive current gives the exact number of parallel strings of 5 mm LEDs **604** in the each particular LED array, here LED array **600**. The total number of 5 mm LEDs **604** in series within each LED string **636** is arbitrary since each 5 mm LED **604** in each LED string **636** will see the same current. Again in this example, twenty 5 mm LEDs **604** are shown connected in series within each LED string **636**. Ballast assembly **576** provides 300 mA of current, which when divided by the fifteen LED strings **636** of twenty 5 mm LEDs **604** per LED string **636** gives 20 mA per LED string **636**. Each of the twenty 5 mm LEDs **604** connected in series within each LED string **636** sees this 20 mA. In accordance with the type of ballast assembly **576** used, when ballast assembly **576** is first energized, a high voltage may be applied momentarily across ballast socket contacts **580**A and **580**B, which conduct to pin contacts **582**A and **582**B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry **628** and voltage surge absorber **632** absorbs the voltage applied by ballast circuitry **624**, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

FIG. **53**B shows another alternate arrangement of LED array circuitry **628**. LED array circuitry **628** consists of a single LED string **636** of SMD LEDs **606** arranged in series relationship including for exposition purposes only forty SMD LEDs **606** all electrically connected in series. Positive voltage V+ is connected to optional resettable fuse **634**, which in turn is connected to one side of current limiting resistor **638**. The anode of the first LED in the series string is then connected to the other end of resistor **638**. A number other than forty SMD LEDs **606** can be connected within the series LED string **636** to fill up the entire length of the tubular wall of the present invention. The cathode of the first SMD LED **606** in the series LED string **636** is connected to the anode of the second SMD LED **606**, the cathode of the second SMD LED **606** in the series LED string **636** is then connected to the anode of the third SMD LED **606**, and so forth. The cathode of the last SMD LED **606** in the series LED string **636** is likewise connected to ground or the negative potential V−. The individual SMD LEDs **606** in the single series LED string **636** are so positioned and arranged such that each of the forty LEDs is spaced equidistant from one another substantially filling the entire length of tubular wall **586**. SMD LEDs **606** are positioned in equidistant relationship with one another and extend substantially the length of tubular wall **586**, that is, generally between tubular wall ends **590**A and **590**B. As shown in FIG. **53**B, the single series LED string **636** includes an optional resistor **638** in respective series alignment with single series LED string **636** at the current input. Each SMD LED **606** is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When LED array circuitry **628** is energized, the positive voltage that is applied through resistor **638** to the anode end of single series LED string **636** and the negative voltage that is applied to the cathode end of single series LED string **636** will forward bias SMD LEDs **606** connected in series within single series LED string **636**, and cause SMD LEDs **606** to turn on and emit light.

The single series LED string **636** of SMD LEDs **606** as described above works ideally with the high-brightness or brighter high flux white SMD LEDs **606**A available from Lumileds and Nichia in the SMD packages as discussed earlier herein. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The high-brightness SMD LEDs **606**A have to be connected in series, so that each high-brightness SMD LED **606**A within the same single LED string **636** will see the same current and therefore output the same brightness. The total voltage required by all the high-brightness SMD LEDs **606**A within the same single LED string **636** is equal to the sum of all the individual voltage drops across each high-brightness SMD LED **606**A and should be less than the maximum voltage output of ballast assembly **576**.

FIG. **53**C shows a simplified arrangement of the LED array circuitry **628** of SMD LEDs **606** for the overall electrical circuit shown in FIG. **53**. AC lead lines **642** and **646** and DC positive lead line **648** and DC negative lead line **650** are connected to integral electronics **602**A and **602**B. Four parallel LED strings **636** each including a resistor **638** are each connected to DC positive lead line **648** on one side, and to LED positive lead line **656** or the anode side of each LED **604** and on the other side. The cathode side of each LED **604** is then connected to LED negative lead line **658** and to DC negative lead line **650** directly. AC lead lines **642** and **646** simply pass through LED array circuitry **628**.

FIG. **53**D shows a simplified arrangement of the LED array circuitry **628** of 5 mm LEDs **604** for the overall electrical circuit shown in FIG. **53**A. AC lead lines **642** and **646** and DC positive lead line **648** and DC negative lead line **650** are connected to integral electronics **602**A and **602**B. Two parallel LED strings **636** each including a single resistor **638** are each connected to DC positive lead line **648** on one side, and to LED positive lead line **656** or the anode side of the first 5 mm LED **604** in each LED string **636** on the other side. The cathode side of the first 5 mm LED **604** is connected to LED negative lead line **658** and to adjacent LED positive lead line **656** or the anode side of the second 5 mm LED **604** in the same LED string **636**. The cathode side of the second 5 mm LED **604** is then connected to LED negative lead line **658** and to DC negative lead line **650** directly in the same LED string **636**. AC lead lines **642** and **646** simply pass through LED array circuitry **628**.

FIG. **53**E shows a simplified arrangement of the LED array circuitry **628** of LEDs for the overall electrical circuit shown in FIG. **53**B. AC lead lines **642** and **646** and DC positive lead line **648** and DC negative lead line **650** are connected to integral electronics **602**A and **602**B. Single parallel LED string **636** including a single resistor **638** is connected to DC positive lead line **648** on one side, and to LED positive lead line **656** or the anode side of the first high-brightness SMD LED **606**A in the LED string **636** on the other side. The cathode side of the first high-brightness SMD LED **606**A is connected to LED negative lead line **658** and to adjacent LED positive lead line **656** or the anode side of the second LED **606**A. The cathode side of the second LED **606**A is connected to LED negative lead line **658** and to adjacent LED positive lead line **656** or the anode side of the third high-brightness SMD LED **606**A. The cathode side of the third high-brightness SMD LED **606**A is connected to LED negative lead line

658 and to adjacent LED positive lead line 656 or the anode side of the fourth high-brightness SMD LED 606A. The cathode side of the fourth high-brightness SMD LED 606A is then connected to LED negative lead line 658 and to DC negative lead line 650 directly. AC lead lines 642 and 646 simply pass through LED array circuitry 628.

The term high-brightness as describing LEDs herein is a relative term. In general, for the purposes of the present application, high-brightness LEDs refer to LEDs that offer the highest luminous flux outputs. Luminous flux is defined as lumens per watt. For example, Lumileds Luxeon high-brightness LEDs produce the highest luminous flux outputs at the present time. Luxeon 5-watt high-brightness LEDs offer extreme luminous density with lumens per package that is four times the output of an earlier Luxeon 1-watt LED and up to 50 times the output of earlier discrete 5 mm LED packages. Gelcore is soon to offer an equivalent and competitive product.

With the new high-brightness LEDs in mind, FIG. 53F shows a single high-brightness LED 606A positioned on an electrical string in what is defined herein as an electrical series arrangement with single a high-brightness LED 606A for the overall electrical circuit shown in FIG. 53. The single high-brightness LED 606A fulfills a particular lighting requirement formerly fulfilled by a fluorescent lamp.

Likewise, FIG. 53G shows two high-brightness LEDs 606A in electrical parallel arrangement with one high-brightness LED 606A positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. 53. The two high-brightness LEDs 606A fulfill a particular lighting requirement formerly fulfilled by a fluorescent lamp.

As shown in the schematic electrical and structural representations of FIG. 54, LED array circuit boards 594A and 594B of LED array 600 is positioned between integral electronics 602A and 602B that in turn are electrically connected to ballast circuitry 624 by single contact pins 582A and 582B, respectively. Single contact pins 582A and 582B are mounted to and protrude out from base end caps 592A and 592B, respectively, for electrical connection to integral electronics 602A and 602B. Contact pins 582A and 582B are soldered directly to integral electronics 602A and 602B, respectively mounted onto LED array circuit boards 594A and 594B. In particular, pin inner extension 582D of connecting pin 582A is electrically connected by being soldered directly to the integral electronics 602A. Similarly, being soldered directly to integral electronics 602B electrically connects pin inner extension 582F of connecting pin 582B. It should be noted that someone skilled in the art could use other means of electrically connecting the contact pins 582A and 582B to LED array circuit boards 594A and 594B. These techniques include the use of connectors and headers, plugs and sockets, receptacles, etc. among many others. Integral electronics 602A is in electrical connection with LED array circuit boards 594A and 594B and LED circuitry 626 mounted thereon as shown in FIG. 53. Likewise, integral electronics 602B is in electrical connection with LED array circuit boards 594A and 594B and LED circuitry 626 mounted thereon.

As seen in FIG. 55, a schematic of integral electronics circuitry 640 is mounted on integral electronics 602A. Integral electronics circuit 640 is also shown in FIG. 53 as part of the schematically shown LED circuitry 626. Integral electronics circuitry 640 is in electrical contact with ballast socket contact 580A, which is shown as providing AC voltage. Integral electronics circuitry 640 includes bridge rectifier 630, voltage surge absorber 632, and fuse 634. Bridge rectifier 630 converts AC voltage to DC voltage. Voltage surge absorber 632 limits the high voltage to a workable voltage within the design voltage capacity of 5 mm LEDs 604 or SMD LEDs 606. The DC voltage circuits indicated as plus (+) and minus (−) and indicated as DC leads 648 and 650 lead to and from LED array 600 (not shown). It is noted that FIG. 55 indicates the presence of AC voltage by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies 576 as mentioned earlier herein. In such a case DC voltage would be supplied to LED lighting element array 600 even in the presence of bridge rectifier 630. It is particularly noted that in such a case, voltage surge absorber 632 would remain operative.

FIG. 56 shows a further schematic of integral electronics 602B that includes integral electronics circuitry 644 mounted on integral electronics 602B with voltage protected AC lead line 646 extending from LED array 600 (not shown) and by extension from integral electronics circuitry 640. The AC lead line 646 having passed through voltage surge absorber 632 is a voltage protected circuit and is in electrical contact with ballast socket contact 580B. Integral circuitry 644 includes DC positive and DC negative lead lines 648 and 650, respectively, from LED array circuitry 628 to positive and negative DC terminals 652 and 654, respectively, mounted on integral electronics 602B. Integral circuitry 644 further includes AC lead line 646 from LED array circuitry 628 to ballast socket contact 580B.

FIGS. 55 and 56 show the lead lines going into and out of LED circuitry 626 respectively. The lead lines include AC lead lines 642 and 646, positive DC voltage 648, DC negative voltage 650, LED positive lead line 656, and LED negative lead line 658. The AC lead lines 642 and 646 are basically feeding through LED circuitry 626, while the positive DC voltage lead line 648 and negative DC voltage lead line 650 are used primarily to power the LED array 600. DC positive lead line 648 is the same as LED positive lead line 656 and DC negative lead line 650 is the same as LED negative lead line 658. LED array circuitry 628 therefore consists of all electrical components and internal wiring and connections required to provide proper operating voltages and currents to 5 mm LEDs 604 or to SMD LEDs 606 connected in parallel, series, or any combinations of the two.

FIGS. 57 and 57A show a close-up of elongated linear housing 584 with details of cooling vent holes 589A and 589B located on opposite ends of elongated linear housing 584 in both side and cross-sectional views respectively.

FIG. 58 shows an isolated view of one of the base end caps, namely, base end cap 592A, which is the same as base end cap 592B, mutatis mutandis. Single-pin contact 582A extends directly through the center of base end cap 592A in the longitudinal direction in alignment with center line 588 of tubular wall 586. Single-pin 582A is also shown in FIG. 50 where single-pin contact 582A is mounted into ballast socket contact 580A. Single-pin contact 582A also includes pin extension 582D that is outwardly positioned from base end cap 592A in the direction towards tubular wall 586. Base end cap 592A is a solid cylinder in configuration as seen in FIGS. 58 and 58A and forms an outer cylindrical wall 660 that is concentric with center line 588 of tubular wall 586 and has opposed flat end walls 662A and 662B that are perpendicular to center line 588. Two cylindrical parallel vent holes 664A and 664B are defined between flat end walls 662A and 662B spaced directly above and below and lateral to single-pin contact 582A. Single-pin contact 582A includes external side pin extension 582C and internal side pin extension 582D that each extend outwardly positioned from opposed flat end walls 662A and 662B, respectively, for electrical connection with ballast socket contact 580A and with integral electronics

602A. Analogous external and internal pin extensions for contact pin 582B likewise exist for electrical connections with ballast socket contact 580B and with integral electronics 602B.

As also seen in FIG. 58A, base end cap 592A defines an outer circular slot 666 that is concentric with center line 588 of tubular wall 586 and concentric with and aligned proximate to circular wall 660. Circular slot 666 is spaced from cylindrical wall 660 at a convenient distance. Circular slot 666 is of such a width and circular end 590A of tubular wall 586 is of such a thickness that circular end 590A is fitted into circular slot 666 and is thus supported by circular slot 666. Base end cap 592B (not shown in detail) defines another circular slot (not shown) analogous to circular slot 666 that is likewise concentric with center line 588 of tubular wall 586 so that circular end 590B of tubular wall 586 can be fitted into the analogous circular slot of base end cap 592B wherein circular end 590B is also supported. In this manner tubular wall 586 is mounted to base end caps 592A and 592B.

As also seen in FIG. 58A, base end cap 592A defines inner rectangular slots 668A and 668B that are parallel to each other, but perpendicular with center line 588 of tubular wall 586 and spaced inward from circular slot 666. Rectangular slots 668A and 668B are spaced from circular slot 666 at such a distance that would be occupied by SMD LEDs 606 mounted to LED array circuit boards 594A and 594B within tubular wall 586. Rectangular slots 668A and 668B are of such a width and both circuit board short rectangular edge ends 595A of LED array circuit boards 594A and 594B are of such a thickness that both circuit board short rectangular edge ends 595A are fitted into rectangular slots 668A and 668B, and are thus supported by rectangular slots 668A and 668B. Base end cap 592B (not shown) defines another two rectangular slots analogous to rectangular slots 668A and 668B that are likewise parallel to each other, and also are perpendicular with center line 588 of tubular wall 586 so that both circuit board short rectangular edge ends 595B of LED array circuit boards 594A and 594B can be fitted into the analogous rectangular slots 668A and 668B of base end cap 592B wherein both circuit board short rectangular edge ends 595B are also supported. In this manner LED array circuit boards 594A and 594B are mounted to base end caps 592A and 592B.

Circular ends 590A and 590B of tubular wall 586 and also both circuit board short rectangular edge ends 595A and 595B of LED array circuit boards 594A and 594B can be further secured to base end caps 592A and 592B preferably by gluing in a manner known in the art. Other securing methods known in the art of attaching such as cross-pins or snaps can be used. Circular ends 590A and 590B of tubular wall 586 are optionally press fitted to circular slot 666 of base end cap 592A and the analogous circular slot 666 of base end cap 592B.

FIG. 59 is a sectional view of an alternate LED lamp 670 mounted in tubular wall 676 that is a version of LED lamp 570 as shown in FIG. 52. The sectional view of LED lamp 670 now shows a single SMD LED 606 of LED lamp 670 being positioned at the bottom area 674 of tubular wall 676. LED array circuitry 628 previously described with reference to LED lamp 570 would be the same for LED lamp 670. That is, all thirty SMD LEDs 606 of LED strings 636 of both of the LED arrays 600 of LED lamp 570 would be the same for LED lamp 670, except that now a total of only fifteen SMD LEDs 606 would comprise LED lamp 670 with the fifteen SMD LEDs 606 positioned at the bottom area 674 of tubular wall 676. SMD LEDs 606 are mounted onto the circuit layer 598A, which is separated from metal base layer 598C by dielectric layer 598B of either LED array circuit boards 594A or 594B. Metal base layer 598C is attached to a heat sink 596 separated by thermally conductive grease 597 positioned at the top area 672 of tubular wall 676. Only one of the two LED array circuit boards 594A or 594B is used here to provide illumination on a downward projection only. The reduction to fifteen SMD LEDs 606 of LED lamp 670 from the combined total of thirty SMD LEDs 606 of LED lamp 570 from the two LED array circuit boards 594A and 594B would result in a fifty percent reduction of power demand with an illumination result that would be satisfactory under certain circumstances. Stiffening of LED array circuit boards 594A and 594B for LED lamp 670 is accomplished by single rectangular slots 668A and 668B for both circuit board short edge ends 595A and 595B located in base end caps 592A and 592B, or optionally a vertical stiffening member 678 shown in phantom line that is positioned at the upper area of space 672 between heat sink 596 and the inner side of tubular wall 676 that can extend the length of tubular wall 676 and LED array circuit boards 594A and 594B.

LED lamp 670 as described above will work for both AC and DC voltage outputs from an existing fluorescent ballast assembly 576. In summary, LED array 600 will ultimately be powered by DC voltage. If existing fluorescent ballast 576 operates with an AC output, bridge rectifier 630 converts the AC voltage to DC voltage. Likewise, if existing fluorescent ballast 576 operates with a DC voltage, the DC voltage remains a DC voltage even after passing through bridge rectifier 630.

Another embodiment of a retrofitted LED lamp is shown in FIGS. 60-69. FIG. 60 shows an LED lamp 680 retrofitted to an existing elongated fluorescent fixture 682 mounted to a ceiling 684. A rapid start type ballast assembly 686 including a starter 686A is positioned within the upper portion of fixture 682. Fixture 682 further includes a pair of fixture mounting portions 688A and 688B extending downwardly from the ends of fixture 682 that include ballast electrical contacts shown in FIG. 60A as ballast double contact sockets 690A and 692A and ballast opposed double contact sockets 690B and 692B that are in electrical contact with rapid start ballast assembly 686. Ballast double contact sockets 690A, 692A and 690B, 692B are each double contact sockets in accordance with the electrical operational requirement of a rapid start type ballast. As also seen in FIG. 60A, LED lamp 680 includes bi-pin electrical contacts 694A and 696A that are positioned in ballast double contact sockets 690A and 692A, respectively. LED lamp 680 likewise includes opposed bi-pin electrical contacts 694B and 696B that are positioned in ballast double contact sockets 690B and 692B, respectively. In this manner, LED lamp 680 is in electrical contact with rapid start ballast assembly 686.

As shown in the disassembled mode of FIG. 61 and also indicated schematically in FIG. 63, LED lamp 680 includes an elongated tubular housing 698 particularly configured as a tubular wall 700 circular in cross-section taken transverse to a center line 702. Tubular wall 700 is made of a translucent material such as plastic or glass and preferably has a diffused coating. Tubular wall 700 has opposed tubular wall circular ends 704A and 704B with cooling vent holes 703A and 703B juxtaposed to tubular wall circular ends 704A and 704B. Optional electric micro fans (not shown) can be used to provide forced air-cooling across the electronic components contained within elongated tubular housing 698. The optional cooling micro fans can be arranged in a push or pull configuration. LED lamp 680 further includes a pair of opposed lamp base end caps 706A and 706B mounted to bi-pin electrical contacts 694A, 696A and 694B, 696B, respectively, for insertion in ballast electrical socket contacts 690A, 692A and

690B, 692B, respectively, in electrical power connection to rapid start ballast assembly 686 so as to provide power to LED lamp 680. Tubular wall 700 is mounted to opposed base end caps 706A and 706B at tubular wall circular ends 704A and 704B, respectively, in the assembled mode as shown in FIG. 60. LED lamp 680 also includes electrical LED array circuit boards 708A and 708B that are rectangular in configuration and each has opposed circuit board short edge ends 710A and 710B, respectively.

As seen in FIG. 62, circuit boards 708A and 708B are preferably manufactured each from a Metal Core Printed Circuit Boards (MCPCB) consisting of a circuit layer 716A, a dielectric layer 716B, and a metal base layer 716C. Circuit layer 716A is the actual printed circuit foil containing the electrical connections including pads, traces, vias, etc. Electronic integrated circuit components get mounted to circuit layer 716A. Dielectric layer 716B offers electrical isolation with minimum thermal resistance and bonds the circuit metal layer 716A to the metal base layer 716C. Metal base layer 716C is often aluminum, but other metals such as copper may also be used. The most widely used base material thickness is 0.04" (1.0 mm) in aluminum, although other thicknesses are available. The metal base layer 716C is further attached to heat sink 712 with thermally conductive grease 714 or other material to extract heat away from the LEDs mounted to circuit layer 716A. MCPCBs are designed for attachment to heat sinks using thermal epoxy, Sil-pads, or heat conductive grease 714 between metal base layer 716C and heat sink 712. The metal substrate LED array circuit boards 708A and 708B are each screwed down to heat sink 712 using screws (not shown) or other mounting hardware. The Berquist Company markets their version of a MCPCB called Thermal Clad (T-Clad). Although this embodiment describes a generally rectangular configuration for circuit boards 708A and 708B, it can be appreciated by someone skilled in the art to form circuit boards 708A and 708B into curved shapes or combinations of rectangular and curved portions.

LED array circuit boards 708A and 708B are positioned within tubular wall 700 and supported by opposed lamp base end caps 706A and 706B. In particular, LED array circuit boards 708A and 708B each have opposed circuit board short edge ends 710A and 710B that are positioned from tubular wall ends 704A and 704B, respectively. As mentioned earlier, LED array circuit boards 708A and 708B each have a circuit layer 716A, a dielectric layer 716B, and a metal base layer 716C respectively with heat sink 712 sandwiched between metal base layers 716C between tubular wall circular ends 704A and 704B, and circuit layers 716A being spaced away from tubular wall 700. LED array circuit boards 708A and 708B are shown in FIG. 61 and indicated schematically in FIG. 64. LED lamp 680 further includes an LED array 718 comprising a total of thirty Lumileds Luxeon SMD LED emitters 724 mounted to both LED array circuit boards 708A and 708B. Integral electronics 602A is positioned on one end of LED array circuit boards 708A and 708B in close proximity to base end cap 706A, and integral electronics 602B is positioned on the opposite end of LED array circuit boards 708A and 708B in close proximity to base end cap 706B. As seen in FIG. 61 and FIG. 64, integral electronics 602A is connected to LED array circuit boards 708A and 708B and also to integral electronics 602B. Integral electronics 602A and 602B are identical in both LED array circuit boards 708A and 708B.

Integral electronics 720A and 720B can each be located on a separate circuit board (not shown) that is physically detached from the main LED array circuit boards 708A and 708B, but is electrically connected together by means known in the art including headers and connectors, plug and socket receptacles, hard wiring, etc. The fluorescent retrofit LED lamp of the present invention will work with existing and new fluorescent lighting fixtures that contain ballasts that allow for the dimming of conventional fluorescent lamp tubes. For the majority of cases where the ballast cannot dim, special electronics added to integral electronics circuitry 746A and 746B can make existing and new non-dimming fluorescent lighting fixtures now dimmable. Control data can be applied from a remote control center via Radio Frequency (RF) or Infra Red (IR) wireless carrier communications or by Power Line Carrier (PLC) wired communication means. Optional motion control sensors and related control electronic circuitry can also be supplied where now groups of fluorescent lighting fixtures using the fluorescent retrofit LED lamps of the present invention can be dimmed and/or turned off completely at random or programmed intervals at certain times of the day to conserve electrical energy use.

The sectional view of FIG. 62 comprises a single SMD LED 724 from each LED array 718 in LED array circuit boards 708A and 708B shown in FIG. 63. SMD LED 724 is representative of one of the fifteen SMD LEDs 724 connected in series in each LED array 718 as shown in FIG. 63. Each SMD LED 724 includes an LED light emitting lens portion 726, an LED body portion 728, and an LED base portion 730. A cylindrical space 732 is defined between circuit layer 716A of each LED array circuit board 708A and 708B and cylindrical tubular wall 700. Each SMD LED 724 is positioned in space 732 as seen in the detailed view of FIG. 62A. LED lens portion 726 is in juxtaposition with the inner surface of tubular wall 700, and LED base portion 730 is mounted to metal base layer 716C of LED array circuit boards 708A and 708B. A detailed view of a single SMD LED 724 shows a rigid LED electrical lead 734 extending from LED base portion 730 to LED array circuit boards 708A and 708B for electrical connection therewith. Lead 734 is secured to LED array circuit boards 708A and 708B by solder 736. An LED center line 738 is aligned transverse to center line 702 of tubular wall 700. As shown in the sectional view of FIG. 62, light is emitted through tubular wall 700 by the two SMD LEDs 724 in substantially equal strength about the entire circumference of tubular wall 700. Projection of this arrangement is such that all fifteen SMD LEDs 724 are likewise arranged to emit light rays in substantially equal strength the entire length of tubular wall 700 in substantially equal strength about the entire 360-degree circumference of tubular wall 700. The distance between LED center line 738 and LED circuit boards 708A and 708B is the shortest that is geometrically possible with heat sink 712 sandwiched between LED array circuit boards 708A and 708B. In FIG. 62A, LED center line 738 is perpendicular to tubular wall center line 702. FIG. 62A indicates a tangential plane 740 relative to the cylindrical inner surface of tubular wall 700 in phantom line at the apex of LED lens portion 726 that is perpendicular to LED center line 738 so that all SMD LEDs 724 emit light through tubular wall 700 in a direction perpendicular to tangential plane 740, so that maximum illumination is obtained from all SMD LEDs 724.

FIG. 63 shows the total LED electrical circuitry for LED lamp 680. The LED electrical circuitry for both LED array circuit boards 708A and 708B are identically described herein, mutatis mutandis. The total LED circuitry comprises two major circuit assemblies, namely, existing ballast circuitry 742, which includes starter circuit 742A, and LED circuitry 744. LED circuitry 744 includes integral electronics circuitry 746A and 746B, which are associated with integral

electronics **720**A and **720**B. LED circuitry **744** also includes an LED array circuitry **744**A and an LED array voltage protection circuit **744**B.

When electrical power, normally 120 volt VAC or 240 VAC at 50 or 60 Hz is applied to rapid start ballast assembly **686**, existing ballast circuitry **742** provides an AC or DC voltage with a fixed current limit across ballast socket electrical contacts **692**A and **692**B, which is conducted through LED circuitry **744** by way of LED circuit bi-pin electrical contacts **696**A and **696**B, respectively, (or in the event of the contacts being reversed, by way of LED circuit bi-pin contacts **694**A and **694**B) to the input of bridge rectifiers **748**A and **748**B, respectively.

Rapid start ballast assembly **686** limits the current going into LED lamp **680**. Such limitation is ideal for the present embodiment of the inventive LED lamp **680** because LEDs in general are current driven devices and are independent of the driving voltage, that is, the driving voltage does not affect LEDs. The actual number of SMD LEDs **724** will vary in accordance with the actual rapid start ballast assembly **686** used. In the example of the embodiment of LED lamp **680**, rapid start ballast assembly **686** provides a maximum current limit of 300 mA, but higher current ratings are also available.

Voltage surge absorbers **750**A, **750**B, **750**C and **750**D are positioned on LED voltage protection circuit **744**B for LED array circuitry **744**A in electrical association with integral electronics control circuitry **746**A and **746**B. Bridge rectifiers **748**A and **748**B are connected to the anode and cathode end buses, respective of LED circuitry **744** and provide a positive voltage V+ and a negative voltage V−, respectively as is also shown in FIGS. **65** and **66**. FIGS. **65** and **66** also show schematic details of integral electronics circuitry **746**A and **746**B. As seen in FIG. **65** an optional resettable fuse **752** is integrated with integral electronics circuitry **746**A. Resettable fuse **752** provides current protection for LED array circuitry **744**A. Resettable fuse **752** is normally closed and will open and de-energize LED array circuitry **744**A in the event the current exceeds the current allowed. The value for resettable fuse **752** is equal to or is lower than the maximum current limit of rapid start ballast assembly **686**. Resettable fuse **752** will reset automatically after a cool down period.

When rapid start ballast assembly **686** is first energized, starter **686**A may close creating a low impedance path from bi-pin electrical contact **694**A to bi-pin electrical contact **694**B, which is normally used to briefly heat the filaments in a fluorescent lamp in order to help the establishment of conductive phosphor gas. Such electrical action is unnecessary for LED lamp **680**, and for that reason such electrical connection is disconnected from LED circuitry **744** by way of the biasing of bridge rectifiers **748**A and **748**B.

LED array circuitry **744**A includes a single LED string **754** with all SMD LEDs **724** within LED string **754** being electrically wired in series. Each SMD LED **724** is preferably positioned and arranged equidistant from one another in LED string **754**. Each LED array circuitry **744**A includes fifteen SMD LEDs **724** electrically mounted in series within LED string **754** for a total of fifteen SMD LEDs **724** that constitute each LED array **718** in LED array circuit boards **708**A and **708**B. SMD LEDs **724** are positioned in equidistant relationship with one another and extend substantially the length of tubular wall **700**, that is, generally between tubular wall ends **704**A and **704**B. As shown in FIG. **63**, LED string **754** includes a resistor **756** in respective series alignment with LED string **754** at the current anode input. The current limiting resistor **756** is purely optional, because the existing fluorescent ballast used here is already a current limiting device. The resistor **756** then serves as secondary protection devices. A higher number of individual SMD LEDs **724** can be connected in series at each LED string **754**. The maximum number of SMD LEDs **724** being configured around the circumference of the 1.5-inch diameter of tubular wall **700** in the particular example herein of LED lamp **680** is two. Each SMD LED **724** is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When rapid start ballast **686** is energized, positive voltage that is applied through resistor **756** to the anode end of LED string **754**, and the negative voltage that is applied to the cathode end of LED string **754** will forward bias SMD LEDs **724** connected within LED string **754** and cause SMD LEDs **724** to turn on and emit light.

Rapid start ballast assembly **686** regulates the electrical current through SMD LEDs **724** to the correct value of 300 mA for each SMD LED **724**. Each LED string **754** sees the total current applied to LED array circuitry **744**A. Those skilled in the art will appreciate that different ballasts provide different current outputs to drive LEDs that require higher operating currents. To provide additional current to drive the newer high-flux LEDs that require higher currents to operate, the electronic ballast outputs can be tied together in parallel to "overdrive" the LED retrofit lamp of the present invention.

The total number of LEDs in series within each LED string **754** is arbitrary since each SMD LED **724** in each LED string **754** will see the same current. The maximum number of LEDs is dependent on the maximum power capacity of the ballast. Again in this example, fifteen SMD LEDs **724** are shown connected in each series within each LED string **754**. Each of the fifteen SMD LEDs **724** connected in series within each LED string **754** sees this 300 mA. In accordance with the type of ballast assembly **686** used, when rapid start ballast assembly **686** is first energized, a high voltage may be applied momentarily across ballast socket contacts **692**A and **692**B, which conducts to bi-pin contacts **696**A and **696**B (or **694**A and **694**B). This is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but is unnecessary for this circuit and is absorbed by voltage surge absorbers **750**A, **750**B, **750**C, and **750**D to limit the high voltage to an acceptable level for the circuit.

As can be seen from FIG. **63**A, there can be more than fifteen 5 mm LEDs **722** connected in series within each string **754**A-**754**O. There are twenty 5 mm LEDs **722** in this example, but there can be more 5 mm LEDs **722** connected in series within each string **754**A-**754**O. LED array circuitry **744**A includes fifteen electrical strings **754** individually designated as strings **754**A, **754**B, **754**C, **754**D, **754**E, **754**F, **754**G, **754**H, **754**I, **754**J, **754**K, **754**L, **754**M, **754**N and **754**O all in parallel relationship with all 5 mm LEDs **722** within each string **754**A-**754**O being electrically wired in series. Parallel strings **754** are so positioned and arranged that each of the fifteen strings **754** is equidistant from one another. LED array circuitry **744**A includes twenty 5 mm LEDs **722** electrically mounted in series within each of the fifteen parallel strings of 5 mm LED strings **754**A-**754**O for a total of three-hundred 5 mm LEDs **722** that constitute LED array **718**. 5 mm LEDs **722** are positioned in equidistant relationship with one another and extend generally the length of tubular wall **700**, that is, generally between tubular wall ends **704**A and **704**B. As shown in FIG. **63**A, each of strings **754**A-**754**O includes an optional resistor **756** designated individually as resistors **756**A, **756**B, **756**C, **756**D, **756**E, **756**F, **756**G, **756**H, **756**I, **756**J, **756**K, **756**L, **756**M, **756**N, and **756**O in respective series alignment with strings **754**A-**754**O at the current input for a total of fifteen resistors **756**. Again, a higher number of individual 5 mm LEDs **722** can be connected in series within each LED string **754**A-**754**O. Each 5 mm LED **722** is con-

figured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When LED array circuitry **744**A is energized, the positive voltage that is applied through resistors **756**A-**756**O to the anode end of 5 mm LED strings **754**A-**754**O and the negative voltage that is applied to the cathode end of 5 mm LED strings **754**A-**754**O will forward bias 5 mm LEDs **722** connected to LED strings **754**A-**754**O and cause 5 mm LEDs **722** to turn on and emit light.

Rapid start ballast assembly **686** regulates the electrical current through 5 mm LEDs **722** to the correct value of 20 mA for each 5 mm LED **722**. The fifteen 5 mm LED strings **754**A-**754**O equally divide the total current applied to LED array circuitry **744**A. Those skilled in the art will appreciate that different ballasts provide different current outputs.

If the forward drive current for each 5 mm LEDs **722** is known, then the output current of rapid start ballast assembly **686** divided by the forward drive current gives the exact number of parallel strings of 5 mm LEDs **722** in the particular LED array, here LED array **718**. The total number of 5 mm LEDs **722** in series within each LED string **754**A-**754**O is arbitrary since each 5 mm LED **722** in each LED string **754**A-**754**O will see the same current. Again in this example, twenty 5 mm LEDs **722** are shown connected in series within each LED string **754**. Rapid start ballast assembly **686** provides 300 mA of current, which when divided by the fifteen strings **754** of twenty 5 mm LEDs **722** per LED string **754** gives 20 mA per LED string **754**. Each of the twenty 5 mm LEDs **722** connected in series within each LED string **754** sees this 20 mA. In accordance with the type of ballast assembly **686** used, when rapid start ballast assembly **686** is first energized, a high voltage may be applied momentarily across ballast socket contacts **690**A, **692**A and **690**B, **692**B, which conduct to pin contacts **694**A, **696**A and **694**B, **696**B. Such high voltage is normally used to help ignite a fluorescent tube and establish conductive phosphor gas, but high voltage is unnecessary for LED array circuitry **744**A and voltage surge absorbers **750**A, **750**B, **750**C, and **750**D suppress the voltage applied by ballast circuitry **742**, so that the initial high voltage supplied is limited to an acceptable level for the circuit.

FIG. **63**B shows another alternate arrangement of LED array circuitry **744**A. LED array circuitry **744**A consists of a single LED string **754** of SMD LEDs **724** including for exposition purposes only, forty SMD LEDs **724** all electrically connected in series. Positive voltage V+ is connected to optional resettable fuse **752**, which in turn is connected to one side of current limiting resistor **756**. The anode of the first SMD LED in the series string is then connected to the other end of resistor **756**. A number other than forty SMD LEDs **724** can be connected within the series LED string **754** to fill up the entire length of the tubular wall of the present invention. The cathode of the first SMD LED **724** in the series LED string **754** is connected to the anode of the second SMD LED **724**, the cathode of the second SMD LED **724** in the series LED string **754** is then connected to the anode of the third SMD LED **724**, and so forth. The cathode of the last SMD LED **724** in the series LED string **754** is likewise connected to ground or the negative potential V−. The individual SMD LEDs **724** in the single series LED string **754** are so positioned and arranged such that each of the forty LEDs is spaced equidistant from one another substantially filling the entire length of the tubular wall **700**. SMD LEDs **724** are positioned in equidistant relationship with one another and extend substantially the length of tubular wall **700**, that is, generally between tubular wall ends **704**A and **704**B. As shown in FIG. **63**B, the single series LED string **754** includes an optional resistor **756** in respective series alignment with single series LED string **754** at the current input. Each SMD LED **724** is configured with the anode towards the positive voltage V+ and the cathode towards the negative voltage V−. When LED array circuitry **744**A is energized, the positive voltage that is applied through resistor **756** to the anode end of single series LED string **754** and the negative voltage that is applied to the cathode end of single series LED string **754** will forward bias SMD LEDs **724** connected in series within single series LED string **754**, and cause SMD LEDs **724** to turn on and emit light.

The present invention works ideally with the brighter high flux white LEDs available from Lumileds and Nichia in the SMD packages. Since these new devices require more current to drive them and run on low voltages, the high current available from existing fluorescent ballast outputs with current outputs of 300 mA and higher, along with their characteristically higher voltage outputs provide the perfect match for the present invention. The high-brightness SMD LEDs **724**A have to be connected in series, so that each high-brightness SMD LED **724**A within the same single LED string **754** will see the same current and therefore output the same brightness. The total voltage required by all the high-brightness SMD LEDs **724**A within the same single LED string **754** is equal to the sum of all the individual voltage drops across each high-brightness SMD LED **724**A and should be less than the maximum voltage output of rapid start ballast assembly **686**.

FIG. **63**C shows a simplified arrangement of the LED array circuitry **744**A of SMD LEDs **724** for the overall electrical circuit shown in FIG. **63**. AC lead lines **766**A, **766**B and **768**A, **768**B and DC positive lead lines **770**A, **770**B and DC negative lead lines **772**A, **772**B are connected to integral electronics **720**A and **720**B. Four parallel LED strings **754** each including a resistor **756** are each connected to DC positive lead lines **770**A, **770**B on one side, and to LED positive lead line **770** or the anode side of each SMD LED **724** and on the other side. The cathode side of each SMD LED **724** is then connected to LED negative lead line **772** and to DC negative lead lines **772**A, **772**B directly. AC lead lines **766**A, **766**B and **768**A, **768**B simply pass through LED array circuitry **744**A.

FIG. **63**D shows a simplified arrangement of the LED array circuitry **744**A of 5 mm LEDs **722** for the overall electrical circuit shown in FIG. **63**A. AC lead lines **766**A, **766**B and **768**A, **768**B and DC positive lead lines **770**A, **770**B and DC negative lead lines **772**A, **772**B are connected to integral electronics boards **720**A and **720**B. Two parallel LED strings **754** each including a single resistor **756** are each connected to DC positive lead lines **770**A, **770**B on one side, and to LED positive lead line **770** or the anode side of the first 5 mm LED **722** in each LED string **754** on the other side. The cathode side of the first 5 mm LED **722** is connected to LED negative lead line **772** and to adjacent LED positive lead line **770** or the anode side of the second 5 mm LED **722** in the same LED string **754**. The cathode side of the second 5 mm LED **722** is then connected to LED negative lead line **772** and to DC negative lead lines **772**A, **772**B directly in the same LED string **754**. AC lead lines **766**A, **766**B and **768**A, **768**B simply pass through LED array circuitry **744**A.

FIG. **63**E shows a simplified arrangement of the LED array circuitry **744**A of SMD LEDs **724** for the overall LED array electrical circuit shown in FIG. **63**B. AC lead lines **766**A, **766**B and **768**A, **768**B and DC positive lead lines **770**A, **770**B and DC negative lead lines **772**A, **772**B are connected to integral electronics boards **720**A and **720**B. Single parallel LED string **754** including a single resistor **756** is connected to DC positive lead lines **770**A, **770**B on one side, and to LED positive lead line **770** on the anode side of the first SMD LED **724** in the LED string **754** on the other side. The cathode side

of the first SMD LED **724** is connected to LED negative lead line **772** and to adjacent LED positive lead line **770** or the anode side of the second SMD LED **724**. The cathode side of the second SMD LED **724** is connected to LED negative lead line **772** and to adjacent LED positive lead line **770** or the anode side of the third SMD LED **724**. The cathode side of the third SMD LED **724** is connected to LED negative lead line **772** and to adjacent LED positive lead line **770** or the anode side of the fourth SMD LED **724**. The cathode side of the fourth SMD LED **724** is then connected to LED negative lead line **772** and to DC negative lead lines **772**A, **772**B directly. AC lead lines **766**A, **766**B and **768**A, **768**B simply pass through LED array circuitry **744**A.

The term high-brightness as describing LEDs herein is a relative term. In general, for the purposes of the present application, high-brightness LEDs refer to LEDs that offer the highest luminous flux outputs. Luminous flux is defined as lumens per watt. For example, Lumileds Luxeon high-brightness LEDs produce the highest luminous flux outputs at the present time. Luxeon 5-watt high-brightness LEDs offer extreme luminous density with lumens per package that is four times the output of an earlier Luxeon 1-watt LED and up to 50 times the output of earlier discrete 5 mm LED packages. Luxeon LED emitters are also available in 3-watt packages with Gelcore soon to offer equivalent and competitive products.

With the new high-brightness SMD LEDs **724**A in mind, FIG. **63**F shows a single high-brightness SMD LED **724**A positioned on an electrical string in what is defined herein as an electrical series arrangement for the overall electrical circuit shown in FIG. **63** and also analogous to FIG. **63**B. The single high-brightness SMD LED **724**A fulfills a particular lighting requirement formerly fulfilled by a fluorescent lamp.

Likewise, FIG. **63**G shows two high-brightness SMD LEDs **724**A in electrical parallel arrangement with one high-brightness SMD LED **724**A positioned on each of the two parallel strings for the overall electrical circuit shown in FIG. **63** and also analogous to the electrical circuit shown in FIG. **63**A. The two high-brightness SMD LEDs **724**A fulfill a particular lighting requirement formerly fulfilled by a fluorescent lamp.

As shown in the schematic electrical and structural representations of FIG. **64**, LED array circuit boards **708**A and **708**B for LED array **718**, which have mounted thereon LED array circuitry **744**A is positioned between integral electronics **720**A and **720**B that in turn are electrically connected to ballast assembly circuitry **742** by bi-pin electrical contacts **694**A, **696**A and **694**B, **696**B, respectively, which are then mounted to base end caps **706**A and **706**B, respectively. Bi-pin contact **694**A includes an external extension **758**A that protrudes externally outwardly from base end cap **706**A for electrical connection with ballast socket contact **690**A and an internal extension **758**B that protrudes inwardly from base respect **706**A for electrical connection to integral electronics circuit boards **720**A. Bi-pin contact. **696**A includes an external extension **760**A that protrudes externally outwardly from base end cap **706**A for electrical connection with ballast socket contact **692**A and an internal extension **760**B that protrudes inwardly from base end cap **706**A for electrical connection to integral electronics circuit boards **720**A. Bi-pin contact **694**B includes an external extension **762**A that protrudes externally outwardly from base end cap **706**B for electrical connection with ballast socket contact **690**B and an internal extension **762**B that protrudes inwardly from base end cap **706**B for electrical connection to integral electronics circuit board **720**B. Bi-pin contact **696**B includes an external extension **764**A that protrudes externally outwardly from base end cap **706**B for electrical connection with ballast socket contact **692**B and an internal extension **764**B that protrudes inwardly from base end cap **706**B for electrical connection to integral electronics circuit board **720**B. Bi-pin contacts **694**A, **696**A, **694**B, and **696**B are soldered directly to integral electronics **720**A and **720**B, respectively mounted onto LED array circuit boards **708**A and **708**B. In particular, bin-pin contact extensions **758**A and **760**A are associated with bi-pin contacts **694**A and **696**A, respectively, and bi-pin contact extensions **762**A and **764**A are associated with bi-pin contacts **694**B and **696**B, respectively. Being soldered directly to integral electronics circuit board **720**A electrically connects bi-pin contact extensions **758**B and **760**B. Similarly, being soldered directly to integral electronics circuit board **720**B electrically connects bi-pin contact extensions **762**B and **764**B. It should be noted that someone skilled in the art could use other means of electrically connecting the contact pins **694**A, **696**A and **694**B, **696**B to LED array circuit boards **708**A and **708**B. These techniques include the use of connectors and headers, plugs and connectors, receptacles, etc. among may others.

FIG. **65** shows a schematic of integral electronics circuit **746**A mounted on integral electronics **720**A. Integral electronics circuit **746**A is also indicated in part in FIG. **63** as connected to LED array circuitry **744**A. Integral electronics circuit **746**A is in electrical contact with bi-pin contacts **694**A, **696**A, which are shown as providing either AC or DC voltage. Integral electronics circuit **746**A includes bridge rectifier **748**A, voltage surge absorbers **750**A and **750**C, and resettable fuse **752**. Integral electronic circuit **746**A leads to or from LED array circuitry **744**A. It is noted that FIG. **65** indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies **686** as mentioned earlier herein. In such a case DC voltage would be supplied to LED array **718** even in the presence of bridge rectifier **748**A. It is particularly noted that in such a case, voltage surge absorbers **750**A and **750**C would remain operative. AC lead lines **766**A and **768**A are in a power connection with ballast assembly **686**. DC lead lines **770**A and **772**A are in positive and negative direct current relationship with LED array circuitry **744**A. Bridge rectifier **748**A is in electrical connection with four lead lines **766**A, **768**A, **770**A and **772**A. A voltage surge absorber **750**A is in electrical contact with lead lines **766**A and **768**A and voltage surge absorber **750**C is positioned on lead line **766**A. Lead lines **770**A and **772**A are in electrical contact with bridge rectifier **748**A and in power connection with LED array circuitry **744**A. Fuse **752** is positioned on lead line **770**A between bridge rectifier **748**A and LED array circuitry **744**A.

FIG. **66** shows a schematic of integral electronics circuit **746**B mounted on integral electronics **720**B. Integral electronics circuit **746**B is also indicated in part in FIG. **63** as connected to LED array circuitry **744**A. Integral electronics circuit **746**B is a close mirror image or electronics circuit **746**A mutatis mutandis. Integral electronics circuit **746**B is in electrical contact with bi-pin contacts **694**B, **696**B, which are shown as providing either AC or DC voltage. Integral electronics circuit **746**B includes bridge rectifier **748**B, voltage surge absorbers **750**B and **750**D. Integral electronic circuit **746**B leads to or from LED array circuitry **744**A. It is noted that FIG. **66** indicates the presence of possible AC voltage (rather than possible DC voltage) by an AC wave symbol ~. Each AC voltage could be DC voltage supplied by certain ballast assemblies **686** as mentioned earlier herein. In such a case DC voltage would be supplied to LED array **718** even in the presence of bridge rectifier **748**B. It is particularly noted

that in such a case, voltage surge absorbers **750**B and **750**D would remain operative. AC lead lines **766**B and **768**B are in a power connection with ballast assembly **686**. DC lead lines **770**B and **772**B are in positive and negative direct current relationship with LED array circuitry **744**A. Bridge rectifier **748**B is in electrical connection with four lead lines **766**B, **768**B, **770**B and **772**B. A voltage surge absorber **750**B is in electrical contact with lead lines **766**B and **768**B and voltage surge absorber **750**D is positioned on lead line **768**B. Lead lines **770**B and **772**B are in electrical contact with bridge rectifier **748**B and in power connection with LED array circuitry **744**A.

FIGS. **65** and **66** show the lead lines going into and out of LED circuitry **744** respectively. The lead lines include AC lead lines **766**B and **768**B, positive DC voltage **770**B, and DC negative voltage **772**B. The AC lead lines **766**B and **768**B are basically feeding through LED circuitry **744**, while the positive DC voltage lead line **770**B and negative DC voltage lead line **772**B are used primarily to power the LED array **718**. DC positive lead lines **770**A and **770**B are the same as LED positive lead line **770** and DC negative lead lines **772**A and **772**B are the same as LED negative lead line **772**. LED array circuitry **744**A therefore consists of all electrical components and internal wiring and connections required to provide proper operating voltages and currents to 5 mm LEDs **722** or to SMD LEDs **724** connected in parallel, series, or any combinations of the two.

FIGS. **67** and **67**A show a close-up of elongated tubular housing **698** with details of cooling vent holes **703**A and **703**A located on opposite ends of elongated tubular housing **698** in both side and cross-sectional views respectively.

FIG. **68** shows an isolated view of one of the base end caps, namely, base end cap **706**A, which is analogous to base end cap **706**B, mutatis mutandis. Bi-pin electrical contacts **694**A, **696**A extend directly through base end cap **706**A in the longitudinal direction in alignment with center line **702** of tubular wall **700** with bi-pin external extensions **758**A, **760**A and internal extensions **758**B, **760**B shown. Base end cap **706**A is a solid cylinder in configuration as seen in FIGS. **68** and **68**A and forms an outer cylindrical wall **774** that is concentric with center line **702** of tubular wall **700** and has opposed flat end walls **776**A and **776**B that are perpendicular to center line **702**. Two cylindrical parallel vent holes **778**A and **778**B are defined between end walls **776**A and **776**B in vertical alignment with center line **702**.

As also seen in FIG. **68**A, base end cap **706**A defines an outer circular slot **780** that is concentric with center line **702** of tubular wall **700** and concentric with and aligned proximate to circular wall **774**. Outer circular slot **780** is of such a width and circular end **704**A of tubular wall **700** is of such a thickness and diameter that outer circular slot **780** accepts circular end **704**A into a fitting relationship and circular end **704**A is thus supported by circular slot **780**. Base end cap **706**B defines another outer circular slot (not shown) analogous to outer circular slot **780** that is likewise concentric with center line **702** of tubular wall **700** so that circular end **704**B of tubular wall **700** can be fitted into the analogous circular slot of base end cap **706**B wherein circular end **704**B of tubular wall **700** is also supported. In this manner tubular wall **700** is mounted to end caps **706**A and **706**B.

As also seen in FIG. **68**A, base end cap **706**A defines inner rectangular slots **782**A and **782**B that are parallel to each other, but perpendicular with center line **702** of tubular wall **700** and spaced inward from outer circular slot **780**. Rectangular slots **782**A and **782**B are spaced from outer circular slot **780** at such a distance that would be occupied by SMD LEDs **724** mounted to LED array circuit boards **708**A and **708**B within tubular wall **700**. Rectangular slots **782**A and **782**B are of such a width and circuit board short rectangular edge ends **710**A of LED array circuit boards **708**A and **708**B is of such a thickness that circuit board short rectangular edge ends **710**A are fitted into rectangular slots **782**A and **782**B, and are thus supported by rectangular slots **782**A and **782**B. Base end cap **706**B (not shown) defines another two rectangular slots analogous to rectangular slots **782**A and **782**B that are likewise parallel to each other, but perpendicular with center line **702** of tubular wall **700** so that circuit board short rectangular edge ends **710**B of LED array circuit boards **708**A and **708**B can be fitted into the analogous rectangular slots **782**A and **782**B of base end cap **706**B wherein circuit board short rectangular edge ends **710**B are also supported. In this manner LED array circuit boards **708**A and **708**B are mounted to end caps **706**A and **706**B.

Circular ends **704**A and **704**B of tubular wall **700** and also circuit board short rectangular edge ends **710**A and **710**B of LED array circuit boards **708**A and **708**B are secured to base end caps **706**A and **706**B preferably by gluing in a manner known in the art. Other securing methods known in the art of attaching such as cross-pins or snaps can be used. Circular ends **704**A and **704**B of tubular wall **700** are optionally press fitted to circular slot **780** of base end cap **706**A and the analogous circular slot **780** of base end cap **706**B.

FIG. **69** is a sectional view of an alternate LED lamp **784** mounted in tubular wall **790** that is a version of LED lamp **680** as shown in FIG. **62**. The sectional view of LED lamp **784** now shows a single SMD LED **724** of LED lamp **784** being positioned at the bottom area **788** of tubular wall **790**. LED array circuitry **744** previously described with reference to LED lamp **680** would be the same for LED lamp **784**. That is, all thirty SMD LEDs **724** of LED strings **754** of both of the LED arrays **718** of LED lamp **680** would be the same for LED lamp **784**, except that now a total of only fifteen SMD LEDs **724** would comprise LED lamp **784** with the fifteen SMD LEDs **724** positioned at the bottom area **788** of tubular wall **790**. SMD LEDs **724** are mounted onto the circuit layer **716**A, which is separated from metal base layer **716**C by dielectric layer **716**B of either LED array circuit boards **708**A or **708**B. Metal base layer **716**C is attached to a heat sink **712** separated by thermally conductive grease **714** positioned at the top area **786** of tubular wall **790**. Only one of the two LED array circuit boards **708**A or **708**B is used here to provide illumination on a downward projection only. The reduction to fifteen SMD LEDs **724** of LED lamp **784** from the combined total of thirty SMD LEDs **724** of LED lamp **680** from the two LED array circuit boards **708**A and **708**B would result in a fifty percent reduction of power demand with an illumination result that would be satisfactory under certain circumstances. Stiffening of LED array circuit boards **708**A and **708**B for LED lamp **784** is accomplished by single rectangular slots **782**A and **782**B for circuit board short edge ends **710**A and **710**B located in base end caps **706**A and **706**B, or optionally a vertical stiffening member **792** shown in phantom line that is positioned at the upper area of space **786** between heat sink **712** and the inner side of tubular wall **790** that can extend the length of tubular wall **790** and LED array circuit boards **708**A and **708**B.

LED lamp **784** as described above will work for both AC and DC voltage outputs from an existing fluorescent rapid start ballast assembly **686**. In summary, LED array **718** will ultimately be powered by DC voltage. If existing fluorescent rapid start ballast assembly **686** operates with an AC output, bridge rectifiers **748**A and **748**B convert the AC voltage to DC voltage. Likewise, if existing fluorescent rapid start ballast

686 operates with a DC voltage, the DC voltage remains a DC voltage even after passing through bridge rectifiers 748A and 748B.

Another embodiment of a retrofitted LED lamp is shown in FIGS. 70 and 71 that show an LED lamp 794 retrofitted to an existing elongated fluorescent fixture 796 mounted to a wall 798. A rapid start type ballast assembly 800 is positioned within fixture 796. Fluorescent fixture 796 further includes a pair of ballast double electrical socket contacts 802A and 802B that are in electrical contact with bi-pin electrical contacts 804A and 804B of LED 794. In a manner analogous to the structure of LED lamp 680 relative to rapid start ballast assembly 686 described earlier, LED lamp 794 is in electrical contact with rapid start ballast assembly 800.

LED lamp 794 includes an elongated tubular housing 806 particularly configured as a tubular wall 808 circular in cross-section. Tubular wall 808 includes an apex portion 812 and a pair of pier portions 814A and 814B. Tubular wall 808 is made of a translucent material such as plastic or glass and preferably has a diffused coating. Tubular wall 808 has opposed tubular wall circular ends 816A and 816B. LED lamp 794 also includes electrical LED array upper and lower circuit boards 818 and 820, respectively, that are positioned within tubular housing 806, and that are configured to conform with apex portion 812 and pier portions 814A and 814B. The electric circuitry for LED lamp 794 is analogous to the electric circuitry as described relative to LED lamp 680. Circuit boards 818 and 820 are preferably manufactured each from a Metal Core Printed Circuit Boards (MCPCB) and comprise circuit layers 818A and 820A, respectively, dielectric layers 818B and 820B, respectively, and metal base layers 818C and 820C, respectively. A heat sink 822 is mounted to metal base layers 818C and 820C. A plurality of upper LEDs 826 and a plurality of lower LEDs 828 are mounted to and electrically connected to circuit boards 818 and 820, respectively, and in particular to circuit layers 818A and 820A, respectively. LEDs 826 and 828 can selectively be typical 5 mm LEDs, 10 mm LEDs, SMD LEDs, and optionally can be high-brightness LEDs.

FIG. 72 is a section view of an LED lamp 828A that is for mounting to an instant start ballast assembly (not shown) with opposed single pin contacts generally analogous to LED lamp 570 discussed previously. FIG. 72 also represents a section view of an LED lamp 828B with opposed bi-pin contacts generally analogous to LED lamp 680 discussed previously. FIG. 72A is an interior view of one circular single pin base end cap 830A taken in isolation representing both opposed base end caps of LED lamp 828A. FIG. 72B is an interior view of one circular bi-pin base end cap 830B taken in isolation representing both opposed base end caps of LED lamp 828B.

LED lamp 828A and LED lamp 828B both include a lamp tubular housing 832 having a tubular wall 834 circular in configuration. Three elongated rectangular metal substrate circuit boards 836, 838, and 840 mounted in lamp housing 832 spaced from tubular wall 834 are connected at their long edges so as to form a triangle in cross-section. Other configurations including squares, hexagons, etc. can be used. Circuit boards 836, 838, and 840 include circuit layers 836A, 838A, and 840A respectively; dielectric layers 836B, 838B, and 840B respectively, and metal base layers 836C, 838C, and 840C respectively. Specially extruded heat sink 842 is mounted to metal base layers 836C, 838C, and 840C respectively. Metal base layers 836C, 838C, and 840C are connected at their rectangular edges to the single pin base end caps such as single pin base end cap 830A to secure circuit boards 836, 838, and 840 in the triangular cross-sectional shape. Heat sink 842 is mounted to the inner surfaces of metal base layers 836C, 838C, and 840C. LEDs 844A, 844B, and 844C each represent a plurality of LEDs mounted in linear alignment on each metal substrate boards 836, 838, and 840 respectively, in particular to circuit layers 836A, 838A, and 840A respectively. The electrical connections are analogous to those described in relation to LED lamp 570 previously described herein. Metal substrate circuit boards 836, 838, and 840 as are LEDs 844A, 844B, and 844C are spaced from tubular wall 834.

Circular single pin base end cap 830A shown in FIG. 72A is one of the two base end caps for triangular LED lamp 828A, and is analogous to base end caps 592A and 592B of LED lamp 570 shown in FIGS. 50 and 51. Triangularly arranged rectangular mounting slots 846A, 846B, and 846C formed in base end cap 830A are aligned to receive the tenon ends of metal substrate circuit boards 836, 838, and 840, which are rectangular in shape and are analogous to circuit board short end edges 595A and 595B of LED array circuit boards 594A and 594B shown in FIG. 51. An outer circular mounting slot 848 formed in base end cap 830A is aligned to receive the circular end of tubular wall 834, and the opposed base end cap likewise forms a circular end slot that receives the opposed end of tubular wall 834, so that both slots mount both ends of tubular wall 834 of triangular LED lamp 828A. A single pin contact 850 is located at the center of circular single pin base end cap 830A. Single pin base end cap 830A also defines three base end cap venting holes 852A, 852B, and 852C located between circular slot 848 and each rectangular slot 846A, 846B, and 846C. Locations for venting holes 852A, 852B, and 852C can be positioned anywhere within base end cap 830A.

Circular bi-pin base end cap 830B shown in FIG. 72B is one of the two base end caps for triangular LED lamp 828B and is analogous to base end caps 706A and 706B of LED lamp 680 shown in FIGS. 60 and 61. Triangular arranged rectangular mounting slots 852A, 852B, and 852C formed in bi-pin base end cap 830B are aligned to receive the tenon ends of metal substrate circuit boards 836, 838 and 840, which are rectangular in shape and are analogous to circuit board short end edges 710A and 710B of LED array circuit boards 708A and 708B shown in FIG. 61. An outer circular mounting slot 854 formed in base end cap 830B is aligned to receive the circular end of tubular wall 834, and the opposed base end cap likewise forms a circular end slot that receives the other end of tubular wall 834, so that both slots mount both ends of tubular wall 834 of triangular LED lamp 828B. Bi-pin contacts 856A and 856B are located at the center area of circular bi-pin base end cap 830B. Bi-pin base end cap 830B also defines three base end cap venting holes 858A, 858B, and 858C located between circular slot 854 and each rectangular slot 852A, 852B, and 852C. Locations for venting holes 858A, 858B, and 858C can be positioned anywhere within base end cap 830B.

Although the invention thus far set forth has been described in some detail by way of illustration and example for purposes of clarity and understanding, it will of course, be understood that various changes and modifications may be made in the form, details, and arrangements of the parts without departing from the scope of the invention. For example, more than three metal substrate circuit boards can be mounted in any of LED lamps 570, 670, 680, 784, 794, and 828.

FIGS. 73, 73A, 74, 74A, 74B, 75, 75A, 75B, 75C, 76, 76A, 77, 78, 78A, 79A, and 79B show various embodiments and details of the present invention that is directed to the control of the delivery of electrical power from a ballast assembly to an LED array positioned in a tube as described herein.

In certain conditions and locations, direct hard-wire connections and wireless transmissions may not be possible, or may not offer the best performance. The use of existing power lines as a data information carrier serves as an alternate method of getting data input control to the on-board computer. X10 protocol and other PLC methods can be used. Thus, the data control signal can also be a direct hard-wire connection including DMX512, RS232, Ethernet, DALI, Lonworks, RDM, TCPIP, CEBus Standard EIA-600, X10, and other Power Line Carrier Communication (PLC) protocols.

FIG. **73** shows an embodiment of the present invention, in particular shown as a schematic block diagram of an LED lamp **860** that includes an LED array **862** comprising a plurality of LEDs positioned in an elongated translucent tube **864**. LED array **862** is connected to a power supply comprising a source of VAC power **866** electrically connected to a ballast **868**, which is external to tube **864**. An electrical connection **870**A positioned in tube **864** is powered from ballast **868** and transmits AC power to AC-DC power converter **869**, which in turn transmits DC power to an on-off switch **872** also positioned in tube **864** by way of electrical connection **870**B. Power from ballast **868** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **869**, DC power will continue to be sent to on-off switch **872**. Switch **872** is electrically connected to LED array **862** by electrical connection **874**. LED array **862** contains the necessary electrical components to further reduce the power transmitted by switch **972** by way of electrical connection **874** to properly drive the plurality of LEDs in LED array **862**.

A manual control unit **876** positioned external to LED lamp **860** is operationally connected to on-off switch **872** by any of three optional signal paths **878**A, **878**B, or **878**C. Signal path **878**A is an electrical signal line wire extending directly from manual control unit **876** to switch **872**. Signal path **878**B is a wireless signal line shown in dash line extending directly to switch **872**. Signal path **878**C is a signal line wire that is connected to a PLC line **880** that extends from VAC **866** through tube **860** to switch **872**. Switch **872** also contains the necessary electronics to decode the data information imposed on PLC line **880** via signal path **878**C. Manual control unit **876** may be powered from an external VAC power source **866** or directly from switch **872**.

In operation, manual activation of manual control unit **876** sends a signal by whichever signal line is being used of signal lines **878**A, **878**B, or **878**C with the result that switch **872** is operated to turn either on or off, depending on the prior setting. If, for example, LED array is in an illumination mode with power coming from ballast **868** through switch **872**, operation of switch **872** from the on mode to the off mode will cause termination of electrical power from ballast **868** to LED array **862**, so that LED array will cease to illuminate. If, on the other hand, LED array **862** is in a non-illumination mode, with no power passing form ballast **868** through switch **872**, operation of switch **872** from the off mode to the on mode will cause passage of electrical power from ballast **868** to LED array **862**, so that LED array **862** will be in an illumination mode.

FIG. **73**A shows another embodiment of the present invention, in particular shown as a schematic block diagram of an LED lamp **882** that includes an LED array **884** comprising a plurality of LEDs positioned in a translucent tube **886**. LED array **884** is connected to a power supply comprising a source of VAC power **888** electrically connected to a ballast **890**, which is external to tube **886**. An electrical connection **892**A positioned in tube **886** is powered from ballast **890** and transmits AC power to AC-DC power converter **891**, which in turn transmits DC power to a computer **894** by way of electrical connection **892**B and to dimmer **898** by way of a similar electrical connection (not shown). Both computer **894** and dimmer **898** are also positioned in tube **886**. Power from ballast **890** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **891**, DC power will continue to be sent to computer **894** and dimmer **898**. Computer **894** is electrically and operatively connected by an electrical control connection **896** to dimmer **898**. An electrical connection **900** connects dimmer **898** to LED array **884**. Dimmer **898** will contain the necessary electronics needed to decode the data control signals sent by computer **894**, and will provide the proper current drive power required to operate LED array **884**. Single LED array **884** controlled by dimmer **898** can represent multiple LED arrays **884** each correspondingly controlled by one of a plurality of dimmers **898** (not shown), wherein the plurality of dimmers **898** are each independently controlled by computer **894**. Computer **894** includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

A manual control unit **902** positioned external to LED lamp **882** is operationally connected to computer **894** by any of three optional alternative signal paths **904**A, **904**B, or **904**C connected to a PLC line **906** extending from VAC **888** through tube **886** to computer **894**. Signal path **904**A is an electrical signal line wire extending directly from manual control unit **902** to computer **894**. Signal path **904**B is a wireless signal path shown in dash line extending directly to computer **894**. Signal path **904**C is a signal line wire that is connected to a PLC line **906** that extends from VAC **888** through tube **886** to computer **894**. Computer **894** also contains the necessary electronics to decode the data information imposed on PLC line **906** via signal path **904**C. Manual control unit **902** may be powered from an external VAC power source **888** or directly from computer **894**.

Activation of manual control unit **902** activates computer **894** to signal dimmer **898** to increase or decrease delivery of electrical power to LED array **884** by a power factor that is preset in computer **894**. The delivery power factor can be preset to range anywhere from a theoretical reduced power deliver of zero percent from dimmer **898** to LED array **884** to any reduction of power of 100 percent delivery of power, but as a practical matter the actual setting would be in a middle range of power delivery to LED array **884** depending on circumstances. Computer **894** includes a computer signal input port and a computer signal output port. Manual control unit **902** is manually operable between an first activation mode wherein a control signal is sent to the computer signal input port by way of signal paths **904**A, **904**B, or **904**C to activate computer **894** to send from the computer signal output port, a computer output signal to dimmer **898** to operate at the preset power less than full power, and a second activation mode wherein a control signal is sent to the computer input signal port by way of signal paths **904**A, **904**B, or **904**C to activate computer **894** to send from the computer signal output port, a computer output signal to dimmer **898** to operate LED array **884** at full power.

FIG. **74** shows another embodiment of the present invention, in particular shown as a schematic block diagram of an LED lamp **908** that includes an LED array **910** comprising a plurality of LEDs positioned in a translucent tube **912**. LED array **910** is connected to a power supply comprising a source of VAC power **914** electrically connected to a ballast **916**, which is external to tube **912**. An electrical connection **918**A positioned in tube **912** is powered from ballast **916** and transmits AC power to AC-DC power converter **917**, which in turn transmits DC power to a timer **920** by way of electrical

connection **918**B and to an on-off switch **924** by way of a similar electrical connection (not shown). Both timer **920** and switch **924** are also positioned in tube **912**. Power from ballast **916** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **917**, DC power will continue to be sent to timer **920** and switch **924**. Timer **920** is electrically and operatively connected by an electrical control connection **922** to switch **924**. An electrical connection **926** connects switch **924** to LED array **910**. LED array **910** contains the necessary electrical components to further reduce the power transmitted by switch **924** by way of electrical connection **926** to properly drive the plurality of LEDs in LED array **910**.

A manual timer control unit **928** positioned external to LED lamp **908** is operationally connected to timer **920** by any of three optional alternative signal paths **930**A, **930**B, or **930**C. Signal path **930**A is an electrical signal line wire extending directly from manual control unit **928** to timer **920**. Signal path **930**B is a wireless signal path shown in dash line extending directly to timer **920**. Signal path **930**C is a signal line wire that is connected to a PLC line **932** that extends from VAC **914** through tube **912** to timer **920**. Timer **920** also contains the necessary electronics to decode the data information imposed on PLC line **932** via signal path **930**C. Manual control unit **928** may be powered from an external VAC power source **914** or directly from timer **920**.

In operation, manual timer control unit **928** is manually set to activate timer **920** at a particular on mode time to close switch **924**, and in addition at a particular off mode time to open switch **924**. In the on mode, power is passed from ballast **916**, to power converter **917**, to switch **924**, and then to LED array **910**. In the off mode, switch **924** terminates the transmission of power from ballast **916**, to power converter **917**, to switch **924**, and then to LED array **910**.

Referring now to FIGS. **73**A and **74**, computer **894** can be replaced with timer **920** in operational control of dimmer **898** in FIG. **73**A, and timer **20** can be replaced with computer **894** in operational control of switch **924** in FIG. **74** to achieve the similar functionality and illumination results.

FIG. **74**A shows another embodiment of the present invention, in particular shown is a schematic block diagram of an LED lamp **938** that includes an LED array **940** comprising a plurality of LEDs positioned in a translucent tube **942**. LED array **940** is connected to a power supply comprising a source of VAC power **944** electrically connected to a ballast **946**, which is external to tube **942**. An electrical connection **948**A positioned in tube **942** is powered from ballast **946** and transmits AC power to AC-DC power converter **947**, which in turn transmits DC power to a computer **950** by way of electrical connection **948**B and to dimmer **954** by way of a similar electrical connection (not shown). Both computer **950** and dimmer **954** are also positioned in tube **942**. Power from ballast **946** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **947**, DC power will continue to be sent to computer **950** and dimmer **954**. Computer **950** is electrically and operatively connected by an electrical control connection **952** to dimmer **954**. An electrical connection **956** connects dimmer **954** to LED array **940**. Dimmer **954** will contain the necessary electronics needed to decode the data control signals sent by computer **950**, and will provide the proper current drive power required to operate LED array **940**. Single LED array **940** controlled by dimmer **954** can represent multiple LED arrays **940** each correspondingly controlled by one of a plurality of dimmers **954** (not shown), wherein the plurality of dimmers **954** are each independently controlled by computer **950**. Computer **950** includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

An on-off switch **958** external to tube **942** is operationally connected to computer **950**. A timer **960** also external to tube **942** is positioned adjacent to or integral with switch **958**, is operationally connected to switch **958** by an electrical connection **962**. Timer **960** can be manually set to automatically activate switch **958** to an on mode or an off mode at preset times wherein computer **950** is activated by switch **958** to signal dimmer **954** to increase or decrease delivery of electrical power to LED array **940** by a power factor that is preset in either dimmer **954** or in computer **950**. The reduced delivery power factor can be preset to range anywhere from a theoretical zero percent delivery of power from dimmer **954** to LED array **940** to approaching a theoretical 100 percent delivery of power, but as a practical matter the actual reduced power setting would be in a middle range of power delivery to LED array **940** depending on the circumstances.

Switch **958** is operationally connected to computer **950** by any of three optional alternative signal paths **964**A, **964**B, or **964**C. Signal path **964**A is an electrical signal line wire extending directly from switch **958** to computer **950**. Signal path **964**B is a wireless signal path shown in dash line extending directly to computer **950**. Signal path **964**C is a signal line wire that is connected to a PLC line **966** that extends from VAC **944** through tube **942** to computer **950**. Computer **950** also contains the necessary electronics to decode the data information imposed on PLC line **966** via signal path **964**C. Timer **960** and switch **958** may be individually or mutually powered from an external VAC power source **944** or directly from computer **950**.

Computer **950** includes a computer signal input port and a computer signal output port. Switch **958** is operable between an first activation mode wherein a control signal is sent by switch **958** to the computer signal input port by way of signal paths **964**A, **964**B, or **964**C to activate computer **950** to send from the computer signal output port, a computer output signal to dimmer **954** to operate at the preset power less than full power, and a second activation mode wherein a control signal is sent by switch **958** to the computer input signal port by way of signal paths **964**A, **964**B, or **964**C to activate computer **950** to send from the computer signal output port, a computer output signal to dimmer **954** to operate LED array **940** at full power.

FIG. **74**B shows another embodiment of the present invention. It is similar to FIG. **74**A with the timer and switch now inside the LED lamp. In particular is shown a schematic block diagram of an LED lamp **968** that includes an LED array **970** comprising a plurality of LEDs positioned in a translucent tube **972**. LED array **970** is connected to a power supply comprising a source of VAC power **974** electrically connected to a ballast **976**, which is external to tube **972**. An electrical connection **978**A positioned in tube **972** is powered from ballast **976** and transmits AC power to AC-DC power converter **977**, which in turn transmits DC power to a timer **980** by way of electrical connection **978**B, to on-off switch **984**, to computer **986**, and to dimmer **990** by way of similar electrical power connections (not shown). Timer **980**, switch **984**, computer **986**, and dimmer **990** are all positioned in tube **972**. Power from ballast **976** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **977**, DC power will continue to be sent to timer **980**, switch **984**, computer **986**, and dimmer **990**. Computer **986** is electrically and operatively connected by an electrical control connection **988** to dimmer **990**. An electrical connection **992** connects dimmer **990** to LED array **970**. Dimmer **990** will contain the necessary electronics needed to decode the data control sig-

nals sent by computer **986**, and will provide the proper current drive power required to operate LED array **970**. Single LED array **970** controlled by dimmer **990** can represent multiple LED arrays **970** each correspondingly controlled by one of a plurality of dimmers **990** (not shown), wherein the plurality of dimmers **990** are each independently controlled by computer **986**. Computer **986** includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

Timer **980** is activated at preset times that in turn activate or deactivate switch **984** by electrical connection **982**. Such time presetting can be done, for example, at the assembly site or programmable by the customer. The activation of switch **984** by timer **980** signals the activation of computer **986** to emit a signal from the computer output signal port relating to dimmer **990** to control the power input to LED array **970** in accordance with the computer command. Thus, the degree of illumination emitted by LED array **970** can be increased or decreased at set times.

FIG. **75** shows another embodiment of the present invention. In particular shown is a schematic block diagram of an LED lamp **994** that includes an LED array **996** comprising a plurality of LEDs positioned in a translucent tube **998**. LED array **996** is connected to a power supply comprising a source of VAC power **1000** electrically connected to a ballast **1002**, which is external to tube **998**. An electrical connection **1004**A positioned in tube **998** is powered from ballast **1002** and transmits AC power to AC-DC power converter **1003**, which in turn transmits DC power to an on-off switch **1006** also positioned in tube **998** by way of electrical connection **1004**B. An occupancy motion sensor **1010** also positioned in tube **998** transmits control signals to switch **1006** by way of signal line **1012**. Electrical power is transmitted to sensor **1010** also by electrical connection **1004**B connected to power converter **1003**. AC or DC voltage depending on the model and type of design may power sensor **1010**. Occupancy motion sensor control in response to the movement or presence of a person in the illumination area of LED array **996** are set at the place of manufacture or assembly in accordance with methods known in the art. Power from ballast **1002** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1003**, DC power will continue to be sent to on-off switch **1006** and occupancy motion sensor **1010**. Switch **1006** is electrically connected to LED array **996** by electrical connection **1008**. LED array **996** contains the necessary electrical components to further reduce the power transmitted by switch **1006** by way of electrical connection **1008** to properly drive the plurality of LEDs in LED array **996**.

When sensor **1010** detects movement or the presence of a person in the illumination area of LED array **996**, an instant on-mode output signal is transmitted from sensor **1010** to switch **1006** wherein power is transmitted through switch **1006** to LED array **996**. When sensor **1010** ceases to detect movement or the presence of a person in the illumination area of LED array **996**, a delayed off-mode signal is transmitted from sensor **1010** to switch **1006** wherein switch **1006** is turned to the off-mode and power from ballast **1002** to power converter **1003** through switch **1006** and to LED array **996** is terminated. At such time when sensor **1010** again senses motion or the presence of a person in the illumination area of LED array **996**, an instant on-mode signal is again transmitted from sensor **1010** to switch **1006** wherein switch **1006** is turned to the on-mode and power from ballast **1002** to power converter **1003** through switch **1006** and to LED array **996** is activated, so that LED array **996** illuminates the area. The time delay designed into the off mode prevents intermittent illumination cycling in the area around LED array **996** and can be preset at the factory or can be set in the field.

FIG. **75**A shows another embodiment of the present invention. In particular shown is a schematic block diagram of an LED lamp **1014** that includes an LED array **1016** comprising a plurality of LEDs positioned in a translucent tube **1018**. LED array **1016** is connected to a power supply comprising a source of VAC power **1020** electrically connected to a ballast **1022**, which is external to tube **1018**. An electrical connection **1024**A positioned in tube **1018** is powered from ballast **1022** and transmits AC power to AC-DC power converter **1023**, which in turn transmits DC power to a computer **1026** by way of electrical connection **1024**B and to dimmer **1030** by way of a similar electrical connection (not shown). Both computer **1026** and dimmer **1030** are also positioned in tube **1018**. Computer **1026** has a computer input signal port and a computer output signal port. An occupancy motion sensor **1034** also positioned in tube **1018** transmits control signals to computer **1026** by way of input control signal line **1036** to the computer input signal port of computer **1026**. Electrical power is transmitted to sensor **1034** also by electrical connection **1024**B connected to power converter **1023**. AC or DC voltage depending on the model and type of design may power sensor **1034**. Occupancy motion sensor control in response to the movement or presence of a person in the illumination area of LED array **1016** are set at the place of manufacture or assembly in accordance with methods known in the art. Power from ballast **1022** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1023**, DC power will continue to be sent to computer **1026**, occupancy motion sensor **1034**, and dimmer **1030**. Computer **1026** is electrically and operatively connected by an electrical control connection **1028** to dimmer **1030**. An electrical connection **1032** connects dimmer **1030** to LED array **1016**. Dimmer **1030** will contain the necessary electronics needed to decode the data control signals sent by the computer output signal port of computer **1026**, and will provide the proper current drive power required to operate LED array **1016**. Single LED array **1016** controlled by dimmer **1030** can represent multiple LED arrays **1016** each correspondingly controlled by one of a plurality of dimmers **1030** (not shown), wherein the plurality of dimmers **1030** are each independently controlled by computer **1026**. Computer **1026** includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

When sensor **1034** detects motion or the presence of a person in the illumination area of LED array **1016**, sensor **1034** sends a signal to the computer signal input port of computer **1026** by way of signal line **1036** wherein computer **1026** then sends a signal from the computer signal output port to dimmer **1030** to provide full power to LED array **1016** for full illumination. When sensor **1034** ceases to detect motion or the presence of a person in the illumination area of LED array **1016** after a set time period, a sensor signal to computer **1026** by way of signal line **1036** causes computer **1026** to send a computer output signal to dimmer **1024** to decrease the power to LED array **1016** by a preset amount, so that LED array **1016** reduces full illumination of the area, that is, illumination is continued, but reduced to a preset illumination output.

Sensor **1034**, computer **1026**, and dimmer **1030** can be optionally organized into an integral circuit module. This system is used primarily for energy conservation and savings for residential, commercial, and industrial buildings and facilities. Sensor **1034** can be one of many varieties of space occupancy motion sensors. Such sensors can include, for example, optical incremental encoders, interrupters, photo-

reflective sensors, proximity and Hall Effect sensors, laser interferometers, triangulation sensors, magnetostrictive sensors, ultrasonic sensors, cable extension sensors, LVDT sensors, and tachometer sensors. Occupancy motion sensor **1034** gets its power from the main power supply VAC **1020** or internally from LED lamp **1014**. On-board computer **1026** constantly runs a monitoring program that looks at the output of occupancy motion sensor **1034**. Power to LED array **1016** is normally on and will dim between a fully off zero percent to a preset intensity of less than 100 percent depending on the output of occupancy motion sensor **1034**. When occupancy motion sensor **1034** no longer detects the motion of presence of a person within its operating range, it flags an input to computer **1026**, which signals dimmer **1030** to dim the power to LED array **1016**. LED array **1016** can be programmed to dim instantaneously or after some pre-programmed time delay.

FIG. **75**B shows an embodiment of the present invention, in particular shown as a schematic block diagram of an LED lamp **1038** that includes an LED array **1040** comprising a plurality of LEDs positioned in an elongated translucent tube **1042**. LED array **1040** is connected to a power supply comprising a source of VAC power **1044** electrically connected to a ballast **1046**, which is external to tube **1042**. An electrical connection **1048**A positioned in tube **1042** is powered from ballast **1046** and transmits AC power to AC-DC power converter **1047**, which in turn transmits DC power to an on-off switch **1050** also positioned in tube **1042** by way of electrical connection **1048**B. Power from ballast **1046** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1047**, DC power will continue to be sent to on-off switch **1050**. Switch **1050** is electrically connected to LED array **1040** by electrical connection **1052**. LED array **1040** contains the necessary electrical components to further reduce the power transmitted by switch **1050** by way of electrical connection **1052** to properly drive the plurality of LEDs in LED array **1040**.

An external motion sensor **1054** positioned external to LED lamp **1038** is operationally connected to on-off switch **1050** by any of three optional alternative signal paths **1056**A, **1056**B, or **1056**C. Signal path **1056**A is an electrical signal line wire extending directly from sensor **1054** to switch **1050**. Signal path **1056**B is a wireless signal path shown in dash line extending directly to switch **1050**. Signal path **1056**C is a signal line wire that is connected to a PLC line **1058** that extends from VAC **1044** through tube **1042** to switch **1050**. Switch **1050** also contains the necessary electronics to decode the data information imposed on PLC line **1058** via signal path **1056**C. When sensor **1054** detects motion in the illumination area of LED array **1040**, sensor **1054** sends a signal to switch **1050** by way of signal path **1056**A or signal path **1546**B or signal path **1056**C, whatever the case may be, wherein switch **1050** is activated from the off mode to the on mode, so that power is transmitted through switch **1050** to LED array **1040** and LED array **1040** illuminates the area. At such time sensor **1054** no longer detects motion in the illumination area of LED array **1040**, sensor **1054** sends a signal to switch **1050** wherein switch **1050** is activated from the on mode to the off mode, so that power to LED array **1040** is terminated and LED array **1040** no longer illuminates the area.

FIG. **75**C shows another embodiment of the present invention, in particular shown as a schematic block diagram of an LED lamp **1060** that includes an LED array **1062** comprising a plurality of LEDs positioned in a translucent tube **1064**. LED array **1062** is connected to a power supply comprising a source of VAC power **1066** electrically connected to a ballast **1068**, which is external to tube **1064**. An electrical connection **1070**A positioned in tube **1064** is powered from ballast **1068** and transmits AC power to AC-DC power converter **1069**, which in turn transmits DC power to a computer **1072** by way of electrical connection **1070**B and to dimmer **1076** by way of a similar electrical connection (not shown). Both computer **1072** and dimmer **1076** are also positioned in tube **1064**. Power from ballast **1068** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1069**, DC power will continue to be sent to computer **1072** and dimmer **1076**. Computer **1072** is electrically and operatively connected by an electrical control connection **1074** to dimmer **1076**. An electrical connection **1078** connects dimmer **1076** to LED array **1062**. Dimmer **1076** will contain the necessary electronics needed to decode the data control signals sent by computer **1072**, and will provide the proper current drive power required to operate LED array **1062**. Single LED array **1062** controlled by dimmer **1076** can represent multiple LED arrays **1062** each correspondingly controlled by one of a plurality of dimmers **1076** (not shown), wherein the plurality of dimmers **1076** are each independently controlled by computer **1072**. Computer **1072** includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

An external motion sensor **1080** positioned external to LED lamp **1060** is operationally connected to computer **1072** by any of three optional alternative signal paths **1082**A, **1082**B, or **1082**C. Signal path **1082**A is an electrical signal line wire extending directly from sensor **1080** to computer **1072**. Signal path **1082**B is a wireless signal path shown in dash line extending directly to computer **1072**. Signal path **1082**C is a signal line wire that is connected to a PLC line **1084** that extends from VAC **1066** through tube **1064** to computer **1072**. Computer **1072** also contains the necessary electronics to decode the data information imposed on PLC line **1084** via signal path **1082**C.

When sensor **1080** detects motion or the presence of a person in the illumination area of LED array **1062**, sensor **1080** sends a signal to the input port of computer **1072** by way of signal path **1082**A, or signal path **1082**B, or signal path **1082**C, whichever the case may be. Computer **1072** is activated to send or to continue to send a signal from the output port of computer **1072** by electrical line **1074** to dimmer **1076**, so that full power is transmitted through electrical line **1078** to LED array **1062** wherein LED array **1062** provides full illumination of the area.

When sensor **1080** ceases to detect motion or the presence of a person after a preset time period in the illumination area of LED array **1062**, sensor **1080** sends a signal to the signal input port of computer **1072** by way of one of signal paths **1082**A, **1082**B, or **1082**C, whichever the case might be, whereby computer **1072** sends a signal from the computer signal output port to dimmer **1076** by electrical line **1074** wherein dimmer **1076** reduces power being sent by electrical line **1078** to LED array **1062** by a preset amount, so that LED array **1062** reduces full illumination of the area, that is, illumination is continued, but reduced to a lower illumination output level preset in dimmer **1076** or computer **1072**.

FIG. **76** shows another embodiment of the present invention in particular a schematic block diagram of a network **1086** of two LED lamps **1086**A and **1086**B in general proximity. LED lamp **1086**A includes an LED array **1088**A positioned in a translucent tube **1090**A that is connected to a power supply comprising a source of VAC power **1092**A electrically connected to a ballast **1094**A, which is external to tube **1090**A. An electrical connection **1096**A connects ballast **1094**A to an AC-DC power converter **1095**A, which in turn

provides DC power to occupancy motion sensor **1098**A and dimmer **1102**A both positioned in LED lamp **1086**A, that is, in tube **1090**A by way of electrical connections **1096**B and **1100**A respectively. Dimmer **1102**A is connected to LED array **1088**A by an electrical connection **1104**A. LED lamp **1086**B includes an LED array **1088**B positioned in a translucent tube **1090**B that is connected to a power supply comprising a source of VAC power **1092**B electrically connected to a ballast **1094**B, which is external to tube **1090**B. An electrical connection **1096**C connects ballast **1094**B to an AC-DC power converter **1095**B, which in turn provides DC power to occupancy motion sensor **1098**B and dimmer **1102**B both positioned in LED lamp **1086**B, that is, in tube **1090**B by way of electrical connections **1096**D and **1100**B respectively. Dimmer **1102**B is connected to LED array **1088**B by an electrical connection **1104**B. LED arrays **1088**A and **1088**B can each include either a plurality of LEDs or a single LED. The number of individual LEDs in each LED array **1088**A and **1088**B can differ. Likewise, dimmers **1102**A and **1102**B can represent a plurality of dimmers **1102**A and **1102**B, each controlling individual LEDs arrays **1088**A and **1088**B respectively.

An external central computer **1106** shown positioned between LED lamps **1086**A and **1086**B is in network signal communication with sensors **1098**A and **1098**B, and ultimately with dimmers **1102**A and **1102**B, respectively. Sensor **1098**A sends a sensor data output signal by wire signal path **1108**X or alternative wireless signal path **1108**Y as shown by dash line to computer **1106**; and sensor **1098**B sends a sensor data output signal by wire signal path **110**X or alternative wireless signal path **110**Y as shown by dash line to computer **1106**. In programmed response to the sensor signals, computer **1106** sends a computer data output signal by wire signal path **1112**X or alternative wireless signal path **1112**Y as shown by dash line to control dimmer **1102**A; and computer **1106** also sends a computer data output signal by wire signal path **1114**X or alternative wireless signal path **1114**Y as shown by dash line to control dimmer **1102**B. Dimmers **1102**A and **1102**B both contain the electronics needed to decode the data control signals sent by computer **1106**, and will provide the proper current drive power required to operate LED arrays **1088**A and **1088**B respectively. Computer **1106** includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

Computer **1106** continuously compares the sensor data signals received in accordance with a computer monitoring program and transmits computer signals to dimmers **1102**A and **1102**B in accordance with a computer program, so as to control the current output of dimmers **1102**A and **1102**B, so as to prevent flickering of LED lamps **1086**A and **1086**B. Thus signaling dimmers **1102**A and **1102**B either to maintain full power to LED arrays **1088**A and **1088**B in accordance with preset power reductions, so that LED arrays **1088**A and **1088**B emit full capacity light, or on the other hand to reduce power after a set time delay to LED arrays **1088**A and **1088**B with the result that as a person walks about the illumination areas of LED lamps **1086**A and **1086**B, both lamps emit the same less than full capacity illumination with the result that continuous flickering caused by different power controls at dimmers **1102**A and **1102**B is avoided. In summary, the operational networking of LED lamp network **1086** prevents flickering from occurring.

As indicated in FIGS. **76** and **76**A, four combinations of signals from both sensors **1098**A and **1098**B to computer **1106** are possible. For purposes of elucidation herein, when motion is detected by sensors **1098**A and **1098**B, signals from the sensors are indicated by YES, and when no motion is detected by sensors **1098**A and **1098**B, negative signals from the sensors are indicated by NO. Computer **1106** is programmed to send computer control signals to dimmers **1102**A and **1102**B as a result of the received sensor signals. Full power at dimmers **1102**A and **1102**B is indicated by a plus sign (+) and reduced power to dimmers **1102**A and **1102**B is indicated by a minus sign (−).

The four combinations of sensor signals as received by computer **1106** are shown in FIG. **76**A as follows:

1. Sensor **1098**A does detect motion and sensor **1098**B also does detect motion wherein computer **1106** sends a computer signal (+) to both dimmers **1102**A and **1102**B to maintain full power to LED arrays **1088**A and **1088**B respectively.

2. Sensor **1098**A does not detect motion and sensor **1098**B does detect motion wherein computer **1106** sends a computer signal (−) to dimmer **1102**A to reduce full power to LED array **1088**A, and a computer signal (+) to dimmer **1102**B to maintain full power to LED array **1088**B.

3. Sensor **1098**A does detect motion and sensor **1098**B does not detect motion wherein computer **1106** sends a computer signal (+) to dimmer **1102**A to maintain full power to LED array **1088**A, and a computer signal (−) to dimmer **1102**B to reduce full power to LED array **1088**B.

4. Sensor **1098**A does not detect motion and sensor **1098**B does not detect motion wherein computer **1106** sends a computer signal (−) to both dimmers **1102**A and **1102**B to reduce full power to LED arrays **1088**A and **1088**B respectively in accordance with preset power reduction settings.

FIG. **77** shows another embodiment of the present invention in particular schematic block diagram of a network **1116** of two LED lamps including first and second LED lamps, namely, LED lamp **1116**A and LED lamp **1116**B, respectively, in general proximity. First LED lamp **1116**A includes an LED array **1118**A positioned in a translucent tube **1120**A that is connected to a power supply comprising a source of VAC power **1122**A electrically connected to a ballast **1124**A, which is external to tube **1120**A. An electrical connection **1126**A connects ballast **1124**A to an AC-DC power converter **1125**A, which in turn provides DC power by way of electrical connection **1126**B to a computer **1128**A, an occupancy motion sensor **1130**A, a timer **1134**A, and dimmer **1138**A all positioned within tube **1120**A, that is, LED lamp **1116**A. Occupancy motion sensor **1130**A sends signals to computer **1128**A by a signal path **1132**A. Optional timer **1134**A sends signals to computer **1128**A by signal path **1136**A. Computer **1128**A sends programmed activation signals to dimmer **1138**A by electrical connection **1140**A. Dimmer **1138**A contains the electronics needed to decode the data control signals sent by computer **1128**A, and will provide the proper current drive power required to operate LED array **1118**A. Dimmer **1138**A transmits power to LED array **1118**A by an electrical connection **1141**A. Computer **1128**A includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means. Second LED lamp **1116**B includes an LED array **1118**B positioned in a translucent tube **1120**B that is connected to a power supply comprising a source of VAC power **1122**B electrically connected to a ballast **1124**B, which is external to tube **1120**B. An electrical connection **1126**C connects ballast **1124**B to an AC-DC power converter **1125**B, which in turn provides DC power by way of electrical connection **1126**D to a computer **1128**B, an occupancy motion sensor **1130**B, a timer **1134**B, and dimmer **1138**B all positioned within tube **1120**B, that is, LED lamp **1116**B. Occupancy motion sensor **1130**B sends signals to computer **1128**B by a signal path **1132**B. Optional timer **1134**B sends signals to computer **1128**B by signal path **1136**B. Computer **1128**B sends programmed activation sig-

nals to dimmer **1138**B by electrical connection **1140**B. Dimmer **1138**B contains the electronics needed to decode the data control signals sent by computer **1128**B, and will provide the proper current drive power required to operate LED array **1118**B. Dimmer **1138**B transmits power to LED array **1118**B by an electrical connection **1141**B. Computer **1128**B includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

Computers **1128**A and **1128**B are in network signal communication with sensors **1130**A and **1130**B, respectively, and ultimately with dimmers **1138**A and **1138**B, respectively. Sensor **1130**A sends data output signals to computer **1128**A by signal path **1132**A, and sensor **1130**B sends data output signals to computer **1128**B by signal path **1132**B. In programmed response to the signals from sensor **1130**A, computer **1128**A sends computer data out communication signals **1142** by wire signal path **1144**X or alternative wireless signal path **1144**Y as shown by dash line or by PLC signal path **1144**Z, any one signal path by itself or in combination with any other input communication signal path to the data in **1146** of computer **1128**B. Simultaneously in programmed response to the signals from sensor **1130**B, computer **1128**B sends computer data out communication signals **1148** by wire signal path **1150**X or alternative wireless signal path **1150**Y as shown by dash line or by PLC signal path **1150**Z, any one signal path by itself or in combination with any other input communication signal path to the data in **1152** of computer **1128**A.

Computers **1128**A and **1128**B continuously process the sensor data signals from both sensors **1130**A and **1130**B received in accordance with a computer monitoring program and transmit resultant computer signals to dimmers **1138**A and **1138**B in accordance with the computer program, so as to control the current output of dimmers **1138**A and **1138**B, so as to prevent flickering of LED lamps **1116**A and **1116**B by 1) simultaneously signaling both dimmers **1138**A and **1138**B either to maintain full power and emit maximum light output, or 2) simultaneously signaling both dimmers **1138**A and **1138**B to reduce power by a preset amount and emit less than maximum light by a preset amount with the result that as a person walks about the combined illumination area of LED lamps **1116**A and **1116**B, both lamps emit the same illumination with the result that continuous flickering between the lamps caused by different power controls at dimmers **1138**A and **1138**B is avoided. In summary, the operational networking of LED lamp network **1116** creates a continuous identical illumination, so that flickering is prevented.

Four combinations of signals from both sensors **1030**A and **1030**B to computers **1128**A and **1128**B are possible. The four combinations of sensor signals as received by computers **1128**A and **1128**B, which are analogous to those shown in FIG. **76**A, are as follows:

1. Sensor **1030**A does detect motion and sensor **1030**B also does detect motion wherein computers **1128**A and **1128**B both send a computer signal (+) to both dimmers **1138**A and **1138**B to maintain full power to LED arrays **1118**A and **1118**B respectively.

2. Sensor **1030**A does not detect motion and sensor **1030**B does detect motion wherein computer **1128**A sends a computer signal (−) to dimmer **1138**A to reduce full power to LED array **1118**A, and computer **1128**B sends a computer signal (+) to dimmer **1138**B to maintain full power to LED array **1118**B.

3. Sensor **1030**A does detect motion and sensor **1030**B does not detect motion wherein computer **1128**A sends a computer signal (+) to dimmer **1138**A to maintain full power to LED array **1118**A, and computer **1128**B sends a computer signal (−) to dimmer **1138**B to reduce full power to LED array **1118**B.

4. Sensor **1098**A does not detect motion and sensor **1098**B does not detect motion wherein computers **1128**A and **1128**B both send a computer signal (−) to both dimmers **1138**A and **1138**B to reduce full power to LED arrays **1118**A and **1118**B respectively in accordance with preset power reduction settings.

LED arrays **1118**A and **1118**B can each include either a plurality of LEDs or a single LED. The number of individual LEDs in each LED array **1118**A and **1118**B can differ. Likewise, dimmers **1138**A and **1138**B can represent a plurality of dimmers **1138**A and **1138**B, each controlling individual LED arrays **1118**A and **1118**B respectively.

Optional timer **1134**A can be preset to self-activate in various modes. Timer **1134**A can be preset to send a signal to computer **1128**A to reduce or increase power to dimmer **1138**A to a preset amount at a preset time by sending a timer signal by signal path **1136**A to computer **1128**A. For example, timer **1134**A can be preset to activate a power reduction signal to computer **1128**A at 10 PM. Timer **1134**A can also be preset to activate a normal power turn on signal to computer **1128**A at 8 AM. Likewise optional timer **1134**B can be preset to self-activate in various modes. Timer **1134**B can be preset to send a signal to computer **1128**B to reduce or increase power to dimmer **1138**B to a preset amount at a preset time by sending a timer signal by signal path **1136**B to computer **1128**B. For example, timer **1134**B can be preset to activate a power reduction signal to computer **1128**B at 10 PM. Timer **1134**B can also be preset to activate a normal power turn on signal to computer **1128**B at 8 AM.

It is possible to preset timers **1134**A and **1134**B at the same preset power reduction and normal power on modes and at the same preset time modes. It is also possible to preset timers **1134**A and **1134**B at different preset power reduction modes and different preset time modes. For example, timer **1134**A could be set to send a 50 percent power reduction signal to computer **1128**A at 10 PM and set to send a full power on mode signal to computer **1128**A at 8 AM. At the same time, timer **1134**B could be set to send a 50 percent power reduction signal to computer **1128**B at 8 PM and set to send a full power on mode signal to computer **1128**B at 7 AM.

FIG. **78** shows another embodiment of the present invention in particular a schematic block diagram of a network **1154** of two LED lamps including first and second LED lamps, namely, LED lamp **1156**A and LED lamp **1156**B, respectively, in general proximity. LED lamp **1156**A includes an LED array **1158**A positioned in a translucent tube **1160**A that is connected to a power supply comprising a source of VAC power **1162**A electrically connected to a ballast **1164**A, which is external to tube **1160**A. An electrical connection **1166**A connects ballast **1164**A to an AC-DC power converter **1165**A, which in turn provides DC power to occupancy motion sensor **1168**A and on-off switch **1172**A both positioned in LED lamp **1156**A, that is, in tube **1160**A by way of electrical connections **1166**B and **1170**A respectively. Switch **1172**A is connected to LED array **1158**A by an electrical connection **1174**A. LED lamp **1156**B includes an LED array **1158**B positioned in a translucent tube **1160**B that is connected to a power supply comprising a source of VAC power **1162**B electrically connected to a ballast **1164**B, which is external to tube **1160**B. An electrical connection **1166**C connects ballast **1164**B to an AC-DC power converter **1165**B, which in turn provides DC power to occupancy motion sensor **1168**B and on-off switch **1172**B both positioned in LED lamp **1156**B, that is, in tube **1160**B by way of electrical connections

1166D and 1170B respectively. Switch 1172B is connected to LED array 1158B by an electrical connection 1174B.

A logic gate array 1176 is positioned between LED lamp 1156A and LED lamp 1156B. Logic gate array 1176 is an arrangement of electronically controlled switches, but can be constructed from relays, diodes, transistors, and optical elements that outputs a signal when specified input conditions are met.

When sensor 1168A detects motion in the illumination area of LED lamp 1156A, sensor 1168A sends a sensor output signal to logic gate array 1176 by a wire signal path 1180AX or alternatively by a wireless signal path 1180AY. In the same manner, when sensor 1168B detects motion in the illumination area of LED lamp 1156B, sensor 1168B sends a sensor output signal to logic gate array 1176 by a wire signal path 1180BX or alternatively by a wireless signal path 1180BY.

The logic circuit of logic gate array 1176 continuously processes output signals received from sensors 1168A and 1168B with the result that logic gate array 1176 sends a logic input signal to switch 1172A by a logic wire signal path 1184AX or by a logic wireless signal path 1184AY. Likewise, the logic circuit of logic gate array 1176 continuously processes output signals received from sensors 1168A and 1168B with the result that logic gate array 1176 also sends a logic input signal to switch 1172B by a logic wire signal path 1184BX or by an alternative logic wireless signal path 1184BY.

Four combinations of signals from both sensors 1168A and 1168B to logic gate array 1176 are possible. The four combinations of sensor signals as received by logic gate array 1176, which are analogous to those shown in FIG. 76A, are as follows:

1. Sensor 1168A does detect motion and sensor 1168B also does detect motion wherein logic gate array 1176 sends a logic signal (+) to both switches 1172A and 1172B to maintain full power to LED arrays 1158A and 1158B respectively.

2. Sensor 1168A does not detect motion and sensor 1168B does detect motion wherein logic gate array 1176 sends a logic signal (−) to switch 1172A to reduce full power to LED array 1158A, and a logic signal (+) to switch 1172B to maintain full power to LED array 1158B.

3. Sensor 1168A does detect motion and sensor 1168B does not detect motion wherein logic gate array 1176 sends a logic signal (+) to switch 1172A to maintain full power to LED array 1158A, and a logic signal (−) to switch 1172B to reduce full power to LED array 1158B.

4. Sensor 1168A does not detect motion and sensor 1168B does not detect motion wherein logic gate array 1176 sends a logic signal (−) to both switches 1172A and 1172B to reduce full power to LED arrays 1158A and 1158B respectively in accordance with preset power reduction settings.

FIG. 78A shows another embodiment of the present invention in particular schematic block diagram of a network 1186 of two LED lamps including first and second LED lamps, namely, LED lamp 1186A and LED lamp 1186B, respectively, in general proximity. First LED lamp 1186A includes an LED array 1188A positioned in a translucent tube 1190A that is connected to a power supply comprising a source of VAC power 1192A electrically connected to a ballast 1194A, which is external to tube 1190A. An electrical connection 1196A connects ballast 1194A to an AC-DC power converter 1195A, which in turn provides DC power by way of electrical connection 1196B to a logic gate array 1198A, an occupancy motion sensor 1200A, a timer 1204A, and dimmer 1208A all positioned within tube 1190A, that is, LED lamp 1186A. Occupancy motion sensor 1200A sends signals to logic gate array 1198A by a signal path 1202A. Optional timer 1204A sends signals to logic gate array 1198A by signal path 1206A. Logic gate array I 198A sends activation signals to dimmer 1208A by electrical connection 1210A. Dimmer 1208A contains the electronics needed to decode the data control signals sent by logic gate array 1198A, and will provide the proper current drive power required to operate LED array 1188A. Dimmer 1208A transmits power to LED array 1188A by an electrical connection 1211A. Logic gate array 1198A is an arrangement of electronically controlled switches, but can be constructed from relays, diodes, transistors, and optical elements that outputs a signal when specified input conditions are met. Second LED lamp 1186B includes an LED array 1188B positioned in a translucent tube 1190B that is connected to a power supply comprising a source of VAC power 1192B electrically connected to a ballast 1194B, which is external to tube 1190B. An electrical connection 1196C connects ballast 1194B to an AC-DC power converter 1195B, which in turn provides DC power by way of electrical connection 1196D to a logic gate array 1198B, an occupancy motion sensor 1200B, a timer 1204B, and dimmer 1208B all positioned within tube 1190B, that is, LED lamp 1186B. Occupancy motion sensor 1200B sends signals to logic gate array 1198B by a signal path 1202B. Optional timer 1204B sends signals to logic gate array 1198B by signal path 1206B. Logic gate array 1198B sends activation signals to dimmer 1208B by electrical connection 1210B. Dimmer 1208B contains the electronics needed to decode the data control signals sent by logic gate array 1198B, and will provide the proper current drive power required to operate LED array 1188B. Dimmer 1208B transmits power to LED array 1188B by an electrical connection 1211B. Logic gate array 1198B is an arrangement of electronically controlled switches, but can be constructed from relays, diodes, transistors, and optical elements that outputs a signal when specified input conditions are met.

Logic gate arrays 1198A and 1198B are in network signal communication with sensors 1200A and 1200B, respectively, and ultimately with dimmers 1208A and 1208B, respectively. Sensor 1200A sends data output signals to logic gate array 1198A by signal path 1202A, and sensor 1200B sends data output signals to logic gate array 1198B by signal path 1202B. In response to the signals from sensor 1200A, logic gate array 1198A sends data out communication signals 1212 by wire signal path 1214X or alternative wireless signal path 1214Y as shown by dash line or by PLC signal path 1214Z, any one signal path by itself or in combination with any other input communication signal path to the data in 1216 of logic gate array 1198B. Simultaneously in response to the signals from sensor 1200B, logic gate array 1198B sends data out communication signals 1218 by wire signal path 1220X or alternative wireless signal path 1220Y as shown by dash line or by PLC signal path 1220Z, any one signal path by itself or in combination with any other input communication signal path to the data in 1222 of logic gate array 1198A.

Logic gate array 1198A and 1198B continuously process the sensor data signals from both sensors 1200A and 1200B received in accordance with a logic monitoring program and transmit resultant signals to dimmers 1208A and 1208B in accordance with the logic program, so as to control the current output of dimmers 1208A and 1208B, so as to prevent flickering of LED lamps 1186A and 1186B by 1) simultaneously signaling both dimmers 1208A and 1208B either to maintain full power and emit maximum light output, or 2) simultaneously signaling both dimmers 1208A and 1208B to reduce power by a preset amount and emit less than maximum light by a preset amount with the result that as a person walks about the combined illumination area of LED lamps 1186A

and **1186**B, both lamps emit the same illumination with the result that continuous flickering between the lamps caused by different power controls at dimmers **1208**A and **1208**B is avoided. In summary, the operational networking of LED lamp network **1186** creates a continuous identical illumination, so that flickering is prevented.

Four combinations of signals from both sensors **1200**A and **1200**B to logic gate arrays **1198**A and **1198**B are possible. The four combinations of sensor signals as received by logic gate arrays **1198**A and **1198**B, which are analogous to those shown in FIG. **76**A, are as follows:

1. Sensor **1200**A does detect motion and sensor **1200**B also does detect motion wherein logic gate arrays **1198**A and **1198**B both send a logic signal (+) to both dimmers **1208**A and **1208**B to maintain full power to LED arrays **1188**A and **1188**B respectively.

2. Sensor **1200**A does not detect motion and sensor **1200**B does detect motion wherein logic gate array **1198**A sends a logic signal (−) to dimmer **1208**A to reduce full power to LED array **1188**A, and logic gate array **1198**B sends a logic signal (+) to dimmer **1208**B to maintain full power to LED array **1188**B.

3. Sensor **1200**A does detect motion and sensor **1200**B does not detect motion wherein logic gate array **1198**A sends a logic signal (+) to dimmer **1208**A to maintain full power to LED array **1188**A, and logic gate array **1198**B sends a logic signal (−) to dimmer **1208**B to reduce full power to LED array **1188**B.

4. Sensor **1200**A does not detect motion and sensor **1200**B does not detect motion wherein logic gate arrays **1198**A and **1198**B both send a logic signal (−) to both dimmers **1208**A and **1208**B to reduce full power to LED arrays **1188**A and **1188**B respectively in accordance with preset power reduction settings.

LED arrays **1188**A and **1188**B can each include either a plurality of LEDs or a single LED. The number of individual LEDs in each LED array **1188**A and **1188**B can differ. Likewise, dimmers **1208**A and **1208**B can represent a plurality of dimmers **1208**A and **1208**B, each controlling individual LED arrays **1188**A and **1188**B respectively.

Optional timer **1204**A can be preset to self-activate in various modes. Timer **1204**A can be preset to send a signal to logic gate array **1198**A to reduce or increase power to dimmer **1208**A to a preset amount at a preset time by sending a timer signal by signal path **1206**A to logic gate array **1198**A. For example, timer **1204**A can be preset to activate a power reduction signal to logic gate array **1198**A at 10 PM. Timer **1204**A can also be preset to activate a normal power turn on signal to logic gate array **1198**A at 8 AM. Likewise optional timer **1204**B can be preset to self-activate in various modes. Timer **1204**B can be preset to send a signal to logic gate array **1198**B to reduce or increase power to dimmer **1208**B to a preset amount at a preset time by sending a timer signal by signal path **1206**B to logic gate array **1198**B. For example, timer **1204**B can be preset to activate a power reduction signal to logic gate array **1198**B at 10 PM. Timer **1204**B can also be preset to activate a normal power turn on signal to logic gate array **1198**B at 8 AM.

It is possible to preset timers **1204**A and **1204**B at the same preset power reduction and normal power on modes and at the same preset time modes. It is also possible to preset timers **1204**A and **1204**B at different preset power reduction modes and different preset time modes. For example, timer **1204**A could be set to send a 50 percent power reduction signal to logic gate array **1198**A at 10 PM and set to send a full power on mode signal to logic gate array **1198**A at 8 AM. At the same time, timer **1204**B could be set to send a 50 percent power reduction signal to logic gate array **1198**B at 8 PM and set to send a full power on mode signal to logic gate array **1198**B at 7 AM.

FIG. **79**A shows an electrical circuit **1256** for providing power to four LED arrays **1258** that is essentially the same as the electrical circuits shown in FIGS. **4**, **14**, **53**, and **63** described hereinbefore. The circuit module shown is a by-pass or feed-thru circuit that simply passes the voltage to LED arrays **1258**. The hardware for the by-pass or feed-thru circuit module can consist of straight electrical conductors or headers with jumpers installed. The combination of the by-pass or feed-thru circuit module and LED array **1258** represents the LED lamp. AC voltage inputs of 200-300 volts and 0-4 volts are typical outputs from a rapid start fluorescent ballast (not shown). But the input can be any AC voltage including 120 volts, 240 volts, or 277 volts as present in line power voltages. A voltage reducer or voltage suppressor **1262** is connected across the two input AC voltages. A reduced AC voltage is tied to a full bridge rectifier **1260** as a result of voltage suppressor **1262**. Bridge rectifier **1260** and voltage suppressor **1262** represent the AC to DC power converters as described herein as **869**, **891**, **917**, **947**, **977**, **1003**, **1023**, **1047**, **1069**, **1095**A, **1095**B, **1125**A, **1125**B, **1165**A, **1165**B, **1195**A, and **1195**B. The positive DC voltage output of bridge rectifier **1260** is connected to optional current limiting resistors R**2**, R**3**, R**4**, and R**5**. The other side of current limiting resistors R**2**, R**3**, R**4**, and R**5** are connected to the anode side of first LEDs D**1**, D**3**, D**5**, and D**7** respectively. The cathode side of first LEDs D**1**, D**3**, D**5**, and D**7** are in turn connected to the anode side of second LEDs D**2**, D**4**, D**6**, and D**8** respectively. The cathode side of second LEDs D**2**, D**4**, D**6**, and D**8** are in turn connected to the anode side of third LEDs in series (not shown). The cathode side of the last LED in each LED string is in turn connected to the negative DC voltage or ground output of bridge rectifier **1260**.

FIG. **79**B shows an alternative electrical circuit **1264** for four parallel LED arrays **1266** analogous to that shown in FIG. **79**A for providing power to a plurality of LEDs. The AC voltage inputs of 200-300 volts and 0-4 volts are typical outputs from a rapid start fluorescent ballast, but the input can be any AC voltage including 120 volts, 240 volts, or 277 volts as present in line power voltages. A capacitor **1268** is used to drop the line input voltage and a small resistor RI is used to limit the inrush current to the circuit. A larger capacitor C will increase the current into the circuit and a smaller one will reduce it. Capacitor **1268** must be a non-polarized type with a voltage rating of 200 volts or more. The value of capacitor **1268** can range from 1 uF to 4 uF for adequate current to drive LED arrays **1266**. A voltage absorber (ZNR), movistor (MOV), varistor (V), or transformer can be used to suppress or reduce the voltage on the other side of capacitor **1268** to within a lower workable AC voltage, and is interchangeable with voltage suppressor **1262** described in FIG. **79**A. Since the capacitor **1268** must pass current in both directions, a diode and in particular, a zener diode Z is connected in parallel with voltage suppressor V to provide a path for the negative half cycle. The zener diode Z serves as a regulator and provides a path for the negative half cycle current when it conducts in the forward direction. A power rated diode or similar rectifier can be used in place of zener diode Z to produce similar results. A voltage suppressor V is connected across the two input AC voltages. The reduced AC voltage is tied to full bridge rectifier **1270**. Bridge rectifier **1270** and voltage suppressor V represent the AC to DC power converters as described herein as **869**, **891**, **917**, **947**, **977**, **1003**, **1023**, **1047**, **1069**, **1095**A, **1095**B, **1125**A, **1125**B, **1165**A,

1165B, 1195A, and 1195B. The positive DC voltage output of bridge rectifier 1270 is connected to optional current limiting resistors R2, R3, R4, and R5. There can be more LED strings in parallel (not shown). The other side of current limiting resistors R2-R5 are each connected to the anode side of first LEDs D1, D3, D5, and D7 of LED arrays 1266, respectively. The cathode side of first LEDs D1, D3, D5, and D7 are connected to the anode side of second LEDs D2, D4, D6, and D8, of LED arrays 1266, respectively. The cathode side of second LEDs D2, D4, D6, and D8 are connected to the anode side of third LEDs in series (not shown). The cathode side of the last LED in each LED string is connected to the negative DC voltage or ground output of bridge rectifier 1270. An optional filter capacitor 1272 can be used in parallel with the LED strings across the DC voltage leads to absorb the surge that passes through the capacitor 1268. Most LEDs will operate more efficiently with filter capacitor 1272 installed.

It should be noted that even though one electronic component consisting of a capacitor, a voltage suppressor, a diode, a bridge rectifier, etc. is shown in either one or both FIGS. 79A and 79B, more than one electronic component of each type herein described can be used in the final design of the present LED lamp.

In addition, in standalone LED lamps of the present invention using computers, a self-contained program stored in the computer operates the current driver outputs of each dimmer controlling each LED array depending on the condition of the sensor and timer outputs. In the network systems of FIG. 77 and 78A, there are shown three optional alternative methods of providing external data communications to the individual computers or logic gate arrays contained in each LED lamp of the present invention. An external and remote data control signal can be imposed on the power line to provide instructions to computer to operate the current driver outputs of dimmer to control the LED arrays. The data input can be connected to one of many varieties of external control consoles including a PC, wall mounted keypad, PDA, etc. An on-board computer constantly runs a monitoring program that looks at the PLC data input line or wireless data communications input line or direct hard-wired data line. Power to the LED array is normally on and will go off or dim to a certain intensity depending on the data input control instructions. The data input control instructions can tell the on-board computer to turn the LED arrays on or off or set the output of the LED arrays at various dimming levels as desired by the user.

It should be noted that a network of similarly configured plurality of LED lamps of the present invention as described in FIGS. 73 through 78A can be combined to form a complete intelligent system. Any one LED lamp can be set as a master and all other LED lamps in the network can be set up as slaves. For example, the sensor input of all LED lamps can be monitored as a whole and as long as one occupancy motion detector senses the presence of a person, all LED lamps will remain on. Only after all occupancy motion detectors acknowledge that no one is in the occupied space will all or some of the LED lamps go off or go dim to a certain preset level. The use of an on-board computer offers the flexibility to perform various operational tasks, although logic gate arrays will work as well.

FIGS. 80A, 80B, 80C, 80D, 81, 82, 83, 84, 85, and 86 show embodiments of the present invention that include at least one light level photosensor by itself or in combination with at least one occupancy sensor for increasing energy conservation and savings.

FIG. 80A shows an embodiment of the present invention. In particular shown is a schematic block diagram of an LED lamp 1274 that includes an LED array 1276 comprising a plurality of LEDs positioned in a translucent tube 1278. LED array 1276 is connected to a power supply comprising a source of VAC power 1280 electrically connected to a ballast 1282, which is external to tube 1278. An electrical connection 1284A positioned in tube 1278 is powered from ballast 1282 and transmits AC power to AC-DC power converter 1283, which in turn transmits DC power to an on-off switch 1286 also positioned in tube 1278 by way of electrical connection 1284B. A light level photosensor 1290 also positioned in tube 1278 transmits control signals to switch 1286 by way of signal line 1292. Electrical power is transmitted to photosensor 1290 also by electrical connection 1284B connected to AC-DC power converter 1283. AC or DC voltage depending on the model and type of design may power Photosensor 1290. For DC voltage power to photosensor 1290, an optional voltage regulator or DC-DC converter may be used. Photosensor control in response to the light level amounts of daylight around the illumination area of LED array 1276 are set at the place of manufacture or assembly in accordance with methods known in the art. Power from ballast 1282 can be either AC or DC voltage. In the case of DC power going into AC-DC power converter 1283, DC power will continue to be sent to on-off switch 1286 and photosensor 1290. Switch 1286 is electrically connected to LED array 1276 by electrical connection 1288. LED array 1276 contains the necessary electrical components to further reduce the power transmitted by switch 1286 by way of electrical connection 1288 to properly drive the plurality of LEDs in LED array 1276.

When photosensor 1290 detects a lower level of daylight around the illumination area of LED array 1276, an instant on-mode output signal is transmitted from photosensor 1290 to switch 1286, wherein power is transmitted through switch 1286 to LED array 1276. When photosensor 1290 detects a higher level of daylight around the illumination area of LED array 1276, a delayed off-mode signal is transmitted from photosensor 1290 to switch 1286, wherein switch 1286 is turned to the off-mode and power from ballast 1282 to AC-DC power converter 1283 through switch 1286 and to LED array 1276 is terminated. At such time when photosensor 1290 again detects a lower level of daylight around the illumination area of LED array 1276, an instant on-mode signal is again transmitted from photosensor 1290 to switch 1286, wherein switch 1286 is turned to the on-mode and power from ballast 1282 to AC-DC power converter 1283 through switch 1286 and to LED array 1276 is activated, so that LED array 1276 illuminates the area. The time delay designed into the off-mode prevents intermittent illumination cycling in the area around LED array 1276 and can be preset at the factory or can be set in the field. A delayed on-mode can also be set as well.

FIG. 80B shows another embodiment of the present invention. In particular, shown is a schematic block diagram of an LED lamp 1294 that includes an LED array 1296 comprising a plurality of LEDs positioned in a translucent tube 1298. LED array 1296 is connected to a power supply comprising a source of VAC power 1300 electrically connected to a ballast 1302, which is external to tube 1298. An electrical connection 1304A positioned in tube 1298 is powered from ballast 1302 and transmits AC power to AC-DC power converter 1303, which in turn transmits DC power to a computer or logic gate array 1306 by way of electrical connection 1304B and to dimmer 1310 by way of a similar electrical connection (not shown). Both computer or logic gate array 1306 and dimmer 1310 are also positioned in tube 1298. Computer or logic gate array 1306 has an input signal port and an output signal port. A light level photosensor 1314 also positioned in tube 1298,

transmits control signals to computer or logic gate array **1306** by way of input control signal line **1316** to the input signal port of computer or logic gate array **1306**. Electrical power is transmitted to photosensor **1314** also by electrical connection **1304**B connected to AC-DC power converter **1303**. AC or DC voltage depending on the model and type of design may power Photosensor **1314**. For DC voltage power to photosensor **1314**, an optional voltage regulator or DC-DC converter may be used. Photosensor control in response to the light level amounts of daylight around the illumination area of LED array **1296** are set at the place of manufacture or assembly in accordance with methods known in the art. Power from ballast **1302** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1303**, DC power will continue to be sent to computer or logic gate array **1306**, photosensor **1314**, and dimmer **1310**. Computer or logic gate array **1306** is electrically and operatively connected by an electrical control connection **1308** to dimmer **1310**. An electrical connection **1312** connects dimmer **1310** to LED array **1296**. Dimmer **1310** will contain the necessary electronics needed to decode the data control signals sent by the output signal port of computer or logic gate array **1306**, and will provide the proper current drive power required to operate LED array **1296**. Single LED array **1296** controlled by dimmer **1310** can represent multiple LED arrays (not shown), each correspondingly controlled by one of a plurality of dimmers **1310** (not shown), wherein the plurality of dimmers **1310** are each independently controlled by computer or logic gate array **1306**. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

When photosensor **1314** detects a lower level of daylight around the illumination area of LED array **1296**, photosensor **1314** sends a signal to the signal input port of computer or logic gate array **1306** by way of signal line **1316**, wherein computer or logic gate array **1306** then sends a signal from the signal output port to dimmer **1310** to provide full power to LED array **1296** for full illumination. When photosensor **1314** detects a higher level of daylight around the illumination area of LED array **1296** after a set time period, a photosensor signal to computer or logic gate array **1306** by way of signal line **1316** causes computer or logic gate array **1306** to send an output signal to dimmer **1310** to decrease the power to LED array **1296** by a preset amount, so that LED array **1296** reduces full illumination of the area, that is, illumination is continued, but reduced to a preset illumination output.

Photosensor **1314**, computer or logic gate array **1306**, and dimmer **1310** can be optionally organized into an integral circuit module. This system is used primarily for energy conservation and savings for residential, commercial, and industrial buildings and facilities. Photosensor **1314** can be one of many varieties of photosensors. Such sensors can include photodiodes, bipolar phototransistors, and the photoFET (photosensitive field-effect transistor). Light level photosensor **1314** gets its power from the main power supply VAC **1300** or internally from LED lamp **1294**. On-board computer or logic gate array **1306** constantly runs a monitoring program that looks at the output of photosensor **1314**. Power to LED array **1296** is normally on and will dim between a fully off zero percent to a preset intensity of less than 100 percent depending on the output of photosensor **1314**. When photosensor **1314** detects a higher level of daylight within its operating range, it flags an input to computer or logic gate array **1306**, which signals dimmer **1310** to dim the power to LED array **1296**. LED array **1296** can be programmed to dim instantaneously or after some pre-programmed time delay.

FIG. **80**C shows yet another embodiment of the present invention, in particular, shown as a schematic block diagram of an LED lamp **1318** that includes an LED array **1320** comprising a plurality of LEDs positioned in an elongated translucent tube **1322**. LED array **1320** is connected to a power supply comprising a source of VAC power **1324** electrically connected to a ballast **1326**, which is external to tube **1322**. An electrical connection **1328**A positioned in tube **1322** is powered from ballast **1326** and transmits AC power to AC-DC power converter **1327**, which in turn transmits DC power to an on-off switch **1330** also positioned in tube **1322** by way of electrical connection **1328**B. Power from ballast **1326** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1327**, DC power will continue to be sent to on-off switch **1330**. Switch **1330** is electrically connected to LED array **1320** by electrical connection **1332**. LED array **1320** contains the necessary electrical components to further reduce the power transmitted by switch **1330** by way of electrical connection **1332** to properly drive the plurality of LEDs in LED array **1320**.

An external light level photosensor **1334** positioned external to LED lamp **1318** is operationally connected to on-off switch **1330** by any of three optional alternative signal paths **1336**A, **1336**B, or **1336**C. Signal path **1336**A is an electrical signal line wire extending directly from photosensor **1334** to switch **1330**. Signal path **1336**B is a wireless signal path shown in dash line extending directly to switch **1330**. Signal path **1336**C is a signal line wire that is connected to a PLC line **1338** that extends from VAC **1324** through tube **1322** to switch **1330**. Switch **1330** also contains the necessary electronics to decode the data information imposed on PLC line **1338** via signal path **1336**C. When photosensor **1334** detects a lower level of daylight around the illumination area of LED array **1320**, photosensor **1334** sends a signal to switch **1330** by way of signal path **1336**A or signal path **1336**B or signal path **1336**C, whatever the case may be, wherein switch **1330** is activated from the off-mode to the on-mode, so that power is transmitted through switch **1330** to LED array **1320** and LED array **1320** illuminates the area. At such time photosensor **1334** detects a higher level of daylight around the illumination area of LED array **1320**, photosensor **1334** sends a signal to switch **1330**, wherein switch **1330** is activated from the on-mode to the off-mode, so that power to LED array **1320** is terminated and LED array **1320** no longer illuminates the area.

FIG. **80**D shows as a schematic block diagram of an LED lamp **1340** that includes an LED array **1342** comprising a plurality of LEDs positioned in a translucent tube **1344**. LED array **1342** is connected to a power supply comprising a source of VAC power **1346** electrically connected to a ballast **1348**, which is external to tube **1344**. An electrical connection **1350**A positioned in tube **1344** is powered from ballast **1348** and transmits AC power to an AC-DC power converter **1349**, which in turn transmits DC power to a computer or logic gate array **1352** by way of electrical connection **1350**B and to a current driver dimmer **1356** by way of a similar electrical connection (not shown). Both computer or logic gate array **1352** and dimmer **1356** are also positioned in tube **1344**. Power from ballast **1348** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1349**, DC power will continue to be sent to computer or logic gate array **1352** and dimmer **1356**. Computer or logic gate array **1352** is electrically and operatively connected by an electrical control connection **1354** to dimmer **1356**. An electrical connection **1358** connects dimmer **1356** to LED array **1342**. Dimmer **1356** will contain the necessary electronics needed to decode the data control signals sent by computer or

logic gate array **1352**, and will provide the proper current drive power required to operate LED array **1342**. A single LED array **1342** controlled by dimmer **1356** can represent multiple LED arrays (not shown), each correspondingly controlled by one of a plurality of dimmers (not shown), wherein the plurality of dimmers are each independently controlled by computer or logic gate array **1352**. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

As shown in FIG. **80**D, a light level photosensor **1360** positioned external to LED lamp **1340** is operationally connected to computer or logic gate array **1352** by any of three optional alternative signal paths **1362**A, **1362**B, or **1362**C. Signal path **1362**A is an electrical signal line wire extending directly from photosensor **1360** to computer or logic gate array **1352**. Signal path **1362**B is a wireless signal path shown in dash line extending directly to computer or logic gate array **1352**. Signal path **1362**C is a signal line wire that is connected to a PLC line **1364** that extends from VAC **1346** through tube **1344** to computer or logic gate array **1352**. Computer or logic gate array **1352** also contains the necessary electronics to decode the data information imposed on PLC line **1364** via signal path **1362**C.

When photosensor **1360** detects a higher level of daylight after a preset time period around the illumination area of LED array **1342**, photosensor **1360** sends a signal to the input port of computer or logic gate array **1352** by way of signal path **1362**A, signal path **1362**B, or signal path **1362**C, whichever the case may be. Computer or logic gate array **1352** is activated to send or to continue to send a signal from the output port of computer or logic gate array **1352** by electrical line **1354** to dimmer **1356**, so that reduced power is transmitted through electrical line **1358** to LED array **1342** by a preset amount, and LED array **1342** reduces illumination from the prior full illumination of the area to a reduced lower illumination output level preset in dimmer **1356**, or computer or logic gate array **1352**, thus accomplishing a power savings.

When photosensor **1360** detects a lower level of daylight present around the illumination area of LED array **1342**, photosensor **1360** sends a signal to the input port of computer or logic gate array **1352** by way of one of signal paths **1362**A, **1362**B, or **1362**C, whichever the case might be. Computer or logic gate array **1352** then sends or continues to send a signal from the signal output port to dimmer **1356** by electrical line **1354**, wherein dimmer **1356** increases power being sent by electrical line **1358** to LED array **1342**, and LED array **1342** increases to full illumination by an output level preset in dimmer **1356**, or computer or logic gate array **1352**.

FIG. **81** shows another embodiment of the present invention. In particular, shown is a schematic block diagram of an LED lamp **1366** that includes an LED array **1368** comprising a plurality of LEDs positioned in a translucent tube **1370**. LED array **1368** is connected to a power supply comprising a source of VAC power **1372** electrically connected to a ballast **1374**, which is external to tube **1370**. An electrical connection **1376**A positioned in tube **1370** is powered from ballast **1374** and transmits AC or DC power to AC-DC power converter **1378**, which in turn transmits DC power to an on-off switch **1380** also positioned in tube **1370** by way of electrical connection **1376**B. Power is sent from power on-off switch **1380** to LED array **1368** by electrical connection **1382**. A light level photosensor **1384** and an occupancy sensor **1386** are also positioned in tube **1370**. Photosensor **1384** can include photodiodes, bipolar phototransistors, and the photoFET (photosensitive field-effect transistor). Occupancy sensor **1386** can be an infrared temperature occupancy sensor, an ultrasonic motion occupancy sensor, or a hybrid of both types being known in the art. Both photosensor **1384** and occupancy sensor **1386** transmit control signals to power switch **1380** by way of a signal line **1388**. Electrical power is transmitted to photosensor **1384** and occupancy sensor **1386** by electrical connection **1390** connected to AC-DC power converter **1378**. Photosensor **1384** and occupancy sensor **1386** can be powered by AC or DC voltage depending on the model and type of design. For DC voltage power to photosensor **1384** and occupancy sensor **1386**, an optional voltage regulator or DC-DC converter may be used. Light level photosensor **1384** controls are set at the place of manufacture or assembly in response to the light level of daylight present around the illumination area of LED array **1368** in accordance with methods known in the art. Power from ballast **1374** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1378**, DC power will continue to be sent to on-off power switch **1380**, photosensor **1384**, and occupancy sensor **1386**. LED array **1368** contains the necessary electrical components to further reduce or increase the power transmitted by power switch **1380** by way of electrical connection **1382** to properly drive the plurality of LEDs in LED array **1368**.

When photosensor **1384** detects a lower light level of daylight present around the illumination area of LED array **1368** and occupancy sensor **1386** detects a person in the illumination area of LED array **1368**, an instant on-mode output signal is transmitted from photosensor **1384** and occupancy sensor **1386** to power switch **1380**, wherein power is transmitted through power switch **1380** to LED array **1368** for full illumination. When photosensor **1384** detects a higher light level of daylight present around the illumination area of LED array **1368** and occupancy sensor **1386** ceases to detect movement or the presence of a person, a delayed off-mode signal is transmitted from photosensor **1384** and occupancy sensor **1386** to power switch **1380**, wherein power switch **1380** is turned to the off-mode, and power from ballast **1374** to AC-DC power converter **1378** through power switch **1380** and to LED array **1368** is terminated. At such time photosensor **1384** again senses a lower light level of daylight present around the illumination area of LED array **1368** and occupancy sensor **1386** detects the presence of a person, an instant on-mode signal is transmitted from photosensor **1384** and occupancy sensor **1386** to power switch **1380**, wherein power switch **1380** is turned to the on-mode and power from ballast **1374** to AC-DC power converter **1378** through power switch **1380** and to LED array **1368** is activated, so that LED array **1368** illuminates the area. A time delay designed into the on-mode and off-mode that prevents intermittent illumination cycling in the area around LED array **1368** can be preset at the factory or can be set in the field.

FIG. **82** shows another embodiment of the present invention and is analogous to FIG. **80**B, but is now shown with at least two sensors. In particular, shown is a schematic block diagram of an LED lamp **1392** that includes an LED array **1394** comprising a plurality of LEDs positioned in a translucent tube **1396**. LED array **1394** is connected to a power supply comprising a source of VAC power **1398** electrically connected to a ballast **1400**, which is external to tube **1396**. An electrical connection **1402**A positioned in tube **1396** is powered from ballast **1400** and transmits AC power to AC-DC power converter **1404**, which in turn transmits DC power to a computer or logic gate array **1406** by way of electrical connection **1402**B and to a current driver dimmer **1408** by way of an electrical connection (not shown). Both computer or logic gate array **1406** and dimmer **1408** are also positioned in tube **1396**. Computer or logic gate array **1406** has an input signal port and an output signal port (not shown). A light level photosensor **1410** and an occupancy sensor **1412** are also

positioned in tube **1396**. Occupancy sensor **1412** can be an infrared temperature occupancy sensor, or an ultrasonic motion occupancy sensor, or a hybrid of both types being known in the art. Dimmer **1408** is electrically connected to computer or logic gate array **1406** by electrical connection **1414**, and LED array **1394** is electrically connected to dimmer **1408** by electrical connection **1416**.

Both photosensor **1410** and occupancy sensor **1412** transmit control signals to computer or logic gate array **1406** by way of input control signal line **1418** to the input signal port of computer or logic gate array **1406**. Electrical power is transmitted to photosensor **1410** and occupancy sensor **1412** by electrical connection **1402**C connected to AC-DC power converter **1404**. Photosensor **1410** and occupancy sensor **1412** may be powered by AC or DC voltage depending on the model and type of design. For DC voltage power to photosensor **1410** and occupancy sensor **1412**, an optional voltage regulator or DC-DC converter may be used. Occupancy sensor controls responding to the movement or presence of a person and photosensor controls responding to the light level of daylight present around the illumination area of LED array **1394** are set at the place of manufacture or assembly in accordance with methods known in the art. Power from ballast **1400** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1404**, DC power will continue to be sent to computer or logic gate array **1406**, photosensor **1410**, occupancy sensor **1412**, and dimmer **1408**. Dimmer **1408** will contain the necessary electronics needed to decode the control signals sent by the output signal port of computer or logic gate array **1406**, and will provide the proper current drive power required to operate LED array **1394**. Single LED array **1394** controlled by dimmer **1408** can represent multiple LED arrays **1394**A each correspondingly controlled by one of a plurality of dimmers **1408**A and each independently controlled by computer or logic gate array **1406**. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

When photosensor **1410** detects a lower light level of daylight around the illumination area of LED array **1394** and occupancy sensor **1412** detects motion or the presence of a person, photosensor **1410** and occupancy sensor **1412** send a signal to the signal input port of computer or logic gate array **1406** by way of a signal line **1418**, wherein computer or logic gate array **1406** then sends a signal from the signal output port to dimmer **1408** by control line electrical connection **1414** to provide full power to LED array **1394** for full illumination. When photosensor **1410** detects a higher light level of daylight present around the illumination area of LED array **1394** after a set time period and occupancy sensor **1412** does not detect motion or the presence of a person in the illumination area of LED array **1394** after a set time period, a sensor signal to computer or logic gate array **1406** by way of signal line **1418** activates computer or logic gate array **1406** to send an output signal to dimmer **1408** to decrease the power to LED array **1394** by a preset amount, so that LED array **1394** decreases illumination of the area. When either of the opposite situations occur relative to the increase of light level of daylight or the lack of motion or presence of a person around the illumination area of LED array **1394**, light level photosensor **1410** and occupancy sensor **1412** signal dimmer **1408** to reduce the light from LED array **1394** to a preset illumination output.

Photosensor **1410**, occupancy sensor **1412**, computer or logic gate array **1406**, and dimmer **1408** can be optionally organized into an integral circuit module. This system is used primarily for energy conservation and savings for residential, commercial, and industrial buildings and facilities. Photosensor **1410** can be one of many varieties of light level detecting photosensors, and occupancy sensor **1412** can be one of many varieties of space occupancy sensors. Light level photosensor **1410** and occupancy sensor **1412** can get their power from the main power supply VAC **1398** or internally from LED lamp **1392**. An optional command system for the on-board computer when used, could constantly runs a monitoring program that looks at the output of light level photosensor **1410** and occupancy sensor **1412**. Both photosensor **1410** and occupancy sensor **1412** would have the same activation output in order to trigger computer or logic gate array **1406** to command dimmer **1408** to turn on LED array **1394**. Likewise, both photosensor **1410** and occupancy sensor **1412** would have the same deactivation output in order to trigger computer or logic gate array **1406** to command dimmer **1408** to turn off or to dim LED array **1394**. The latter would occur when photosensor **1410** detects a higher light level of daylight present and occupancy sensor **1412** does not detect motion or a person in the area. In certain instances, LED array **1394** will remain off or at a preset dimmed light level to best conserve energy. Power to LED array **1394** is normally on and will dim between a fully off zero percent to a preset intensity of less than 100 percent depending on the output of light level photosensor **1410** and occupancy sensor **1412**. When light level photosensor **1410** detects a higher light level of daylight present within its operating range and occupancy sensor **1412** no longer detects the motion or presence of a person, such sensors activate an input to computer or logic gate array **1406**, which signals dimmer **1408** to dim the power to LED array **1394**. LED array **1394** can be programmed to dim instantaneously or after some pre-programmed time delay.

FIG. **83** shows another embodiment of the present invention that includes a schematic block diagram of an LED lamp **1420** that includes an LED array **1422** comprising a plurality of LEDs positioned in an elongated translucent tube **1424**. LED array **1422** is connected to a power supply comprising a source of VAC power **1426** electrically connected to a ballast **1428**, which is external to tube **1424**. An electrical connection **1430**A positioned in tube **1424** is powered from ballast **1428** and transmits AC power to AC-DC power converter **1432**, which in turn transmits DC power to an on-off switch **1434** also positioned in tube **1424** by way of electrical connection **1430**B. Power from ballast **1428** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1432**, DC power will continue to be sent to on-off switch **1434**. Switch **1434** is electrically connected to LED array **1422** by electrical connection **1436**. LED array **1422** contains the necessary electrical components to further reduce the power transmitted by switch **1434** by way of electrical connection **1436** to properly drive the plurality of LEDs in LED array **1422**.

A light level photosensor **1438** and an occupancy sensor **1440** are both positioned external to LED lamp **1420**, and are operationally connected to on-off switch **1434** by any of three optional alternative signal paths **1442**A, **1442**B, or **1442**C. Signal path **1442**A is an electrical signal line wire extending directly from photosensor **1438** and occupancy sensor **1440** to switch **1434**. Signal path **1442**B is a wireless signal path shown in dash line extending directly to switch **1434** from photosensor **1438** and occupancy sensor **1440**. A PLC line **1444** extends from VAC **1426** through tube **1424** to switch **1434** by way of signal path **1442**C. Signal path **1442**C is a PLC electrical signal line extending from photosensor **1438** and occupancy sensor **1440** to switch **1434**. Switch **1434** also contains the necessary electronics to decode the data information imposed on PLC line **1444** via signal path **1442**C.

When photosensor **1438** detects a lower light level of daylight present around the illumination area of LED array **1422** and occupancy sensor **1440** detects motion or a person in the area of LED array **1422**, photosensor **1438** and occupancy sensor **1440**, send a signal to switch **1434** by way of signal path **1442**A or signal path **1442**B or signal path **1442**C, whatever the case may be, whereby switch **1434** is activated from the off-mode to the on-mode, so that power is transmitted through switch **1434** to LED array **1422** and illuminates the area. At such time when either photosensor **1438** detects a higher light level of daylight present around the illumination area of LED array **1422** and occupancy sensor **1440** no longer detects motion or a person, photosensor **1438** and occupancy sensor **1440** both send a signal to switch **1434**, wherein switch **1434** is activated from the on-mode to a delayed off-mode, so that power to LED array **1422** is terminated, and LED array **1422** no longer illuminates the area.

FIG. **84** shows another embodiment of the present invention and is analogous to FIG. **80**D, but is now shown with at least two sensors and in particular, shown as a schematic block diagram of an LED lamp **1446** that includes an LED array **1448** comprising a plurality of LEDs positioned in a translucent tube **1450**. LED array **1448** is connected to a power supply comprising a source of VAC power **1452** electrically connected to a ballast **1454**, which is external to tube **1450**. An electrical connection **1456**A positioned in tube **1450** is powered from ballast **1454** and transmits AC power to an AC-DC power converter **1458**, which in turn transmits DC power to a computer or logic gate array **1460** by way of an electrical connection **1456**B and to a current driver dimmer **1462** by way of a similar electrical connection (not shown). Both computer or logic gate array **1460** and dimmer **1462** are also positioned in tube **1450**. Power from ballast **1454** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1458**, DC power will continue to be sent to computer or logic gate array **1460** and dimmer **1462**. An electrical connection **1466** connects dimmer **1462** to LED array **1448**. Dimmer **1462** will contain the necessary electronics needed to decode the data control signals sent by computer or logic gate array **1460**, and will provide the proper current drive power required to operate LED array **1448**. Single LED array **1448** controlled by dimmer **1462** can represent multiple LED arrays **1448**A each correspondingly controlled by one of a plurality of dimmers **1462**A, wherein the plurality of dimmers **1462**A are each independently controlled by computer or logic gate array **1460**. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

A light level photosensor **1468** and an occupancy sensor **1470** are both positioned external to LED lamp **1446**, and are operationally connected to computer or logic gate array **1460** by any of three optional alternative signal paths **1472**A, **1472**B, or **1472**C. Signal path **1472**A is an electrical signal line wire extending directly from photosensor **1468** and occupancy sensor **1470** to computer or logic gate array **1460**. Signal path **1472**B is a wireless signal path shown in dash line extending directly to computer or logic gate array **1460**. Signal path **1472**C is a signal line wire that is connected to a PLC line **1474** that extends from VAC **1452** through tube **1450** to computer or logic gate array **1460**. Computer or logic gate array **1460** also contains the necessary electronics to decode the data information imposed on PLC line **1474** via signal path **1472**C.

When photosensor **1468** detects a lower light level of daylight present around the illumination area of LED array **1448** and occupancy sensor **1470** detects the presence of a person, photosensor **1468** and occupancy sensor **1470** send a signal to the input port of computer or logic gate array **1460** by way of signal path **1472**A, or signal path **1472**B, or signal path **1472**C, whichever the case might be. Computer or logic gate array **1460** is activated to send or to continue to send a signal from the output port of computer or logic gate array **1460** by electrical line **1464** to dimmer **1462**, so that full power is transmitted through electrical line **1466** to LED array **1448**, wherein LED array **1448** provides full illumination of the area.

When photosensor **1468** detects a higher level of daylight present after a preset time period around the illumination area of LED array **1448** and occupancy sensor **1470** ceases to detect the presence of a person, photosensor **1468** and occupancy sensor **1470** send a signal to the signal input port of computer or logic gate array **1460** by way of one of signal paths **1472**A, **1472**B, or **1472**C, whichever the case might be, whereby computer or logic gate array **1460** sends a signal from the signal output port to dimmer **1462** by electrical line **1464**, wherein dimmer **1462** reduces power being sent by electrical line **1466** to LED array **1448** by a preset amount, so that LED array **1448** reduces full illumination of the area, that is, illumination is either reduced to a lower illumination output level as preset in dimmer **1462**, or computer or logic gate array **1460**, and illumination is terminated.

FIG. **85** is a logic diagram **1476** related to the schematic block diagram shown in FIG. **84** that sets forth the four operational possibilities between the two types of sensors indicated as light level photosensor **1478** and occupancy sensor **1480**. In FIG. **84**, and similarly for FIGS. **82** and **83** that show both a photosensor and an occupancy sensor, four combinations of signals from photosensor **1478** and occupancy sensor **1480** provide data to a computer or logic gate array **1482** as follows:

1. When a LOW light level of daylight is detected by photosensor **1478**, a positive YES signal is transmitted to computer or logic gate array **1482** by any of the signal paths **1472**A, **1472**B, or **1472**C as shown in FIG. **84**; and when motion or the presence of a person ON is detected by occupancy sensor **1480**, a positive YES signal is sent to computer or logic gate array **1482** by any of the signal paths **1472**A, **1472**B, or **1472**C.

2. When a HIGH light level of daylight is detected by photosensor **1478**, a negative NO signal is transmitted to computer or logic gate array **1482** by any of signal paths such as signal paths **1472**A, **1472**B, or **1472**C shown in FIG. **84**; and when motion or the presence of a person ON is detected by occupancy sensor **1480**, a positive YES signal is sent to computer or logic gate array **1482** by any of the signal paths **1472**A, **1472**B, or **1472**C.

3. When a LOW light level of daylight is detected by photosensor **1478**, a positive YES signal is transmitted to computer or logic gate array **1482** by any of the signal paths **1472**A, **1472**B, or **1472**C; and when no motion or no presence of a person indicated by OFF is detected by occupancy sensor **1480**, a negative NO signal is sent to computer or logic gate array **1482** by any of the signal paths **1472**A, **1472**B, or **1472**C.

4. When a HIGH light level of daylight is detected by photosensor **1478**, a negative NO signal is transmitted to computer or logic gate array **1482** by any of the signal paths **1472**A, **1472**B, or **1472**C; and when no motion or no presence of a person indicated by OFF is detected by occupancy sensor **1480**, a negative NO signal is sent to computer or logic gate array **1482** by any of the signal paths **1472**A, **1472**B, or **1472**C.

Computer or logic gate array **1482** is programmed to send control signals to dimmer **1484** as a result of the received

sensor signals. A signal to increase current output from dimmer **1484** to the LED array (not shown) is indicated by a plus sign (+). A signal to decrease current output from dimmer **1484** to the LED array is indicated by a minus sign (−).

The net results of the above four combinations of sensor signals as received by computer or logic gate array **1482** as shown in FIG. **85** are as follows for maximum energy savings:

1. Photosensor **1478** detects a LOW light level of daylight present and occupancy sensor **1480** detects motion or the presence of a person, whereby computer or logic gate array **1482** sends a signal (+) to dimmer **1484** to increase current output to the LED array from OFF to a HIGH dimmer level setting up to a full power ON.

2. Photosensor **1478** detects a HIGH light level of daylight present and occupancy sensor **1480** detects motion or the presence of a person, whereby computer or logic gate array **1482** sends a signal (+) to dimmer **1484** to increase current output to the LED array from OFF to a LOW dimmer level setting.

3. Photosensor **1478** detects a LOW light level of daylight present and occupancy sensor **1480** detects no motion or no presence of a person, whereby computer or logic gate array **1482** sends a signal (−) to dimmer **1484** to decrease current output to the LED array from ON to a LOW dimmer level setting down to a full power OFF.

4. Photosensor **1478** detects a HIGH light level of daylight present and occupancy sensor **1480** detects no motion or no presence of a person, whereby computer or logic gate array **1482** sends a signal (−) to dimmer **1484** to decrease current output to the LED array from ON to a LOW dimmer level setting down to a full power OFF.

FIG. **86** shows another embodiment of the present invention in particular a schematic block diagram of a network **1486** of two LED lamps including first and second LED lamps, namely, LED lamp **1488**A and LED lamp **1488**B, respectively, in general proximity.

LED lamp **1488**A includes an LED array **1490**A positioned in a translucent tube **1492**A that is connected to a power supply comprising a source of VAC power **1494**A electrically connected to a ballast **1496**A, which is external to tube **1492**A. An electrical connection **1498**A connects ballast **1496**A to an AC-DC power converter **1500**A, which in turn provides DC power by way of electrical connection **1498**B to a computer or logic gate array **1502**A. An occupancy sensor **1504**A, a light level photosensor **1506**A, and a dimmer **1508**A are all positioned within tube **1492**A, that is, LED lamp **1488**A. Computer or logic gate array **1502**A send programmed activation signals to a current driver dimmer **1508**A by electrical connection **1510**A. An electrical connection **1510**A provides data control signals from computer or logic gate array **1502**A to dimmer **1508**A, and an electrical connection **1512**A provides power from dimmer **1508**A to LED array **1490**A. An optional timer (not shown) can also be used in LED lamp **1488**A as previously shown in FIGS. **77** and **78**A. Occupancy sensor **1504**A sends signals to computer or logic gate array **1502**A by a signal path **1514**A. Photosensor **1506**A sends signals to computer or logic gate array **1502**A by signal path **1516**A.

Dimmer **1508**A contains the electronics needed to decode the data control signals sent by computer or logic gate array **1502**A, and will provide the proper current drive power required to operate LED array **1490**A. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

LED lamp **1488**B includes an LED array **1490**B positioned in a translucent tube **1492**B that is connected to a power supply comprising a source of VAC power **1494**B electrically connected to a ballast **1496**B, which is external to tube **1492**B. An electrical connection **1498**C connects ballast **1496**B to an AC-DC power converter **1500**B, which in turn provides DC power by way of electrical connection **1498**D to a computer or logic gate array **1502**B. An occupancy sensor **1504**B, a light level photosensor **1506**B, and a current driver dimmer **1508**B are all positioned within tube **1492**B, that is, LED lamp **1488**B. Computer or logic gate array **1502**B sends programmed activation signals to dimmer **1508**B by electrical connection **1510**B. An electrical connection **1510**B provides data control signals from computer or logic gate array **1502**B to dimmer **1508**B, and an electrical connection **1512**B provides power from dimmer **1508**B to LED array **1490**B. An optional timer (not shown) can also be used in LED lamp **1488**B as previously shown in FIGS. **77** and **78**A. Occupancy sensor **1504**B sends signals to computer or logic gate array **1502**B by a signal path **1514**B. Photosensor **1506**B sends signals to computer or logic gate array **1502**B by signal path **1516**B.

Dimmer **1508**B contains the electronics needed to decode the data control signals sent by computer or logic gate array **1502**B, and will provide the proper current drive power required to operate LED array **1490**B. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means.

Computers or logic gate arrays **1502**A and **1502**B are in network signal communication with occupancy sensors **1504**A and **1504**B, respectively and also with photosensors **1506**A and **1506**B, respectively, and ultimately with dimmers **1508**A and **1508**B, respectively.

In programmed response to the signals from occupancy sensor **1504**A and photosensor **1506**A, computer or logic gate array **1502**A sends data out communication signals **1518** by wire signal path **1520**A, or alternative wireless signal path **1520**B as shown by dash line, or by PLC signal path **1520**C. Any one signal path by itself or in combination with any other input communication signal path to data in communication signals **1522** are directed to computer or logic gate array **1502**B.

In programmed response to the signals from occupancy sensor **1504**B and photosensor **1506**B, computer or logic gate array **1502**B send data out communication signals **1524** by wire signal path **1526**A, or alternative wireless signal path **1526**B as shown by dash line, or by PLC signal path **1526**C. Any one signal path by itself or in combination with any other input communication signal path to data in communication signals **1528** are directed to computer or logic gate array **1502**A.

Computers or logic gate arrays **1502**A and **1502**B continuously process the sensor data signals from occupancy sensors **1504**A and **1504**B, and photosensors **1506**A and **1506**B received in accordance with a monitoring program and transmit resultant control signals to dimmers **1508**A and **1508**B in accordance with a program, so as to control the current output of dimmers **1508**A and **1508**B, and to prevent flickering of LED lamps **1488**A and **1488**B by 1) simultaneously signaling both dimmers **1508**A and **1508**B either to maintain full power and emit maximum light output, or 2) simultaneously signaling both dimmers **1508**A and **1508**B to reduce power by a preset amount and emit less than maximum light from LED arrays **1490**A and **1490**B by a preset amount with the result that as a person walks about the combined illumination area, and if there is a change in light levels of daylight present in the illumination areas of LED lamps **1488**A and **1488**B, both lamps emit the same illumination with the result that continuous flickering between the lamps caused by different power controls at dimmers **1508**A and **1508**B is avoided. In sum-

mary, the operational networking of LED lamp network **1486** creates a continuous identical illumination without flicker.

As an alternative, depending on the amount of ambient light or daylight present around the illumination areas of LED lamps **1488**A and **1488**B, and as detected by photosensors **1506**A or **1506**B, the two lamps may emit different levels of illumination, but with the same result also that continuous flickering between both lamps is avoided.

LED arrays **1490**A and **1490**B can each include either a plurality of LEDs or a single LED. The number of individual LEDs in each LED array **1490**A and **1490**B can differ. Likewise, dimmers **1508**A and **1508**B can represent a plurality of dimmers.

Photosensor **1384** can include, for example, photodiodes, bipolar phototransistors, and the photoFET (photosensitive field-effect transistor).

Occupancy sensors can include, for example, optical incremental encoders, interrupters, photoreflective sensors, proximity and Hall Effect sensors, laser interferometers, triangulation sensors, magnetostrictive sensors, infrared temperature sensors, ultrasonic sensors, hybrid infrared and ultrasonic type sensors, cable extension sensors, LVDT sensors, and tachometer sensors.

The disclosure of the present continuation-in-part application relating to FIGS. **87-97** herewith commences.

FIG. **87** shows an LED lamp **1530** retrofitted to an existing elongated fluorescent fixture **1532** mounted to a ceiling **1534**. LED lamp **1530** includes a translucent tube **1536** in which is positioned an LED array **1538** and an AC-DC converter **1540**. An external power source **1542** is positioned in ceiling **1534**. Power source **1542** can be a source of VAC or VDC power. A pair of fixture mounting portions **1544**A and **1544**B extend downwardly from the ends of fixture **1532**. Fixture mounting portions **1544**A and **1544**B include opposed electrical contacts one of which is shown in FIG. **88**A as contact sockets **1546**A and **1546**B at one end of LED lamp **1530** and contact sockets **1546**C and **1546**D at the opposed end of LED lamp **1530**. As seen in FIG. **88**A, LED lamp **1530** includes opposed bi-pin electrical contacts **1548**A and **1548**B of the type used for a bi-pin fluorescent lamp that are positioned in double contact sockets **1546**A and **1546**B, respectively, so that LED lamp **1530** is in operative electrical contact with power source **1542**.

FIG. **88**B shows an alternate cross-sectional view analogous to the view shown in FIG. **88**A except that it relates to opposed single-pin electrical contacts of the type used for a single-pin fluorescent lamp. FIG. **88**B shows fixture mounting portion **1544**A as it would appear having a single contact socket **1546**E and a single-contact pin **1548**E positioned in socket **1546**E.

It is noted that power source **1542** has been installed in place of the former fluorescent ballast prior to the installation of retrofit LED lamp **1530**. The former fluorescent ballast (not shown) has been removed or bypassed. It is also noted that AC-DC converter **1540** shown mounted in tube **1536** passes DC voltage received from power source **1542**. LED lamp **1530** thus is capable either to receive DC voltage or to convert AC voltage received from external power source **1542** and pass DC voltage to LED array **1538**.

Internal AC-DC converter **1540** as shown in FIG. **87** is analogous to AC-DC converters in subsequent FIGS. **89**A-**93** and FIGS. **95** and **96**, which are all in electrical contact with external power sources analogous to the external power source shown in FIG. **87**. Thus, AC-DC converter **1540** is capable of converting external AC voltage to DC voltage or passing external DC voltage to DC voltage. Therefore, AC-DC converter can be used for either VAC and VDC external power sources. The retrofit LED lamps for fluorescent lamps shown in FIGS. **89**A-**93** and FIGS. **95** and **96** showing electrical connections to external power sources convert the received power, whether it be VAC or VDC power to VDC power for the already stated reason that the AC-DC converters can pass DC voltages.

When power source **1542** is a DC power source, AC-DC converter **1540** becomes optional and is not necessary for the operation of LED lamp **1530**. For this reason, another LED lamp (not shown) similar to LED lamp **1530**, but devoid of AC-DC converter **1540** could be substituted for LED lamp **1530** when an external VDC power source is available. It is further noted, however, that when AC-DC converter **1540** is present, LED lamp **1530** can be used for both a VAC and a VDC external power source. There can also be more than one AC-DC converter **1540** used in each LED lamp **1530**. Therefore, it is possible for LED lamp **1530** to contain no AC-DC converters **1540** or at least one AC-DC converter **1540**, and still function with any external power source **1542**.

In certain instances when power source **1542** is an AC power source, AC-DC converter **1540** also becomes optional. This occurs when the LEDs used in LED lamp **1530** are designed to operate directly off line voltage AC.

Optional voltage surge suppression device **1550** is also shown positioned in tube **1536**. Voltage surge suppression device **1550** is used to protect LED array **1538** and other electronics (not shown) contained in LED lamp **1530** from voltage spikes or surges coming in from power source **1542**. Voltage surge suppression device **1550** is usually located between external power source **1542** and AC-DC converter **1540** if present.

Retrofit LED lamp **1530** shows a basic structure that is applicable for inventive retrofit LED lamps **1552**, **1572**, **1596**, **1618**, **1644**, **1668**, **1694**, **1718**, **1758**A, **1758**B, **1800**A, **1800**B, and **1840** shown in FIGS. **89**A-**93** and FIGS. **95** to **97** that further include varying types of sensing devices, power saving devices, controls, and other components not shown in FIGS. **87**, **88**A, and **88**B as will be set forth herein.

Retrofit lamp **1530** is a basic retrofit lamp for an existing fluorescent lamp that is analogous to that described in U.S. Pat. No. 7,049,761 issued to Timmermans et al. on May 23, 2006, mentioned earlier herein. Timmennans, however, does not show, discuss, or suggest any devices for sensing lighting requirement in the illumination area of the LED lamp, nor the power saving devices associated with the devices for sensing lighting requirements as is particularly set forth herein as shown and discussed in the inventive embodiments mentioned above and shown in FIGS. **78-96** as described herein.

FIGS. **89**A, **89**B, **89**C, **89**D, **90**, **91**, **92**, **93**, **94**, **95**, and **96** show embodiments of the present invention that include at least one light level photosensor by itself, or at least one occupancy sensor by itself, or the combination of at least one light level photosensor and at least one occupancy sensor used together for increased energy conservation and savings. The addition of these sensors along with additional components will offer more beneficial energy savings over similar prior art basic LED lamps that do not incorporate power control devices as disclosed in the following figures and detailed descriptions.

FIG. **89**A shows an LED lamp **1552** that is an embodiment of the present invention retrofitted for mounting to an existing fluorescent fixture such as that shown in FIG. **87** with the understanding that one of the opposed bi-pin connectors shown in FIG. **88**A or the opposed single-pin connectors shown in FIG. **88**B are assumed herein although is not actually shown.

In particular shown is a schematic block diagram of LED lamp **1552** that includes an LED array **1554** comprising a plurality of LEDs positioned in a translucent tube **1556** as described in FIG. **88**. LED lamp **1552** is connected to a power source **1558**, which is external to tube **1556**. An electrical connection **1560**A positioned in tube **1556** is powered from power source **1558** and transmits power to AC-DC power converter **1562**, which in turn transmits DC power to an on-off switch **1564** also positioned in tube **1556** by way of electrical connection **1560**B. Voltage surge suppression devices (not shown) may be used between the power source **1558** and AC-DC power converter **1562** to protect the LED lamp **1552** from over-voltages on electrical connection **1560**A. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. A power control sensor **1568** also positioned in tube **1556** transmits control signals to switch **1564** by way of signal line **1570**.

Sensor **1568** may be one of many types of photosensors, or sensor **1568** may be one of many types of occupancy sensors. Electrical power is transmitted to sensor **1568** also by electrical connection **1560**B connected to AC-DC power converter **1562**. AC or DC voltage depending on the model and type of design may power sensor **1568**. For DC voltage power to sensor **1568**, an optional voltage regulator or DC-DC converter may be used. When sensor **1568** is a light level photosensor, control in response to the light level amounts of daylight around the illumination area of LED lamp **1552** are set at the place of manufacture or assembly in accordance with methods known in the art to provide corresponding light level outputs to LED array **1554**. When sensor **1568** is an occupancy sensor, the movement or the presence of a person in the immediate area around the occupancy sensor will determine if power is turned on or turned off to LED array **1554**.

Power from power source **1558** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1562**, DC power will continue to be sent to on-off switch **1564** and sensor **1568**. Switch **1564** is electrically connected to LED array **1554** by electrical connection **1566**. LED array **1554** contains the necessary electrical components known in the art (not shown) to further reduce and current limit the power transmitted by switch **1564** by way of electrical connection **1566** to properly drive the plurality of LEDs in LED array **1554**.

For the case when power control sensor **1568** is a light level photosensor that detects a lower level of daylight around the illumination area of LED lamp **1552**, an instant on-mode output signal is transmitted from sensor **1568** to switch **1564**, wherein power is transmitted through switch **1564** to LED array **1554**. When sensor **1568** detects a higher level of daylight around the illumination area of LED lamp **1552**, a delayed off-mode signal is transmitted from sensor **1568** to switch **1564**, wherein switch **1564** is turned to the off-mode and power from power source **1558** to AC-DC power converter **1562** through switch **1564** and to LED array **1554** is terminated. At such time when sensor **1568** again detects a lower level of daylight around the illumination area of LED lamp **1552**, an instant on-mode signal is again transmitted from sensor **1568** to switch **1564**, wherein switch **1564** is turned to the on-mode and power from power source **1558** to AC-DC power converter **1562** through switch **1564** and to LED array **1554** is activated, so that LED array **1554** illuminates the area. The time delay designed into the off-mode prevents intermittent illumination cycling in the area around LED array **1554** and can be preset at the factory or can be set in the field. A delayed on-mode can also be set as well in a similar manner.

For the case when power control sensor **1568** is an occupancy sensor that detects movement or the presence of a person in the illumination area of LED lamp **1552**, an instant on-mode output signal is transmitted from sensor **1568** to switch **1564**, wherein power is transmitted through switch **1564** to LED array **1554**. When sensor **1568** ceases to detect movement or the presence of a person in the illumination area of LED lamp **1552**, a delayed off-mode signal is transmitted from sensor **1568** to switch **1564**, wherein switch **1564** is turned to the off-mode and power from power source **1558** to power converter **1562** through switch **1564** and to LED array **1554** is terminated. At such time when sensor **1568** again senses motion or the presence of a person in the illumination area of LED lamp **1552**, an instant on-mode signal is again transmitted from sensor **1568** to switch **1564**, wherein switch **1564** is turned to the on-mode and power from power source **1558** to power converter **1562** through switch **1564** and to LED array **1554** is activated, so that LED array **1554** illuminates the area. The time delay designed into the off mode prevents intermittent illumination cycling in the area around LED array **1554** and can be preset at the factory or can be set in the field. A delayed on-mode can also be set as well in a similar manner.

FIG. **89**B shows an LED lamp **1572** that is another embodiment of the present invention retrofitted for mounting to an existing fluorescent fixture such as that shown in FIG. **87** with the understanding that one of the opposed bi-pin connectors shown in FIG. **88**A or the opposed single-pin connectors shown in FIG. **88**B is assumed herein although is not actually shown.

In particular, shown is a schematic block diagram of an LED lamp **1572** that includes an LED array **1574** comprising a plurality of LEDs positioned in a translucent tube **1576**. LED lamp **1572** is connected to a power source **1578**, which is external to tube **1576**. An electrical connection **1580**A positioned in tube **1576** is powered from power source **1578** and transmits power to AC-DC power converter **1582**, which in turn transmits DC power to a computer or logic gate array **1584** by way of electrical connection **1580**B and to dimmer **1588** by way of a similar electrical connection (not shown). Voltage surge suppression devices (not shown) may be used between the power source **1578** and AC-DC power converter **1582** to protect the LED lamp **1576** from over-voltages on electrical connection **1580**A. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. Computer or logic gate array **1584** and dimmer **1588** are also positioned in tube **1576**. Computer or logic gate array **1584** has an input signal port and an output signal port (not shown). A power control sensor **1592** also positioned in tube **1576**, transmits control signals to computer or logic gate array **1584** by way of input control signal line **1594** to the input signal port of computer or logic gate array **1584**. Sensor **1592** may be one of many types of light level photosensors or sensor **1592** may be one of many types of occupancy sensors. Electrical power is transmitted to sensor **1592** also by electrical connection **1580**B connected to AC-DC power converter **1582**. AC or DC voltage depending on the model and type of design may power sensor **1592**. For DC voltage power to sensor **1592**, an optional voltage regulator or DC-DC converter may be used. When sensor **1592** is a light level photosensor, photosensor control in response to the light level amounts of daylight around the illumination area of LED lamp **1572** are set at the place of manufacture or

assembly in accordance with methods known in the art to provide corresponding light level outputs to LED array **1574**. When sensor **1592** is an occupancy sensor, the movement or the presence of a person in the immediate area around the occupancy sensor will determine if power is turned on or off or dimmed to LED array **1574**.

Power from power source **1578** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1582**, DC power will continue to be sent to computer or logic gate array **1584**, sensor **1592**, and dimmer **1588**. Computer or logic gate array **1584** is electrically and operatively connected by an electrical control connection **1586** to dimmer **1588**. An electrical connection **1590** connects dimmer **1588** to LED array **1574**. Dimmer **1588** will contain the necessary electronics needed to decode the data control signals sent by the output signal port of computer or logic gate array **1584**, and will provide the proper current drive power required to operate LED array **1574**. LED array **1574** contains the necessary electrical components (not shown) to further reduce and current limit the power transmitted by dimmer **1588** by way of electrical connection **1590** to properly drive the plurality of LEDs in LED array **1574**. Single LED array **1574** controlled by dimmer **1588** can represent multiple LED arrays (not shown), each correspondingly controlled by one of a plurality of dimmers **1588** (not shown), wherein the plurality of dimmers **1588** are each independently controlled by computer or logic gate array **1584**. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means. A computer can also represent the many self-contained and embedded systems of programmable microcontrollers (MCU) available in the market today. These microcontrollers combine a microprocessor unit with peripherals, plus some additional circuits on the same chip to make a small control module requiring few other external devices. This single peripheral interface controller device can then be embedded into other electronic and mechanical devices for low-cost digital control.

For the case when power control sensor **1592** is a light level photosensor that detects a lower level of daylight around the illumination area of LED lamp **1572**, sensor **1592** sends a signal to the signal input port of computer or logic gate array **1584** by way of signal line **1594**, wherein computer or logic gate array **1584** then sends a signal from the signal output port to dimmer **1588** to provide full power to LED array **1574** for full illumination. When sensor **1592** detects a higher level of daylight around the illumination area of LED lamp **1572** after a set time period, a sensor signal to computer or logic gate array **1584** by way of signal line **1594** causes computer or logic gate array **1584** to send an output signal to dimmer **1588** to decrease the power to LED array **1574** by a preset amount, so that LED array **1574** reduces full illumination of the area, that is, illumination is continued, but reduced to a preset illumination output.

Sensor **1592**, computer or logic gate array **1584**, and dimmer **1588** can be optionally organized into an integral circuit module. This system is used primarily for energy conservation and savings for residential, commercial, and industrial buildings and facilities. Sensor **1592** can be one of many varieties of photosensors. Such light level sensors can include photodiodes, bipolar phototransistors, and the photo FET (photosensitive field-effect transistor). Sensor **1592** gets its power from the main power source **1578** or internally from LED lamp **1576**. On-board computer or logic gate array **1584** constantly looks at the output of sensor **1592**. Power to LED array **1574** is normally on and will dim between a fully off zero percent to a preset intensity of less than 100 percent depending on the output of sensor **1592**. When sensor **1592** detects a higher level of daylight within its operating range, it flags an input to computer or logic gate array **1584**, which signals dimmer **1588** to dim the power to LED array **1574**. LED array **1574** can be programmed to dim instantaneously or after some pre-programmed time delay.

For an alternate mode of operation where the user wants to maintain the same or constant amount of light level around the area of the LED lamp **1576**, power control sensor **1592** can continuously monitor the amount of daylight present and have the computer or logic gate array **1584** continuously adjust dimmer **1588** to raise or lower the brightness of LED array **1574**, so as to maintain the desired light level. This light level setting can be adjusted by the user in the field or can be preset at the factory. In this mode of operation, there is no time delay and the system works instantaneously and automatically.

Now for the case when power control sensor **1592** is an occupancy sensor that detects movement or the presence of a person in the illumination area of LED lamp **1572**, sensor **1592** sends a signal to the computer input port of computer or logic gate array **1584** by way of signal line **1594**, wherein computer or logic gate array **1584** then sends a signal from the output port to dimmer **1588** to provide full power to LED array **1574** for full illumination. When sensor **1592** ceases to detect motion or the presence of a person in the illumination area of LED lamp **1572** after a set time period, a sensor signal to computer or logic gate array **1584** by way of signal line **1594** causes computer or logic gate array **1584** to send an output signal to dimmer **1588** to decrease the power to LED array **1574** by a preset amount, so that LED array **1574** reduces full illumination of the area, that is, illumination is continued, but reduced to a preset illumination output.

Sensor **1592**, computer or logic gate array **1584**, and dimmer **1588** can be optionally organized into an integral circuit module. This system is used primarily for energy conservation and savings for residential, commercial, and industrial buildings and facilities. Sensor **1592** can be one of many varieties of space occupancy motion sensors. Such sensors can include, for example, optical incremental encoders, interrupters, photo-reflective sensors, proximity and Hall Effect sensors, laser interferometers, triangulation sensors, magnetostrictive sensors, ultrasonic sensors, cable extension sensors, LVDT sensors, and tachometer sensors. Sensor **1592** gets its power from the main power source **1578** or internally from LED lamp **1576**, if an internal backup power source is used. On-board computer or logic gate array **1584** constantly looks at the output of sensor **1592**. Power to LED array **1574** is normally on and will dim between a fully off zero percent to a preset intensity of less than 100 percent depending on the output of sensor **1592**. When sensor **1592** no longer detects the motion of presence of a person within its operating range, it flags an input to computer or logic gate array **1584**, which signals dimmer **1588** to dim the power to LED array **1574**. LED array **1574** can dim instantaneously or after some pre-programmed time delay.

FIG. **89**C shows an LED lamp **1596** that is another embodiment of the present invention retrofitted for mounting to an existing fluorescent fixture such as that shown in FIG. **87** with the understanding that one of the opposed bi-pin connectors shown in FIG. **88**A or the opposed single-pin connectors shown in FIG. **88**B is assumed herein although is not actually shown.

In particular, shown is a schematic block diagram of an LED lamp **1596** that includes an LED array **1598** comprising a plurality of LEDs positioned in an elongated translucent tube **1600**. LED lamp **1596** is connected to a power source

1602, which is external to tube 1600. An electrical connection 1604A positioned in tube 1600 is powered from power source 1602 and transmits power to AC-DC power converter 1606, which in turn transmits DC power to an on-off switch 1608 also positioned in tube 1600 by way of electrical connection 1604B. Voltage suppression devices (not shown) may be used between the power source 1602 and AC-DC power converter 1606 to protect the LED lamp 1596 from over-voltages on electrical connection 1604A. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. Power from power source 1602 can be either AC or DC voltage. In the case of DC power going into AC-DC power converter 1606, DC power will continue to be sent to on-off switch 1608. Switch 1608 is electrically connected to LED array 1598 by electrical connection 1610. LED array 1598 contains the necessary electrical components (not shown) to further reduce and current limit the power transmitted by switch 1608 by way of electrical connection 1610 to properly drive the plurality of LEDs in LED array 1598.

A power control sensor 1612 positioned external to LED lamp 1596 is operationally connected to on-off switch 1608 by any of three optional alternative signal paths 1614A, 1614B, or 1614C. Sensor 1612 may be one of many types of photosensors, or sensor 1612 may be one of many types of occupancy sensors. Signal path 1614A is an electrical signal line wire extending directly from sensor 1612 to switch 1608. Signal path 1614B is a wireless signal path shown in dash line extending directly to switch 1608. Signal path 1614C is a signal line wire that is connected to a PLC line 1616 that extends from power source 1602 through tube 1600 to switch 1608. Switch 1608 also contains the necessary electronics to decode the data information imposed on PLC line 1616 via signal path 1614C.

For the case when power control sensor 1612 is a light level photosensor that detects a lower level of daylight around the illumination area of LED lamp 1596, sensor 1612 sends a signal to switch 1608 by way of signal path 1614A or signal path 1614B or signal path 1614C, whatever the case may be, wherein switch 1608 is activated from the off-mode to the on-mode, so that power is transmitted through switch 1608 to LED array 1598 and LED array 1598 illuminates the area. At such time when sensor 1612 detects a higher level of daylight around the illumination area of LED lamp 1596, sensor 1612 sends a signal to switch 1608, wherein switch 1608 is activated from the on-mode to the off-mode, so that power to LED array 1598 is terminated and LED array 1598 no longer illuminates the area.

For the case when power control sensor 1612 is an occupancy sensor that detects movement or the presence of a person in the illumination area of LED lamp 1596, sensor 1612 sends a signal to switch 1608 by way of signal path 1614A or signal path 1614B or signal path 1614C, whatever the case may be, wherein switch 1608 is activated from the off-mode to the on-mode, so that power is transmitted through switch 1608 to LED array 1598 and LED array 1598 illuminates the area. At such time when sensor 1612 ceases to detect movement or the presence of a person in the illumination area of LED lamp 1596, sensor 1612 sends a signal to switch 1608, wherein switch 1608 is activated from the on-mode to the off-mode, so that power to LED array 1598 is terminated and LED array 1598 no longer illuminates the area.

FIG. 89D shows an LED lamp 1618 that is another embodiment of the present invention retrofitted for mounting to an existing fluorescent fixture such as that shown in FIG. 87 with the understanding that one of the opposed bi-pin connectors shown in FIG. 88A or the opposed single-pin connectors shown in FIG. 88B is assumed herein although is not actually shown.

In particular is shown a schematic block diagram of an LED lamp 1618 that includes an LED array 1620 comprising a plurality of LEDs positioned in a translucent tube 1622. LED lamp 1618 is connected to a power source 1624, which is external to tube 1622. An electrical connection 1626A positioned in tube 1622 transmits power to an AC-DC power converter 1628, which in turn transmits DC power to a computer or logic gate array 1630 by way of electrical connection 1626B and to a current driver dimmer 1634 by way of a similar electrical connection (not shown). Voltage suppression devices (not shown) may be used between the power source 1624 and AC-DC power converter 1628 to protect the LED lamp 1618 from over-voltages on electrical connection 1626A. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. Computer or logic gate array 1630 and dimmer 1634 are also positioned in tube 1622.

Power from power source 1624 can be either AC or DC voltage. In the case of DC power going into AC-DC power converter 1628, DC power will continue to be sent to computer or logic gate array 1630 and dimmer 1634. Computer or logic gate array 1630 is electrically and operatively connected by an electrical control connection 1632 to dimmer 1634. An electrical connection 1636 connects dimmer 1634 to LED array 1620. Dimmer 1634 will contain the necessary electronics needed to decode the data control signals sent by the output port of computer or logic gate array 1630, and will provide the proper current drive power required to operate LED array 1620. LED array 1620 contains the necessary electrical components (not shown) to further reduce and current limit the power transmitted by dimmer 1634 by way of electrical connection 1636 to properly drive the plurality of LEDs in LED array 1620. Single LED array 1620 controlled by dimmer 1634 can represent multiple LED arrays (not shown), each correspondingly controlled by one of a plurality of dimmers 1634 (not shown), wherein the plurality of dimmers 1634 are each independently controlled by computer or logic gate array 1630. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means. A computer can also represent the many self-contained and embedded systems of programmable microcontrollers (MCU) available in the market today. These microcontrollers combine a microprocessor unit with peripherals, plus some additional circuits on the same chip to make a small control module requiring few other external devices. This single peripheral interface controller device can then be embedded into other electronic and mechanical devices for low-cost digital control.

A power control sensor 1638 positioned external to LED lamp 1618 is operationally connected to computer or logic gate array 1630 by any of three optional alternative signal paths 1640A, 1640B, or 1640C. Sensor 1638 may be one of many types of photosensors, or sensor 1638 may be one of many types of occupancy sensors. Signal path 1640A is an electrical signal line wire extending directly from sensor 1638 to computer or logic gate array 1630. Signal path 1640B is a wireless signal path shown in dash line extending directly to computer or logic gate array 1630. Signal path 1640C is a signal line wire that is connected to a PLC line 1642 that extends from power source 1624 through tube 1622 to computer or logic gate array 1630. Computer or logic gate array

1630 also contains the necessary electronics to decode the data information imposed on PLC line 1642 via signal path 1640C.

For the case when power control sensor 1638 is a light level photosensor that detects a lower level of daylight around the illumination area of LED lamp 1618, sensor 1638 sends a signal to the input port of computer or logic gate array 1630 by way of signal line 1640A, 1640B, or 1640C, whichever the case may be, wherein computer or logic gate array 1630 then sends a signal from the output port to dimmer 1634 to provide full power to LED array 1620 for full illumination. When sensor 1638 detects a higher level of daylight around the illumination area of LED lamp 1618 after a set time period, a sensor signal to computer or logic gate array 1630 by way of signal line 1640A, 1640B, or 1640C, whichever the case may be, causes computer or logic gate array 1630 to send an output signal to dimmer 1634 to decrease the power to LED array 1620 by a preset amount, so that LED array 1620 reduces full illumination of the area, that is, illumination is continued, but reduced to a preset illumination output, thus accomplishing a power savings.

Sensor 1638, computer or logic gate array 1630, and dimmer 1634 can be optionally organized into an integral circuit module. This system is used primarily for energy conservation and savings for residential, commercial, and industrial buildings and facilities. Sensor 1638 can be one of many varieties of photosensors. Such light level sensors can include photodiodes, bipolar phototransistors, and the photo FET (photosensitive field-effect transistor). Sensor 1638 gets its power from the main power source 1624 or internally from LED lamp 1618. On-board computer or logic gate array 1630 constantly looks at the output of sensor 1638. Power to LED array 1620 is normally on and will dim between a fully off zero percent to a preset intensity of less than 100 percent depending on the output of sensor 1638. When sensor 1638 detects a higher level of daylight within its operating range, it flags an input to computer or logic gate array 1630, which signals dimmer 1634 to dim the power to LED array 1620. LED array 1620 can be programmed to dim instantaneously or after some pre-programmed time delay.

For an alternate mode of operation where the user wants to maintain the same or constant amount of light level around the area of the LED lamp 1618, power control sensor 1638 can continuously monitor the amount of daylight present, and have the computer or logic gate array 1630 continuously adjust dimmer 1634 to raise or lower the brightness of LED array 1620, so as to maintain the desired light level. This light level setting can be adjusted by the user in the field or can be preset at the factory. In this mode of operation, there is no time delay and the system works instantaneously and automatically.

For the case when power control sensor 1638 is an occupancy sensor that detects movement or the presence of a person in the illumination area of LED lamp 1618, sensor 1638 sends a signal to the computer input port of computer or logic gate array 1630 by way of signal line 1640A, 1640B, or 1640C, whichever the case may be, wherein computer or logic gate array 1630 then sends a signal from the output port to dimmer 1634 to provide full power to LED array 1620 for full illumination. When sensor 1638 ceases to detect motion or the presence of a person in the illumination area of LED lamp 1618 after a set time period, a sensor signal to computer or logic gate array 1630 by way of signal line 1640A, 1640B, or 1640C, whichever the case may be, causes computer or logic gate array 1630 to send an output signal to dimmer 1634 to decrease the power to LED array 1620 by a preset amount, so that LED array 1620 reduces full illumination of the area, that is, illumination is continued, but reduced to a preset illumination output, thus accomplishing a power savings.

Sensor 1638, computer or logic gate array 1630, and dimmer 1634 can be optionally organized into an integral circuit module. This system is used primarily for energy conservation and savings for residential, commercial, and industrial buildings and facilities. Sensor 1638 can be one of many varieties of space occupancy motion sensors. Such sensors can include, for example, optical incremental encoders, interrupters, photo-reflective sensors, proximity and Hall Effect sensors, laser interferometers, triangulation sensors, magnetostrictive sensors, ultrasonic sensors, cable extension sensors, LVDT sensors, and tachometer sensors. Sensor 1638 gets its power from the main power source 1624 or internally from LED lamp 1618. On-board computer or logic gate array 1630 constantly looks at the output of sensor 1638. Power to LED array 1620 is normally on and will dim between a fully off zero percent to a preset intensity of less than 100 percent depending on the output of sensor 1638. When sensor 1638 no longer detects the motion of presence of a person within its operating range, it flags an input to computer or logic gate array 1630, which signals dimmer 1634 to dim the power to LED array 1620. LED array 1620 can dim instantaneously or after some pre-programmed time delay.

FIG. 90 shows an LED lamp 1644 that is another embodiment of the present invention retrofitted for mounting to an existing fluorescent fixture such as that shown in FIG. 87 with the understanding that one of the opposed bi-pin connectors shown in FIG. 88A or the opposed single-pin connectors shown in FIG. 88B is assumed herein although is not actually shown.

LED lamp 1644 is analogous to FIG. 89A, but is now shown with at least two sensors. In particular, shown is a schematic block diagram of an LED lamp 1644 that includes an LED array 1646 comprising a plurality of LEDs positioned in a translucent tube 1648. LED lamp 1644 is connected to a power source 1650, which is external to tube 1648. An electrical connection 1652A positioned in tube 1648 transmits power to AC-DC power converter 1654, which in turn transmits DC power to an on-off switch 1656 also positioned in tube 1648 by way of electrical connection 1652B. Voltage suppression devices (not shown) may be used between the power source 1650 and AC-DC power converter 1654 to protect the LED lamp 1644 from over-voltages on electrical connection 1652A. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. Power is sent from power on-off switch 1656 to LED array 1646 by electrical connection 1658. A light level photosensor 1660 and an occupancy sensor 1662 are also positioned in tube 1648. Photosensor 1660 can include photodiodes, bipolar phototransistors, and the photo FET (photosensitive field-effect transistor). Occupancy sensor 1662 can be an infrared temperature occupancy sensor, an ultrasonic motion occupancy sensor, or a hybrid of both types being known in the art. Both photosensor 1660 and occupancy sensor 1662 transmit control signals to power switch 1656 by way of a signal line 1664. Electrical power is transmitted to photosensor 1660 and occupancy sensor 1662 by electrical connection 1666 connected to AC-DC power converter 1654. Photosensor 1660 and occupancy sensor 1662 can be powered by AC or DC voltage depending on the model and type of design. For DC voltage power to photosensor 1660 and occupancy sensor 1662, an optional voltage regulator or DC-DC converter may be used. Light level photosensor 1660 controls are set at the place of manufacture or assembly in response to the light level of daylight present

around the illumination area of LED lamp **1644** in accordance with methods known in the art.

Power from power source **1650** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1654**, DC power will continue to be sent to on-off power switch **1656**, photosensor **1660**, and occupancy sensor **1662**. LED array **1646** contains the necessary electrical components (not shown) to further reduce and current limit the power transmitted by power switch **1656** by way of electrical connection **1658** to properly drive the plurality of LEDs in LED array **1646**.

When photosensor **1660** detects a lower light level of daylight present around the illumination area of LED lamp **1644** and occupancy sensor **1662** detects a person in the illumination area of LED lamp **1644**, an instant on-mode output signal is transmitted from photosensor **1660** and occupancy sensor **1662** to power switch **1656**, wherein power is transmitted through power switch **1656** to LED array **1646** for full illumination. When photosensor **1660** detects a higher light level of daylight present around the illumination area of LED lamp **1644** and occupancy sensor **1662** ceases to detect movement or the presence of a person, a delayed off-mode signal is transmitted from photosensor **1660** and occupancy sensor **1662** to power switch **1656**, wherein power switch **1656** is turned to the off-mode, and power from power source **1650** to AC-DC power converter **1654** through power switch **1656** and to LED array **1646** is terminated. At such time photosensor **1660** again senses a lower light level of daylight present around the illumination area of LED lamp **1644** and occupancy sensor **1662** detects the presence of a person, an instant on-mode signal is transmitted from photosensor **1660** and occupancy sensor **1662** to power switch **1656**, wherein power switch **1656** is turned to the on-mode and power from power source **1650** to AC-DC power converter **1654** through power switch **1656** and to LED array **1646** is activated, so that LED array **1646** illuminates the area. A time delay designed into the on-mode and off-mode that prevents intermittent illumination cycling in the area around LED array **1646** can be preset at the factory or can be set in the field.

FIG. **91** shows an LED lamp **1668** that is another embodiment of the present invention retrofitted for mounting to an existing fluorescent fixture such as that shown in FIG. **87** with the understanding that one of the opposed bi-pin connectors shown in FIG. **88**A or the opposed single-pin connectors shown in FIG. **88**B is assumed herein although is not actually shown.

FIG. **91** is analogous to FIG. **89**B, but is now shown with at least two sensors. In particular, shown is a schematic block diagram of an LED lamp **1668** that includes an LED array **1670** comprising a plurality of LEDs positioned in a translucent tube **1672**. LED lamp **1668** is connected to a power source **1674**, which is external to tube **1672**. An electrical connection **1676**A positioned in tube **1672** is powered from power source **1674** and transmits power to AC-DC power converter **1678**, which in turn transmits DC power to a computer or logic gate array **1680** by way of electrical connection **1676**B and to a current driver dimmer **1682** by way of an electrical connection (not shown). Voltage suppression devices (not shown) may be used between the power source **1674** and AC-DC power converter **1678** to protect the LED lamp **1668** from over-voltages on electrical connection **1676**A. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. Both computer or logic gate array **1680** and dimmer **1682** are also positioned in tube **1672**. Computer or logic gate array **1680** has an input signal port and an output signal port (not shown). A light level photosensor **1684** and an occupancy sensor **1686** are also positioned in tube **1672**. Photosensor **1684** can include photodiodes, bipolar phototransistors, and the photo FET (photosensitive field-effect transistor). Occupancy sensor **1686** can be an infrared temperature occupancy sensor, or an ultrasonic motion occupancy sensor, or a hybrid of both types being known in the art. Dimmer **1682** is electrically connected to computer or logic gate array **1680** by electrical connection **1688**, and LED array **1670** is electrically connected to dimmer **1682** by electrical connection **1690**.

Both photosensor **1684** and occupancy sensor **1686** transmit control signals to computer or logic gate array **1680** by way of input control signal line **1692** to the input signal port of computer or logic gate array **1680**. Electrical power is provided to photosensor **1684** and occupancy sensor **1686** by electrical connection **1676**C connected to AC-DC power converter **1678** by way of electrical connection **1676**B. Photosensor **1684** and occupancy sensor **1686** may be powered by AC or DC voltage depending on the model and type of design. For DC voltage power to photosensor **1684** and occupancy sensor **1686**, an optional voltage regulator or DC-DC converter may be used. Occupancy sensor controls responding to the movement or presence of a person and photosensor controls responding to the light level of daylight present around the illumination area of LED lamp **1668** are set at the place of manufacture or assembly in accordance with methods known in the art.

Power from power source **1674** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1678**, DC power will continue to be sent to computer or logic gate array **1680**, photosensor **1684**, occupancy sensor **1686**, and dimmer **1682**. Dimmer **1682** will contain the necessary electronics (not shown) needed to decode the control signals sent by the output signal port of computer or logic gate array **1680**, and will provide the proper current drive and current limiting power required to operate LED array **1670**. Single LED array **1670** controlled by single dimmer **1682** can represent multiple LED arrays **1670**A each correspondingly controlled by one of a plurality of dimmers **1682**A, and each independently controlled by computer or logic gate array **1680**. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means. A computer can also represent the many self-contained and embedded systems of programmable microcontrollers (MCU) available in the market today. These microcontrollers combine a microprocessor unit with peripherals, plus some additional circuits on the same chip to make a small control module requiring few other external devices. This single peripheral interface controller device can then be embedded into other electronic and mechanical devices for low-cost digital control.

When photosensor **1684** detects a lower light level of daylight around the illumination area of LED lamp **1668** and occupancy sensor **1686** detects motion or the presence of a person, photosensor **1684** and occupancy sensor **1686** send a signal to the signal input port of computer or logic gate array **1680** by way of a signal line **1692**, wherein computer or logic gate array **1680** then sends a signal from the signal output port to dimmer **1682** by control line electrical connection **1688** to provide full power to LED array **1670** for full illumination. When photosensor **1684** detects a higher light level of daylight present around the illumination area of LED lamp **1668** after a set time period and occupancy sensor **1686** does not detect motion or the presence of a person in the illumination area of LED lamp **1668** after a set time period, a sensor signal to computer or logic gate array **1680** by way of signal line

1692 activates computer or logic gate array 1680 to send an output signal to dimmer 1682 to decrease the power to LED array 1670 by a preset amount, so that LED array 1670 decreases illumination of the area. When either of the opposite situations occur relative to the increase of light level of daylight or the lack of motion or presence of a person around the illumination area of LED lamp 1668, light level photosensor 1684 and occupancy sensor 1686 signal dimmer 1682 to reduce the light from LED array 1670 to a preset illumination output amount.

Photosensor 1684, occupancy sensor 1686, computer or logic gate array 1680, and dimmer 1682 can be optionally organized into an integral circuit module. This system is used primarily for energy conservation and savings for residential, commercial, and industrial buildings and facilities. Photosensor 1684 can be one of many varieties of light level detecting photosensors, and occupancy sensor 1686 can be one of many varieties of space occupancy sensors. Light level photosensor 1684 and occupancy sensor 1686 can get their power from the main power source 1674 or internally from LED lamp 1668. An optional command system for the on-board computer when used, could constantly runs a monitoring program that looks at the output of light level photosensor 1684 and occupancy sensor 1686. Both photosensor 1684 and occupancy sensor 1686 would have the same activation output in order to trigger computer or logic gate array 1680 to command dimmer 1682 to turn on LED array 1670. Likewise, both photosensor 1684 and occupancy sensor 1686 would have the same deactivation output in order to trigger computer or logic gate array 1680 to command dimmer 1682 to turn off or to dim LED array 1670. The latter would occur when photosensor 1684 detects a higher light level of daylight present and occupancy sensor 1686 does not detect motion or a person in the area. In certain instances, LED array 1670 will remain off or at a preset dimmed light level to best conserve energy. Power to LED array 1670 is normally on and will dim between a fully off zero percent to a preset intensity of less than 100 percent depending on the output of light level photosensor 1684 and occupancy sensor 1686. When light level photosensor 1684 detects a higher light level of daylight present within its operating range and occupancy sensor 1686 no longer detects the motion or presence of a person, such sensors activate an input to computer or logic gate array 1680, which signals dimmer 1682 to dim the power to LED array 1670. LED array 1670 can be programmed to dim instantaneously or after some pre-programmed time delay.

For an alternate mode of operation where the user wants to maintain the same or constant amount of light level around the area of the LED lamp 1668, light level photosensor 1684 can continuously monitor the amount of daylight present, and have the computer or logic gate array 1680 continuously adjust dimmer 1682 to raise or lower the brightness of LED array 1670, so as to maintain the desired light level. This light level setting can be adjusted by the user in the field or can be preset at the factory. In this mode of operation, there is no time delay and the system works instantaneously and automatically.

FIG. 92 shows an LED lamp 1694 that is another embodiment of the present invention retrofitted for mounting to an existing fluorescent fixture such as that shown in FIG. 87 with the understanding that one of the opposed bi-pin connectors shown in FIG. 88A or the opposed single-pin connectors shown in FIG. 88B is assumed herein although not actually shown.

FIG. 92 is similar to FIG. 89C, but now shows two sensors. FIG. 92 includes a schematic block diagram of an LED lamp 1694 that includes an LED array 1696 comprising a plurality of LEDs positioned in an elongated translucent tube 1698. LED lamp 1694 is connected to a power supply comprising a power source 1700, which is external to tube 1698. An electrical connection 1702A going into tube 1698 is powered from power source 1700 and transmits power to AC-DC power converter 1704, which in turn transmits DC power to an on-off switch 1706 positioned in tube 1698 by way of electrical connection 1702B. Voltage suppression devices (not shown) may be used between the power source 1700 and AC-DC power converter 1704 to protect the LED lamp 1694 from over-voltages on electrical connection 1702A. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. Power from power source 1700 can be either AC or DC voltage. In the case of DC power going into AC-DC power converter 1704, DC power will continue to be sent to on-off switch 1706. Switch 1706 is electrically connected to LED array 1696 by electrical connection 1708. LED array 1696 contains the necessary electrical components (not shown) to further reduce and current limit the power transmitted by switch 1706 by way of electrical connection 1708 to properly drive the plurality of LEDs in LED array 1696.

A light level photosensor 1710 and an occupancy sensor 1712 are both positioned external to LED lamp 1694, and are operationally connected to on-off switch 1706 by any of three optional alternative signal paths 1714A, 1714B, or 1714C. Signal path 1714A is an electrical signal line wire extending directly from photosensor 1710 and occupancy sensor 1712 to switch 1706. Signal path 1714B is a wireless signal path shown in dash line extending directly to switch 1706 from photosensor 1710 and occupancy sensor 1712. A PLC line 1716 extends from power source 1700 through tube 1698 to switch 1706 by way of signal path 1714C. Signal path 1714C is also an electrical signal line extending from photosensor 1710 and occupancy sensor 1712 to switch 1706. Switch 1706 also contains the necessary electronics to decode the data information imposed on PLC line 1716 via signal path 1714C.

When photosensor 1710 detects a lower light level of daylight present around the illumination area of LED lamp 1694 and occupancy sensor 1712 detects motion or a person in the area of LED array 1696, photosensor 1710 and occupancy sensor 1712, send a signal to switch 1706 by way of signal path 1714A or signal path 1714B or signal path 1714C, whatever the case may be, whereby switch 1706 is activated from the off-mode to the on-mode, so that power is transmitted through switch 1706 to LED array 1696 and illuminates the area. At such time when either photosensor 1710 detects a higher light level of daylight present around the illumination area of LED lamp 1694 and occupancy sensor 1712 no longer detects motion or a person, photosensor 1710 and occupancy sensor 1712 both send a signal to switch 1706, wherein switch 1706 is activated from the on-mode to a delayed off-mode, so that power to LED array 1696 is terminated, and LED array 1696 no longer illuminates the area.

FIG. 93 shows an LED lamp 1718 that is another embodiment of the present invention retrofitted for mounting to an existing fluorescent fixture such as that shown in FIG. 87 with the understanding that one of the opposed bi-pin connectors shown in FIG. 88A or the opposed single-pin connectors shown in FIG. 88B is assumed herein although not actually shown.

FIG. 93 is analogous to FIG. 89D, but is now shown with at least two sensors and in particular, shown as a schematic block diagram of an LED lamp 1718 that includes an LED array 1720 comprising a plurality of LEDs positioned in a

translucent tube **1722**. LED lamp **1718** is connected to a power supply comprising a power source **1724**, which is external to tube **1722**. An electrical connection **1726**A positioned in tube **1722** is powered from power source **1724** and transmits power to an AC-DC power converter **1728**, which in turn transmits DC power to a computer or logic gate array **1730** by way of an electrical connection **1726**B and to a current driver dimmer **1732** by way of a similar electrical connection (not shown). Voltage suppression devices (not shown) may be used between the power source **1724** and AC-DC power converter **1728** to protect the LED lamp **1718** from over-voltages on electrical connection **1726**A. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. Both computer or logic gate array **1730** and dimmer **1732** are also positioned in tube **1722**. Power from power source **1724** can be either AC or DC voltage. In the case of DC power going into AC-DC power converter **1728**, DC power will continue to be sent to computer or logic gate array **1730** and dimmer **1732**. An electrical connection **1736** connects dimmer **1732** to LED array **1720**. Dimmer **1732** will contain the necessary electronics (not shown) needed to decode the data control signals sent by computer or logic gate array **1730**, and will provide the proper current drive and current limiting power required to operate LED array **1720**. Single LED array **1720** controlled by single dimmer **1732** can represent multiple LED arrays **1720**A each correspondingly controlled by one of a plurality of dimmers **1732**A, wherein the plurality of dimmers **1732**A are each independently controlled by computer or logic gate array **1730**. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means. A computer can also represent the many self-contained and embedded systems of programmable microcontrollers (MCU) available in the market today. These microcontrollers combine a microprocessor unit with peripherals, plus some additional circuits on the same chip to make a small control module requiring few other external devices. This single peripheral interface controller device can then be embedded into other electronic and mechanical devices for low-cost digital control.

A light level photosensor **1738** and an occupancy sensor **1740** are both positioned external to LED lamp **1718**, and are operationally connected to computer or logic gate array **1730** by any of three optional alternative signal paths **1742**A, **1742**B, or **1742**C. Signal path **1742**A is an electrical signal line wire extending directly from photosensor **1738** and occupancy sensor **1740** to computer or logic gate array **1730**. Signal path **1742**B is a wireless signal path shown in dash line extending directly to computer or logic gate array **1730**. Signal path **1742**C is a signal line wire that is connected to a PLC line **1744** that extends from power source **1724** through tube **1722** to computer or logic gate array **1730**. Computer or logic gate array **1730** also contains the necessary electronics to decode the data information imposed on PLC line **1744** via signal path **1742**C.

When photosensor **1738** detects a lower light level of daylight present around the illumination area of LED lamp **1718** and occupancy sensor **1740** detects the presence of a person, photosensor **1738** and occupancy sensor **1740** send a signal to the input port of computer or logic gate array **1730** by way of signal path **1742**A, or signal path **1742**B, or signal path **1742**C, whichever the case might be. Computer or logic gate array **1730** is activated to send or to continue to send a signal from the output port of computer or logic gate array **1730** by electrical line **1734** to dimmer **1732**, so that full power is transmitted through electrical line **1736** to LED array **1720**, wherein LED array **1720** provides full illumination of the area.

When photosensor **1738** detects a higher level of daylight present after a preset time period around the illumination area of LED lamp **1718** and occupancy sensor **1740** ceases to detect the presence of a person, photosensor **1738** and occupancy sensor **1740** send a signal to the signal input port of computer or logic gate array **1730** by way of one of signal paths **1742**A, **1742**B, or **1742**C, whichever the case might be, whereby computer or logic gate array **1730** sends a signal from the signal output port to dimmer **1732** by electrical line **1734**, wherein dimmer **1732** reduces power being sent by electrical line **1736** to LED array **1720** by a preset amount, so that LED array **1720** reduces full illumination of the area, that is, illumination is either reduced to a lower illumination output level as preset in dimmer **1732**, or computer or logic gate array **1730**, or illumination is terminated.

For an alternate mode of operation where the user wants to maintain the same or constant amount of light level around the area of the LED lamp **1718**, light level photosensor **1738** can continuously monitor the amount of daylight present, and have the computer or logic gate array **1730** continuously adjust dimmer **1732** to raise or lower the brightness of LED array **1720**, so as to maintain the desired light level. This light level setting can be adjusted by the user in the field or can be preset at the factory. In this mode of operation, there is no time delay and the system works instantaneously and automatically.

FIG. **94** is a logic diagram **1746** related to the schematic block diagram shown in FIG. **93** that sets forth the four operational possibilities between the two types of sensors indicated as light level photosensor **1748** and occupancy sensor **1750**. In FIG. **93**, and similarly for FIGS. **90**, **91**, and **92** that show both a photosensor and an occupancy sensor, four combinations of signals from photosensor **1748** and occupancy sensor **1750** provide data to a computer or logic gate array **1752** as follows:

1. When a LOW light level of daylight is detected by photosensor **1748**, a positive YES signal is transmitted to computer or logic gate array **1752** by any of the signal paths **1742**A, **1742**B, or **1742**C as shown in FIG. **93**; and when motion or the presence of a person ON is detected by occupancy sensor **1750**, a positive YES signal is sent to computer or logic gate array **1752** by any of the signal paths **1742**A, **1742**B, or **1742**C.

2. When a HIGH light level of daylight is detected by photosensor **1748**, a negative NO signal is transmitted to computer or logic gate array **1752** by any of signal paths such as signal paths **1742**A, **1742**B, or **1742**C shown in FIG. **93**; and when motion or the presence of a person ON is detected by occupancy sensor **1750**, a positive YES signal is sent to computer or logic gate array **1752** by any of the signal paths **1742**A, **1742**B, or **1742**C.

3. When a LOW light level of daylight is detected by photosensor **1748**, a positive YES signal is transmitted to computer or logic gate array **1752** by any of the signal paths **1742**A, **1742**B, or **1742**C; and when no motion or no presence of a person indicated by OFF is detected by occupancy sensor **1750**, a negative NO signal is sent to computer or logic gate array **1752** by any of the signal paths **1742**A, **1742**B, or **1742**C.

4. When a HIGH light level of daylight is detected by photosensor **1748**, a negative NO signal is transmitted to computer or logic gate array **1752** by any of the signal paths **1742**A, **1742**B, or **1742**C; and when no motion or no presence of a person indicated by OFF is detected by occupancy sensor

1750, a negative NO signal is sent to computer or logic gate array 1752 by any of the signal paths 1742A, 1742B, or 1742C.

Computer or logic gate array 1752 is programmed to send control signals to dimmer 1754 as a result of the received sensor signals. A signal to increase current output from dimmer 1754 to the LED array (not shown) is indicated by a plus sign (+). A signal to decrease current output from dimmer 1754 to the LED array is indicated by a minus sign (−).

The net results of the above four combinations of sensor signals as received by computer or logic gate array 1752 as shown in FIG. 94 are as follows for maximum energy savings:

1. Photosensor 1748 detects a LOW light level of daylight present and occupancy sensor 1750 detects motion or the presence of a person, whereby computer or logic gate array 1752 sends a signal (+) to dimmer 1754 to increase current output to the LED array from OFF to a HIGH dimmer level setting up to a full power ON.

2. Photosensor 1748 detects a HIGH light level of daylight present and occupancy sensor 1750 detects motion or the presence of a person, whereby computer or logic gate array 1752 sends a signal (+) to dimmer 1754 to increase current output to the LED array from OFF to a LOW dimmer level setting.

3. Photosensor 1748 detects a LOW light level of daylight present and occupancy sensor 1750 detects no motion or no presence of a person, whereby computer or logic gate array 1752 sends a signal (−) to dimmer 1754 to decrease current output to the LED array from ON to a LOW dimmer level setting down to a full power OFF.

4. Photosensor 1748 detects a HIGH light level of daylight present and occupancy sensor 1750 detects no motion or no presence of a person, whereby computer or logic gate array 1752 sends a signal (−) to dimmer 1754 to decrease current output to the LED array from ON to a LOW dimmer level setting down to a full power OFF.

FIG. 95 shows another embodiment of the present invention in particular a schematic block diagram of a network 1756 of two LED lamps including first and second LED lamps, namely, LED lamp 1758A and LED lamp 1758B, respectively, in general proximity. LED lamp 1758A represents a master lamp in a first zone and LED lamp 1758B represents a master lamp in a second zone. Multiple master lamps with automated or remote control can exist in this network.

Each LED lamp 1758A and LED lamp 1758B is retrofitted for mounting to an existing fluorescent fixture such as that shown in FIG. 87 with the understanding that one of the opposed bi-pin connectors shown in FIG. 88A or the opposed single-pin connectors shown in FIG. 88B is assumed herein although not actually shown.

LED lamp 1758A includes an LED array 1760A positioned in a translucent tube 1762A that is connected to a power supply comprising a power source 1764A, which is external to tube 1762A. An electrical connection 1766A connects power source 1764A to an AC-DC power converter 1768A, which in turn provides DC power by way of electrical connection 1766B to a computer or logic gate array 1770A. Voltage suppression devices (not shown) may be used between the power source 1764A and AC-DC power converter 1768A to protect the LED lamp 1758A from overvoltages on electrical connection 1766A. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. An occupancy sensor 1772A, a light level photosensor 1774A, and a dimmer 1776A are all positioned within tube 1762A, that is, LED lamp 1758A. Computer or logic gate array 1770A send programmed activation signals to a current driver dimmer 1776A by electrical connection 1778A. Electrical connection 1778A provides data control signals from computer or logic gate array 1770A to dimmer 1776A, and an electrical connection 1780A provides power from dimmer 1776A to LED array 1760A. An optional timer (not shown) can also be used in LED lamp 1758A. Occupancy sensor 1772A sends signals to computer or logic gate array 1770A by a signal path 1782A. Photosensor 1774A sends signals to computer or logic gate array 1770A by signal path 1784A.

Dimmer 1776A contains the electronics (not shown) needed to decode the data control signals sent by computer or logic gate array 1770A, and will provide the proper current drive and current limiting power required to operate LED array 1760A. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means. A computer can also represent the many self-contained and embedded systems of programmable microcontrollers (MCU) available in the market today. These microcontrollers combine a microprocessor unit with peripherals, plus some additional circuits on the same chip to make a small control module requiring few other external devices. This single peripheral interface controller device can then be embedded into other electronic and mechanical devices for low-cost digital control.

LED lamp 1758B includes an LED array 1760B positioned in a translucent tube 1762B that is connected to a power supply comprising a power source 1764B, which is external to tube 1762B. An electrical connection 1766C connects power source 1764B to an AC-DC power converter 1768B, which in turn provides DC power by way of electrical connection 1766D to a computer or logic gate array 1770B. Voltage suppression devices (not shown) may be used between the power source 1764B and AC-DC power converter 1768B to protect the LED lamp 1758B from overvoltages on electrical connection 1766C. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. An occupancy sensor 1772B, a light level photosensor 1774B, and a current driver dimmer 1776B are all positioned within tube 1762B, that is, LED lamp 1758B. Computer or logic gate array 1770B sends programmed activation signals to dimmer 1776B by electrical connection 1778B. Electrical connection 1778B provides data control signals from computer or logic gate array 1770B to dimmer 1776B, and an electrical connection 1780B provides power from dimmer 1776B to LED array 1760B. An optional timer (not shown) can also be used in LED lamp 1758B. Occupancy sensor 1772B sends signals to computer or logic gate array 1770B by a signal path 1782B. Photosensor 1774B sends signals to computer or logic gate array 1770B by signal path 1784B.

Dimmer 1776B contains the electronics (not shown) needed to decode the data control signals sent by computer or logic gate array 1770B, and will provide the proper current drive and current limiting power required to operate LED array 1760B. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means. A computer can also represent the many self-contained and embedded systems of programmable microcontrollers (MCU) available in the market today. These microcontrollers combine a microprocessor unit with peripherals, plus some additional circuits on the same chip to make a small control module requiring few other external devices. This single peripheral interface controller

device can then be embedded into other electronic and mechanical devices for low-cost digital control.

Computers or logic gate arrays **1770**A and **1770**B are in network signal communication with occupancy sensors **1772**A and **1772**B, respectively and also with photosensors **1774**A and **1774**B, respectively, and ultimately with dimmers **1776**A and **1776**B, respectively.

In automatic programmed response to the signals from occupancy sensor **1772**A and photosensor **1774**A, computer or logic gate array **1770**A sends data out communication signals **1786** by wire signal path **1788**A, or alternative wireless signal path **1788**B as shown by dash line, or by PLC signal path **1788**C. Any one signal path by itself or in combination with any other input communication signal path to data in communication signals **1790** are directed to computer or logic gate array **1770**B.

In automatic programmed response to the signals from occupancy sensor **1772**B and photosensor **1774**B, computer or logic gate array **1770**B send data out communication signals **1792** by wire signal path **1794**A, or alternative wireless signal path **1794**B as shown by dash line, or by PLC signal path **1794**C. Any one signal path by itself or in combination with any other input communication signal path to data in communication signals **1796** are directed to computer or logic gate array **1770**A.

As an alternate manual control of LED lamps **1758**A and **1758**B, the automatic monitoring of the occupancy sensors **1772**A and **1772**B and of photosensors **1774**A and **1774**B can be suspended and the control of the computer or logic gate arrays **1770**A and **1770**B to control dimmers **1776**A and **1776**B that power LED arrays **1760**A and **1760**B can be taken over by the use of a remote serial data dimming controller (not shown) by way of input to the data in ports **1796** or **1790**. The dimming controller (not shown) can be used to program presets during the day or have a manual adjustment to dim the LED lamp down to full off or anywhere between 0% and 100% brightness. This remote dimming controller (not shown) will send the control signal directly to the LED lamps **1758**A and **1758**B, and does not change the input power to the light fixture like conventional dimmers do. The data control signal to a computer based control system driving the dimming controller can be direct hard-wired connections including DMX512, RS232, Ethernet, DALI, Lonworks, Remote Device Management (RDM), TCPIP, CEBus Standard EIA-600 by way of wire signal paths **1794**A or **1788**A; or can be wireless, including using IR (Infra-Red), RF (Radio-Frequency), WiFi/802.11, FHSS (Frequency Hopping Spread Spectrum, Bluetooth technology, and ZigBee by way of alternative wireless signal paths **1794**B or **1788**B as shown by dash line; and Power Line Carrier Communication (PLC) protocols using PLC signal paths **1794**C or **1788**C. Besides controlling the dimmer, the data control signal can be use to change the internal computer programming including timer settings, luminance levels and sensitivity adjustments, getting status and present state feedbacks, as well as other computer functions.

Computers or logic gate arrays **1770**A and **1770**B continuously and automatically process the sensor data signals from occupancy sensors **1772**A and **1772**B, and photosensors **1774**A and **1774**B received in accordance with a monitoring program and transmit resultant control signals to dimmers **1776**A and **1776**B in accordance with a program, so as to control the current output of dimmers **1776**A and **1776**B, and to prevent flickering of LED lamps **1758**A and **1758**B by 1) simultaneously signaling both dimmers **1776**A and **1776**B either to maintain full power and emit maximum light output, or 2) simultaneously signaling both dimmers **1776**A and **1776**B to reduce power by a preset amount and emit less than maximum light from LED arrays **1760**A and **1760**B by a preset amount with the result that as a person walks about the combined illumination area, and if there is a change in light levels of daylight present in the illumination areas of LED lamps **1758**A and **1758**B, both lamps emit the same illumination with the result that continuous flickering between the lamps caused by different power controls at dimmers **1776**A and **1776**B is avoided. In summary, the operational networking of LED lamp network **1756** creates a continuous identical illumination without flicker.

As an alternative, depending on the amount of ambient light or daylight present around the illumination areas of LED lamps **1758**A and **1758**B, and as detected by photosensors **1774**A or **1774**B, the two lamps may emit different levels of illumination, but with the same result also that continuous flickering between both lamps is avoided.

For another alternate mode of operation where the user wants to maintain the same or constant amount of light level around the area of the LED lamps **1758**A and **1758**B, photosensors **1774**A and **1774**B can continuously monitor the amount of daylight present around their immediate area, and have their respective computer or logic gate arrays **1770**A and **1770**B continuously adjust dimmers **1776**A and **1776**B, to individually raise or lower the brightness of LED arrays **1760**A and **1760**B, so as to maintain the desired light level. This light level setting can be adjusted by the user in the field or can be preset at the factory. In this mode of operation, there is no time delay and the system works instantaneously and automatically to cover a wider area of the desired light level.

In addition, LED arrays **1760**A and **1760**B can each include either a plurality of LEDs or a single LED. The number of individual LEDs in each LED array **1760**A and **1760**B can differ. Likewise, dimmers **1776**A and **1776**B can represent a plurality of dimmers.

FIG. **96** shows another embodiment of the present invention in particular a schematic block diagram of a network **1798** of two LED lamps including first and second LED lamps, namely, LED lamp **1800**A and LED lamp **1800**B, respectively, in general proximity. LED lamp **1800**A represents a master lamp in a first zone and LED lamp **1800**B represents a slave lamp in the same first zone. Master lamps and multiple slave lamps with automated or manual remote control can exist in this network.

Each LED lamp **1800**A and **1800**B is retrofitted for mounting to an existing fluorescent fixture such as that shown in FIG. **87** with the understanding that one of the opposed bi-pin connectors shown in FIG. **88**A or the opposed single-pin connectors shown in FIG. **88**B is assumed herein although not actually shown.

A typical master and slave configuration is described as follows.

LED lamp **1800**A includes an LED array **1802**A positioned in a translucent tube **1804**A that is connected to a power supply comprising a power source **1806**A, which is external to tube **1804**A. An electrical connection **1808**A connects power source **1806**A to an AC-DC power converter **1810**A, which in turn provides DC power by way of electrical connection **1808**B to a computer or logic gate array **1812**A. Voltage suppression devices (not shown) may be used between the power source **1806**A and AC-DC power converter **1810**A to protect the LED lamp **1800**A from overvoltages on electrical connection **1808**A. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. An occupancy sensor **1814**, a light level photosensor **1816**, and a

dimmer **1818**A are all positioned within tube **1804**A, that is, LED lamp **1800**A. Computer or logic gate array **1812**A send programmed activation signals to a current driver dimmer **1818**A by electrical connection **1820**A. Electrical connection **1820**A provides data control signals from computer or logic gate array **1812**A to dimmer **1818**A, and an electrical connection **1822**A provides power from dimmer **1818**A to LED array **1802**A. An optional timer (not shown) can also be used in LED lamp **1800**A. Occupancy sensor **1814** sends signals to computer or logic gate array **1812**A by a signal path **1824**. Photosensor **1816** sends signals to computer or logic gate array **1812**A by signal path **1826**.

Dimmer **1818**A contains the electronics (not shown) needed to decode the data control signals sent by computer or logic gate array **1812**A, and will provide the proper current drive and current limiting power required to operate LED array **1802**A. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means. A computer can also represent the many self-contained and embedded systems of programmable microcontrollers (MCU) available in the market today. These microcontrollers combine a microprocessor unit with peripherals, plus some additional circuits on the same chip to make a small control module requiring few other external devices. This single peripheral interface controller device can then be embedded into other electronic and mechanical devices for low-cost digital control.

LED lamp **1800**B includes an LED array **1802**B positioned in a translucent tube **1804**B that is connected to a power supply comprising a power source **1806**B, which is external to tube **1804**B. An electrical connection **1808**C connects power source **1806**B to an AC-DC power converter **1810**B, which in turn provides DC power by way of electrical connection **1808**D to a computer or logic gate array **1812**B. Voltage suppression devices (not shown) may be used between the power source **1806**B and AC-DC power converter **1810**B to protect the LED lamp **1800**B from overvoltages on electrical connection **1808**C. The voltage suppression devices can include inductors, step-down transformers, transient voltage suppressors (TVS), movistors (MOV), transorbs, voltage absorbers, varistors, etc. A current driver dimmer **1818**B is positioned within tube **1804**B, that is, LED lamp **1800**B. Computer or logic gate array **1812**B sends programmed activation signals to dimmer **1818**B by electrical connection **1820**B. Electrical connection **1820**B provides data control signals from computer or logic gate array **1812**B to dimmer **1818**B, and an electrical connection **1822**B provides power from dimmer **1818**B to LED array **1802**B. An optional timer (not shown) can also be used in LED lamp **1800**B.

Dimmer **1818**B contains the electronics (not shown) needed to decode the data control signals sent by computer or logic gate array **1812**B, and will provide the proper current drive and current limiting power required to operate LED array **1802**B. A computer, when used, includes a microprocessor, a data program installed therein, memory, input/output means, and addressing means. A computer can also represent the many self-contained and embedded systems of programmable microcontrollers (MCU) available in the market today. These microcontrollers combine a microprocessor unit with peripherals, plus some additional circuits on the same chip to make a small control module requiring few other external devices. This single peripheral interface controller device can then be embedded into other electronic and mechanical devices for low-cost digital control.

Computers or logic gate arrays **1812**A and **1812**B are in network signal communication with single occupancy sensor **1814** and also with single photosensor **1816**, and ultimately with dimmers **1818**A and **1818**B.

In automatic programmed response to the signals from single occupancy sensor **1814** and single photosensor **1816**, computer or logic gate array **1812**A sends data out communication signals **1828** by wire signal path **1830**A, or alternative wireless signal path **1830**B as shown by dash line, or by PLC signal path **1830**C. Any one signal path by itself or in combination with any other input communication signal path to data in communication signals **1832** are directed to computer or logic gate array **1812**B. The Slave LED lamp **1800**B provides no feedback to the Master LED lamp **1800**A. Slave LED lamp **1800**B simply takes the control signal and data received from Master LED lamp **1800**A and acts upon it. There may more than one Slave LED lamp **1800**B for every one Master LED lamp **1800**A.

As an alternate manual control of LED lamps **1800**A and **1800**B, the automatic monitoring of occupancy sensor **1814** and of photosensor **1816** can be suspended and the control of the computer or logic gate arrays **1812**A and **1812**B to control dimmers **1818**A and **1818**B that power LED arrays **1802**A and **1802**B can be taken over by the use of a remote serial data dimming controller **1834** by way of input to the data in port **1838**. The dimming controller **1834** can be used to program presets during the day or have a manual adjustment to dim the LED lamp down to full off or anywhere between 0% and 100% brightness. This remote dimming controller **1834** will send the control signal directly to LED lamp **1800**A itself, and does not change the input power to the light fixture like conventional dimmers do. The data control signal to a computer based control system driving the dimming controller can be direct hard-wired connections including DMX512, RS232, Ethernet, DALI, Lonworks, Remote Device Management (RDM), TCPIP, CEBus Standard EIA-600 by way of wire signal paths **1836**A or **1830**A; or can be wireless, including using IR (Infra-Red), RF (Radio-Frequency), WiFi/802.11, FHSS (Frequency Hopping Spread Spectrum, Bluetooth technology, and ZigBee by way of alternative wireless signal paths **1836**B or **1830**B as shown by dash line; and Power Line Carrier Communication (PLC) protocols using PLC signal paths **1836**C or **1830**C. Besides controlling the dimmer, the data control signal can be use to change the internal computer programming including timer settings, luminance levels and sensitivity adjustments, getting status and present state feedbacks, as well as other computer functions.

Computers or logic gate arrays **1812**A and **1812**B continuously process the sensor data signals from occupancy sensor **1814** and photosensor **1816** received in accordance with a monitoring program and transmit resultant control signals to dimmers **1818**A and **1818**B in accordance with a program, so as to control the current output of dimmers **1818**A and **1818**B, and to prevent flickering of LED lamps **1800**A and **1800**B by 1) simultaneously signaling both dimmers **1818**A and **1818**B either to maintain full power and emit maximum light output, or 2) simultaneously signaling both dimmers **1818**A and **1818**B to reduce power by a preset amount and emit less than maximum light from LED arrays **1802**A and **1802**B by a preset amount with the result that as a person walks about the combined illumination area, and if there is a change in light levels of daylight present in the illumination areas of LED lamps **1800**A and **1800**B, both lamps emit the same illumination with the result that continuous flickering between the lamps caused by different power controls at dimmers **1818**A and **1818**B is avoided. In summary, the operational networking of LED lamp network **1798** creates a continuous identical illumination without flicker.

As an alternative, depending on the amount of ambient light or daylight present around the illumination areas of LED lamps **1800**A and **1800**B, and as detected by photosensor **1816**, the two lamps may emit different levels of illumination, but with the same result also that continuous flickering between both lamps is avoided.

For another alternate mode of operation where the user wants to maintain the same or constant amount of light level around the area of the LED lamps **1800**A and **1800**B, photosensor **1816** can continuously monitor the amount of daylight present around the immediate area. Computer or logic gate arrays **1812**A and **1812**B continuously adjust dimmers **1818**A and **1818**B to collectively raise or lower the brightness of LED arrays **1802**A and **1802**B, so as to maintain the desired light level. This light level setting can be adjusted by the user in the field or can be preset at the factory. In this mode of operation, there is no time delay and the system works instantaneously and automatically to cover a wider area of the desired light level.

In addition, LED arrays **1802**A and **1802**B can each include either a plurality of LEDs or a single LED. The number of individual LEDs in each LED array **1802**A and **1802**B can differ. Likewise, dimmers **1818**A and **1818**B can represent a plurality of dimmers.

FIG. **97** is a sectional view of an alternate assembled LED lamp **1840** of the present invention that offers better thermal management and longer life for the LEDs. LED lamp **1840** includes a partially open and substantially tubular lens housing **1842** that supports an electrical circuit board **1844** to which at least one LED **1846** is mounted. The partially open and substantially tubular lens housing **1842** supports and holds LED circuit board **1844** by way of internal groove slots **1848** located on opposite sides of tubular lens housing **1842**. A heat dissipating heat sink **1850** is attached to LED circuit board **1844** to which LEDs **1846** are mounted by screws **1852**A or by other mounting means including glue adhesives, double-sided tape, thermal epoxy silicone, press-fit, tongue and groove, etc. A thermal transfer component (not shown) that includes thermal grease, thermal conductive pads, thermal epoxy silicone, etc. is sandwiched between the flat surface bottom of heat sink **1850** to the flat surface bottom of LED circuit board **1844**. Optional mounting screws **1852**B or other mounting means help to secure tubular lens housing **1842** to heat sink **1850**. LED circuit board **1844** can be held and supported by tubular lens housing **1842**, or LED circuit board **1844** can be held and supported by heat sink **1850**, or LED circuit board **1844** can be held and supported by both tubular lens housing **1842** and heat sink **1850**, and heat sink **1850** is also held and supported by tubular lens housing **1842** as well. Additional mounting screws **1852**A and **1852**B are used for the entire length of LED lamp **1840**. Other electrical components are not shown.

Light level photosensors can include, for example, photodiodes, bipolar phototransistors, and the photoFET (photosensitive field-effect transistor). Occupancy sensors can include, for example, optical incremental encoders, interrupters, photo-reflective sensors, proximity and Hall Effect sensors, laser interferometers, triangulation sensors, magnetostrictive sensors, infrared temperature sensors, ultrasonic sensors, hybrid infrared and ultrasonic type sensors, cable extension sensors, LVDT sensors, and tachometer sensors. Motion detectors can be any one of the many known to the art, from active sonar systems or IR detectors, to entirely passive piezoelectric sensors such as those manufactured by Pennwalt Manufacturing Company. Panasonic Corporation also make a miniature passive infrared type of motion sensor with a built-in amplifier selling under the brand name "NaPiOn" MP motion sensor. The compact size and built-in features make it an ideal occupancy motion sensor for use in the tubular LED retrofit lamp of the present invention.

With the development of tighter and more compact LED die arrays with increasingly high-powered LEDs, better thermal management is needed to keep the LEDs cooled and running at optimum life. Specifically, as higher power LEDs are used, and as higher concentrations of LEDs are used, the heat generated detrimentally affects their life span and reduces the LED lamps operational efficiency. Better thermal management may include improved heat sink designs with open tubular housings designs and not always the completely closed tubular housings. The heat sinks are attached directly to the slugs of the LEDs or LED arrays, or to the metal or ceramic substrate, or metal feed through vias of the LEDs or LED array circuit boards. The now open and substantially tubular housing will have provisions to hold the circuit boards or means to hold heat sink to which the printed circuit boards are attached, or to both the printed circuit boards and the heat sink. The heat sink will be exposed on the finned end to ambient air for convection cooling, while the flat surface side of the heat sink will be thermally attached to the LEDs or LED array circuit boards. In this manner, the LEDs or LED arrays are enclosed in the closed end portion of the now open and substantially tubular housing. The substantially tubular housing prevents dirt from collecting onto the LEDs or LED arrays, and can be optically designed to particular illumination requirements. In addition, besides keeping the LEDs or LED arrays mechanically and electrically safe within a protective housing, the substantially tubular housing also provides a surface that can be maintained and cleaned more easily than having the LEDs or LED arrays exposed. As before, the substantially tubular housing can be manufactured out of glass or plastic materials.

Heat spreader plates, additional cooling fins, miniature cooling fans, solid-state thermoelectric modules, heat pipes, etc. may also be incorporated. Some new designs for the LED lamp include openly spacing the LEDs or the LED arrays apart from each other, or even pull the LEDs or LED arrays out of the tubular housing completely and have them externally mounted in an open space. Besides the heat sinks made of aluminum or other efficient heat conductive metal, graphite and other similar lightweight materials or alloys can be used.

Now with the better thermal management included in the design, larger and quick possibly heavier materials will be added to the present LED replacement lamps. The additional weight of the new LED lamps can be used with locking clips that hold the lamp securely to the lampholder, or lampholder with integral locking mechanisms can be used to support the additional weights.

Other embodiments or modifications may be suggested to those having the benefit of the teachings therein, and such other embodiments or modifications are intended to be reserved especially as they fall within the scope and spirit of the subjoined claims.

What is claimed is:

1. A light emitting diode (LED) lamp for mounting to a fluorescent light fixture having the ballast removed or bypassed including opposed electrical sockets, comprising:

a tube having tube ends,

said tube having opposed electrical contacts for positioning into the opposed electrical sockets,

at least one LED positioned within said tube between said tube ends,

a source of electrical power,

electrical circuit means for providing electrical power from said source of electrical power to said at least one LED,

means for electrically connecting said electrical circuit means from said opposed electrical contacts to the opposed electrical sockets,

said electrical circuit means including an LED electrical circuit including at least one electrical string positioned within said tube and generally extending between said tube ends,

said at least one LED being in electrical connection with said at least one electrical string,

said at least one LED being positioned to emit light through said tube,

means for supporting and holding said at least one LED and said LED electrical circuit,

means for sensing requirements for lighting around the illumination area of said at least one LED, and

means for controlling the delivery of said electrical power from said source of electrical power to said at least one LED relating to said means for sensing requirements for lighting around the illumination area of said at least one LED.

2. The LED lamp in accordance with claim **1**, wherein said source of electrical power is AC power.

3. The LED lamp in accordance with claim **1**, wherein said source of electrical power is DC power.

4. The LED lamp in accordance with claim **1**, further including means for transforming AC power to DC power positioned in said tube and in electrical connection with said electrical circuit means.

5. The LED lamp in accordance with claim **1**, further including means for suppressing voltage being delivered from said source of electrical power and in electrical connection with said electrical circuit means.

6. The LED lamp in accordance with claim **1**, wherein said means for controlling includes an on-off switch positioned in said LED lamp in operative association with said at least one LED, said switch being operable between an on mode wherein said electrical power is delivered to said at least one LED, and an off mode wherein said electrical power is not delivered to said at least one LED.

7. The LED lamp in accordance with claim **6**, wherein said means for sensing is at least one photosensor in operative signal association with said switch, wherein said at least one photosensor sends a signal to said switch to operate said switch to an on mode when a lower level of daylight is detected around the illumination area of said at least one LED, wherein power is transmitted to said at least one LED to illuminate, and further wherein said at least one photosensor sends a signal to said switch to operate said switch to an off mode when a higher level of daylight is detected around the illumination area of said at least one LED, and wherein power is not transmitted to said at least one LED and illumination from said at least one LED ceases.

8. The LED lamp in accordance with claim **7**, wherein said means for sending a signal includes a signal path comprising a signal line connection from said at least one photosensor to said switch.

9. The LED lamp in accordance with claim **7**, wherein said means for sending a signal includes a signal path comprising a wireless signal from said at least one photosensor to said switch.

10. The LED lamp in accordance with claim **7**, wherein said means for sending a signal includes a signal path comprising a PLC line extending from said power source to said at least one photosensor and to said switch.

11. The LED lamp in accordance with claim **7**, wherein said at least one photosensor is positioned internal to said LED lamp.

12. The LED lamp in accordance with claim **7**, wherein said at least one photosensor is positioned external to said LED lamp.

13. The LED lamp in accordance with claim **6**, wherein said means for sensing is at least one occupancy sensor in operative signal association with said switch, wherein said at least one occupancy sensor sends a signal to said switch to operate said switch to an on mode when a person is detected around the illumination area of said at least one LED, wherein power is transmitted to said at least one LED to illuminate, and further wherein said at least one occupancy sensor sends a signal to said switch to operate said switch to an off mode when a person is not detected around the illumination area of said at least one LED, and wherein power is not transmitted to said at least one LED and illumination from said at least one LED ceases.

14. The LED lamp in accordance with claim **13**, wherein said at least one occupancy sensor is positioned internal to said LED lamp.

15. The LED lamp in accordance with claim **13**, wherein said at least one occupancy sensor is positioned external to said LED lamp.

16. The LED lamp in accordance with claim **13**, wherein said means for sending a signal includes a signal path from said at least one occupancy sensor to said switch.

17. The LED lamp in accordance with claim **16**, wherein said signal path from said at least one occupancy sensor comprises a signal line connection to said switch.

18. The LED lamp in accordance with claim **16**, wherein said signal path from said at least one occupancy sensor comprises a wireless signal to said switch.

19. The LED lamp in accordance with claim **16**, wherein said means for sending a signal includes a signal path comprising a PLC line extending from said power source to said at least one occupancy sensor and to said switch.

20. The LED lamp in accordance with claim **1**, wherein said means for controlling includes a computer positioned in said LED lamp in operative signal association with said means for sensing requirements for lighting and with said means for controlling the delivery of said electrical power to said at least one LED.

21. The LED lamp in accordance with claim **20**, further including a dimmer in operative association with said computer and with said at least one LED.

22. The LED lamp in accordance with claim **21**, wherein said means for sensing includes at least one photosensor in operative signal association with said computer.

23. The LED lamp in accordance with claim **22**, wherein said at least one photosensor transmits a signal to said computer to control said dimmer to decrease the delivery of said electrical power to said at least one LED when a higher level of daylight is sensed around the illumination area of said at least one LED, so that lower power is transmitted to said at least one LED to reduce illumination in accordance with said means for sensing requirements for lighting, and further wherein said photosensor transmits a signal to said computer to control said dimmer to increase the delivery of said electrical power to said at least one LED when a lower level of daylight is sensed around the illumination area of said at least one LED, so that higher power is transmitted to said at least one LED to increase illumination in accordance with said means for sensing requirements for lighting.

24. The LED lamp in accordance with claim **23**, wherein said means for transmitting a signal includes a signal path comprising a signal line connection from said at least one photosensor to said computer.

25. The LED lamp in accordance with claim 23, wherein said means for transmitting a signal includes a signal path comprising a wireless signal from said at least one photosensor to said computer.

26. The LED lamp in accordance with claim 23, wherein said means for transmitting a signal includes a signal path comprising a PLC line extending from said power source to said at least one photosensor and to said computer.

27. The LED lamp in accordance with claim 21, wherein said means for sensing includes at least one occupancy sensor in operative signal association with said computer.

28. The LED lamp in accordance with claim 27, wherein said at least one occupancy sensor transmits a signal to said computer to control said dimmer to decrease the delivery of said electrical power to said at least one LED when a person is not sensed around the illumination area of said at least one LED, so that lower power is transmitted to said at least one LED to reduce illumination in accordance with said means for sensing requirements for lighting, and further wherein said at least one occupancy sensor transmits a signal to said computer to control said dimmer to increase the delivery of said electrical power to said at least one LED when a person is sensed around the illumination area of said at least one LED, so that higher power is transmitted to said at least one LED to increase illumination in accordance with said means for sensing requirements for lighting.

29. The LED lamp in accordance with claim 28, wherein said means for transmitting a signal includes a signal path comprising a signal line connection from said at least one occupancy sensor to said computer.

30. The LED lamp in accordance with claim 28, wherein said means for transmitting a signal includes a signal path comprising a wireless signal from said at least one occupancy sensor to said computer.

31. The LED lamp in accordance with claim 28, wherein said means for transmitting a signal includes a signal path comprising a PLC line extending from said power source to said at least one occupancy sensor to said computer.

32. The LED lamp in accordance with claim 21, wherein said dimmer is a plurality of dimmers.

33. The LED lamp in accordance with claim 1, wherein said means for controlling the delivery of said electrical power is a logic gate array.

34. The LED lamp in accordance with claim 1, wherein said means for sensing includes at least one photosensor and at least one occupancy sensor.

35. The LED lamp in accordance with claim 1, wherein said at least one LED is a plurality of LEDs.

36. The LED lamp in accordance with claim 21, further including a second LED lamp including,

a second tube,

a second tube at least one LED positioned in said second tube,

second tube circuit means for providing second tube electrical power from said source of electrical power to said second tube at least one LED,

second tube means for sensing requirements for lighting around the illumination area of said second tube at least one LED positioned in said second tube,

second tube means for controlling delivery of said second tube electrical power to said second tube at least one LED relating to said second tube means for sensing requirements for lighting around the second tube at least one LED illumination area,

wherein said means for controlling delivery and said second tube means for controlling delivery are in network signal communication with said means for sensing and said second tube means for sensing, and

said means for sensing including first data signals sent to said means for controlling delivery of said electrical power and said second tube means for sensing including second data signals sent to said second tube means for controlling delivery of said second tube electrical power, said first data signals and said second data signals being continuously compared in accordance with a data program, wherein power outputs to said means for controlling and said second tube means for controlling are regulated in accordance with said data program.

37. The LED lamp in accordance with claim 36, wherein said second tube means for controlling delivery of said second tube electrical power includes a second tube dimmer.

38. The LED lamp in accordance with claim 37, wherein said second tube means for controlling delivery of said second tube electrical power includes a second tube computer, said second tube computer being in operative signal association with said second tube dimmer.

39. The LED lamp in accordance with claim 37, wherein said second tube means for controlling delivery of said second tube electrical power includes a second tube logic gate array, said second tube logic gate array being in operative signal association with said second tube dimmer.

40. The LED lamp in accordance with claim 36, wherein said means for sensing includes at least one photosensor, and said second tube means for sensing includes a second tube at least one photosensor.

41. The LED lamp in accordance with claim 36, wherein said means for sensing includes at least one occupancy sensor, and said second tube means for sensing includes a second tube at least one occupancy sensor.

42. The LED lamp in accordance with claim 36, wherein said means for sensing includes at least one photosensor and at least one occupancy sensor, and said second tube means for sensing includes a second tube at least one photosensor and a second tube at least one occupancy sensor.

43. The LED lamp in accordance with claim 21, further including a second LED lamp including

a second tube,

a second tube at least one LED positioned in said second tube,

second tube circuit means for providing second tube electrical power from said source of electrical power to said second tube at least one LED,

second tube means for controlling delivery of said second tube electrical power to said second at least one LED relating to said means for sensing requirements for lighting around said illumination area of said at least one LED of said LED lamp,

wherein said means for controlling delivery and said second tube means for controlling delivery are in network signal communication with said means for sensing,

said means for sensing including data signals sent to said second tube means for controlling delivery of said second tube electrical power, and

said means for sensing including first data signals sent to said means for controlling delivery of said electrical power and including second data signals sent to said second tube means for controlling delivery of said second tube electrical power, said first data signals and said second data signals being continuously compared in accordance with a data program, wherein power outputs to said means for controlling and said second tube means for controlling are regulated in accordance with said data program.

44. The LED lamp in accordance with claim 43, wherein said second tube means for controlling delivery of said second tube electrical power includes a second tube dimmer.

45. The LED lamp in accordance with claim 44, wherein said second tube means for controlling delivery of said second tube electrical power includes a second tube computer, said second tube computer being in operative signal association with said second tube dimmer.

46. The LED lamp in accordance with claim 44, wherein said second tube means for controlling delivery of said second tube electrical power includes a second tube logic gate array, said second tube logic gate array being in operative signal association with said second tube dimmer.

47. The LED lamp in accordance with claim 43, wherein said means for sensing includes at least one photosensor.

48. The LED lamp in accordance with claim 43, wherein said means for sensing includes at least one occupancy sensor.

49. The LED lamp in accordance with claim 43, wherein said means for sensing includes at least one photosensor and at least one occupancy sensor.

50. The LED lamp in accordance with claim 43, further including a remote controller to provide serial control data to said first data signals of said LED lamp.

51. The LED lamp in accordance with claim 1, wherein said at least one LED is at least one OLED.

52. The LED lamp in accordance with claim 1, wherein said means for controlling includes a timer.

53. The LED lamp in accordance with claim 4, wherein said means for converting AC power to DC power is a rectifier.

54. The LED lamp in accordance with claim 5, wherein said means for suppressing input voltage includes at least one voltage surge absorber (ZNR).

55. The LED lamp in accordance with claim 5, wherein said means for suppressing input voltage includes at least one movistor (MOV).

56. The LED lamp in accordance with claim 5, wherein said means for suppressing input voltage includes at least one varistor.

57. The LED lamp in accordance with claim 5, wherein said means for suppressing input voltage includes at least one inductor.

58. The LED lamp in accordance with claim 1, wherein means for supporting and holding said at least one LED and said LED electrical circuit includes at least one circuit board.

59. The LED lamp in accordance with claim 1, wherein means for supporting and holding said at least one LED and said LED electrical circuit is positioned in the tube.

60. The LED lamp in accordance with claim 1, wherein means for supporting and holding said at least one LED and said LED electrical circuit is located at the tube ends.

61. The LED lamp in accordance with claim 1, wherein means for supporting and holding said at least one LED and said LED electrical circuit includes a heat sink.

62. An LED lighting device for replacing a fluorescent lamp, comprising:

a tube having tube ends,

said tube having electrical contacts,

at least one LED positioned within said tube between said tube ends,

a source of electrical power,

electrical circuit means for providing electrical power from said source of electrical power to said at least one LED,

means for electrically connecting said electrical circuit means with said electrical contacts,

said electrical circuit means including an LED electrical circuit including at least one electrical string positioned within said tube and generally extending between said tube ends,

said at least one LED being in electrical connection with said at least one electrical string,

said at least one LED being positioned to emit light through said tube,

means for sensing requirements for lighting around the illumination area of said at least one LED, and

means for controlling the delivery of said electrical power from said source of electrical power to said at least one LED relating to said means for sensing requirements for lighting around the illumination area of said at least one LED.

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