

EXHIBIT 4

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

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(54) **LED TUBE LAMP**

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(73) Assignee: **Jiaxing Super Lighting Electric Appliance Co., Ltd.**, Jiaxing, Zhejiang (CN)

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This patent is subject to a terminal disclaimer.

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(30) **Foreign Application Priority Data**

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 (Continued)

(51) **Int. Cl.**

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H05B 41/00 (2006.01)

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

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(58) **Field of Classification Search**

None
 See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,454,049 A 11/1948 Floyd, Jr.
 4,059,324 A 11/1977 Snyder et al.
 (Continued)

FOREIGN PATENT DOCUMENTS

CN 200965185 Y 10/2007
 CN 200980183 Y 11/2007
 (Continued)

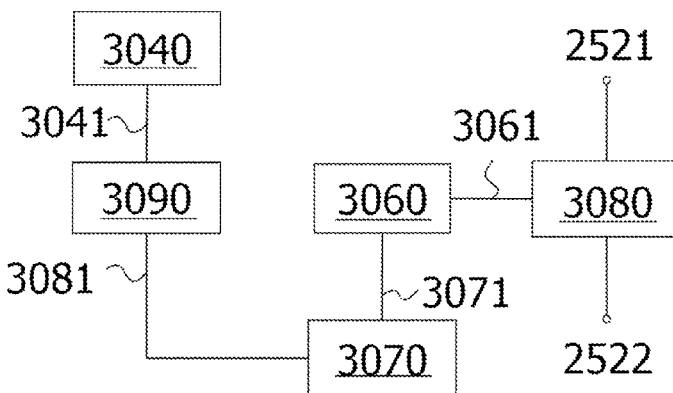
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(57) **ABSTRACT**

An LED tube lamp is disclosed. An installation detection circuit is configured in the LED tube lamp configured to receive an external driving signal. The installation detection circuit is configured to detect during one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket, based on detecting a signal generated from the external driving signal. The installation detection circuit includes a switch circuit coupled to the pulse generating circuit, wherein the one or more pulse signals control turning on and off of the switch circuit. The installation detection circuit is further configured to: when it is detected during one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and when it is detected during one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to

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remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state.

43 Claims, 28 Drawing Sheets

Related U.S. Application Data

continuation-in-part of application No. 15/339,221, filed on Oct. 31, 2016, now Pat. No. 9,939,140, which is a continuation-in-part of application No. 15/210,989, filed on Jul. 15, 2016, now Pat. No. 9,587,817, which is a continuation-in-part of application No. 15/066,645, filed on Mar. 10, 2016, now Pat. No. 9,497,821, which is a continuation-in-part of application No. 14/865,387, filed on Sep. 25, 2015, now Pat. No. 9,609,711, said application No. 15/373,388 is a continuation-in-part of application No. 15/399,221, filed on Oct. 31, 2016, now Pat. No. 9,939,140, which is a continuation-in-part of application No. 15/210,989, filed on Jul. 15, 2016, now Pat. No. 9,587,817, which is a continuation-in-part of application No. 15/205,011, filed on Jul. 8, 2016, now Pat. No. 9,629,211, which is a continuation-in-part of application No. 15/150,458, filed on May 10, 2016, now Pat. No. 9,794,990, which is a continuation-in-part of application No. 14/865,387, filed on Sep. 25, 2015, now Pat. No. 9,609,711, said application No. 15/373,388 is a continuation-in-part of application No. 15/211,813, filed on Jul. 15, 2016, now Pat. No. 9,756,698, which is a continuation-in-part of application No. 15/150,458, filed on May 10, 2016, now Pat. No. 9,794,990, which is a continuation-in-part of application No. 14/865,387, filed on Sep. 25, 2015, now Pat. No. 9,609,711, said application No. 15/373,388 is a continuation-in-part of application No. 15/084,483, filed on Mar. 30, 2016, now Pat. No. 9,521,718, which is a continuation-in-part of application No. 14/865,387, filed on Sep. 25, 2015, now Pat. No. 9,609,711, said application No. 15/373,388 is a continuation-in-part of application No. 15/065,892, filed on Mar. 10, 2016, now Pat. No. 9,526,145, which is a continuation-in-part of application No. 14/865,387, filed on Sep. 25, 2015, now Pat. No. 9,609,711.

(30) Foreign Application Priority Data

Mar. 26, 2015	(CN)	2015 1 0134586
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Apr. 22, 2015	(CN)	2015 1 0193980
May 29, 2015	(CN)	2015 1 0284720
Jun. 17, 2015	(CN)	2015 1 0338027
Jun. 26, 2015	(CN)	2015 1 0364735
Jun. 26, 2015	(CN)	2015 1 0373492
Jun. 29, 2015	(CN)	2015 1 0378322
Jul. 10, 2015	(CN)	2015 1 0406595
Jul. 20, 2015	(CN)	2015 1 0428680
Jul. 27, 2015	(CN)	2015 1 0448220
Aug. 8, 2015	(CN)	2015 1 0486115
Aug. 14, 2015	(CN)	2015 1 0499512
Aug. 26, 2015	(CN)	2015 1 0530110
Sep. 6, 2015	(CN)	2015 1 0557717
Sep. 18, 2015	(CN)	2015 1 0595173
Sep. 25, 2015	(CN)	2015 1 0617370

Oct. 8, 2015	(CN)	2015 1 0645134
Oct. 27, 2015	(CN)	2015 1 0705222
Oct. 30, 2015	(CN)	2015 1 0726365
Nov. 27, 2015	(CN)	2015 1 0848766
Dec. 9, 2015	(CN)	2015 1 0903680
Jan. 22, 2016	(CN)	2016 1 0044148
Jan. 26, 2016	(CN)	2016 1 0050944
Jan. 26, 2016	(CN)	2016 1 0051691
Feb. 15, 2016	(CN)	2016 1 0085895
Feb. 16, 2016	(CN)	2016 1 0087627
Feb. 23, 2016	(CN)	2016 1 0098424
Mar. 3, 2016	(CN)	2016 1 0120993
Mar. 9, 2016	(CN)	2016 1 0132513
Mar. 14, 2016	(CN)	2016 1 0142140
Mar. 25, 2016	(CN)	2016 1 0177706
Apr. 29, 2016	(CN)	2016 1 0281812
May 18, 2016	(CN)	2016 1 0327806
Jun. 14, 2016	(CN)	2016 1 0420790
Jun. 20, 2016	(CN)	2016 1 0452437
Oct. 8, 2016	(CN)	2016 1 0876593
Oct. 8, 2016	(CN)	2016 1 0878349
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Oct. 27, 2016	(CN)	2016 1 0955338
Oct. 27, 2016	(CN)	2016 1 0955342
Nov. 3, 2016	(CN)	2016 1 0975119
Nov. 25, 2016	(CN)	2016 1 1057357

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<i>F21K 9/278</i>	(2016.01)
<i>F21K 9/272</i>	(2016.01)
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<i>F21V 23/02</i>	(2006.01)
<i>F21V 29/70</i>	(2015.01)
<i>F21V 25/02</i>	(2006.01)
<i>F21V 23/00</i>	(2015.01)
<i>F21V 3/06</i>	(2018.01)
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<i>F21Y 103/10</i>	(2016.01)
<i>F21Y 115/10</i>	(2016.01)
<i>F21V 29/83</i>	(2015.01)

(52) U.S. Cl.

CPC *F21V 15/015* (2013.01); *F21V 23/003* (2013.01); *F21V 23/005* (2013.01); *F21V 23/023* (2013.01); *F21V 25/02* (2013.01); *F21V 29/70* (2015.01); *H05B 33/0803* (2013.01); *H05B 33/0815* (2013.01); *H05B 33/0845* (2013.01); *H05B 33/0857* (2013.01); *H05B 33/0887* (2013.01); *H05K 1/00* (2013.01); *F21V 23/02* (2013.01); *F21V 29/83* (2015.01); *F21Y 2103/10* (2016.08); *F21Y 2115/10* (2016.08); *Y02B 20/346* (2013.01)

(56)

References Cited

U.S. PATENT DOCUMENTS

4,156,265	A	5/1979	Rose
4,935,665	A	6/1990	Murata
5,706,177	A	1/1998	Nather et al.
5,803,577	A	9/1998	Stratton
5,936,599	A	8/1999	Reymond
5,964,518	A	10/1999	Shen
6,246,167	B1	6/2001	Sica
7,067,032	B1	6/2006	Bremont et al.
7,135,034	B2	11/2006	Friedman et al.
7,380,961	B2	6/2008	Moriyama

US 10,208,897 B2

Page 3

(56)		References Cited					
		U.S. PATENT DOCUMENTS					
7,594,738	B1	9/2009	Lin et al.	2011/0084627	A1	4/2011	Sloan et al.
7,611,260	B1	11/2009	Lin	2011/0121756	A1	5/2011	Thomas et al.
8,057,084	B2	11/2011	Song et al.	2011/0148313	A1	6/2011	Ramaker
8,240,875	B2	8/2012	Roberts et al.	2011/0149563	A1	6/2011	Hsia et al.
8,360,599	B2	1/2013	Ivey et al.	2011/0175536	A1	7/2011	Fujita et al.
8,421,088	B2	4/2013	Konishi et al.	2011/0176297	A1	7/2011	Hsia et al.
8,456,075	B2	6/2013	Axelsson	2011/0228526	A1	9/2011	Hartikka et al.
8,796,943	B2	2/2014	Miyamichi	2011/0260614	A1	10/2011	Hartikka et al.
8,749,167	B2	6/2014	Hsia et al.	2011/0279063	A1	11/2011	Wang et al.
9,022,632	B2	5/2015	Kim et al.	2011/0286208	A1	11/2011	Chen
9,163,818	B2	10/2015	Hsia et al.	2011/0309745	A1	12/2011	Westermarck et al.
9,210,744	B2	12/2015	Carmen et al.	2012/0049684	A1	3/2012	Bodenstein et al.
9,277,603	B2	3/2016	Hsia et al.	2012/0051039	A1	3/2012	Chang
9,288,867	B2	3/2016	Hsia et al.	2012/0068604	A1	3/2012	Hasnain et al.
9,288,879	B2	3/2016	Tao et al.	2012/0069556	A1	3/2012	Bertram et al.
9,322,531	B2	4/2016	Liang et al.	2012/0146503	A1	6/2012	Negley et al.
9,420,663	B1	8/2016	Hsia et al.	2012/0181952	A1	7/2012	Roerer
9,448,660	B2	9/2016	Seo et al.	2012/0212951	A1	8/2012	Lai et al.
9,480,109	B2	10/2016	Ye et al.	2012/0299501	A1	11/2012	Kost et al.
9,480,123	B2	10/2016	Van Dijk et al.	2012/0300445	A1	11/2012	Chu et al.
9,497,821	B2	11/2016	Liu	2012/0313540	A1	12/2012	Lin
9,521,718	B2	12/2016	Xiong et al.	2012/0319150	A1	12/2012	Shimomura et al.
9,526,145	B2	12/2016	Xiong et al.	2013/0021809	A1	1/2013	Dellian et al.
9,585,221	B1	2/2017	Cheng et al.	2013/0033881	A1	2/2013	Terazawa et al.
9,587,817	B2	3/2017	Liu et al.	2013/0050998	A1	2/2013	Chu et al.
9,609,711	B2	3/2017	Jiang et al.	2013/0051008	A1	2/2013	Shew
9,622,317	B2	4/2017	Ackermann et al.	2013/0069538	A1	3/2013	So
9,625,137	B2	4/2017	Li et al.	2013/0127327	A1	5/2013	Heil et al.
9,629,211	B2	4/2017	Xiong et al.	2013/0135852	A1	5/2013	Chan et al.
9,629,215	B2	4/2017	Xiong et al.	2013/0147350	A1	6/2013	Yang
9,629,216	B2	4/2017	Jiang et al.	2013/0215609	A1	8/2013	Liu et al.
9,689,536	B2	6/2017	Xiong et al.	2013/0223053	A1	8/2013	Liu et al.
9,723,662	B2	8/2017	Ye et al.	2013/0230995	A1	9/2013	Ivey et al.
9,750,096	B2	8/2017	Xiong et al.	2013/0250565	A1	9/2013	Chiang et al.
9,775,215	B2	9/2017	Xiong et al.	2013/0256704	A1	10/2013	Guofu
9,781,805	B2	10/2017	Xiong et al.	2013/0258650	A1	10/2013	Sharrah
9,794,990	B2	10/2017	Ye et al.	2013/0293098	A1	11/2013	Li et al.
9,795,001	B2	10/2017	Ye et al.	2013/0301255	A1	11/2013	Kim et al.
9,801,240	B2	10/2017	Xiong et al.	2013/0320869	A1	12/2013	Jans
9,807,826	B2	10/2017	Xiong et al.	2013/0335959	A1	12/2013	Hsia et al.
9,820,341	B2	11/2017	Xiong et al.	2014/0009923	A1	1/2014	Wu et al.
9,826,585	B2	11/2017	Xiong	2014/0035463	A1	2/2014	Miyamichi Saburo
9,826,595	B2	11/2017	Hsia	2014/0055029	A1	2/2014	Jans
9,841,174	B2	12/2017	Liu et al.	2014/0099801	A1	4/2014	Liao
9,864,438	B2	1/2018	Seo et al.	2014/0117853	A1	5/2014	Miyamichi
2002/0176262	A1	11/2002	Tripathi	2014/0153231	A1	6/2014	Bittmann
2003/0102819	A1	6/2003	Min	2014/0192526	A1	7/2014	Qiu
2003/0189829	A1	10/2003	Shimizu et al.	2014/0203717	A1	7/2014	Zhang
2004/0189218	A1	9/2004	Leong et al.	2014/0225519	A1	8/2014	Yu et al.
2005/0162850	A1	7/2005	Luk	2014/0239827	A1	8/2014	Park
2005/0185396	A1	8/2005	Kutler	2014/0239834	A1	8/2014	Choi et al.
2005/0280017	A1	12/2005	Oshio et al.	2014/0265900	A1	9/2014	Sadwick et al.
2007/0001709	A1	1/2007	Shen	2014/0300274	A1	10/2014	Acatrinei
2007/0114555	A1	5/2007	Takemoto et al.	2014/0331532	A1	11/2014	Deppiessse
2007/0127242	A1	6/2007	Allen et al.	2015/0070885	A1	3/2015	Petro et al.
2008/0192476	A1	8/2008	Hiratsuka	2015/0077001	A1	3/2015	Takahashi
2008/0230790	A1	9/2008	Seko et al.	2015/0173138	A1	6/2015	Roberts
2008/0290814	A1	11/2008	Leong	2015/0176770	A1	6/2015	Wilcox et al.
2008/0302476	A1	12/2008	Bommi et al.	2016/0081147	A1*	3/2016	Guang H05B 33/0803 315/123
2009/0040415	A1	2/2009	Kim	2016/0219658	A1	7/2016	Xiong et al.
2009/0159919	A1	6/2009	Simon et al.	2016/0270163	A1	9/2016	Hu et al.
2010/0085772	A1	4/2010	Song et al.	2016/0270166	A1	9/2016	Xiong et al.
2010/0096976	A1	4/2010	Park	2017/0067627	A1	3/2017	Liu et al.
2010/0102729	A1	4/2010	Katzir	2017/0079115	A1	3/2017	Hsia
2010/0124054	A1	5/2010	Chen et al.	2017/0105263	A1	4/2017	Xiong et al.
2010/0181925	A1	7/2010	Ivey et al.	2017/0164434	A1	6/2017	Xiong et al.
2010/0201269	A1	8/2010	Tzou et al.	2017/0290119	A1	10/2017	Xiong et al.
2010/0220469	A1	9/2010	Ivey et al.	FOREIGN PATENT DOCUMENTS			
2010/0253226	A1	10/2010	Oki	CN	201014273	Y	1/2008
2010/0277918	A1	11/2010	Chen et al.	CN	101228393	A	7/2008
2011/0038146	A1	2/2011	Chen	CN	201363601	Y	12/2009
2011/0043127	A1	2/2011	Yamasaki	CN	201437921	U	4/2010
2011/0057572	A1	3/2011	Kit et al.	CN	101715265	A	5/2010
2011/0084554	A1	4/2011	Tian	CN	102116460	A	7/2011
2011/0084608	A1	4/2011	Lin et al.	CN	102121690	A	7/2011
				CN	102155642	A	8/2011

US 10,208,897 B2

Page 4

(56) References Cited					
	FOREIGN PATENT DOCUMENTS				
CN	201954169 U	8/2011	CN	104776332 A	7/2015
CN	202059618 U	11/2011	CN	104832813 A	8/2015
CN	202100985 U	1/2012	CN	204534210 U	8/2015
CN	202120982 U	1/2012	CN	204573639 U	8/2015
CN	202125774 U	1/2012	CN	204573682 U	8/2015
CN	102355780 A	2/2012	CN	204573684 U	8/2015
CN	102359697 A	2/2012	CN	204573700 U	8/2015
CN	202216003 U	5/2012	CN	204693095 U	10/2015
CN	102518972 A	6/2012	CN	204879985 U	12/2015
CN	202281101 U	6/2012	CN	204268162 U	4/2016
CN	202302841 U	7/2012	CN	104595765 A	5/2016
CN	202392485 U	8/2012	CN	104033772 B	6/2016
CN	102777788 A	11/2012	CN	205447315 U	8/2016
CN	202546330 U	11/2012	CN	106015996 A	10/2016
CN	102932997 A	2/2013	CN	105325058 B	3/2017
CN	103016984 A	4/2013	CN	107079545 A	8/2017
CN	202852551 U	4/2013	DE	202012011550 U1	6/2013
CN	103195999 A	7/2013	EP	2554899 A2	2/2013
CN	203068187 U	7/2013	EP	2914065 A2	9/2015
CN	203162856 U	8/2013	EP	3146803 A1	3/2017
CN	203202766 U	9/2013	GB	2519258 A	4/2015
CN	201866575 U	10/2013	GB	2523275 A	8/2015
CN	203240337 U	10/2013	GB	2531425 A	4/2016
CN	203240362 U	10/2013	GB	2533683 A	6/2016
CN	203464014 U	3/2014	GB	2543380 A	4/2017
CN	103742875 A	4/2014	JP	2005122906 A	5/2005
CN	203517629 U	4/2014	JP	2008117666 A	5/2008
CN	203549435 U	4/2014	JP	3147313 U	12/2008
CN	103822121 A	5/2014	JP	2011061056 A	3/2011
CN	203615157 U	5/2014	JP	2013254667 A	12/2013
CN	103851547 A	6/2014	KR	20090118147 A	11/2009
CN	103943752 A	7/2014	KR	20120055349 A	5/2012
CN	203686635 U	7/2014	WO	2009111098 A2	9/2009
CN	103968272 A	8/2014	WO	2012129301 A1	9/2012
CN	203771102 U	8/2014	WO	2012139691 A1	10/2012
CN	203857296 U	10/2014	WO	2013125803 A1	8/2013
CN	203927469 U	11/2014	WO	2013150417 A1	10/2013
CN	203963553 U	11/2014	WO	2014045523 A1	3/2014
CN	104246348 A	12/2014	WO	2014117435 A1	8/2014
CN	204042527 U	12/2014	WO	2014118754 A1	8/2014
CN	204083927 U	1/2015	WO	2014206785 A1	12/2014
CN	104515014 A	4/2015	WO	2015028329 A1	3/2015
CN	104565931 A	4/2015	WO	2015028639 A1	3/2015
CN	204268162 U	4/2015	WO	2015066566 A1	5/2015
CN	204300737 U	4/2015	WO	WO 2015066566 A1 *	5/2015
CN	103411140 B	5/2015	WO	2015081809 A1	6/2015
CN	104735873 A	6/2015	WO	2016086901 A3	6/2016
CN	204420636 U	6/2015	WO	2016187846 A1	12/2016
			WO	2017012512 A1	1/2017
			WO	2017012514 A1	1/2017

* cited by examiner

..... F21V 25/00

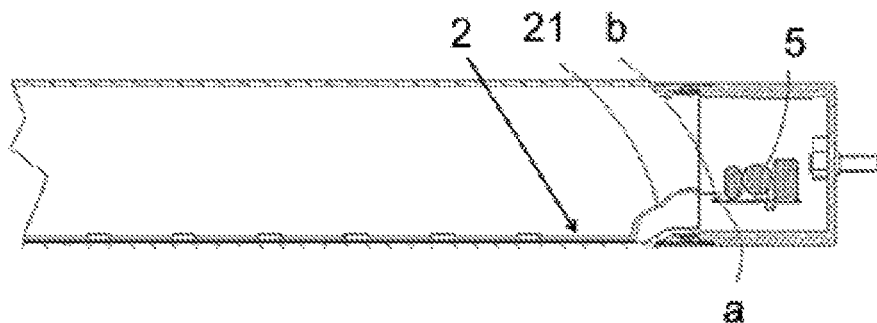


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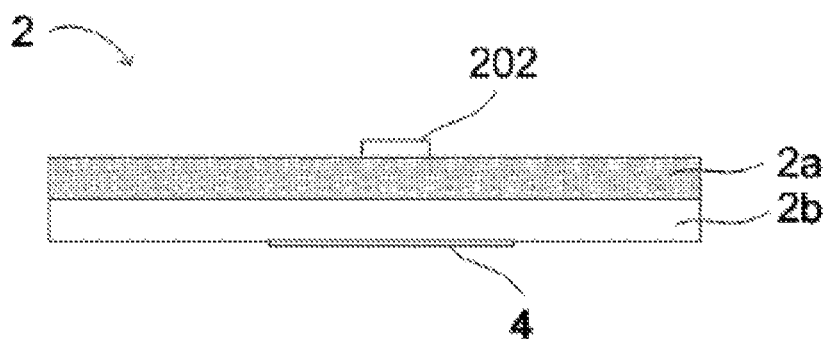


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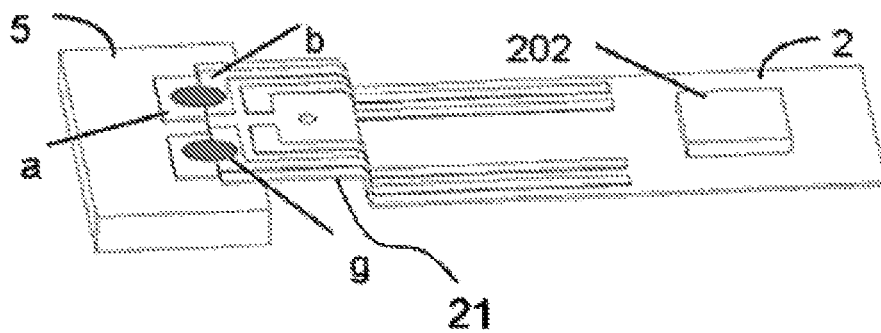


Fig. 3A

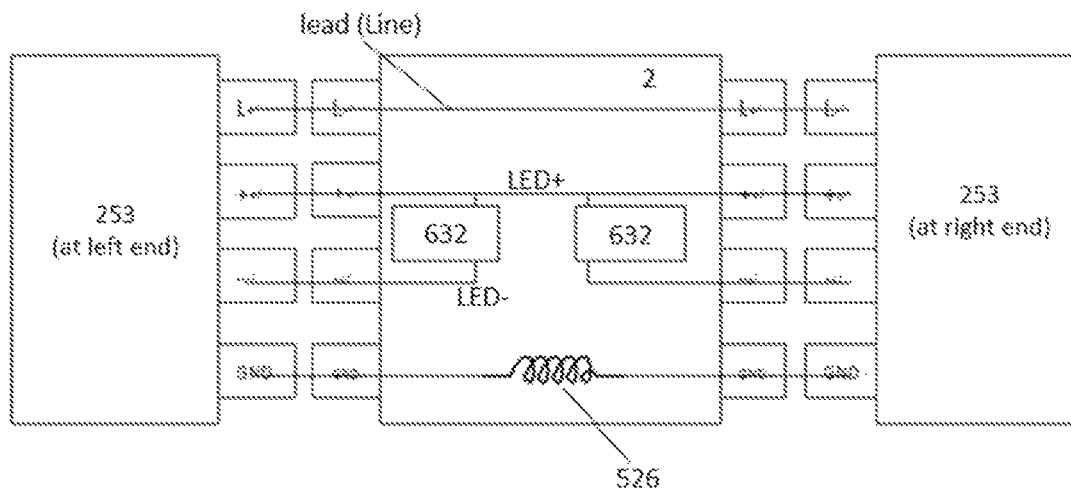


Fig. 3B

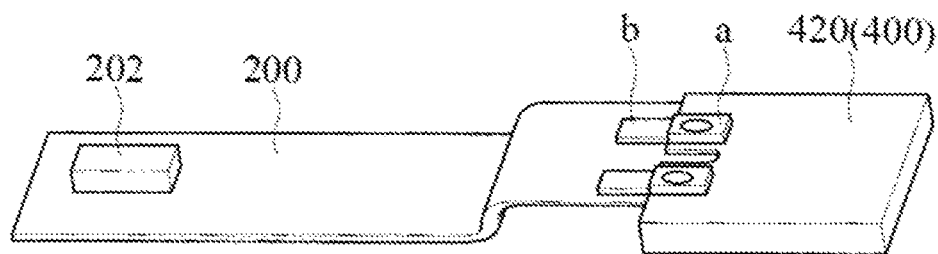


Fig. 4A

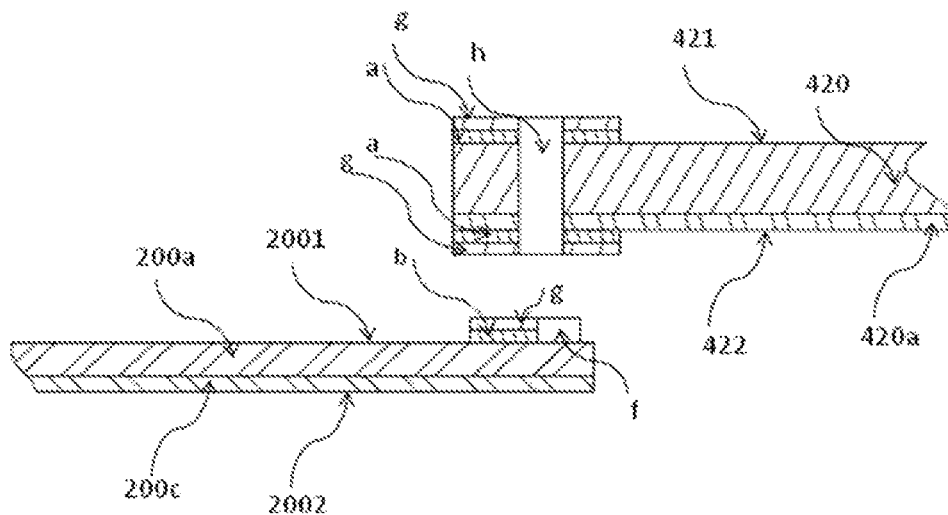


Fig. 4B

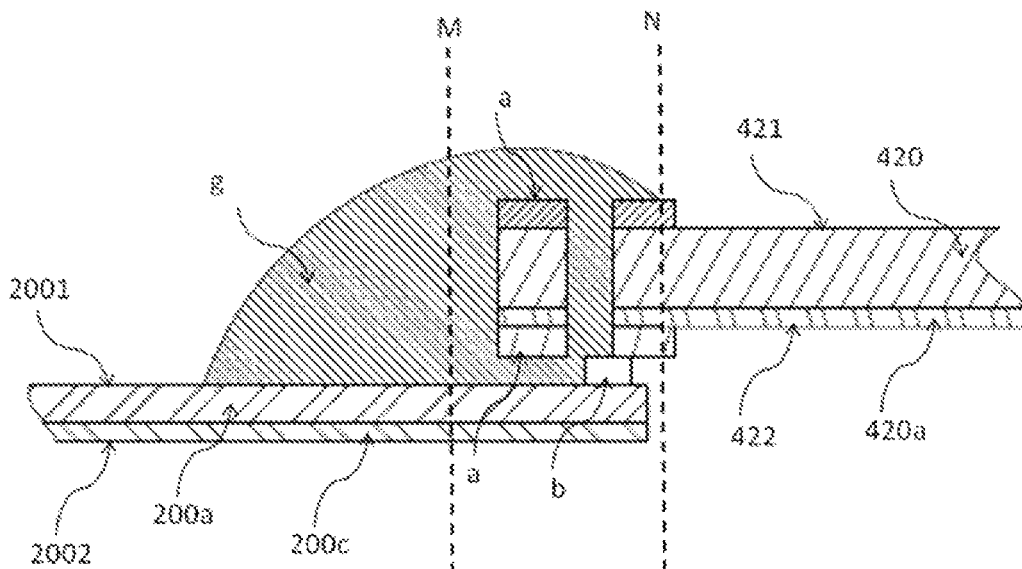


Fig. 4C

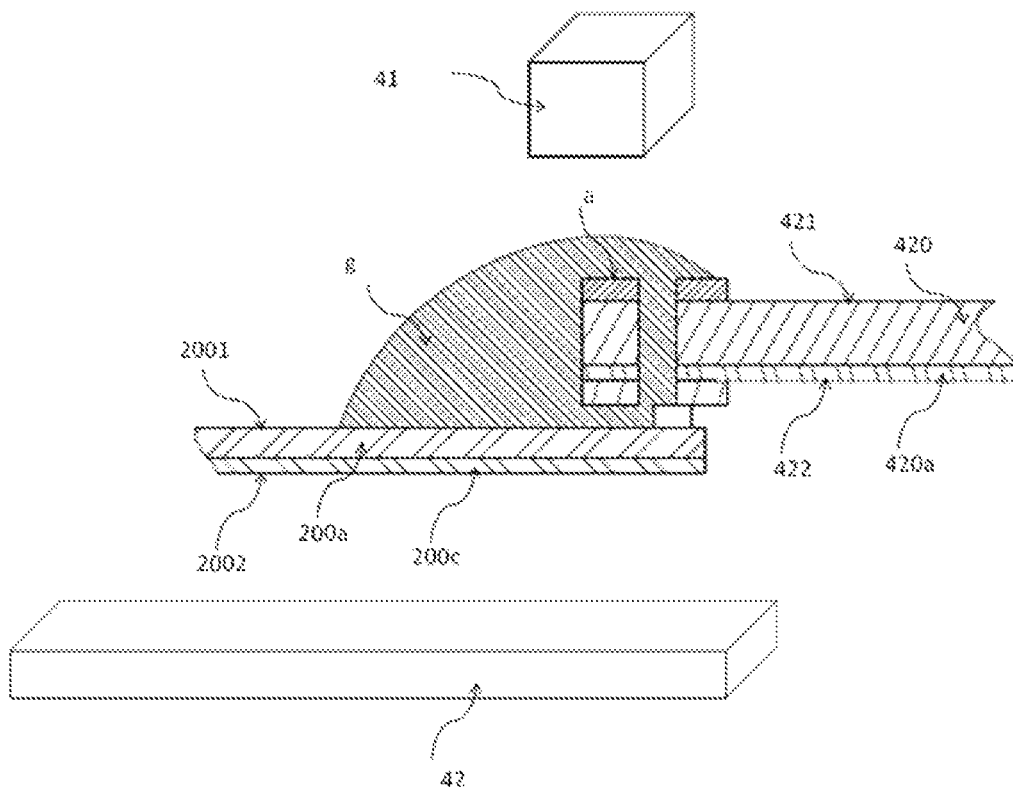


Fig. 4D

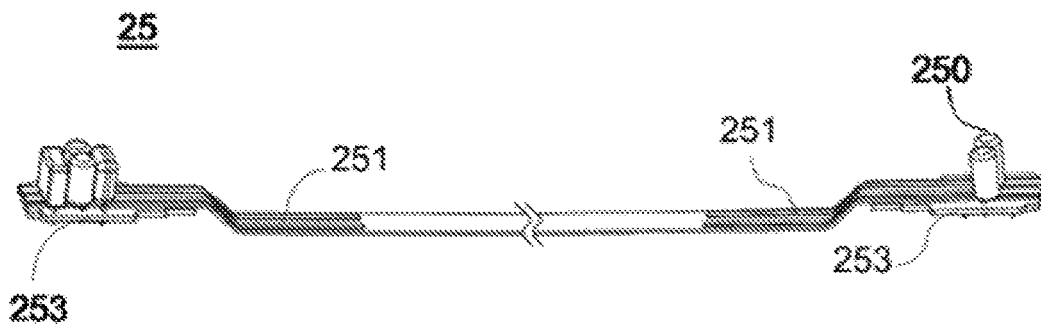


Fig. 5

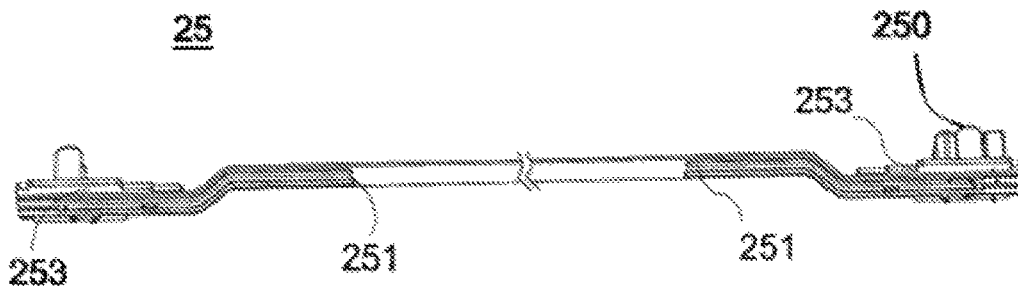


Fig. 6

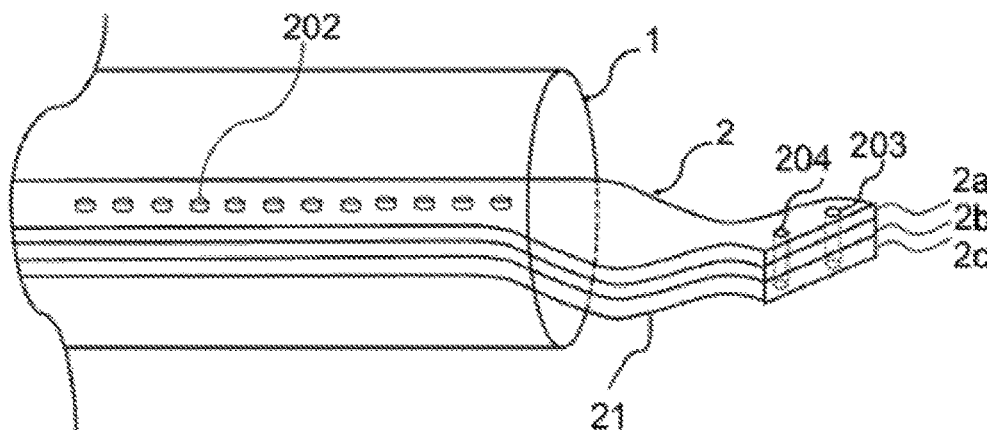


Fig. 7

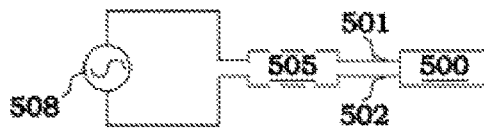


Fig. 8A

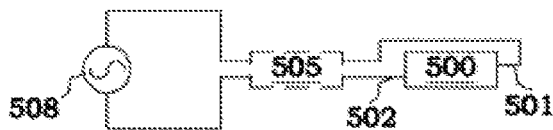


Fig. 8B

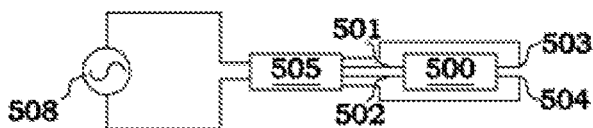


Fig. 8C

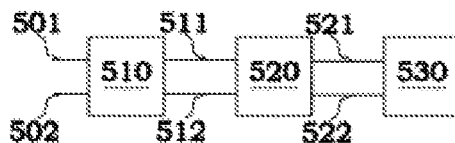


Fig. 8D

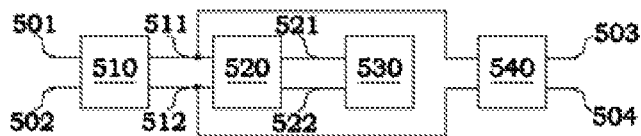


Fig. 8E

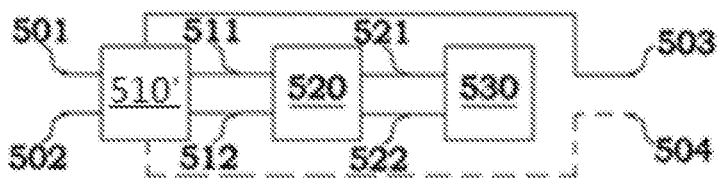


Fig. 8F

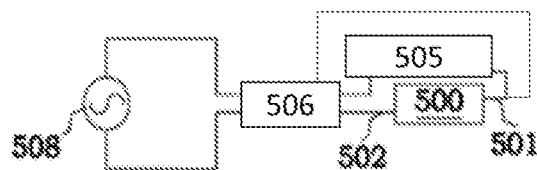


Fig. 8G

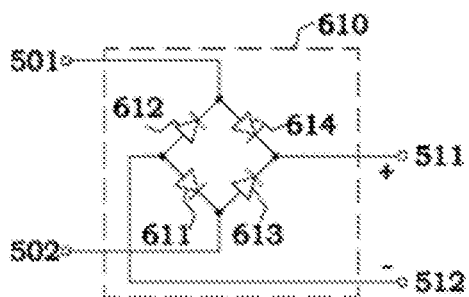


Fig. 9A

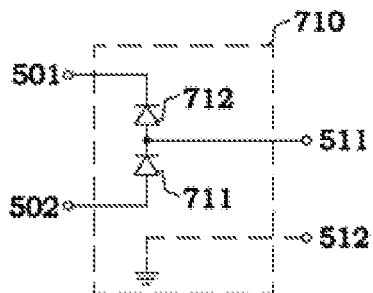


Fig. 9B

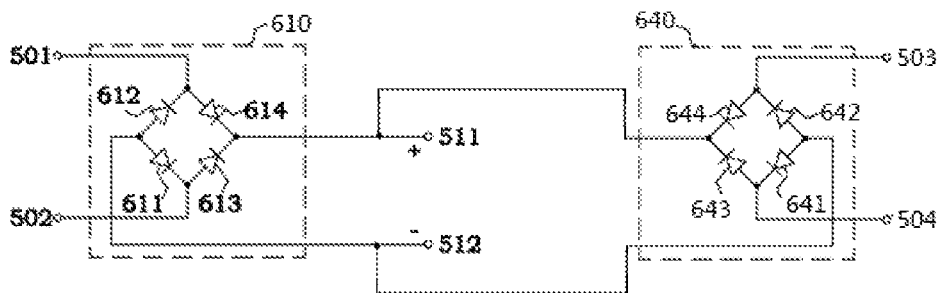


Fig. 9C

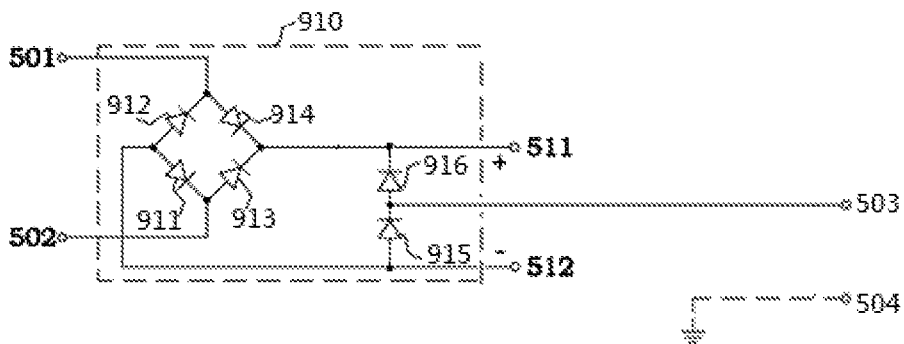


Fig. 9D

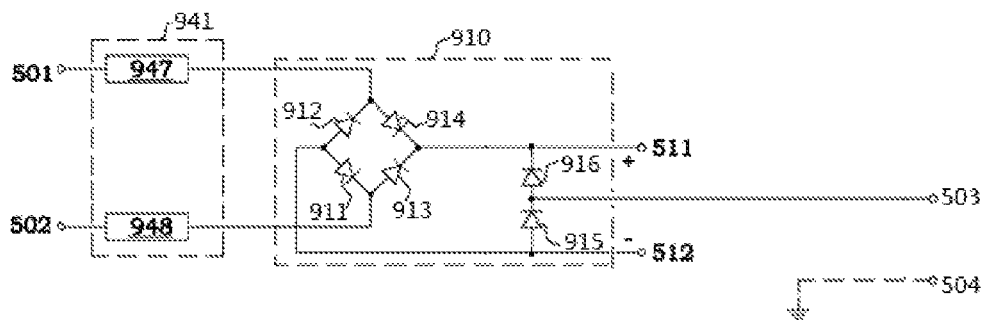


Fig. 9E

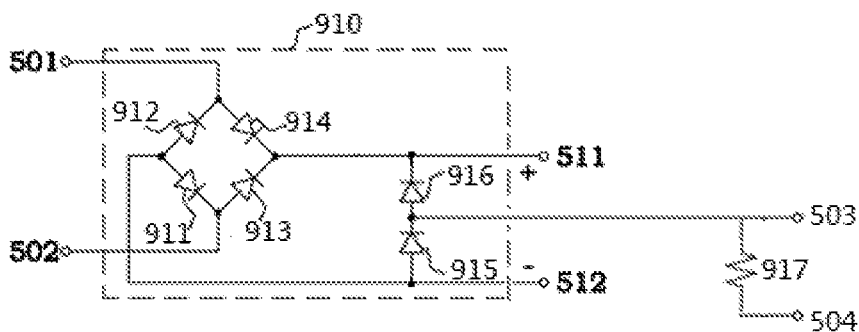


Fig. 9F

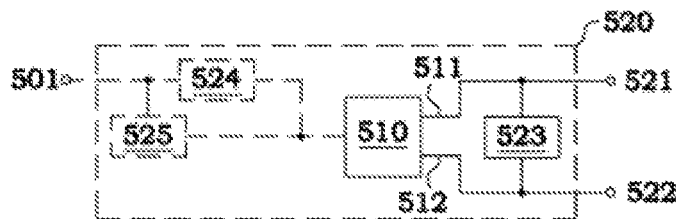


Fig. 10A

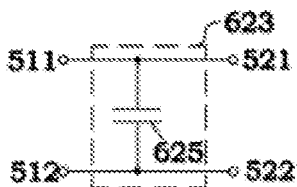


Fig. 10B

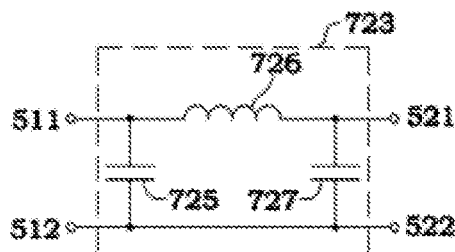


Fig. 10C

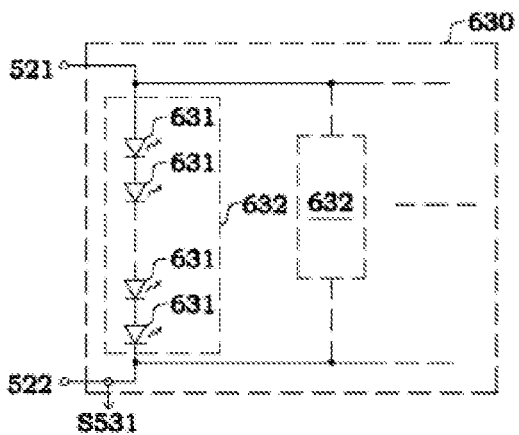


Fig. 11A

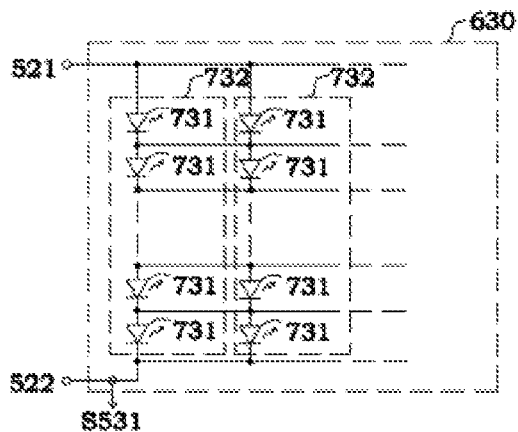


Fig. 11B

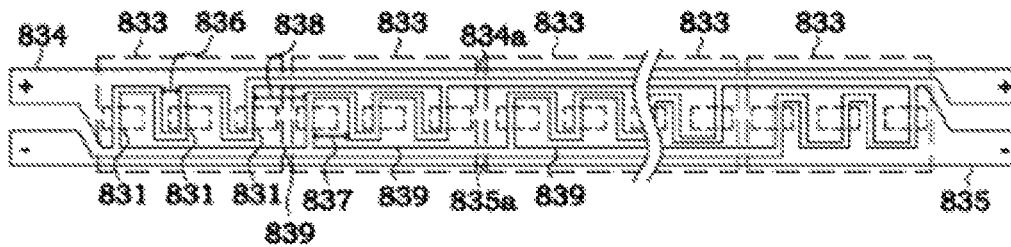


Fig. 11C

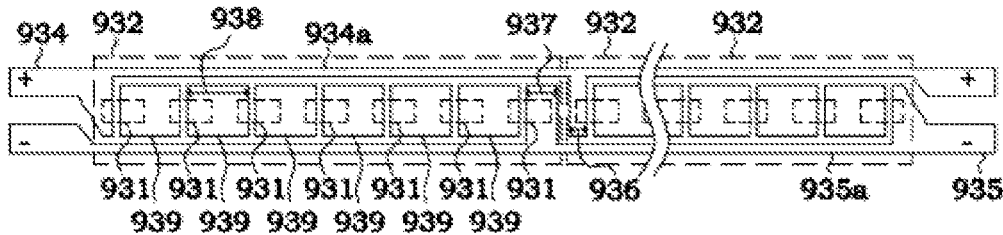


Fig. 11D

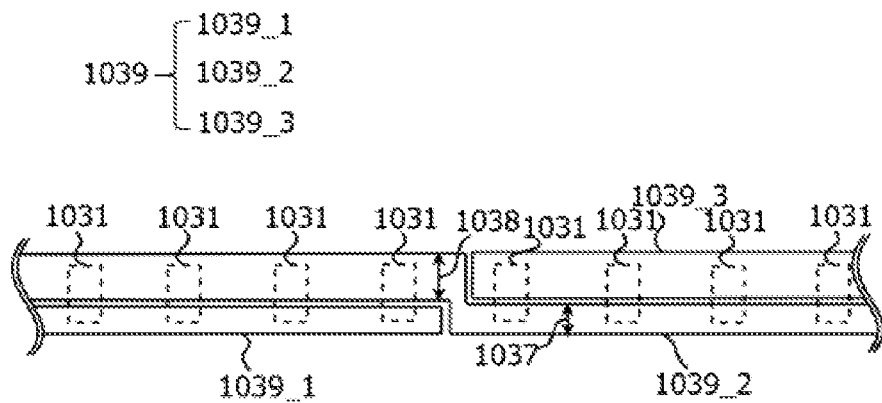


Fig. 11E

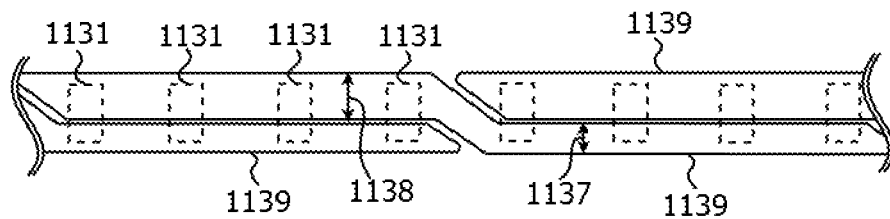


Fig. 11F

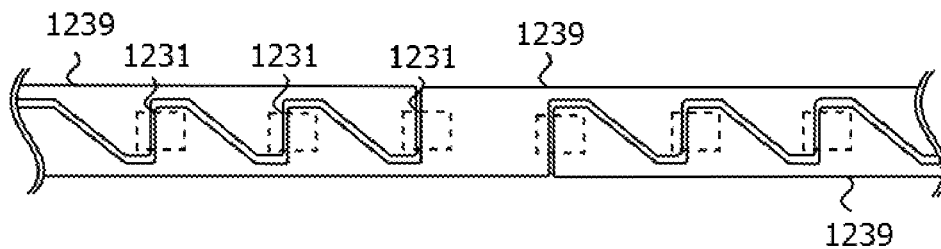


Fig. 11G

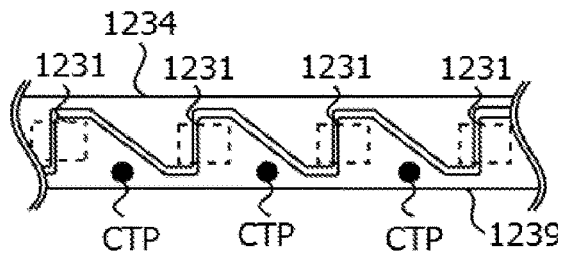


Fig. 11H

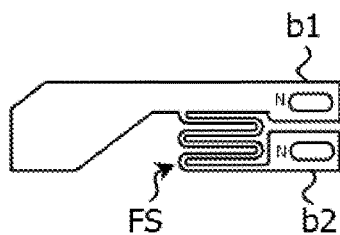


Fig. 11I

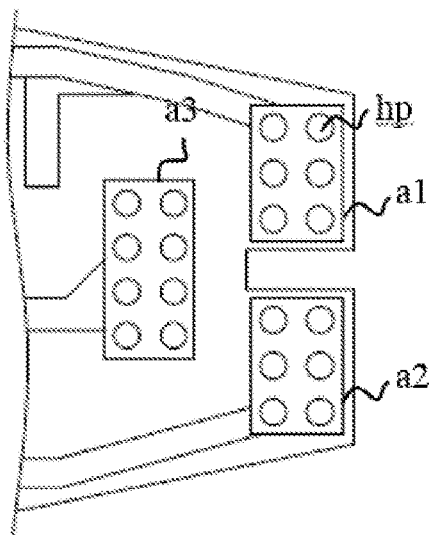


Fig. 11J

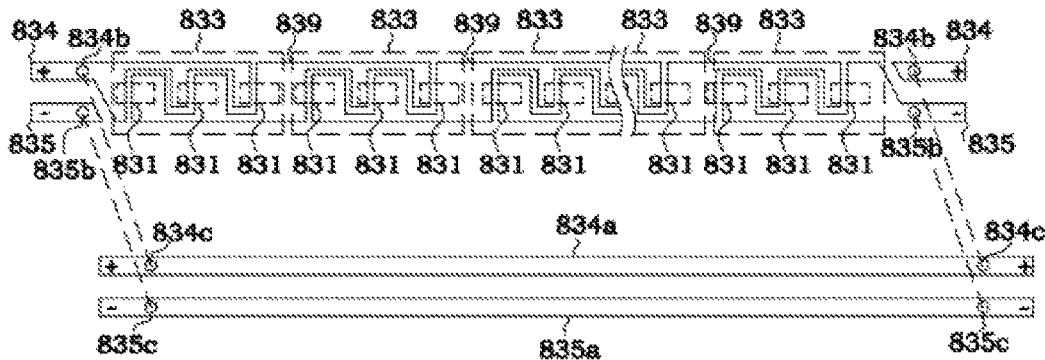


Fig. 11K

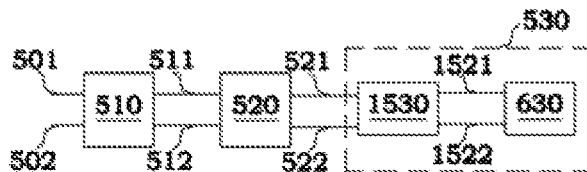


Fig. 12A

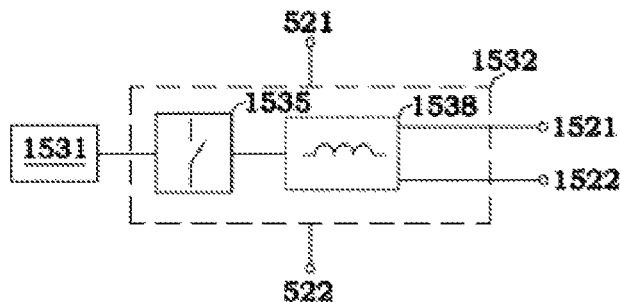


Fig. 12B

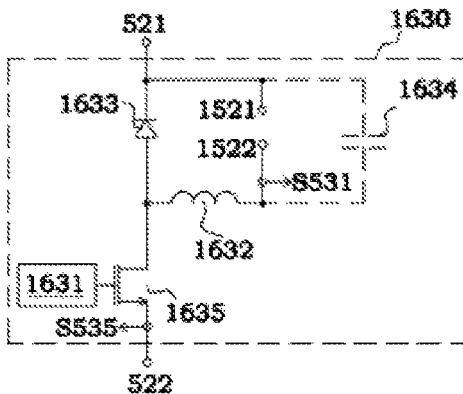


Fig. 12C

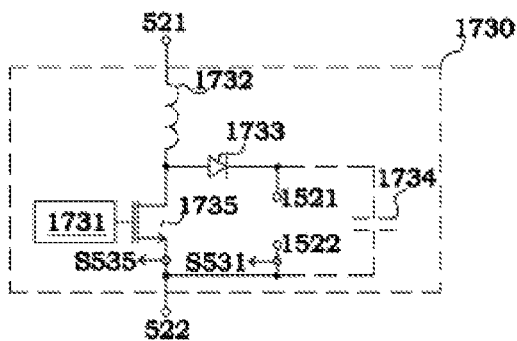


Fig. 12D

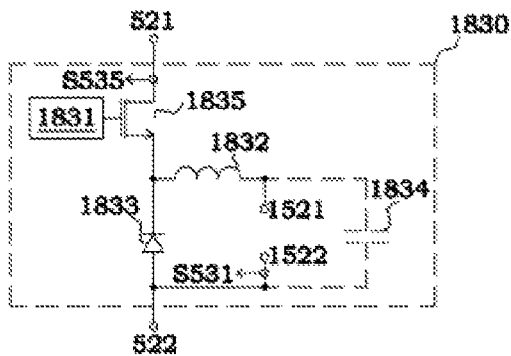


Fig. 12E

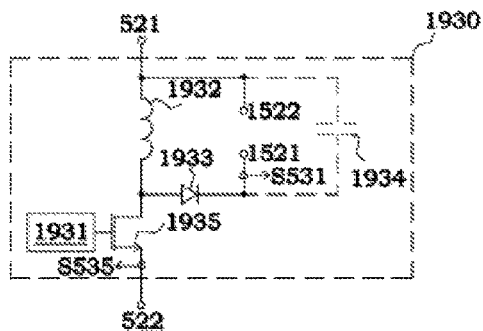


Fig. 12F

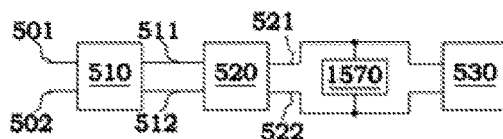


Fig. 13A

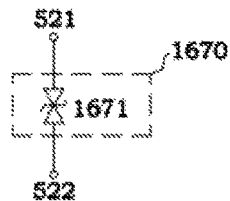


Fig. 13B

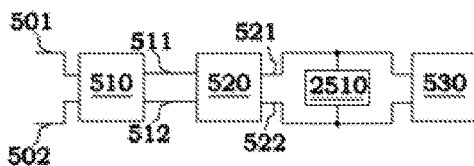


Fig. 14A

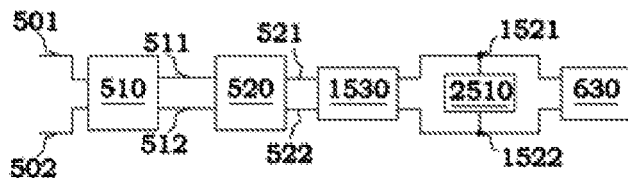


Fig. 14B

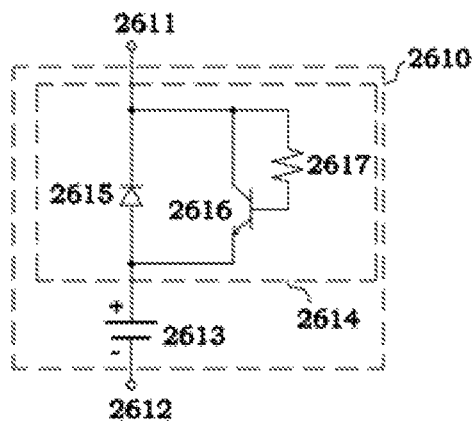


Fig. 14C

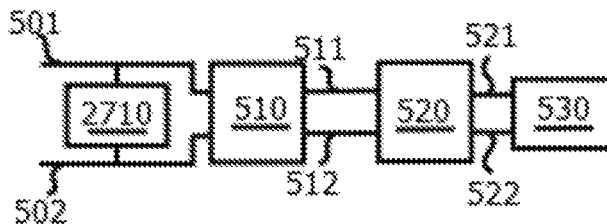


Fig. 14D

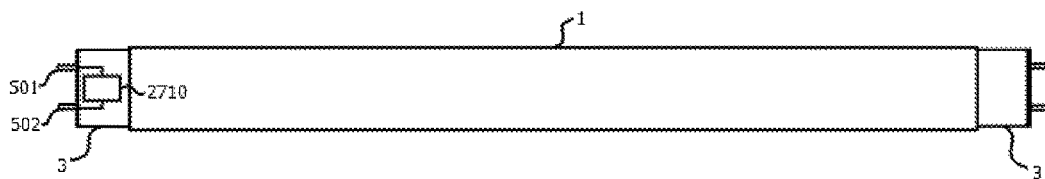


Fig. 14E

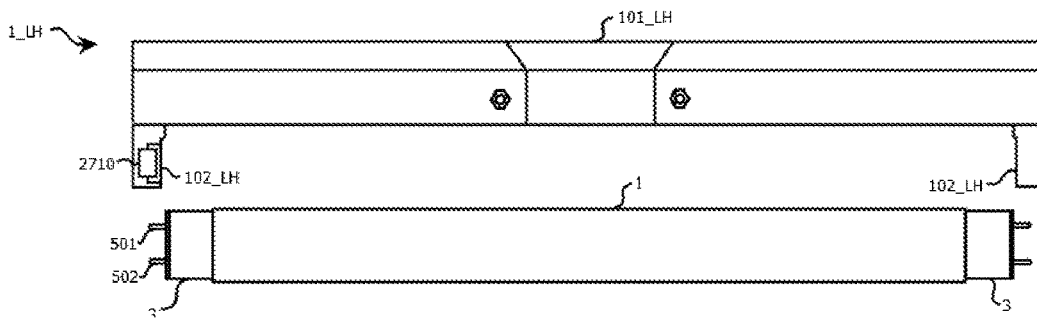


Fig. 14F

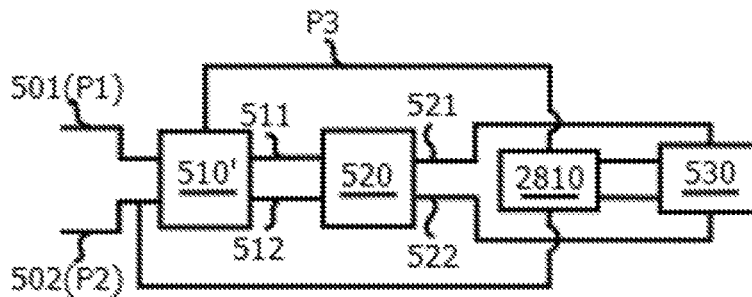


Fig. 14G

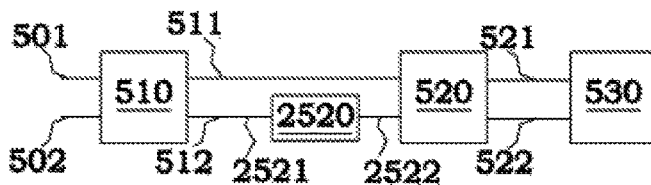


Fig. 15A

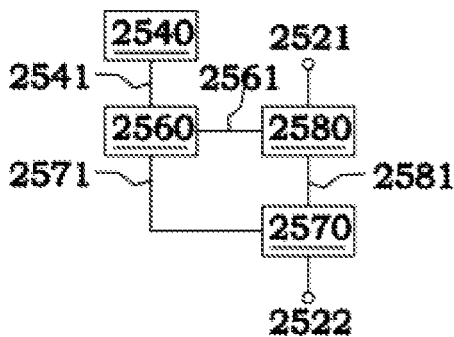


Fig. 15B

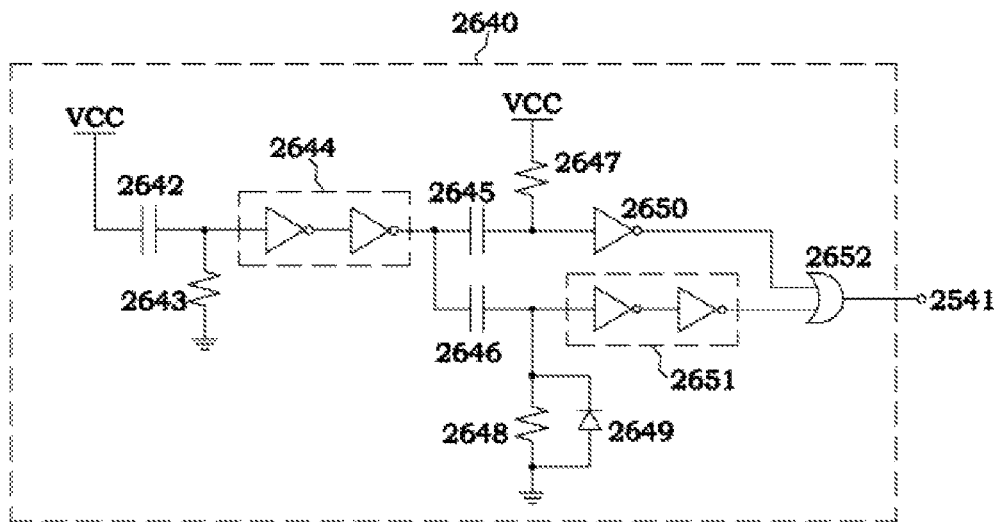


Fig. 15C

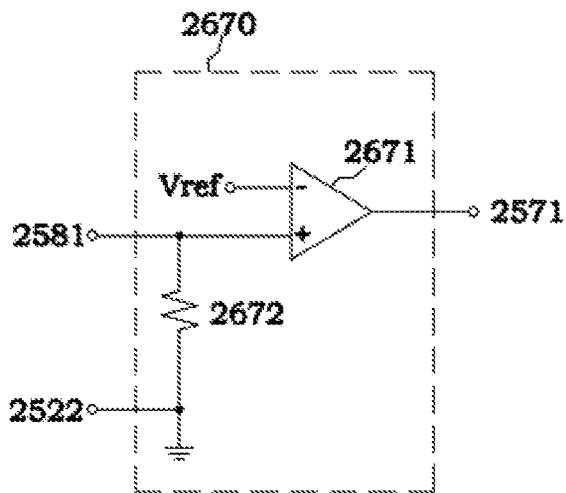


Fig. 15D

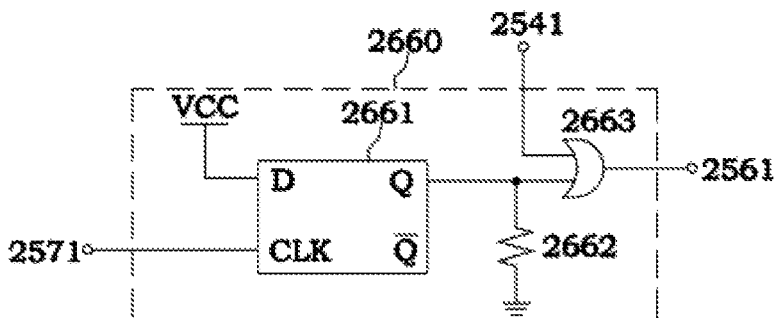


Fig. 15E

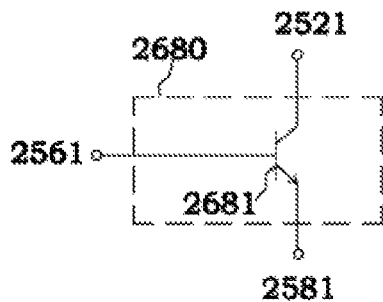


Fig. 15F

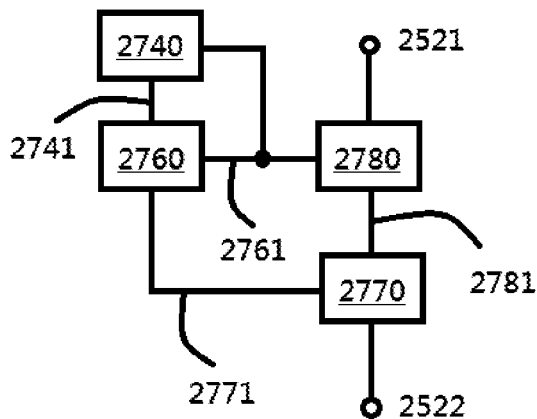


Fig. 15G

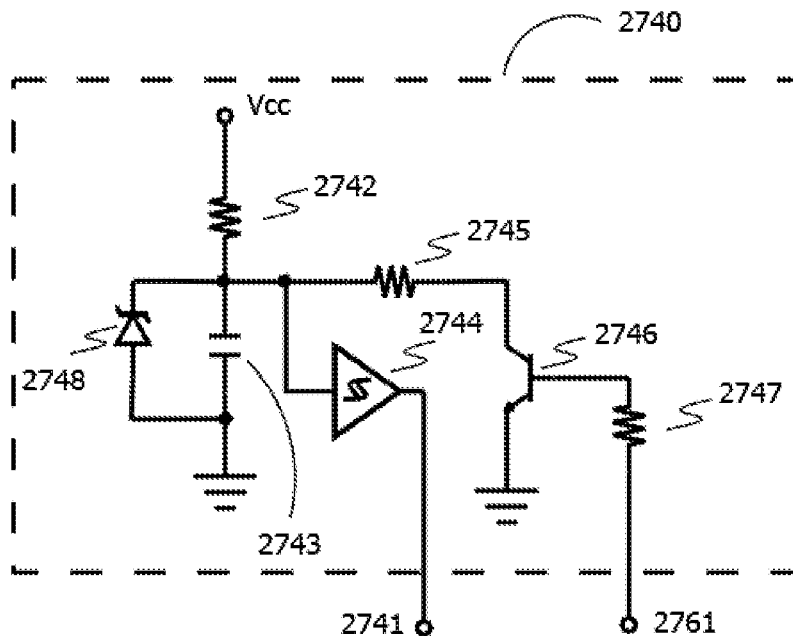


Fig. 15H

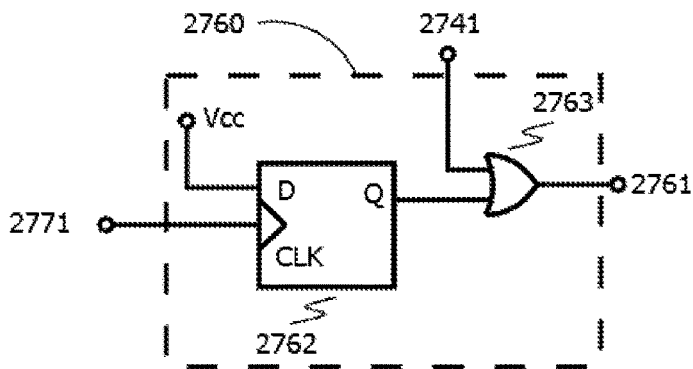


Fig. 15I

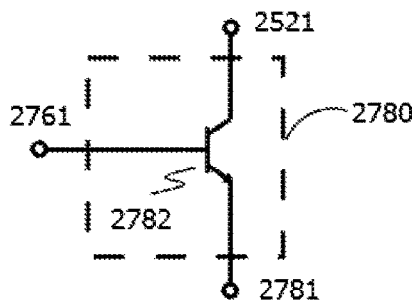


Fig. 15J

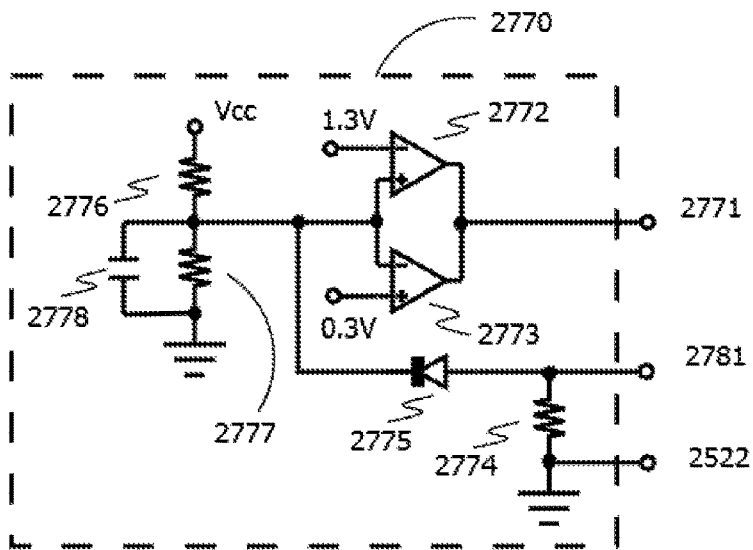


Fig. 15K

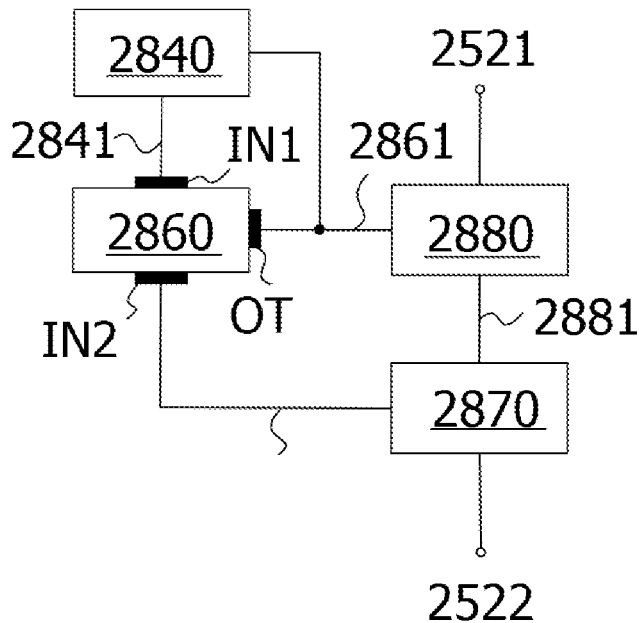


Fig. 15L

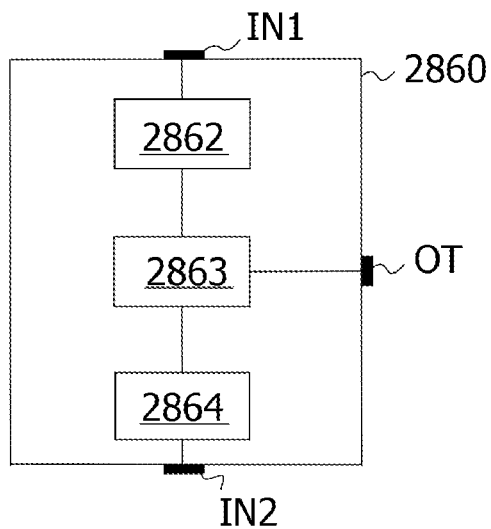


Fig. 15M

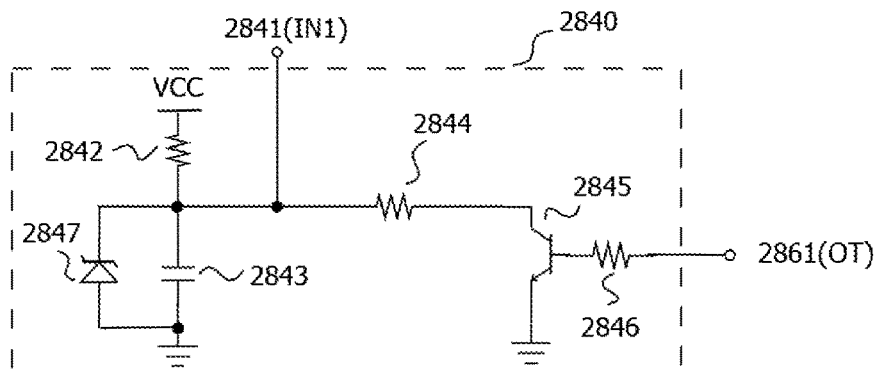


Fig. 15N

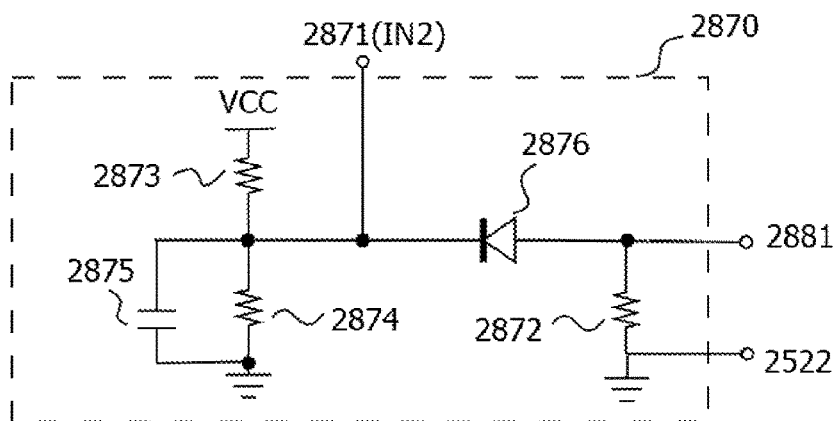


Fig. 15O

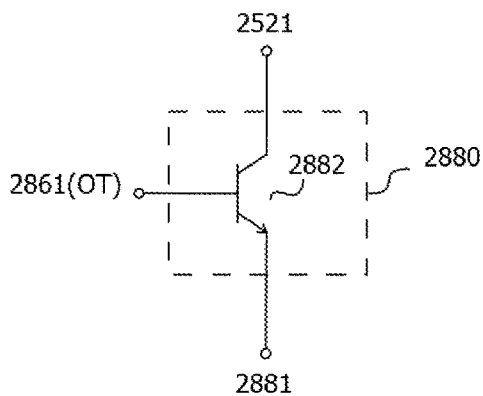


Fig. 15P

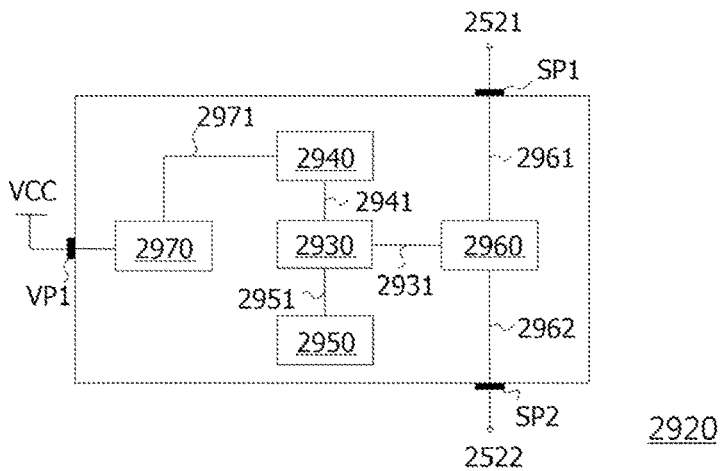


Fig. 15Q

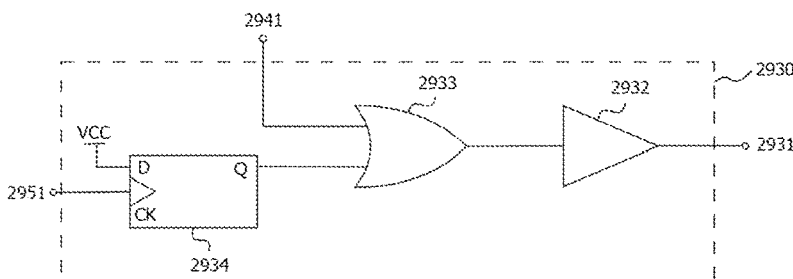


Fig. 15R

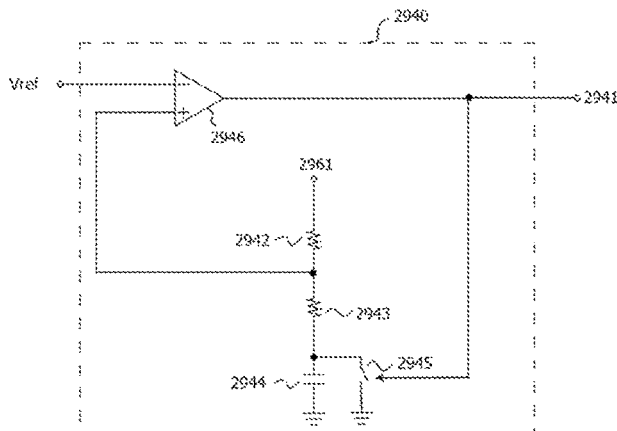


Fig. 15S

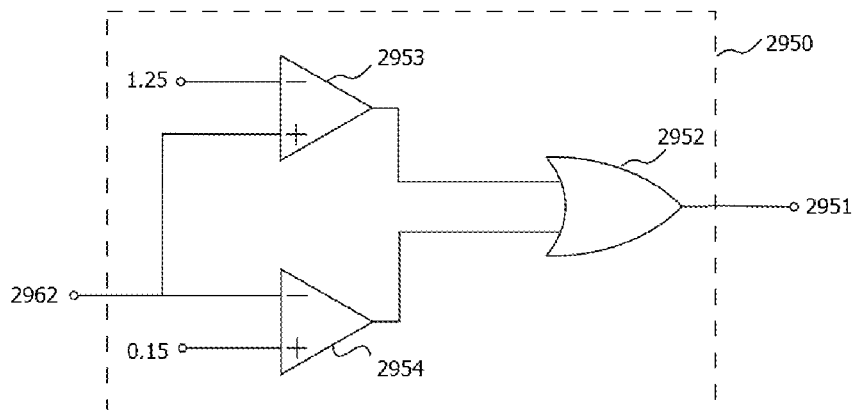


Fig. 15T

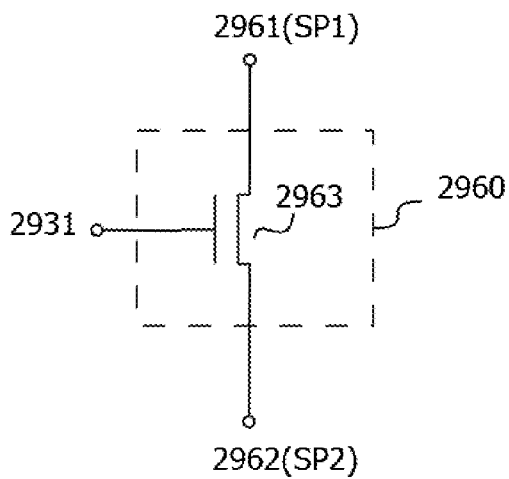


Fig. 15U

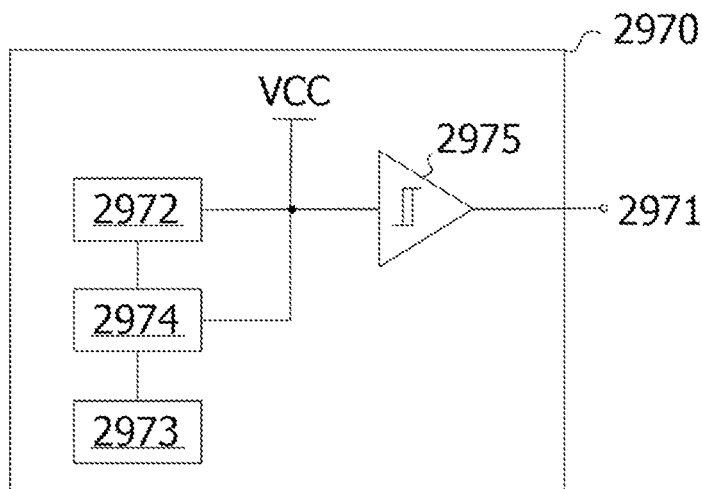


Fig. 15V

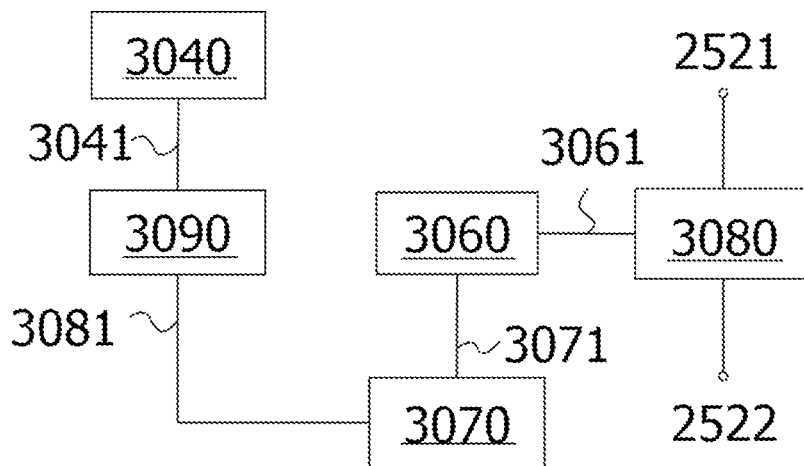


Fig. 15W

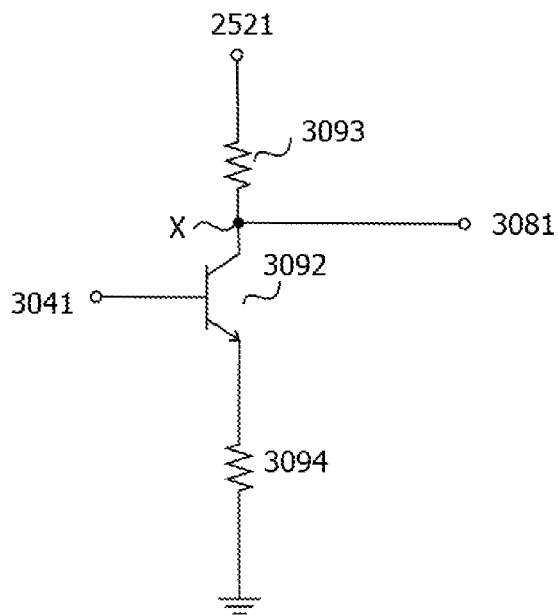


Fig. 15X

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LED TUBE LAMP

RELATED APPLICATIONS

This application is a Continuation application of U.S. patent application Ser. No. 15/373,388, filed on Dec. 8, 2016, which is a Continuation-In-Part application of U.S. patent application Ser. No. 15/339,221, filed on Oct. 31, 2016, U.S. patent application Ser. No. 15/211,813, filed on Jul. 15, 2016, U.S. patent application Ser. No. 15/084,483, filed on Mar. 30, 2016, and U.S. patent application Ser. No. 15/065,892, filed on Mar. 10, 2016. U.S. patent application Ser. No. 15/339,221 is also a Continuation-In-Part application of U.S. patent application Ser. No. 15/210,989, filed on Jul. 15, 2016, which is a Continuation-In-Part application of U.S. patent application Ser. No. 15/066,645, filed on Mar. 10, 2016, which is a Continuation-In-Part application of U.S. patent application Ser. No. 14/865,387, filed on Sep. 25, 2015. The disclosure of each of the above-described applications is incorporated in its entirety by reference herein. U.S. patent application Ser. No. 15/210,989, filed on Jul. 15, 2016 is also a Continuation-In-Part application of U.S. patent application Ser. No. 15/205,011, filed on Jul. 8, 2016, which is a Continuation-In-Part application of U.S. patent application Ser. No. 15/150,458, filed on May 10, 2016, which is a Continuation-In-Part Ser. No. 14/865,387, filed on Sep. 25, 2015, the disclosure of each of which is incorporated in its entirety by reference herein. U.S. patent application Ser. No. 15/211,813 is also a Continuation-In-Part application of U.S. patent application Ser. No. 15/150,458, filed on May 10, 2016, which is a Continuation-In-Part application of U.S. patent application Ser. No. 14/865,387, filed on Sep. 25, 2015. U.S. patent application Ser. No. 15/084,483, filed on Mar. 30, 2016, is also a Continuation-In-Part application of U.S. patent application Ser. No. 14/865,387, filed on Sep. 25, 2015. U.S. patent application Ser. No. 15/065,892, filed on Mar. 10, 2016, is also a Continuation-In-Part application of U.S. patent application Ser. No. 14/865,387, filed on Sep. 25, 2015. U.S. patent application Ser. No. 14/865,387, filed on Sep. 25, 2015, U.S. patent application Ser. No. 14/865,387, filed on Sep. 25, 2015 claims priority under 35 U.S.C. 119(e) to Chinese Patent Applications No.: CN 201410507660.9 filed on 2014 Sep. 28; CN 201410508899.8 filed on 2014 Sep. 28; CN 201510104823.3 filed on 2015 Mar. 10; CN 201510134586.5 filed on 2015 Mar. 26; CN 201510133689.x filed on 2015 Mar. 25; CN 201510155807.7 filed on 2015 Apr. 3; CN 201510193980.6 filed on 2015 Apr. 22; CN 201510284720.x filed on 2015 May 29; CN 201510338027.6 filed on 2015 Jun. 17; CN 201510373492.3 filed on 2015 Jun. 26; CN 201510364735.7 filed on 2015 Jun. 26; CN 201510378322.4 filed on 2015 Jun. 29; CN 201510406595.5 filed on 2015 Jul. 10; CN 201510486115.0 filed on 2015 Aug. 8; CN 201510428680.1 filed on 2015 Jul. 20; CN 201510557717.0 filed on 2015 Sep. 6; CN 201510595173.7 filed on 2015 Sep. 18, the disclosures of each of which are incorporated herein in their entirety by reference.

In addition, U.S. patent application Ser. No. 15/066,645, from which U.S. patent application Ser. No. 15/210,989 claims priority as a Continuation-In-Part also claims priority under 35 U.S.C. 119(e) to Chinese Patent Applications Nos.: CN 201510530110.3 filed on 2015 Aug. 26; CN 201510499512.1 filed on 2015 Aug. 14; CN 201510448220.5 filed on 2015 Jul. 27; and CN 201510645134.3 filed on 2015 Oct. 8, the disclosures of each of which are incorporated herein in their entirety by reference.

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In addition, U.S. patent application Ser. No. 15/205,011, from which U.S. patent application Ser. No. 15/210,989 claims priority as a Continuation-in-Part also claims priority under 35 U.S.C. 119(e) to Chinese Patent Application Nos.: CN 201610327806.0, filed on May 18, 2016; and CN 201610420790.8, filed on Jun. 14, 2016, the disclosures of each of which are incorporated herein in their entirety by reference.

In addition, U.S. patent application Ser. No. 15/210,989 also claims priority under 35 U.S.C. 119(e) to Chinese Patent Application Nos.: CN 201510848766.X, filed on Nov. 27, 2015; CN 201510903680.2, filed on Dec. 9, 2015; CN 201610132513.7, filed on Mar. 9, 2016; CN 201610142140.1, filed on Mar. 14, 2016; and CN 201610452437.8, filed on Jun. 20, 2016, the disclosures of each of which are incorporated herein in their entirety by reference. In addition, U.S. patent application Ser. No. 15/210,989 also claims priority under 35 U.S.C. 119(e) to Chinese Patent Application Nos.: CN 201510530110.3, filed on Aug. 26, 2015; CN 201510499512.1, filed on Aug. 14, 2015; CN 201510617370.4, filed on Sep. 25, 2015; CN 201510645134.3, filed on Oct. 8, 2015; CN 201510726365.7, filed on Oct. 30, 2015; CN 201610044148.4, filed on Jan. 22, 2016; CN 201610051691.7, filed on Jan. 26, 2016; CN 201610085895.2, filed on Feb. 15, 2016; CN 201610087627.4, filed on Feb. 16, 2016; CN 201610281812.7, filed on Apr. 29, 2016; CN 201510705222.8, filed on Oct. 27, 2015; CN 201610050944.9, filed on Jan. 26, 2016; CN 201610098424.5, filed on Feb. 23, 2016; and CN 201610120993.5, filed on Mar. 3, 2016, the disclosures of each of which are incorporated herein by reference in their entirety.

In addition, U.S. patent application Ser. No. 15/339,221 also claims priority under 35 U.S.C. 119(e) to Chinese Patent Application No.: CN 201610876593.7, filed on Oct. 8, 2016, the entire contents of which are incorporated herein by reference.

In addition, U.S. patent application Ser. No. 15/373,388 claims priority under 35 U.S.C. 119(e) to Chinese Patent Application No.: CN 201610878349.4, filed on Oct. 8, 2016; CN 201610955338.1, filed on Oct. 27, 2016; CN 201610955342.8, filed on Oct. 27, 2016; CN 201610975119.X, filed on Nov. 3, 2016; CN 201611057357.9, filed on Nov. 25, 2016; CN 201610177706.4, filed on Mar. 25, 2016; and CN 201610890527.5, filed on Oct. 12, 2016, the disclosures of each of which are incorporated herein by reference in their entirety.

If any terms in this application conflict with terms used in any application(s) to which this application claims priority, or terms incorporated by reference into this application or the application(s) to which this application claims priority, a construction based on the terms as used or defined in this application should be applied.

TECHNICAL FIELD

The disclosed embodiments relate to the features of light emitting diode (LED) lighting. More particularly, the disclosed embodiments describe various improvements for LED tube lamps.

BACKGROUND

LED lighting technology is rapidly developing to replace traditional incandescent and fluorescent lighting. LED tube

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lamps are mercury-free in comparison with fluorescent tube lamps that need to be filled with inert gas and mercury. Thus, it is not surprising that LED tube lamps are becoming a highly desired illumination option among different available lighting systems used in homes and workplaces, which used to be dominated by traditional lighting options such as compact fluorescent light bulbs (CFLs) and fluorescent tube lamps. Benefits of LED tube lamps include improved durability and longevity and far less energy consumption. Therefore, when taking into account all factors, they would typically be considered as a cost effective lighting option.

Typical LED tube lamps have a lamp tube, a circuit board disposed inside the lamp tube with light sources being mounted on the circuit board, and end caps accompanying a power supply provided at two ends of the lamp tube with the electricity from the power supply transmitting to the light sources through the circuit board. However, existing LED tube lamps have certain drawbacks. For example, the typical circuit board is rigid and allows the entire lamp tube to maintain a straight tube configuration when the lamp tube is partially ruptured or broken, and this gives the user a false impression that the LED tube lamp remains usable and is likely to cause the user to be electrically shocked upon handling or installation of the LED tube lamp.

Conventional circuit design of LED tube lamps typically doesn't provide suitable solutions for complying with relevant certification standards. For example, since there are usually no electronic components in a fluorescent lamp, it's fairly easy for a fluorescent lamp to be certified under EMI (electromagnetic interference) standards and safety standards for lighting equipment as provided by Underwriters Laboratories (UL). However, there are a considerable number of electronic components in an LED tube lamp, and therefore consideration of the impacts caused by the layout (structure) of the electronic components is important, resulting in difficulties in complying with such standards.

Further, the driving of an LED uses a DC driving signal, but the driving signal for a fluorescent lamp is a low-frequency, low-voltage AC signal as provided by an AC powerline, a high-frequency, high-voltage AC signal provided by a ballast, or even a DC signal provided by a battery for emergency lighting applications. Since the voltages and frequency spectrums of these types of signals differ significantly, simply performing a rectification to produce the required DC driving signal in an LED tube lamp may not achieve the LED tube lamp's compatibility with traditional driving systems of a fluorescent lamp.

Moreover, when an LED tube lamp has an architecture with dual-end power supply and one end cap thereof is inserted into a lamp socket but the other is not, an electric shock situation could take place for the user touching the metal or conductive part of the end cap which has not been inserted into the lamp socket.

In the prior art, a solution of disposing a mechanical structure on the end cap for preventing electric shock is proposed. In this electric shock protection design, the connection between the external power and the internal circuit of the tube lamp can be cut off or established by the mechanical component's interaction/shifting when a user installs the tube lamp, so as to achieve the electric shock protection.

Currently, LED tube lamps used to replace traditional fluorescent lighting devices can be primarily categorized into two types. One is for ballast-compatible LED tube lamps, e.g., T-LED lamp, which directly replaces fluorescent tube lamps without changing any circuit on the lighting device; and the other one is for ballast by-pass LED tube

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lamps, which omit traditional ballast on their circuit and directly connect the commercial electricity to the LED tube lamp. The latter LED tube lamp is suitable for the new surroundings in fixtures with new driving circuits and LED tube lamps.

SUMMARY

It's specially noted that the present disclosure may actually include one or more inventions claimed currently or not yet claimed, and for avoiding confusion due to unnecessarily distinguishing between those possible inventions at the stage of preparing the specification, the possible plurality of inventions herein may be collectively referred to as "the (present) invention" herein.

Various embodiments are summarized in this section, and may be described with respect to the "present invention," which terminology is used to describe certain presently disclosed embodiments, whether claimed or not, and is not necessarily an exhaustive description of all possible embodiments, but rather is merely a summary of certain embodiments. Certain of the embodiments described below as various aspects of the "present invention" can be combined in different manners to form an LED tube lamp or a portion thereof.

The present disclosure provides a novel LED tube lamp, and aspects thereof.

According to certain embodiments, an installation detection circuit configured in the LED tube lamp configured to receive an external driving signal is disclosed. The installation detection circuit includes: a pulse generating circuit configured to output one or more pulse signals; wherein the installation detection circuit is configured to detect during one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket, based on detecting a signal generated from the external driving signal; and a switch circuit coupled to the pulse generating circuit, wherein the one or more pulse signals control turning on and off of the switch circuit; wherein the installation detection circuit is further configured to: when it is detected during one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and when it is detected during one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain conducting state.

According to certain embodiments, an installation detection circuit configured in a light-emitting diode (LED) tube lamp is disclosed. The installation detection circuit includes: means for generating one or more pulse signals; means for detecting during one or more pulse signals whether the LED tube lamp is properly installed on a lamp socket; and a switch circuit coupled to the means for generating one or more pulse signals, wherein the one or more pulse signals control turning on and off of the switch circuit; wherein the installation detection circuit is further configured to: when it is detected during the one or more pulse signals that the LED tube lamp is not properly installed on the lamp socket, control the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open; and when it is detected during the one or more pulse signals that the LED tube lamp is properly installed on the lamp socket, control the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state.

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According to certain embodiments, a detection method adopted by a light-emitting device (LED) tube lamp for preventing a user from electric shock when the LED tube lamp is being installed on a lamp socket is disclosed. The detection method includes: when at least one end of the LED tube lamp is installed on the lamp socket, generating one or more pulse signals by a pulse generating circuit, wherein the pulse generating circuit is configured in the LED tube lamp; detecting a sample signal on a power loop of the LED tube lamp by a detection determining circuit, to detect during the one or more pulse signals whether the other end of the LED tube lamp is properly installed on the lamp socket; receiving the one or more pulse signals through a detection result latching circuit by a switch circuit, wherein the switch circuit is on the power loop; and comparing the sample signal with a predefined signal, wherein during the one or more pulse signals when the sample signal is smaller than the predefined signal, the detection method further comprises: controlling the switch circuit to remain in an off state to cause the power loop of the LED tube lamp to be open.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a plane cross-sectional view schematically illustrating an LED tube lamp including an LED light strip that is a bendable circuit sheet with ends thereof passing across the transition region of the lamp tube of the LED tube lamp to be connected to a power supply according to some exemplary embodiments;

FIG. 2 is a plane cross-sectional view schematically illustrating a bi-layered structure of a bendable circuit sheet of an LED light strip of an LED tube lamp according to some exemplary embodiments;

FIG. 3A is a perspective view schematically illustrating a soldering pad of a bendable circuit sheet of an LED light strip for a solder connection with a power supply of an LED tube lamp according to some exemplary embodiments;

FIG. 3B is a block diagram illustrating leads that are disposed between two end caps of an LED tube lamp according to some exemplary embodiments;

FIG. 4A is a perspective view of a bendable circuit sheet and a printed circuit board of a power supply soldered to each other in accordance with an exemplary embodiment;

FIGS. 4B, 4C, and 4D are diagrams of a soldering process of the bendable circuit sheet and the printed circuit board of the power supply of FIG. 4A in accordance with an exemplary embodiment;

FIG. 5 is a perspective view schematically illustrating a circuit board assembly composed of a bendable circuit sheet of an LED light strip and a printed circuit board of a power supply according to some exemplary embodiments;

FIG. 6 is a perspective view schematically illustrating another arrangement of a circuit board assembly, according to some exemplary embodiments;

FIG. 7 is a perspective view schematically illustrating a bendable circuit sheet of an LED light strip formed with two conductive wiring layers according to some exemplary embodiments;

FIG. 8A is a block diagram of an exemplary power supply system for an LED tube lamp according to some exemplary embodiments;

FIG. 8B is a block diagram of an exemplary power supply system for an LED tube lamp according to some exemplary embodiments;

FIG. 8C is a block diagram of an exemplary power supply system for an LED tube lamp according to some exemplary

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FIG. 8D is a block diagram of an exemplary LED lamp according to some exemplary embodiments;

FIG. 8E is a block diagram of an exemplary LED lamp according to some exemplary embodiments;

FIG. 8F is a block diagram of an exemplary LED lamp according to some exemplary embodiments;

FIG. 8G is a block diagram of a connection configuration between an LED lamp and an external power source according to some exemplary embodiments;

FIG. 9A is a schematic diagram of a rectifying circuit according to some exemplary embodiments;

FIG. 9B is a schematic diagram of a rectifying circuit according to some exemplary embodiments;

FIG. 9C is a schematic diagram of a rectifying circuit according to some exemplary embodiments;

FIG. 9D is a schematic diagram of a rectifying circuit according to some exemplary embodiments;

FIG. 9E is a schematic diagram of a rectifying circuit according to some exemplary embodiments;

FIG. 9F is a schematic diagram of a rectifying circuit according to some exemplary embodiments;

FIGS. 10A-10C are block diagrams of exemplary filtering circuits according to some exemplary embodiments;

FIGS. 11A-11B are schematic diagrams of exemplary LED modules according to some exemplary embodiments;

FIGS. 11C-11I, 11K are plan views of a circuit layout of an LED module according to some exemplary embodiments;

FIG. 11J is a schematic view of a power pad according to an exemplary embodiment.

FIG. 12A is a block diagram of an exemplary power supply module in an LED lamp according to some exemplary embodiments;

FIG. 12B is a block diagram of a driving circuit according to some exemplary embodiments;

FIGS. 12C-12F are schematic diagrams of exemplary driving circuits according to some exemplary embodiments;

FIG. 13A is a block diagram of an exemplary power supply module in an LED tube lamp according to some exemplary embodiments;

FIG. 13B is a schematic diagram of an over-voltage protection (OVP) circuit according to some exemplary embodiments;

FIG. 14A is a block diagram of an exemplary power supply module in an LED tube lamp according to some exemplary embodiments;

FIG. 14B is a block diagram of an exemplary power supply module in an LED tube lamp according to some exemplary embodiments;

FIG. 14C is a schematic diagram of an auxiliary power module according to some exemplary embodiments;

FIG. 14D is a block diagram of an exemplary power supply module in an LED tube lamp according to some exemplary embodiments;

FIG. 14E-14F are schematic structures of an auxiliary power supply module disposed in an LED tube lamp according to some exemplary embodiments;

FIG. 14G is a block diagram of a power supply module in an LED tube lamp according to an exemplary embodiment.

FIG. 15A is a block diagram of an LED tube lamp according to some exemplary embodiments;

FIG. 15B is a block diagram of an installation detection module according to some exemplary embodiments;

FIG. 15C is a schematic detection pulse generating module according to some exemplary embodiments;

FIG. 15D is a schematic detection determining circuit according to some exemplary embodiments;

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FIG. 15E is a schematic detection result latching circuit according to some exemplary embodiments;

FIG. 15F is a schematic switch circuit according to some exemplary embodiments;

FIG. 15G is a block diagram of an installation detection module according to some exemplary embodiments;

FIG. 15H is a schematic detection pulse generating module according to some exemplary embodiments;

FIG. 15I is a schematic detection result latching circuit according to some exemplary embodiments;

FIG. 15J is a schematic switch circuit according to some exemplary embodiments; and

FIG. 15K is a schematic detection determining circuit according to some exemplary embodiments.

FIG. 15L is a block diagram of an installation detection module according to some exemplary embodiments;

FIG. 15M is an internal circuit block diagram of an integrated control module according to some exemplary embodiments;

FIG. 15N is a schematic pulse generating auxiliary circuit according to some exemplary embodiments;

FIG. 15O is a schematic detection determining auxiliary circuit according to some exemplary embodiments;

FIG. 15P is a schematic switch circuit according to some exemplary embodiments;

FIG. 15Q is an internal circuit block diagram of a three-terminal switch device according to some exemplary embodiments;

FIG. 15R is a schematic signal processing unit according to some exemplary embodiments;

FIG. 15S is a schematic signal generating unit according to some exemplary embodiments;

FIG. 15T is a schematic signal capturing unit according to some exemplary embodiments;

FIG. 15U is a schematic switch unit according to some exemplary embodiments;

FIG. 15V is a schematic internal power detection unit according to some exemplary embodiments;

FIG. 15W is a block diagram of an installation detection module according to an exemplary embodiment; and

FIG. 15X is a block diagram of a detection path circuit according to an exemplary embodiment.

DETAILED DESCRIPTION

The present disclosure provides a novel LED tube lamp. The present disclosure will now be described in the following embodiments with reference to the drawings. The following descriptions of various embodiments of this invention are presented herein for purpose of illustration and giving examples only. It is not intended to be exhaustive or to be limited to the precise form disclosed. These example embodiments are just that—examples—and many implementations and variations are possible that do not require the details provided herein. It should also be emphasized that the disclosure provides details of alternative examples, but such listing of alternatives is not exhaustive. Furthermore, any consistency of detail between various examples should not be interpreted as requiring such detail—it is impracticable to list every possible variation for every feature described herein. The language of the claims should be referenced in determining the requirements of the invention.

In the drawings, the size and relative sizes of components may be exaggerated for clarity. Like numbers refer to like elements throughout.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be

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limiting of the invention. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items and may be abbreviated as “/”.

It will be understood that, although the terms first, second, third etc. may be used herein to describe various elements, components, regions, layers, or steps, these elements, components, regions, layers, and/or steps should not be limited by these terms. Unless the context indicates otherwise, these terms are only used to distinguish one element, component, region, layer, or step from another element, component, region, or step, for example as a naming convention. Thus, a first element, component, region, layer, or step discussed below in one section of the specification could be termed a second element, component, region, layer, or step in another section of the specification or in the claims without departing from the teachings of the present invention. In addition, in certain cases, even if a term is not described using “first,” “second,” etc., in the specification, it may still be referred to as “first” or “second” in a claim in order to distinguish different claimed elements from each other.

It will be further understood that the terms “comprises” and/or “comprising,” or “includes” and/or “including” when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

It will be understood that when an element is referred to as being “connected” or “coupled” to or “on” another element, it can be directly connected or coupled to or on the other element or intervening elements may be present. In contrast, when an element is referred to as being “directly connected” or “directly coupled” to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent,” etc.). However, the term “contact,” as used herein refers to direct connection (i.e., touching) unless the context indicates otherwise.

Embodiments described herein will be described referring to plane views and/or cross-sectional views by way of ideal schematic views. Accordingly, the exemplary views may be modified depending on manufacturing technologies and/or tolerances. Therefore, the disclosed embodiments are not limited to those shown in the views, but include modifications in configuration formed on the basis of manufacturing processes. Therefore, regions exemplified in figures may have schematic properties, and shapes of regions shown in figures may exemplify specific shapes of regions of elements to which aspects of the invention are not limited.

Spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper” and the like, may be used herein for ease of description to describe one element’s or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90

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degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

Terms such as "same," "equal," "planar," or "coplanar," as used herein when referring to orientation, layout, location, shapes, sizes, amounts, or other measures do not necessarily mean an exactly identical orientation, layout, location, shape, size, amount, or other measure, but are intended to encompass nearly identical orientation, layout, location, shapes, sizes, amounts, or other measures within acceptable variations that may occur, for example, due to manufacturing processes. The term "substantially" may be used herein to emphasize this meaning, unless the context or other statements indicate otherwise. For example, items described as "substantially the same," "substantially equal," or "substantially planar," may be exactly the same, equal, or planar, or may be the same, equal, or planar within acceptable variations that may occur, for example, due to manufacturing processes.

Terms such as "about" or "approximately" may reflect sizes, orientations, or layouts that vary only in a small relative manner, and/or in a way that does not significantly alter the operation, functionality, or structure of certain elements. For example, a range from "about 0.1 to about 1" may encompass a range such as a 0%-5% deviation around 0.1 and a 0% to 5% deviation around 1, especially if such deviation maintains the same effect as the listed range.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and/or the present application, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

As used herein, items described as being "electrically connected" are configured such that an electrical signal can be passed from one item to the other. Therefore, a passive electrically conductive component (e.g., a wire, pad, internal electrical line, etc.) physically connected to a passive electrically insulative component (e.g., a prepreg layer of a printed circuit board, an electrically insulative adhesive connecting two devices, an electrically insulative underfill or mold layer, etc.) is not electrically connected to that component. Moreover, items that are "directly electrically connected," to each other are electrically connected through one or more passive elements, such as, for example, wires, pads, internal electrical lines, resistors, etc. As such, directly electrically connected components do not include components electrically connected through active elements, such as transistors or diodes. Directly electrically connected elements may be directly physically connected and directly electrically connected.

Components described as thermally connected or in thermal communication are arranged such that heat will follow a path between the components to allow the heat to transfer from the first component to the second component. Simply because two components are part of the same device or board does not make them thermally connected. In general, components which are heat-conductive and directly connected to other heat-conductive or heat-generating components (or connected to those components through intermediate heat-conductive components or in such close proximity as to permit a substantial transfer of heat) will be described as thermally connected to those components, or in thermal communication with those components. On the contrary,

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two components with heat-insulative materials therebetween, which materials significantly prevent heat transfer between the two components, or only allow for incidental heat transfer, are not described as thermally connected or in thermal communication with each other. The terms "heat-conductive" or "thermally-conductive" do not apply to any material that provides incidental heat conduction, but are intended to refer to materials that are typically known as good heat conductors or known to have utility for transferring heat, or components having similar heat conducting properties as those materials.

Embodiments may be described, and illustrated in the drawings, in terms of functional blocks, units and/or modules. Those skilled in the art will appreciate that these blocks, units and/or modules are physically implemented by electronic (or optical) circuits such as logic circuits, discrete components, analog circuits, hard-wired circuits, memory elements, wiring connections, and the like, which may be formed using semiconductor-based fabrication techniques or other manufacturing technologies. In the case of the blocks, units and/or modules being implemented by microprocessors or similar, they may be programmed using software (e.g., microcode) to perform various functions discussed herein and may optionally be driven by firmware and/or software. Alternatively, each block, unit and/or module may be implemented by dedicated hardware, or as a combination of dedicated hardware to perform some functions and a processor (e.g., one or more programmed microprocessors and associated circuitry) to perform other functions. Also, each block, unit and/or module of the embodiments may be physically separated into two or more interacting and discrete blocks, units and/or modules. Further, the blocks, units and/or modules of the various embodiments may be physically combined into more complex blocks, units and/or modules.

If any terms in this application conflict with terms used in any application(s) from which this application claims priority, or terms incorporated by reference into this application or the application(s) from which this application claims priority, a construction based on the terms as used or defined in this application should be applied.

It should be noted that, the following description of various embodiments of the present disclosure is described herein in order to clearly illustrate the inventive features of the present disclosure. However, it is not intended that various embodiments can only be implemented alone. Rather, it is contemplated that various of the different embodiments can be and are intended to be used together in a final product, and can be combined in various ways to achieve various final products. Thus, people having ordinary skill in the art may combine the possible embodiments together or replace the components/modules between the different embodiments according to design requirements. The embodiments taught herein are not limited to the form described in the following examples, any possible replacement and arrangement between the various embodiments are included.

Applicant's prior U.S. patent application Ser. No. 14/724,840 (US PGPub No. 2016/0091156, the disclosure of which is incorporated herein in its entirety by reference), as an illustrated example, has addressed certain issues associated with the occurrence of electric shock in using a conventional LED lamp by providing a bendable circuit sheet. Some of the embodiments disclosed in U.S. patent application Ser. No. 14/724,840 can be combined with one or more of the example embodiments disclosed herein to further reduce the occurrence of electric shock in using an LED lamp.

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Referring to FIG. 1, an LED tube lamp may include an LED light strip 2. In certain embodiments, the LED light strip 2 may be formed from a bendable circuit sheet, for example that may be flexible. As described further below, the bendable circuit sheet is also described as a bendable circuit board. The LED light strip 2, and for example the bendable circuit sheet, may also be a flexible strip, such as a flexible or non-rigid tape or a ribbon. The bendable circuit sheet may have ends thereof passing across a transition region of the lamp tube of the LED tube lamp to be connected to a power supply 5. In some embodiments, the ends of the bendable circuit sheet may be connected to a power supply in an end cap of the LED tube lamp. For example, the ends may be connected in a manner such that a portion of the bendable circuit sheet is bent away from the lamp tube and passes through the transition region where a lamp tube narrows, and such that the bendable circuit sheet vertically overlaps part of a power supply within an end cap of the LED tube lamp.

Referring to FIG. 2, to form an LED light strip 2, a bendable circuit sheet includes a wiring layer 2a with conductive effect. An LED light source 202 is disposed on the wiring layer 2a and is electrically connected to the power supply through the wiring layer 2a. Though only one LED light source 202 is shown in FIG. 2, a plurality of LED light sources 202, as shown in FIG. 1, may be arranged on the LED light strip 2. For example, light sources 202 may be arranged in one or more rows extending along a length direction of the LED light strip 2, which may extend along a length direction of the lamp tube as illustrated in FIG. 1. The wiring layer with conductive effect, in this specification, is also referred to as a conductive layer. Referring to FIG. 2 again, in one embodiment, the LED light strip 2 includes a bendable circuit sheet having a conductive wiring layer 2a and a dielectric layer 2b that are arranged in a stacked manner. In some embodiments, the wiring layer 2a and the dielectric layer 2b may have the same areas or the area of the wiring layer 2a may slightly be smaller than that of the dielectric layer 2b. The LED light source 202 is disposed on one surface of the wiring layer 2a, the dielectric layer 2b is disposed on the other surface of the wiring layer 2a that is away from the LED light sources 202 (e.g., a second, opposite surface from the first surface on which the LED light source 202 is disposed). The wiring layer 2a is electrically connected to a power supply 5 (as shown in FIG. 1) to carry direct current (DC) signals. In some embodiments, the surface of the dielectric layer 2b away from the wiring layer 2a (e.g., a second surface of the dielectric layer 2b opposite a first surface facing the wiring layer 2a) is fixed to an inner circumferential surface of a lamp tube, for example, by means of an adhesive sheet 4. The portion of the dielectric layer 2b fixed to the inner circumferential surface of the lamp tube 1 may substantially conform to the shape of the inner circumferential surface of the lamp tube 1. The wiring layer 2a can be a metal layer or a power supply layer including wires such as copper wires.

A power supply as described herein may include a circuit that converts or generates power based on a received voltage, in order to supply power to operate an LED module and the LED light sources 202 of the LED tube lamp. A power supply, as described in connection with power supply 5, may be otherwise referred to as a power conversion module or circuit, or a power module. A power conversion module or circuit, or power module, may supply or provide power from external signal(s), such as from an AC power line or from a ballast, to an LED module and the LED light sources 202. For example, a power supply 5 may refer to a circuit that

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converts ac line voltage to dc voltage and supplies power to the LED or LED module. The power supply 5 may include one or more power components mounted thereon for converting and/or generating power.

In some example embodiments, the outer surface of the wiring layer 2a or the dielectric layer 2b may be covered with a circuit protective layer made of an ink with function of resisting soldering and increasing reflectivity. Alternatively, in other example embodiments, the dielectric layer may be omitted and the wiring layer may be directly bonded to the inner circumferential surface of the lamp tube, and the outer surface of the wiring layer 2a may be coated with the circuit protective layer. Whether the wiring layer 2a has a one-layered, or two-layered structure, the circuit protective layer may be adopted. In some embodiments, the circuit protective layer is disposed only on one side/surface of the LED light strip 2, such as the surface having the LED light source 202. In some embodiments, the bendable circuit sheet is a one-layered structure made of just one wiring layer 2a, or a two-layered structure made of one wiring layer 2a and one dielectric layer 2b, and thus is more bendable or flexible to curl when compared with the conventional three-layered flexible substrate (one dielectric layer sandwiched with two wiring layers). As a result, the bendable circuit sheet of the LED light strip 2 may be installed in a lamp tube with a customized shape or non-tubular shape, and fitly mounted to the inner surface of the lamp tube. A bendable circuit sheet closely mounted to the inner surface of the lamp tube is desirable in some cases. In addition, using fewer layers of the bendable circuit sheet improves the heat dissipation, lowering the material cost, and is more environmental friendly, and provides the opportunity to increase the flexible effect.

Nevertheless, the bendable circuit sheet is not limited to being one-layered or two-layered; in other embodiments, the bendable circuit sheet may include multiple layers of the wiring layers 2a and multiple layers of the dielectric layers 2b, in which the dielectric layers 2b and the wiring layers 2a are sequentially stacked in a staggered manner, respectively. These stacked layers may be between the outermost wiring layer 2a (with respect to the inner circumferential surface of the lamp tube), which has the LED light source 202 disposed thereon, and the inner circumferential surface of the lamp tube, and may be electrically connected to the power supply 5 (as shown in FIG. 1.) Moreover, in some embodiments, the length of the bendable circuit sheet (e.g., the length along a surface of the bendable circuit sheet from one end of the circuit sheet to a second end of the circuit sheet) (or an axial projection of the length of the bendable circuit sheet) is greater than the length of the lamp tube (or an axial projection of the length of the lamp tube), or at least greater than a central portion of the lamp tube between two transition regions (e.g., where the circumference of the lamp tube narrows) on either end. For example, the length following along the contours of one surface of the bendable circuit sheet (e.g., a top surface of the circuit sheet) may be longer than the length from one terminal end to an opposite terminal end of the lamp tube. Also, a length along a straight line that extends in the same direction as the direction in which the lamp tube extends, from a first end of the bendable circuit sheet to a second, opposite end of the bendable circuit sheet, may be longer than the length along the same straight line of the lamp tube.

Referring to FIG. 7, in one embodiment, an LED light strip 2 includes a bendable circuit sheet having in sequence a first wiring layer 2a, a dielectric layer 2b, and a second wiring layer 2c. In one example, the thickness of the second

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wiring layer 2c (e.g., in a direction in which the layers 2a through 2c are stacked) is greater than that of the first wiring layer 2a, and the length of the LED light strip 2 (or an axial projection of the length of the LED light strip 2) is greater than that of a lamp tube 1, or at least greater than a central portion of the lamp tube between two transition regions (e.g., where the circumference of the lamp tube narrows) on either end. The end region of the LED light strip 2 extending beyond the end portion of the lamp tube 1 without having a light source 202 disposed thereon is formed with two separate through holes 203 and 204 to respectively electrically communicate the first wiring layer 2a and the second wiring layer 2c. The through holes 203 and 204 are not in communication with each other to avoid short.

In this way, the greater thickness of the second wiring layer 2c allows the second wiring layer 2c to support the first wiring layer 2a and the dielectric layer 2b, and meanwhile allows the LED light strip 2 to be mounted onto the inner circumferential surface without being liable to shift or deform, and thus the yield rate of product can be improved. In addition, the first wiring layer 2a and the second wiring layer 2c are in electrical communication such that the circuit layout of the first wiring layer 2a can be extended downward to the second wiring layer 2c to reach the circuit layout of the entire LED light strip 2. Moreover, since the circuit layout becomes two-layered, the area of each single layer and therefore the width of the LED light strip 2 can be reduced such that more LED light strips 2 can be put on a production line to increase productivity.

Furthermore, in some embodiments, the first wiring layer 2a and the second wiring layer 2c of the end region of the LED light strip 2 that extends beyond the end portion of the lamp tube 1 without disposition of the light source 202 can be used to accomplish the circuit layout of a power supply module so that the power supply module can be directly disposed on the bendable circuit sheet of the LED light strip 2.

In a case where two ends of the LED light strip 2 are detached from the inner surface of the lamp tube 1 and where the LED light strip 2 is connected to the power supply 5 via wire-bonding, certain movements in subsequent transportation are likely to cause the bonded wires to break. Therefore, a desirable option for the connection between the LED light strip 2 and the power supply 5 (as shown in FIG. 1) could be soldering. Specifically, referring to FIG. 1, the ends of the LED light strip 2 including the bendable circuit sheet are arranged to pass over the strengthened transition region of a lamp tube, and to be directly solder bonded to an output terminal of the power supply 5. This may improve product quality by avoiding using wires and/or wire bonding. As discussed herein, a transition region of the lamp tube refers to regions outside a central portion of the lamp tube and inside terminal ends of the lamp tube. For example, a central portion of the lamp tube may have a constant diameter, and each transition region between the central portion and a terminal end of the lamp tube may have a changing diameter (e.g., at least part of the transition region may become more narrow moving in a direction from the central portion to the terminal end of the lamp tube).

Referring to FIG. 3A, an output terminal of a printed circuit board of the power supply 5 may have soldering pads "a" (as shown in FIG. 1 as well) provided with an amount of solder (e.g., tin solder) with a thickness sufficient to later form a solder joint "g" (or a solder ball "g"). Correspondingly, the ends of the LED light strip 2 may have soldering pads "b" (as shown in FIG. 1 as well). The soldering pads "a" on the output terminal of the printed circuit board of the

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power supply 5 are soldered to the soldering pads "b" on the LED light strip 2 via the tin solder on the soldering pads "a". The soldering pads "a" and the soldering pads "b" may be face to face during soldering such that the connection between the LED light strip 2 and the printed circuit board of the power supply 5 may be the firmest. However, this kind of soldering typically includes a thermo-compression head pressing on the rear surface of the LED light strip 2 and heating the tin solder, i.e., the LED light strip 2 intervenes between the thermo-compression head and the tin solder, and therefore may cause reliability problems. In some embodiments, a through hole may be formed in each of the soldering pads "b" on the LED light strip 2 to allow the soldering pads "b" to overlay the soldering pads "a" without being face-to-face (e.g., both soldering pads "a" and soldering pads "b" can have exposed surfaces that face the same direction) and the thermo-compression head directly presses tin solders on the soldering pads "a" on surface of the printed circuit board of the power supply 5 when the soldering pads "a" and the soldering pads "b" are vertically aligned. This example provides a simple process for manufacturing.

Referring again to FIG. 3A, two ends of the LED light strip 2 detached from the inner surface of the lamp tube 1 (as shown in FIG. 7) are formed as freely extending portions 21 (as shown in FIGS. 1 and 7 as well), while most of the LED light strip 2 is attached and secured to the inner surface of the lamp tube. One of the freely extending portions 21 has the soldering pads "b" as mentioned above. Upon assembling of the LED tube lamp, the freely extending end portions 21 along with the soldered connection of the printed circuit board of the power supply 5 and the LED light strip 2 would be coiled, curled up or deformed to be fittingly accommodated inside the lamp tube as shown in FIG. 1. When the bendable circuit sheet of the LED light strip 2 includes in sequence the first wiring layer 2a, the dielectric layer 2b, and the second wiring layer 2c as shown in FIG. 7, the freely extending end portions 21, which are the end regions of the LED light strip 2 extending beyond the lamp tube without disposition of the light sources 202, can be used to accomplish the connection between the first wiring layer 2a and the second wiring layer 2c and arrange the circuit layout of the power supply 5. As described above, the freely extending portions 21 may be different from a fixed portion of the LED light strip 2 in that the fixed portion may conform to the shape of the inner surface of the lamp tube and may be fixed thereto, while the freely extending portion 21 may have a shape that does not conform to the shape of the lamp tube. As shown in FIG. 1, the freely extending portion 21 may be bent away from the lamp tube. For example, there may be a space between an inner surface of the lamp tube and the freely extending portion 21.

In designing the conductive pin or external connection terminal in the LED tube lamp, various arrangements of pins may be provided in one end or both ends of the LED tube lamp according to exemplary embodiments. For example, two pins may be provided in one end and no pins may be provided on the other end. Alternatively, in some embodiments, two pins in corresponding ends of two ends of the LED tube lamp, or four pins in corresponding ends of two ends of the LED tube lamp may be provided. When a dual-end power supply between two ends of the LED tube lamp is utilized to provide power to the LED tube lamp, at least one pin of each end of the LED tube lamp is used to receive the external driving signal from the power supply.

FIG. 3B is a block diagram illustrating leads that are disposed between two end caps of an LED tube lamp according to some exemplary embodiments.

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Referring to FIG. 3B, in some embodiments, the LED tube lamp includes a lamp tube (not shown in FIG. 3B), end caps (not shown in FIG. 3B), a light strip **2**, short circuit boards **253** (also referred to as right end short circuit board **253** and left end short circuit board **253**) respectively provided at two ends of the lamp tube, and an inductive element **526**. Each of the lamp tube's two ends may have at least one pin or external connection terminal for receiving the external driving signal. The end caps are disposed respectively at the two ends of the lamp tube, and (at least partial electronic components of) the short circuit boards **253** shown as located respectively at the left and right ends of the lamp tube in FIG. 3B may be disposed respectively in the end caps. The short circuit boards may be, for example, a rigid circuit board such as depicted in and described in connection with FIG. 1 and the various other rigid circuit boards described herein. For example, these circuit boards may include mounted thereon one or more power supply components for generating and/or converting power to be used to light the LED light sources on the light strip **2**. The light strip **2** is disposed in the lamp tube and includes an LED module, which includes an LED unit **632**.

For an LED tube lamp, such as an 8 ft. 42 W LED tube lamp, to receive a dual-end power supply between two ends of the LED tube lamp, two (partial) power-supply circuits (each having a power rating of e.g. 21 W) are typically disposed respectively in the two end caps of the lamp tube, and a lead (typically referred to as lead Line or Neutral) disposed between two end caps of the lamp tube (e.g., between two pins or external connection terminals at respective end caps of the lamp tube) and as an input signal line may be needed. The lead Line may be disposed along an LED light strip that may include, e.g., a bendable circuit sheet or flexible circuit board, for receiving and transmitting an external driving signal from the power supply. This lead Line is distinct from two leads typically referred to as LED+ and LED- that are respectively connected to a positive electrode and a negative electrode of an LED unit in the lamp tube. This lead Line is also distinct from a Ground lead which is disposed between respective ground terminals of the LED tube lamp. Because the lead Line is typically disposed along the light strip, and because parasitic capacitance(s) (e.g., about 200 pF) may be caused between the lead Line and the lead LED+ due to their close proximity to each other, some high frequency signals (not the intended frequency range of signal for supplying power to the LED module) passing through the lead LED+ will be reflected to the lead Line through the parasitic capacitance(s) and then can be detected there as undesirable EMI effects. The unfavorable EMI effects may lower or degrade the quality of power transmission in the LED tube lamp.

Again referring to FIG. 3B, in some embodiments, the right and left short circuit boards **253** are electrically connected to the light strip **2**. In some embodiments, the electrical connection (such as through soldering or bond pad(s)) between the short circuit boards **253** and the light strip **2** may comprise a first terminal (denoted by "L"), a second terminal (denoted by "+" or "LED+"), a third terminal (denoted by "-" or "LED-"), and a fourth terminal (denoted by "GND" or "ground"). The light strip **2** includes the first through fourth terminals at a first end of the light strip **2** adjacent to the right end short circuit board **253** near one end cap of the lamp tube and includes the first through fourth terminals at a second end, opposite to the first end, of the light strip **2** adjacent to the left end short circuit board **253** near the other end cap of the lamp tube. The right end short circuit board **253** also includes the first through fourth

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terminals to respectively connect to the first through fourth terminals of the light strip **2** at the first end of the light strip **2**. The left end short circuit board **253** also includes the first through fourth terminals to respectively connect to the first through fourth terminals of the light strip **2** at the second end of the light strip **2**. For example, the first terminal L is utilized to connect a lead (typically referred to as Line or Neutral) for connecting both of the at least one pin of each of the two ends of the lamp tube; the second terminal LED+ is utilized to connect each of the short circuit boards **253** to the positive electrode of the LED unit **632** of the LED module included in the light strip **2**. The third terminal LED- is utilized to connect each of the short circuit boards **253** to the negative electrode of the LED unit **632** of the LED module included in the light strip **2**. The fourth terminal GND is utilized to connect to a reference potential. Preferably and typically, the reference potential is defined as the electrical potential of ground. Therefore, the fourth terminal is utilized for a grounding purpose of the power supply module of the LED tube lamp.

To address the undesirable EMI effects mentioned above caused by parasitic capacitance(s) between the lead Line and the lead LED+, inductive element **526** disposed in the Ground lead serves to reduce or prevent the EMI effects by blocking the forming of a complete circuit between the lead LED+ and the Ground lead for the high frequency signals mentioned above to pass through, since at these high frequencies inductive element **526** behaves like an open circuit. When the complete circuit is prevented or blocked by inductive element **526**, the high frequency signals will be prevented on the lead LED+ and therefore will not be reflected to the lead Line, thus preventing the undesirable EMI effects. In some embodiments, the inductive element **526** is connected between two of the fourth terminals respectively of the right end and left end short circuit boards **253** at the two ends of the lamp tube. In some embodiments, the inductive element **526** may comprise an inductor such as a choke inductor or a dual-inline-package inductor capable of achieving a function of eliminating or reducing the above-mentioned EMI effects of the lead ("Line") disposed along the light strip **2** between two of the first terminals ("L") respectively at two ends of the lamp tube. Therefore, this function can improve signal transmission (which may include transmissions through leads "L", "LED+", and "LED-") of the power supply in the LED tube lamp, and thus the qualities of the LED tube lamp. Therefore, the LED tube lamp comprising the inductive element **526** may effectively reduce EMI effects of the lead "L" or "Line". Moreover, such an LED tube lamp may further comprise an installation detection circuit or module, which is described below with reference to FIG. 15, for detecting whether or not the LED tube lamp is properly installed in a lamp socket.

Referring to FIGS. 5 and 6, in another embodiment, the LED light strip and the power supply may be connected by utilizing a circuit board assembly **25** configured with a power supply module **250** instead of solder bonding as described previously. The circuit board assembly **25** has a long circuit sheet **251** and a short circuit board **253** that are adhered to each other with the short circuit board **253** being adjacent to the side edge of the long circuit sheet **251**. The short circuit board **253** may be provided with the power supply module **250** to form the power supply. The short circuit board **253** is stiffer or more rigid than the long circuit sheet **251** to be able to support the power supply module **250**.

The long circuit sheet **251** may be the bendable circuit sheet of the LED light strip **2** including a wiring layer **2a** as

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shown in FIG. 2. The wiring layer **2a** of the LED light strip **2** and the power supply module **250** may be electrically connected in various manners depending on the demand in practice. As shown in FIG. 5, the power supply module **250** and the long circuit sheet **251** having the wiring layer **2a** on surface are on the same side of the short circuit board **253** such that the power supply module **250** is directly connected to the long circuit sheet **251**. As shown in FIG. 6, alternatively, the power supply module **250** and the long circuit sheet **251** including the wiring layer **2a** on surface are on opposite sides of the short circuit board **253** such that the power supply module **250** is directly connected to the short circuit board **253** and indirectly connected to the wiring layer **2a** of the LED light strip **2** by way of the short circuit board **253**.

The power supply module **250** and power supply **5** described above may include various elements for providing power to the LED light strip **2**. For example, they may include power converters or other circuit elements and/or components for providing power to the LED light strip **2**. Also, it should be noted that the power supply **5** depicted and discussed in FIG. 1 may also include a power supply module **250**, though one is not labeled in FIG. 1. For example, the power supply module may be mounted on the circuit board, as shown in FIG. 1, and may include power converters or other circuit elements and/or components for providing power to the LED light strip **2**.

FIG. 4A is a perspective view of an exemplary bendable circuit sheet **200** and a printed circuit board **420** of a power supply **400** soldered to each other. FIG. 4B to FIG. 4D are diagrams illustrating an exemplary soldering process of the bendable circuit sheet **200** and the printed circuit board **420** of the power supply **400**. In an embodiment, the bendable circuit sheet **200** and the freely extending end portion have the same structure. The freely extending end portions are the portions of two opposite ends of the bendable circuit sheet **200** and are utilized for being connected to the printed circuit board **420**. The bendable circuit sheet **200** and the power supply **400** are electrically connected to each other by soldering. The bendable circuit sheet **200** comprises a circuit layer **200a** and a circuit protection layer **200c** over a side of the circuit layer **200a**. Moreover, the bendable circuit sheet **200** comprises two opposite surfaces which are a first surface **2001** and a second surface **2002**. The first surface **2001** is the one on the circuit layer **200a** and away from the circuit protection layer **200c**. The second surface **2002** is the other one on the circuit protection layer **200c** and away from the circuit layer **200a**. Several LED light sources **202** are disposed on the first surface **2001** and are electrically connected to circuits of the circuit layer **200a**. The circuit protection layer **200c** is made, for example, by polyimide (PI) having less thermal conductivity but being beneficial to protect the circuits. The first surface **2001** of the bendable circuit sheet **200** comprises soldering pads "b" (or referred as first soldering pads). Soldering material "g" can be placed on the soldering pads "b". In one embodiment, the bendable circuit sheet **200** further comprises a notch "f". The notch "f" is disposed on an edge of the end of the bendable circuit sheet **200** soldered to the printed circuit board **420** of the power supply **400**. In some embodiments instead of a notch, a hole near the edge of the end of the bendable circuit sheet **200** may be used, which may thus provide additional contact material between the printed circuit board **420** and the bendable circuit sheet **200**, thereby providing a stronger connection. The printed circuit board **420** comprises a power circuit layer **420a** and soldering pads "a". Moreover, the printed circuit board **420** comprises two opposite surfaces

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which are a first surface (or a top surface) **421** and a second surface (or a bottom surface) **422**. The second surface **422** is the one on the power circuit layer **420a**. The soldering pads "a" are respectively disposed on the first surface **421** (those soldering pads "a" on the first surface **421** may be referred as second soldering pads) and the second surface **422** (those soldering pads "a" on the second surface **422** may be referred as third soldering pads). The soldering pads "a" on the first surface **421** are corresponding to those on the second surface **422**. Soldering material "g" can be placed on the soldering pad "a". In one embodiment, considering the stability of soldering and the optimization of automatic process, the bendable circuit sheet **200** is disposed below the printed circuit board **420** (the direction is referred to FIG. 4B). For example, the first surface **2001** of the bendable circuit sheet **200** is connected to the second surface **422** of the printed circuit board **420**. Also, as shown, the soldering material "g" can contact, cover, and be soldered to a top surface of the bendable circuit sheet **200** (e.g., first surface **2001**), end side surfaces of soldering pads "a," soldering pad "b," and power circuit layer **420a** formed at an edge of the printed circuit board **420**, and a top surface of soldering pad "a" at the top surface **421** of the printed circuit board **420**. In addition, the soldering material "g" can contact side surfaces of soldering pads "a," soldering pad "b," and power circuit layer **420a** formed at a hole in the printed circuit board **420** and/or at a hole or notch in bendable circuit sheet **200**. The soldering material may therefore form a bump-shaped portion covering portions of the bendable circuit sheet **200** and the printed circuit board **420**, and a rod-shaped portion passing through the printed circuit board **420** and through a hole or notch in the bendable circuit sheet **200**. The two portions (e.g., bump-shaped portion and rod-shaped portion) may serve as a rivet, for maintaining a strong connection between the bendable circuit sheet **200** and the printed circuit board **420**.

As shown in FIG. 4C and FIG. 4D, in an exemplary soldering process of the bendable circuit sheet **200** and the printed circuit board **420**, the circuit protection layer **200c** of the bendable circuit sheet **200** is placed on a supporting table **42** (i.e., the second surface **2002** of the bendable circuit sheet **200** contacts the supporting table **42**) in advance of soldering. The soldering pads "a" on the second surface **422** of the printed circuit board **420** contact the soldering pads "b" on the first surface **2001** of the bendable circuit sheet **200**. And then a heating head **41** presses on a portion of soldering material "g" where the bendable circuit sheet **200** and the printed circuit board **420** are soldered to each other. When soldering, the soldering pads "b" on the first surface **2001** of the bendable circuit sheet **200** contact the soldering pads "a" on the second surface **422** of the printed circuit board **420**, and the soldering pads "a" on the first surface **421** of the printed circuit board **420** contact the soldering material "g," which is pressed on by the heating head **41**. Under this circumstance, the heat from the heating head **41** can transmit through the soldering pads "a" on the first surface **421** of the printed circuit board **420** and the soldering pads "a" on the second surface **422** of the printed circuit board **420** to the soldering pads "b" on the first surface **2001** of the bendable circuit sheet **200**. The transmission of the heat between the heating heads **41** and the soldering pads "a" and "b" won't be affected by the circuit protection layer **200c** which has relatively less thermal conductivity, since the circuit protection layer **200c** is not between the heating head **41** and the circuit layer **200a**. Consequently, the efficiency and stability regarding the connections and soldering process of the

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soldering pads "a" and "b" of the printed circuit board **420** and the bendable circuit sheet **200** can be improved.

As shown in the exemplary embodiment of FIG. 4C, the printed circuit board **420** and the bendable circuit sheet **200** are firmly connected to each other by the soldering material "g". Components between the virtual line M and the virtual line N of FIG. 4C from top to bottom are the soldering pads "a" on the first surface **421** of printed circuit board **420**, the power circuit layer **420a**, the soldering pads "a" on the second surface **422** of printed circuit board **420**, the soldering pads "b" on the first surface **2001** of bendable circuit sheet **200**, the circuit layer **200a** of the bendable circuit sheet **200**, and the circuit protection layer **200c** of the bendable circuit sheet **200**. The connection of the printed circuit board **420** and the bendable circuit sheet **200** are firm and stable. The soldering material "g" may extend higher than the soldering pads "a" on the first surface **421** of printed circuit board **420** and may fill in other spaces, as described above.

In other embodiments, an additional circuit protection layer (e.g., PI layer) can be disposed over the first surface **2001** of the circuit layer **200a**. For example, the circuit layer **200a** may be sandwiched between two circuit protection layers, and therefore the first surface **2001** of the circuit layer **200a** can be protected by the circuit protection layer. A part of the circuit layer **200a** (the part having the soldering pads "b") is exposed for being connected to the soldering pads "a" of the printed circuit board **420**. Other parts of the circuit layer **200a** are exposed by the additional circuit protection layer so they can connect to LED light sources **202**. Under these circumstances, a part of the bottom of each LED light source **202** contacts the circuit protection layer on the first surface **2001** of the circuit layer **200a**, and another part of the bottom of the LED light source **202** contacts the circuit layer **200a**.

According to the exemplary embodiments shown in FIG. 4A to FIG. 4D, the printed circuit board **420** comprises through holes "h" passing through the soldering pads "a". In an automatic soldering process, when the heating head **41** automatically presses the printed circuit board **420**, the soldering material "g" on the soldering pads "a" can be pushed into the through holes "h" by the heating head **41** accordingly. As a result, a soldered connection may be formed as shown in FIGS. 4C and 4D.

FIG. 8A is a block diagram of a system including an LED tube lamp including a power supply module according to certain embodiments. Referring to FIG. 8A, an alternating current (AC) power supply **508** is used to supply an AC supply signal, and may be an AC powerline with a voltage rating, for example, in 100-277V and a frequency rating, for example, of 50 Hz or 60 Hz. A lamp driving circuit **505** receives the AC supply signal from the AC power supply **508** and then converts it into an AC driving signal. The power supply module and power supply **508** described above may include various elements for providing power to the LED light strip **2**. For example, they may include power converters or other circuit elements for providing power to the LED light strip **2**. In some embodiments, the power supply **508** and the lamp driving circuit **505** are outside of the LED tube lamp. For example, the lamp driving circuit **505** may be part of a lamp socket or lamp holder into which the LED tube lamp is inserted. The lamp driving circuit **505** could be an electronic ballast and may be used to convert the signal of commercial electricity into high-frequency and high-voltage AC driving signal. The common types of electronic ballast, such as instant-start electronic ballast, program-start electronic ballast, and rapid-start electronic ballast, can be applied to the LED tube lamp. In some

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embodiments, the voltage of the AC driving signal is bigger than 300V and in some embodiments 400-700V with frequency being higher than 10 kHz and in some embodiments 20-50 kHz. An LED tube lamp **500** receives the AC driving signal from the lamp driving circuit **505** and is thus driven to emit light. In the present embodiment, the LED tube lamp **500** is in a driving environment in which it is power-supplied at its one end cap having two conductive pins **501** and **502** (which can be referred to the external connection terminals), which are used to receive the AC driving signal. The two pins **501** and **502** may be electrically coupled to, either directly or indirectly, the lamp driving circuit **505**.

In some embodiments, the lamp driving circuit **505** may be omitted and is therefore depicted by a dotted line. In certain embodiments, if the lamp driving circuit **505** is omitted, the AC power supply **508** is directly coupled to the pins **501** and **502**, which then receive the AC supply signal as the AC driving signal.

In an alternative to the application of the single-ended power supply mentioned above, the LED tube lamp may be power-supplied at its both end caps respectively having two conductive pins, which are coupled to the lamp driving circuit to concurrently receive the AC driving signal. Under the structure where the LED tube lamp having two end caps and each end cap has two conductive pins, the LED tube lamp can be designed for receiving the AC driving signal by one pin in each end cap, or by two pins in each end cap. An example of a circuit configuration of the power supply module receiving the AC driving signal by one pin in each end cap can be seen in FIG. 8B (referred to as a "dual-end-single-pin configuration" hereinafter), which illustrates a block diagram of an exemplary power supply module for an LED tube lamp according to some exemplary embodiments. Referring to FIG. 8B, each end cap of the LED tube lamp **500** could have only one conductive pin for receiving the AC driving signal. For example, it is not required to have two conductive pins used in each end cap for the purpose of passing electricity through the both ends of the LED tube lamp. Compared to FIG. 8A, the conductive pins **501** and **502** in FIG. 8B are correspondingly configured at both end caps of the LED tube lamp **500**, and the AC power supply **508** and the lamp driving circuit **505** are the same as those mentioned above. The circuit configuration of the power supply module receiving the AC driving signal by two pins in each end cap can be referred to FIG. 8C (referred to "dual-end-dual-pin configuration" hereinafter), which illustrates a block diagram of an exemplary power supply module for an LED tube lamp according to some exemplary embodiments. Compared to FIG. 8A and FIG. 8B, the present embodiment further includes pins **503** and **504**. One end cap of the lamp tube has the pins **501** and **502**, and the other end cap of the lamp tube has the pins **503** and **504**. The pins **501** to **504** are connected to the lamp driving circuit **505** to collectively receive the AC driving signal, and thus the LED light sources (not shown) in the LED tube lamp **500** are driven to emit light.

Under the dual-end-dual-pin configuration, no matter whether the AC driving signal is provided to one pin on each end cap, or two pins on each end cap, the AC driving signal can be used for the operating power of the LED tube lamp by rearranging the circuit configuration of the power supply module. When the AC driving signal is provided to one pin on each end cap (i.e., different polarities of the AC driving signal are respectively provided to the two end caps), in an exemplary embodiment, another one pin on each end cap is set to a floating state. For example, the pins **502** and **503** can be set to the floating state, so that the tube lamp receives the

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AC driving signal via the pins **501** and **504**. The power supply module performs rectification and filtering to the AC driving signal received from the pins **501** and **504**. In another exemplary embodiment, both pins on the same end cap are connected to each other, for example, the pin **501** is connected to the pin **502** on the left end cap, and the pin **503** is connected to the pin **504** on the right end cap. Therefore, the pins **501** and **502** can be used for receiving the positive or negative AC driving signal, and the pins **503** and **504** can be used for receiving the AC driving signal having opposite polarity with the signal received by the pins **501** and **502**. Thus, the power supply module within the tube lamp may perform the rectification and filtering to the received signal. When the AC driving signal is provided to two pins on each end cap, the pins on the same side may receive the AC driving signal having different polarity. For example, the pins **501** and **502** may receive the AC driving signal having opposite polarity, the pins **503** and **504** may receive the AC driving signal having opposite polarity, and the power supply module within the tube lamp may perform the rectification and filtering to the received signal.

FIG. **8D** is a block diagram of an LED lamp according to one embodiment. Referring to FIG. **8D**, the power supply module of the LED lamp includes a rectifying circuit **510**, a filtering circuit **520**, and may further include some parts of an LED lighting module **530**. The rectifying circuit **510** is coupled to two pins **501** and **502** to receive and then rectify an external driving signal, so as to output a rectified signal at two rectifying output terminals **511** and **512**. In some embodiments, the external driving signal may be the AC driving signal or the AC supply signal described with reference to FIGS. **8A** and **8B**. In some embodiments, the external driving signal may be a direct current (DC) signal without altering the LED tube lamp. The filtering circuit **520** is coupled to the rectifying circuit for filtering the rectified signal to produce a filtered signal. For instance, the filtering circuit **520** is coupled to the rectifying circuit output terminals **511** and **512** to receive and then filter the rectified signal, so as to output a filtered signal at two filtering output terminals **521** and **522**. The LED lighting module **530** is coupled to the filtering circuit **520** to receive the filtered signal for emitting light. For instance, the LED lighting module **530** may include a circuit coupled to the filtering output terminals **521** and **522** to receive the filtered signal and thereby to drive an LED unit (not shown) in the LED lighting module **530** to emit light. Details of these operations are described below in accordance with certain embodiments.

FIG. **8E** is a block diagram of an exemplary LED lamp according to some exemplary embodiments. Referring to FIG. **8E**, the power supply module of the LED lamp includes a first rectifying circuit **510**, a filtering circuit **520**, an LED lighting module **530** and a second rectifying circuit **540**, which can be utilized in the dual-end power supply configuration illustrated in FIG. **8C**. The first rectifying circuit **510** is coupled to the pins **501** and **502** to receive and then rectify an external driving signal transmitted by the pins **501** and **502**; the second rectifying circuit **540** is coupled to the pins **503** and **504** to receive and then rectify an external driving signal transmitted by pins **503** and **504**. The first rectifying circuit **510** and the second rectifying circuit **540** of the power supply module collectively output a rectified signal at two rectifying circuit output terminals **511** and **512**. The filtering circuit **520** is coupled to the rectifying circuit output terminals **511** and **512** to receive and then filter the rectified signal, so as to output a filtered signal at two filtering output terminals. The LED lighting module **530** is

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coupled to the filtering output terminals to receive the filtered signal, so as to drive the LED light source (not shown) for emitting light.

FIG. **8F** is a block diagram of an exemplary LED lamp according to some exemplary embodiments. Referring to FIG. **8F**, the power supply module of LED tube lamp includes a rectifying circuit **510'**, a filtering circuit **520** and part of an LED light module **530**, which can also be utilized in the dual-end power supply configuration illustrated in FIG. **8C**. The difference between the embodiments illustrated in FIG. **8F** and FIG. **8E** is that the rectifying circuit **510'** has three input terminals to be coupled to the pins **501** to **503**, respectively. The rectifying circuit **510'** rectifies the signals received from the pins **501** to **503**, in which the pin **504** can be set to the floating state or connected to the pin **503**. Therefore, the second rectifying circuit **540** can be omitted in the present embodiment. The rest of circuitry operates substantially the same as the embodiment illustrated in FIG. **8E**, so that the detailed description is not repeated herein.

Although there are two rectifying output terminals **511** and **512** and two filtering output terminals **521** and **522** in the embodiments of these Figs., in practice the number of ports or terminals for coupling between the rectifying circuit **510**, the filtering circuit **520**, and the LED lighting module **530** may be one or more depending on the needs of signal transmission between the circuits or devices.

In addition, the power supply module of the LED lamp described in FIG. **8D**, and embodiments of a power supply module of an LED lamp described below, may each be used in the LED tube lamp **500** in FIGS. **8A** and **8B**, and may instead be used in any other type of LED lighting structure having two conductive pins used to conduct power, such as LED light bulbs, personal area lights (PAL), plug-in LED lamps with different types of bases (such as types of PL-S, PL-D, PL-T, PL-L, etc.), etc. Further, the implementation for LED light bulbs may provide better effects on protecting from electric shock by combining aspects of this invention and the structures disclosed, for example, in EU patent application WO2016045631.

When the LED tube lamp **500** is applied to the dual-end power structure with at least one pin, retrofit can be performed to a lamp socket including a lamp driving circuit or a ballast **505**, so as to bypass the ballast **505** and provide the AC power supply (e.g., commercial electricity) as the power source of the LED tube lamp. FIG. **8G** is a block diagram of a connection configuration between an LED lamp and an external power source according to some exemplary embodiments. Compared to FIG. **8A**, the embodiment illustrated in FIG. **8G** further provides a ballast bypass module **506** disposed between the AC power supply **508** and the ballast **505**. The rest of the circuit modules perform the same or similar function with the embodiment illustrated in FIG. **8B**. The ballast bypass module **506**, also described as a ballast bypass circuit, receives the power provided by the AC power supply **508**, and is connected to the pins **501** and **502** of the LED tube lamp **500** illustrated in FIG. **8G** (in which the ballast bypass module **506** is also connected to the ballast **505** for performing specific control). The ballast bypass module **506** is configured to bypass the electricity received from the AC power supply **508** and then output to the pins **501** and **502** for providing power to the LED tube lamp **500**. In some exemplary embodiments, the ballast bypass module **506** includes a switch circuit configured to bypass the ballast **505**, in which the switch circuit includes, for example, a component or a device such as an electrical switch or an electronic switch. One skilled in the art of

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fluorescent lighting may understand or design a feasible structure or circuit that constitutes the ballast bypass module **506**. Furthermore, the ballast bypass module **506** can be disposed in a traditional fluorescent lamp socket having the ballast **505**, or in the power supply module **5** or **250** of the LED tube lamp **500**. Furthermore, if the bypass function of the ballast bypass module **506** is suspended, the equivalent connection configuration between the LED tube lamp and the external power source is similar to the configuration illustrated in FIG. **8A** to FIG. **8C**, in which the ballast **505** is still coupled to the pins **501** and **502**, so that the LED tube lamp **500** still can be powered (i.e., receive AC power supply **508**) through the ballast **505**. This modification (adding the ballast bypass module **506**) allows the LED tube lamp **500** to compatibly receive power, provided by the AC power supply **508** (but not provided by the ballast **505**), through the dual-end pin configuration even though the LED tube lamp **500** is installed on a lamp socket having the ballast **505**.

FIG. **9A** is a schematic diagram of a rectifying circuit according to an embodiment. Referring to FIG. **9A**, a rectifying circuit **610**, i.e. a bridge rectifier, includes four rectifying diodes **611**, **612**, **613**, and **614**, configured to full-wave rectify a received signal. The diode **611** has an anode connected to the output terminal **512**, and a cathode connected to the pin **502**. The diode **612** has an anode connected to the output terminal **512**, and a cathode connected to the pin **501**. The diode **613** has an anode connected to the pin **502**, and a cathode connected to the output terminal **511**. The diode **614** has an anode connected to the pin **501**, and a cathode connected to the output terminal **511**.

When the pins **501** and **502** receive an AC signal, the rectifying circuit **610** operates as follows. During the connected AC signal's positive half cycle, the AC signal is input through the pin **501**, the diode **614**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **611**, and the pin **502** in sequence. During the connected AC signal's negative half cycle, the AC signal is input through the pin **502**, the diode **613**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **612**, and the pin **501** in sequence. Therefore, during the connected AC signal's full cycle, the positive pole of the rectified signal produced by the rectifying circuit **610** keeps at the output terminal **511**, and the negative pole of the rectified signal remains at the output terminal **512**. Accordingly, the rectified signal produced or output by the rectifying circuit **610** is a full-wave rectified signal.

When the pins **501** and **502** are coupled to a DC power supply to receive a DC signal, the rectifying circuit **610** operates as follows. When the pin **501** is coupled to the positive end of the DC power supply and the pin **502** to the negative end of the DC power supply, the DC signal is input through the pin **501**, the diode **614**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **611**, and the pin **502** in sequence. When the pin **501** is coupled to the negative end of the DC power supply and the pin **502** to the positive end of the DC power supply, the DC signal is input through the pin **502**, the diode **613**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **612**, and the pin **501** in sequence. Therefore, no matter what the electrical polarity of the DC signal is between the pins **501** and **502**, the positive pole of the rectified signal produced by the rectifying circuit **610** keeps at the output terminal **511**, and the negative pole of the rectified signal remains at the output terminal **512**.

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Therefore, the rectifying circuit **610** in this embodiment can output or produce a proper rectified signal regardless of whether the received input signal is an AC or DC signal.

FIG. **9B** is a schematic diagram of a rectifying circuit according to an embodiment. Referring to FIG. **9B**, a rectifying circuit **710** includes two rectifying diodes **711** and **712**, configured to half-wave rectify a received signal. The rectifying diode **711** has an anode connected to the pin **502**, and a cathode connected to the rectifying output terminal **511**. The rectifying diode **712** has an anode connected to the rectifying output terminal **511**, and a cathode connected to the pin **501**. The rectifying output terminal **512** can be omitted or connect to ground according to the practical application. Detailed operations of the rectifying circuit **710** are described below.

During the connected AC signal's positive half cycle, the signal level of the AC signal input through the pin **501** is greater than the signal level of the AC signal input through the pin **502**. At that time, both the rectifying diodes **711** and **712** are cut off since being reverse biased, and thus the rectifying circuit **710** stops outputting the rectified signal. During the connected AC signal's negative half cycle, the signal level of the AC signal input through the pin **501** is less than the signal level of the AC signal input through the pin **502**. At that time, both the rectifying diodes **711** and **712** are conducting since they are forward biased, and thus the AC signal is input through the pin **502**, the rectifying diode **711**, and the rectifying output terminal **511** in sequence, and later output through the rectifying output terminal **512** or another circuit or ground of the LED tube lamp. Accordingly, the rectified signal produced or output by the rectifying circuit **710** is a half-wave rectified signal.

It should be noted that, when the pins **501** and **502** shown in FIG. **9A** and FIG. **9B** are respectively changed to the pins **503** and **504**, the rectifying circuit **610** and **710** can be considered as the rectifying circuit **540** illustrated in FIG. **8E**. More specifically, in an exemplary embodiment, when the full-wave rectifying circuit **610** shown in FIG. **9A** is applied to the dual-end tube lamp shown in FIG. **8E**, the configuration of the rectifying circuits **510** and **540** is shown in FIG. **9C**. FIG. **9C** is a schematic diagram of a rectifying circuit according to an embodiment.

Referring to FIG. **9C**, the rectifying circuit **640** has the same configuration as the rectifying circuit **610**, which is the bridge rectifying circuit. The rectifying circuit **610** includes four rectifying diodes **611** to **614**, which has the same configuration as the embodiment illustrated in FIG. **9A**. The rectifying circuit **640** includes four rectifying diodes **641** to **644** and is configured to perform full-wave rectification on the received signal. The rectifying diode **641** has an anode coupled to the rectifying output terminal **512**, and a cathode coupled to the pin **504**. The rectifying diode **642** has an anode coupled to the rectifying output terminal **512**, and a cathode couple to the pin **503**. The rectifying diode **643** has an anode coupled to the pin **502**, and a cathode coupled to the rectifying output terminal **511**. The rectifying diode **644** has an anode coupled to the pin **503**, and a cathode coupled to the rectifying output terminal **511**.

In the present embodiment, the rectifying circuits **610** and **640** are configured to correspond to each other, in which the difference between the rectifying circuits **610** and **640** is that the input terminal of the rectifying circuit **610** (which can be used as the rectifying circuit **510** shown in FIG. **8E**) is coupled to the pins **501** and **502**, buy the input terminal of the rectifying circuit **640** (which can be used as the rectifying circuit **540** shown in FIG. **8E**) is coupled to the pins **503** and **504**. Therefore, the present embodiment applies a

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structure including two full-wave rectifying circuits for implementing the dual-end-dual-pin circuit configuration.

In some embodiments, in the rectifying circuit illustrated in the example of FIG. 9C, although the circuit configuration is disposed as the dual-end-dual-pin configuration, the external driving signal is not limited to be provided through both pins on each end cap. Under the configuration shown in FIG. 9C, no matter whether the AC signal is provided through both pins on single end cap or through signal pin on each end cap, the rectifying circuit shown in FIG. 9C may correctly rectify the received signal and generate the rectified signal for lighting the LED tube lamp. Detailed operations are described below.

When the AC signal is provided through both pins on single end cap, the AC signal can be applied to the pins 501 and 502, or to the pins 503 and 504. When the AC signal is applied to the pins 501 and 502, the rectifying circuit 610 performs full-wave rectification on the AC signal based on the operation illustrated in the embodiment of FIG. 9A, and the rectifying circuit 640 does not operate. On the contrary, when the external driving signal is applied to the pins 503 and 504, the rectifying circuit 640 performs full-wave rectification on the AC signal based on the operation illustrated in the embodiment of FIG. 9A, and the rectifying circuit 610 does not operate.

When the AC signal is provided through a single pin on each end cap, the AC signal can be applied to the pins 501 and 504, or to the pins 502 and 503. For example, the dual pins on each end cap can be arranged based on standard socket configuration so that the AC signal will be applied to either pins 501 and 504 or pins 502 and 503, but not pins 501 and 503 or pins 502 and 504 (e.g., based on the physical positioning of the pins at each end cap).

When the AC signal is applied to the pins 501 and 504, during the AC signal's positive half cycle (e.g., the voltage at pin 501 is higher than the voltage at pin 504), the AC signal is input through the pin 501, the diode 614, and the output terminal 511 in sequence, and later output through the output terminal 512, the diode 641, and the pin 504 in sequence. In this manner, output terminal 511 remains at a higher voltage than output terminal 512. During the AC signal's negative half cycle (e.g., the voltage at pin 504 is higher than the voltage at pin 501), the AC signal is input through the pin 504, the diode 643, and the output terminal 511 in sequence, and later output through the output terminal 512, the diode 612, and the pin 501 in sequence. In this manner, output terminal 511 still remains at a higher voltage than output terminal 512. Therefore, during the AC signal's full cycle, the positive pole of the rectified signal remains at the output terminal 511, and the negative pole of the rectified signal remains at the output terminal 512. Accordingly, the diodes 612 and 614 of the rectifying circuit 610 and the diodes 641 and 643 of the rectifying circuit 640 are configured to perform the full-wave rectification on the AC signal and thus the rectified signal produced or output by the diodes 612, 614, 641, and 643 is a full-wave rectified signal.

On the other hand, when the AC signal is applied to the pins 502 and 503, during the AC signal's positive half cycle (e.g., the voltage at pin 502 is higher than the voltage at pin 503), the AC signal is input through the pin 502, the diode 613, and the output terminal 511 in sequence, and later output through the output terminal 512, the diode 642, and the pin 503. During the AC signal's negative half cycle (e.g., the voltage at pin 503 is higher than the voltage at pin 502), the AC signal is input through the pin 503, the diode 644, and the output terminal 511 in sequence, and later output through the output terminal 512, the diode 611, and the pin

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502 in sequence. Therefore, during the AC signal's full cycle, the positive pole of the rectified signal remains at the output terminal 511, and the negative pole of the rectified signal remains at the output terminal 512. Accordingly, the diodes 611 and 613 of the rectifying circuit 610 and the diodes 642 and 644 of the rectifying circuit 640 are configured to perform the full-wave rectification on the AC signal and thus the rectified signal produced or output by the diodes 611, 613, 642, and 644 is a full-wave rectified signal.

When the AC signal is provided through two pins on each end cap, the operation in each of the rectifying circuits 610 and 640 can be referred to the embodiment illustrated in FIG. 9A, and it will not be repeated herein. The rectified signal produced by the rectifying circuits 610 and 640 is output to the rear-end circuit after superposing on the output terminals 511 and 512.

In an exemplary embodiment, the rectifying circuit 510' illustrated in FIG. 8F can be implemented by the configuration illustrated in FIG. 9D. FIG. 9D is a schematic diagram of a rectifying circuit according to an embodiment. Referring to FIG. 9D, the rectifying circuit 910 includes diodes 911 to 914, which are configured as the embodiment illustrated in FIG. 9A. In the present embodiment, the rectifying circuit 910 further includes rectifying diodes 915 and 916. The diode 915 has an anode coupled to the rectifying output terminal 512, and a cathode coupled to the pin 503. The diode 916 has an anode coupled to the pin 503, and a cathode coupled to the rectifying output terminal 511. The pin 504 is set to the float state in the present embodiment.

Specifically, the rectifying circuit 910 can be regarded as a rectifying circuit including three sets of bridge arms, in which each of the bridge arms provides an input signal receiving terminal. For example, the diodes 911 and 913 constitute a first bridge arm for receiving the signal on the pin 502; the diodes 912 and 914 constitute a second bridge arm for receiving the signal on the pin 501; and the diodes 915 and 916 constitute a third bridge arm for receiving the signal on the pin 503. According to the rectifying circuit 910 illustrated in FIG. 9D, the full-wave rectification can be performed as long as different polarity AC signal is respectively received by two of the bridge arms. Accordingly, under the configuration illustrated in FIG. 9D, no matter what kind of power supply configuration, such as the AC signal being provided to both pins on single end cap, a single pin on each end cap, or both pins on each end cap, the rectifying circuit 910 is compatible for producing the rectified signal, correctly. Detailed operations of the present embodiment are described below.

When the AC signal is provided through both pins on single end cap, the AC signal can be applied to the pins 501 and 502. The diodes 911 to 914 perform full-wave rectification on the AC signal based on the operation illustrated in the embodiment of FIG. 9A, and the diodes 915 and 916 do not operate.

When the AC signal is provided through single pin on each end cap, the AC signal can be applied to the pins 501 and 503, or to the pins 502 and 503. When the AC signal is applied to the pins 501 and 503, during the AC signal's positive half cycle (e.g., when the signal on pin 501 has a larger voltage than the signal on pin 503), the AC signal is input through the pin 501, the diode 914, and the output terminal 511 in sequence, and later output through the output terminal 512, the diode 915, and the pin 503 in sequence. During the AC signal's negative half cycle (e.g., when the signal on pin 503 has a larger voltage than the signal on pin 501), the AC signal is input through the pin 503, the diode 916, and the output terminal 511 in sequence, and later

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output through the output terminal **512**, the diode **912**, and the pin **501** in sequence. Therefore, during the AC signal's full cycle, the positive pole of the rectified signal remains at the output terminal **511**, and the negative pole of the rectified signal remains at the output terminal **512**. Accordingly, the diodes **912**, **914**, **915**, and **916** of the rectifying circuit **910** are configured to perform the full-wave rectification on the AC signal and thus the rectified signal produced or output by the diodes **912**, **914**, **915**, and **916** is a full-wave rectified signal.

On the other hand, when the AC signal is applied to the pins **502** and **503**, during the AC signal's positive half cycle (e.g., when the signal on pin **502** has a larger voltage than the signal on pin **503**), the AC signal is input through the pin **502**, the diode **913**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **915**, and the pin **503**. During the AC signal's negative half cycle (e.g., when the signal on pin **503** has a larger voltage than the signal on pin **502**), the AC signal is input through the pin **503**, the diode **916**, and the output terminal **511** in sequence, and later output through the output terminal **512**, the diode **911**, and the pin **502** in sequence. Therefore, during the AC signal's full cycle, the positive pole of the rectified signal remains at the output terminal **511**, and the negative pole of the rectified signal remains at the output terminal **512**. Accordingly, the diodes **911**, **913**, **915**, and **916** of the rectifying circuit **910** are configured to perform the full-wave rectification on the AC signal and thus the rectified signal produced or output by the diodes **911**, **913**, **915**, and **916** is a full-wave rectified signal.

When the AC signal is provided through two pins on each end cap, the operation of the diodes **911** to **914** can be referred to the embodiment illustrated in FIG. **9A**, and it will not be repeated herein. Also, if the signal polarity of the pin **503** is the same as the pin **501**, the operation of the diodes **915** and **916** is similar to that of the diodes **912** and **914** (i.e., the first bridge arm). On the other hand, if the signal polarity of the pin **503** is the same as that of the pin **502**, the operation of the diodes **915** and **916** is similar with the diodes **912** and **914** (i.e., the second bridge arm).

FIG. **9E** is a schematic diagram of a rectifying circuit according to an embodiment. Referring to FIG. **9E**, the difference between the embodiments of FIG. **9E** and FIG. **9D** is that the rectifying circuit shown in FIG. **9E** further includes a terminal adapter circuit **941**. The terminal adapter circuit **941** includes fuses **947** and **948**. One end of the fuse **947** is coupled to the pin **501**, and the other end of the fuse **947** is coupled to the connection node of the diodes **912** and **914** (i.e., the input terminal of the first bridge arm). One end of the fuse **948** is coupled to the pin **502**, and the other end of the fuse **948** is coupled to the connection node of the diodes **911** and **913** (i.e., the input terminal of the second bridge arm). Accordingly, when the current flowing through any one of the pins **501** and **502** is higher than the rated current of the fuses **947** and **948**, the fuse **947/948** will be fused (e.g., broken) in response to the current so as to form an open circuit between the pin **501/502** and the rectifying circuit **910**, thereby achieving the function of over current protection. In the case of only one of the fuses **947** and **948** being fused (e.g., the over current situation just happens in a brief period and then is eliminated), if the AC driving signal is provided through both pins on each end cap, the rectifying circuit still works, after the over current situation is eliminated, since the AC driving signal can be provided through single pin on each end cap.

FIG. **9F** is a schematic diagram of a rectifying circuit according to an embodiment. Referring to FIG. **9F**, the

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difference between the embodiments of FIG. **9F** and FIG. **9D** is that the pins are connected to each other through a thin wire **917**. Compared to the embodiments illustrated in FIG. **9D** or FIG. **9E**, when the AC signal is applied to the dual-end-single-pin configuration, no matter the AC signal is applied to the pin **503** or the pin **504**, the rectifying circuit of the present embodiment can be normally operated. Furthermore, when the pins **503** and **504** are installed on the wrong lamp socket which provides the AC signal to the single end cap, the thin wire **917** can be reliably fused. Therefore, when the lamp is installed on the correct lamp socket, the tube lamp utilizing the rectifying illustrated in FIG. **9F** may keep working, normally.

According to the embodiments mentioned above, the rectifying circuits illustrated in FIG. **9C** to **9F** are compatible for receiving the AC signal through both pins on single end cap, through single pin on each end cap, and through both pins on each end cap, such that the compatibility of the LED tube lamp's application is improved. In this manner, an LED tube lamp can include a rectifying circuit that is arranged to rectify an AC signal in all of the following situations: when the LED tube lamp is connected (e.g., coupled to a socket) to receive the AC signal through both of two pins on a single end cap; when the LED tube lamp is connected (e.g., coupled to a socket) to receive the AC signal through both of two pins on each end cap; and when the LED tube lamp is connected (e.g., coupled to a socket) to receive the AC signal through a single pin on each end cap. In addition, based on the aspect of the actual circuit layout scenario, the embodiments illustrated in FIG. **9D** to **9F** require only three power pads (e.g., on the power supply) for connecting the corresponding pins, so that the process yield can be significantly enhanced since the manufacture process of the three pads configuration is easier than the four power pads configuration.

FIG. **10A** is a block diagram of the filtering circuit according to an embodiment. A rectifying circuit **510** is shown in FIG. **10A** for illustrating its connection with other components, without intending a filtering circuit **520** to include the rectifying circuit **510**. Referring to FIG. **10A**, the filtering circuit **520** includes a filtering unit **523** coupled to two rectifying output terminals **511** and **512** to receive and to filter out ripples of a rectified signal from the rectifying circuit **510**. Accordingly, the waveform of a filtered signal is smoother than that of the rectified signal. The filtering circuit **520** may further include another filtering unit **524** coupled between a rectifying circuit and a pin correspondingly, for example, between the rectifying circuit **510** and the pin **501**, the rectifying circuit **510** and the pin **502**, the rectifying circuit **540** and the pin **503**, and/or the rectifying circuit **540** and the pin **504**. The filtering unit **524** is used to filter a specific frequency, for example, to filter out a specific frequency of an external driving signal. In this embodiment, the filtering unit **524** is coupled between the rectifying circuit **510** and the pin **501**. The filtering circuit **520** may further include another filtering unit **525** coupled between one of the pins **501** and **502** and one of the diodes of the rectifying circuit **510**, or between one of the pins **503** and **504** and one of the diodes of the rectifying circuit **540** to reduce or filter out electromagnetic interference (EMI). In this embodiment, the filtering unit **525** is coupled between the pin **501** and one of diodes (not shown in FIG. **10A**) of the rectifying circuit **510**. Since the filtering units **524** and **525** may be present or omitted depending on actual circumstances of their uses, they are depicted by a dotted line in FIG. **10A**.

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FIG. 10B is a schematic diagram of the filtering unit according to an embodiment. Referring to FIG. 10B, a filtering unit 623 includes a capacitor 625 having an end coupled to the output terminal 511 and a filtering output terminal 521 and the other end thereof coupled to the output terminal 512 and a filtering output terminal 522, and is configured to low-pass filter a rectified signal from the output terminals 511 and 512, so as to filter out high-frequency components of the rectified signal and thereby output a filtered signal at the filtering output terminals 521 and 522.

FIG. 10C is a schematic diagram of the filtering unit according to an embodiment. Referring to FIG. 10C, a filtering unit 723 includes a pi filter circuit including a capacitor 725, an inductor 726, and a capacitor 727. As is well known, a pi filter circuit looks like the symbol π in its shape or structure. The capacitor 725 has an end connected to the output terminal 511 and coupled to the filtering output terminal 521 through the inductor 726, and has another end connected to the output terminal 512 and the filtering output terminal 522. The inductor 726 is coupled between output terminal 511 and the filtering output terminal 521. The capacitor 727 has an end connected to the filtering output terminal 521 and coupled to the output terminal 511 through the inductor 726, and has another end connected to the output terminal 512 and the filtering output terminal 522.

As seen between the output terminals 511 and 512 and the filtering output terminals 521 and 522, the filtering unit 723 compared to the filtering unit 623 in FIG. 10B additionally has an inductor 726 and a capacitor 727, which perform the function of low-pass filtering like the capacitor 725 does. Therefore, the filtering unit 723 in this embodiment compared to the filtering unit 623 in FIG. 10B has a better ability to filter out high-frequency components to output a filtered signal with a smoother waveform.

The inductance values of the inductor 726 in the embodiments mentioned above are chosen in the range of, for example in some embodiments, about 10 nH to 10 mH. And the capacitance values of the capacitors 625, 725, and 727 in the embodiments stated above are chosen in the range of, for example in some embodiments, about 100 pF to 1 μ F.

FIG. 11A is a schematic diagram of an LED module according to an embodiment. Referring to FIG. 11A, an LED module 630 has an anode connected to a filtering output terminal 521, a cathode connected to a filtering output terminal 522, and includes at least one LED unit 632, such as the light source mentioned above. When two or more LED units are included, they are connected in parallel. The anode of each LED unit 632 is connected to the anode of LED module 630 to couple with the filtering output terminal 521, and the cathode of each LED unit 632 is connected to the cathode of LED module 630 to couple to the filtering output terminal 522. Each LED unit 632 includes at least one LED 631. When multiple LEDs 631 are included in an LED unit 632, they are connected in series with the anode of the first LED 631 connected to the anode of this LED unit 632 (the anode of the first LED 631 and the anode of the LED unit 632 may be the same terminal) and the cathode of the first LED 631 connected to the next or second LED 631. And the anode of the last LED 631 in this LED unit 632 is connected to the cathode of a previous LED 631 and the cathode of the last LED 631 connected to the cathode of this LED unit 632 (the cathode of the last LED 631 and the cathode of the LED unit 632 may be the same terminal).

In some embodiments, the LED module 630 may produce a current detection signal S531 reflecting the magnitude of

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current through the LED module 630 and being used for controlling or detecting the LED module 630.

FIG. 11B is a schematic diagram of an LED module according to an exemplary embodiment. Referring to FIG. 11B, an LED module 630 has an anode connected to a filtering output terminal 521, a cathode connected to a filtering output terminal 522, and includes at least two LED units 732 with the anode of each LED unit 732 connected to the anode of LED module 630 and the cathode of each LED unit 732 connected to the cathode of LED module 630 (the anode of each LED unit 732 and the anode of the LED module 630 may be the same terminal, and the cathode of each LED unit 732 and the cathode of the LED module 630 may be the same terminal). Each LED unit 732 includes at least two LEDs 731 connected in the same way as those described in FIG. 11A. For example, the anode of the first LED 731 in an LED unit 732 is connected to the anode of this LED unit 732, the cathode of the first LED 731 is connected to the anode of the next or second LED 731, and the cathode of the last LED 731 is connected to the cathode of this LED unit 732. Further, LED units 732 in an LED module 630 are connected to each other in this embodiment. All of the n-th LEDs 731 in the related LED units 732 thereof are connected by their anodes and cathodes, such as those shown in FIG. 8B but not limit to, where n is a positive integer. In this way, the LEDs in the LED module 630 of this embodiment are connected in the form of a mesh.

In some embodiments, the LED lighting module 530 in the above embodiments includes the LED module 630, but doesn't include a driving circuit for the LED module 630.

Also, the LED module 630 in this embodiment may produce a current detection signal S531 reflecting the magnitude of current through the LED module 630 and being used for controlling or detecting the LED module 630.

In some embodiments, the number of LEDs 731 included by an LED unit 732 is in the range of 15-25, and may be in some embodiments in the range of 18-22.

FIG. 11C is a plan view of a circuit layout of the LED module according to an embodiment. Referring to FIG. 11C, in this embodiment, multiple LEDs 831 are connected in the same way as described in FIG. 11B, and three LED units are assumed in the LED module 630 and described as follows for illustration. A positive conductive line 834 and a negative conductive line 835 are to receive a driving signal for supplying power to the LEDs 831. For example, the positive conductive line 834 may be coupled to the filtering output terminal 521 of the filtering circuit 520 described above, and the negative conductive line 835 coupled to the filtering output terminal 522 of the filtering circuit 520 to receive a filtered signal. For the convenience of illustration, all three of the n-th LEDs 831 in the three related LED units thereof are grouped as an LED set 833 in FIG. 11C.

The positive conductive line 834 connects the three first LEDs 831 of the leftmost three related LED units thereof, for example, connects the anodes on the left sides of the three first LEDs 831 as shown in the leftmost LED set 833 of FIG. 11C. The negative conductive line 835 connects the three last LEDs 831 of the rightmost three corresponding LED units thereof, for example, connects the cathodes on the right sides of the three last LEDs 831 as shown in the rightmost LED set 833 of FIG. 11C. The cathodes of the three first LEDs 831, the anodes of the three last LEDs 831, and the anodes and cathodes of all the remaining LEDs 831 are connected by conductive lines or parts 839.

For example, the anodes of the three LEDs 831 in the leftmost LED set 833 may be connected together by the positive conductive line 834, and their cathodes may be

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connected together by a leftmost conductive part **839**. The anodes of the three LEDs **831** in the second, next-leftmost LED set **833** are also connected together by the leftmost conductive part **839**, whereas their cathodes are connected together by a second, next-leftmost conductive part **839**. Since the cathodes of the three LEDs **831** in the leftmost LED set **833** and the anodes of the three LEDs **831** in the second, next-leftmost LED set **833** are connected together by the same leftmost conductive part **839**, the cathode of the first LED **831** in each of the three LED units is connected to the anode of the next or second LED **831**. As for the remaining LEDs **831** are also connected in the same way. Accordingly, all the LEDs **831** of the three LED units are connected to form the mesh as shown in FIG. 11B.

In this embodiment, the length **836** of a portion of each conductive part **839** that connects to the anode of an LED **831** is smaller than the length **837** of another portion of each conductive part **839** that connects to the cathode of an LED **831**. This makes the area of the latter portion connecting to the cathode larger than that of the former portion connecting to the anode. Moreover, the length **837** may be smaller than a length **838** of a portion of each conductive part **839** that connects the cathode of an LED **831** and the anode of the next LED **831** in two adjacent LED sets **833**. This makes the area of the portion of each conductive part **839** that connects a cathode and an anode larger than the area of any other portion of each conductive part **839** that connects to only a cathode or an anode of an LED **831**. Due to the length differences and area differences, this layout structure improves heat dissipation of the LEDs **831**.

In some embodiments, the positive conductive line **834** includes a lengthwise portion **834a**, and the negative conductive line **835** includes a lengthwise portion **835a**, which are conductive to make the LED module have a positive "+" connective portion and a negative "-" connective portion at each of the two ends of the LED module, as shown in FIG. 11C. Such a layout structure allows for coupling any of other circuits of the power supply module of the LED lamp, including e.g. the filtering circuit **520** and the rectifying circuits **510** and **540**, to the LED module through the positive connective portion and/or the negative connective portion at each or both ends of the LED lamp. Thus the layout structure increases the flexibility in arranging actual circuits in the LED lamp.

FIG. 11D is a plan view of a circuit layout of the LED module according to another embodiment. Referring to FIG. 11D, in this embodiment, multiple LEDs **931** are connected in the same way as described in FIG. 11A, and three LED units each including 7 LEDs **931** are assumed in the LED module **630** and described as follows for illustration. A positive conductive line **934** and a negative conductive line **935** are to receive a driving signal for supplying power to the LEDs **931**. For example, the positive conductive line **934** may be coupled to the filtering output terminal **521** of the filtering circuit **520** described above, and the negative conductive line **935** is coupled to the filtering output terminal **522** of the filtering circuit **520**, so as to receive a filtered signal. For the convenience of illustration, all seven LEDs **931** of each of the three LED units are grouped as an LED set **932** in FIG. 11D. Thus there are three LED sets **932** corresponding to the three LED units.

The positive conductive line **934** connects the anode on the left side of the first or leftmost LED **931** of each of the three LED sets **932**. The negative conductive line **935** connects the cathode on the right side of the last or rightmost LED **931** of each of the three LED sets **932**. In each LED set **932** of each two adjacent LEDs **931**, the LED **931** on the left

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has a cathode connected by a conductive part **939** to an anode of the LED **931** on the right. By such a layout, the LEDs **931** of each LED set **932** are connected in series.

In some embodiments, the conductive part **939** may be used to connect an anode and a cathode of two consecutive LEDs **931** respectively. The negative conductive line **935** connects the cathode of the last or rightmost LED **931** of each of the three LED sets **932**. And the positive conductive line **934** connects the anode of the first or leftmost LED **931** of each of the three LED sets **932**. Therefore, as shown in FIG. 11D, the length of the conductive part **939** is larger than that of the portion of negative conductive line **935** connecting to a cathode, which length is then larger than that of the portion of positive conductive line **934** connecting to an anode. For example, the length **938** of the conductive part **939** may be larger than the length **937** of the portion of negative conductive line **935** connecting a cathode of an LED **931**, which length **937** is then larger than the length **936** of the portion of the positive conductive line **934** connecting an anode of an LED **931**. Such a layout structure improves heat dissipation of the LEDs **931** in LED module **630**.

The positive conductive line **934** may include a lengthwise portion **934a**, and the negative conductive line **935** may include a lengthwise portion **935a**, which are conductive to make the LED module have a positive "+" connective portion and a negative "-" connective portion at each of the two ends of the LED module, as shown in FIG. 11D. Such a layout structure allows for coupling any of other circuits of the power supply module of the LED lamp, including e.g. the filtering circuit **520** and the rectifying circuits **510** and **540**, to the LED module through the positive connective portion **934a** and/or the negative connective portion **935a** at each or both ends of the LED lamp. Thus the layout structure increases the flexibility in arranging actual circuits in the LED lamp.

Further, the circuit layouts as shown in FIGS. 11C and 11D may be implemented with a bendable circuit sheet or substrate, or may be a flexible circuit board depending on its specific construction. For example, the bendable circuit sheet may comprise one conductive layer where the positive conductive line **834**, the positive lengthwise portion **834a**, the negative conductive line **835**, the negative lengthwise portion **835a**, and the conductive parts **839** shown in FIG. 11C, and the positive conductive line **934**, the positive lengthwise portion **934a**, the negative conductive line **935**, the negative lengthwise portion **935a**, and the conductive parts **939** shown in FIG. 11D are formed by the method of etching.

FIG. 11E is a plan view of a circuit layout of the LED module according to another embodiment. Referring to FIG. 11E, the connection relationship of the LEDs **1031** is the same as FIG. 11B. The configuration of the positive conductive line and the negative conductive line (not shown) and the connection relationship between the conductive lines and other circuits is substantially the same as FIG. 11D. The difference between the present embodiment and the above embodiments is that the LEDs **1031** are modified to be arranged in the longitudinal direction (i.e., the positive and negative electrodes of each LEDs are disposed along the direction perpendicular to the lead extension direction) from the transverse direction such as arrangement of the LEDs **831** shown in FIG. 11C (i.e., the positive and negative electrodes of each LEDs are disposed along the lead extension direction), and the connection configuration of the present embodiment are correspondingly adjusted due to the arrangement direction.

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Specifically, taking a conductive part **1039_2** for example, the conductive part **1039_2** includes a first long-side portion having a width **1037**, a second long-side portion having a width **1038** which is greater than the width of the first long-side portion, and a transition portion connecting the first and the second long-side portions. The conductive part **1039_2** can be formed in a right-angled Z shape, which means the joints of each long-side portions and the transition portion are perpendicular. The first long-side portion of the conductive part **1039_2** and the second long-side portion of the adjacent conductive part **1039_3** are correspondingly disposed; similarly, the second long-side portion of the conductive part **1039_2** and the first long-side portion of the adjacent conductive part **1039_1** are correspondingly disposed. According to the configuration described above, the conductive part **1039** is arranged along the extension direction of the long-side portions, and the first long-side portion of each conductive parts **1039** and the second long-side portion of each adjacent conductive parts **1039** are correspondingly disposed; similarly, the second long-side portion of each conductive parts **1039** and the first long-side portion of each adjacent conductive parts **1039** are correspondingly disposed. Therefore, each of the conductive parts **1039** can be formed as a wiring configuration having consistent width. The configuration of the other conductive parts **1039** can be similar to the description of the conductive part **1039_2** described above.

The conductive part **1039** is taken as an example for explaining the relative configuration of the LEDs **1031** and the conductive parts **1039** as well. In the present embodiment, the positive electrodes of part of the LEDs **1031** (e.g., the four LEDs **1031** at the right-hand side) are connected to the first long-side portion of the conductive part **1039_2** and connected to each other via the first long-side portion; and the negative electrodes of the part of the LEDs **1031** are connected to the second long-side portion of the adjacent conductive part **1039_3** and connected to each other via the conductive part **1039_3**. On the other hand, the positive electrodes of another part of the LEDs **1031** (e.g., the four LEDs **1031** at the left-hand side) are connected to the first long-side portion of the conductive part **1039_1**, and the negative electrodes of the another part of the LEDs **1031** are connected to the second long-side portion of the conductive part **1039_2**.

As can be seen in FIG. **11E**, positive electrodes of the four LEDs **1031** at the left-hand side are connected to each other via the conductive part **1039_1**, and the negative electrodes of the four LEDs **1031** at the left-hand side are connected to each other via the conductive part **1039_2**. The positive electrodes of the four LEDs **1031** at the right-hand side are connected to each other via the conductive part **1039_2**, and the negative electrodes of the four LEDs **1031** at the right-hand side are connected to each other via the conductive part **1039_3**. Since the negative electrodes of the four LEDs **1031** at the left-hand side are connected to the positive electrodes of the four LEDs **1031** at the right-hand side via the conductive part **1039_2**, the left four LEDs **1031** can be respectively referred to as the first LED in the four LED units, and the right four LEDs can be respectively referred to as the second LED in the four LED units. The connection relationship of the other LEDs can be derived from the above configuration, so as to form the mesh connection as shown in FIG. **11B**.

It should be noted that, compared to FIG. **11C**, the LEDs **1031** of the present embodiment are modified to be arranged in the longitudinal direction, such that the gap between the LEDs **1031** can be increased, which allows the effective

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width (which can be referred to the lead width) of the conductive part to be broadened. Therefore, the risk that the circuit is easily punctured when reconditioning the tube lamp can be avoided. Moreover, the short-circuit issue caused by the insufficient coverage area of the copper foil between the LEDs **1031** when the LEDs **1031** require to be arranged tightly can be removed or reduced.

On the other hand, by designing the width **1037** of the first long-side portion connected to the positive electrodes smaller than the width **1038** of the second long-side portion connected to the negative electrodes, the connection area of the negative electrodes on the LEDs **1031** is larger than the connection area of the positive electrodes on the LEDs **1031**. Thus, such wiring architecture facilitates heat dissipation of the LEDs.

FIG. **11F** is a plan view of a circuit layout of the LED module according to another embodiment. Referring to FIG. **11F**, the present embodiment is basically similar to the embodiment illustrated in FIG. **11E**, the difference between those two embodiments is that the conductive part **1139** is formed in a non right-angled Z shape. In other words, in the present embodiment, the transition portion is formed by an oblique wiring, such that the joints of each long-side portion and the transition portion are non-right angle. In the configuration of the present embodiment, in addition to increasing the gap between each LEDs **1031** by disposing the LEDs **1031** along the longitudinal direction and thus the effective width of the conductive part can be broadened, the oblique wiring configuration may reduce the likelihood of the displacement or the offset when attaching the LED to an uneven soldering pad.

Specifically, according to the embodiment utilizing the flexible circuit board as the LED light strip, the vertical conductive parts/leads (e.g., portions that extend in a vertical direction in the configuration shown in FIG. **11C** to FIG. **11E**) cause a regular recessed/indented area at the transition portion, so that the soldering spots of the LED soldering pads on the conductive parts are relatively on a raised position. Since the soldering spots are not a flat surface, it is hard to dispose the LEDs on the predetermined position when attaching the LEDs on the LED light strip. Thus, the present embodiment eliminates the recessed area by adjusting the configuration of the vertical wiring to the oblique wiring, so that the strength of the copper foil of the whole wiring can be uniform without a bulge or uneven situation at a specific position crossing the width of the LED light strip. Accordingly, the LEDs **1131** can be attached on the conductive part easier, so as to enhance the reliability of tube lamp installation process. Also, since each of the LED units only passes the oblique wiring once on the LED light strip, the strength of the entire LED light strip can be greatly improved, therefore, the LED light strip can be prevented from being bent and the length of the LED light strip can be shortened.

In addition, in an exemplary embodiment, the copper foil can be covered (e.g., extend laterally) around the soldering pads of the LEDs **1131**, so as to eliminate effects of an offset generated from attaching the LEDs **1131** and avoid a short-circuit caused by the solder ball. This is particularly the case for an offset in the lengthwise direction of the LED light strip.

FIG. **11G** is a plan view of a circuit layout of the LED module according to another embodiment. Referring to FIG. **11G**, the present embodiment is basically similar to the embodiment illustrated in FIG. **11C**, the difference between the two embodiments is that the corresponding configuration

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between the conductive parts **1239** (i.e., not the soldering pad position of the LEDs **1231**) is modified to the oblique wiring.

In addition, according to the configuration of the present embodiment, the color temperature points CTP can be disposed between the LEDs **1231** as shown in FIG. **11H**. FIG. **11H** is a plan view of a circuit layout of the LED module according to another embodiment. In the present embodiment, by disposing the color temperature points CTP between the LEDs in a consistent manner, the corresponding color temperature points CTP on the different conductive parts/LED units is on the same line and can be at a same relative location compared to each LED. As a result, the entire LED module may only use several tapes for covering all of the color temperature points CTP when soldering (e.g., use three tapes if there has three color temperature points CTP on each conductive parts as shown in FIG. **11H**). Therefore, the smoothness of the assembly process can be improved and the assembly time can be saved as well.

FIG. **11I** is a plan view of a circuit layout of the LED module according to another embodiment. Referring to FIG. **11I**, the soldering pads **b1** and **b2** of the LED light strip are adapted to solder with the soldering pads of the power supply circuit board. The soldering pads of the present embodiment can be adapted to the dual-end-single-pin configuration, which means the soldering pads at the same side will receive the external driving signal having the same polarity.

Specifically, the soldering pads **b1** and **b2** are connected to each other via a S-shaped fuse **FS**, in which the fuse **FS** is constituted by, for example, a thin wire. In one embodiment, the resistance of the thin wire is extremely low, so that the soldering pads **b1** and **b2** can be regarded as short-circuit. In the correct application situation, the soldering pads **b1** and **b2** receive the external driving signal having the same polarity. Even if the soldering pads **b1** and **b2** are mis-connected to the external driving signal having opposite polarities, the fuse will be fused (e.g. broken) by a large current passing through, thereby preventing the tube lamp from being damaged. In addition, the soldering pad **b2** is at the floating state and the soldering pad **b1** is still connected to the LED light strip after the fuse **FS** is fused, therefore, the LED light strip can be continuously used by receiving the external driving signal via the soldering pad **b1**.

In an exemplary embodiment, the thickness of the soldering pads **b1** and **b2** and the wiring connected to the soldering pads **b1** and **b2** at least reach 0.4 mm, and the actual thickness can be selected from any thickness greater than 0.4 mm that is capable of implementing in the LED light strip design based on the understanding of one of the ordinary skill in the art. Based on the verification result, once the thickness of the soldering pads **b1** and **b2** and the connection wire reach 0.4 mm, even if the copper foil at the soldering pads **b1** and **b2** is broken when the soldering pads **b1** and **b2** are connected to the power supply circuit board and disposed into the lamp tube, the copper foil on the periphery of the soldering pads **131** and **b2** can also connect the LED light strip to the circuit on the power supply circuit board, so that the tube lamp can work normally.

In addition, in another exemplary embodiment, the positions where the pads **131** and **b2** on the LED light strip are disposed cause the pads **131** and **b2** to have a gap from the edge of the LED light strip. Through the gap configuration, a fault-tolerant space can be enhanced when bonding the power circuit board and the LED light strip.

FIG. **11J** is a schematic view of a power pad according to an embodiment of the present invention. Referring to FIG.

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11J, the power supply circuit board has, for example, three pads **a1**, **a2**, and **a3**, and the power supply circuit board can be a printed circuit board (PCB), however, the present invention is not limited thereto. There are a plurality of through holes **hp** disposed on each of the pads **a1**, **a2** and **a3**. During the welding process, the soldering material (e.g., soldering tin) is filled with at least one of the through holes **hp** so that the soldering pads **a1** to **a3** on the power supply circuit board (herein described as an after "power soldering pad") are connected to the pad on the LED light strip (hereinafter "LED soldering pad"). Herein, the LED light strip is, for example, a flexible circuit board. It should be noted that in some embodiments, a flexible circuit board has a higher rigidity than a bendable circuit sheet or flexible tape or ribbon. For example, a flexible circuit board may substantially maintain its shape when supported by one or two hands of a person, whereas a flexible or bendable circuit sheet, tape, or ribbon may collapse or coil and thus significantly changes shape when supported by one or two hands. Both a flexible circuit board and bendable circuit sheet may be bent or deformed, but the flexible circuit board may be bent by applying a force, whereas a bendable circuit sheet, when held, may bend on its own without the application of any force.

Due to the through holes **hp**, the contact area between the solder and the power soldering pads **a1** to **a3**, and thus the adhesion force between the power soldering pads **a1** to **a3** and the LED soldering pad can be enhanced. In addition, due to the arrangement of the through holes **hp**, the heat dissipation area can be increased, and the terminal characteristic of the tube lamp can be improved. In the present embodiment, the number of the through holes on each power soldering pads is selected, for example, to be 7 or 9. If the configuration of 7 through holes being selected, the arrangement of the through holes **hp** can be that 6 through holes are arranged on a circumference on the pad, and the remaining is disposed on the center of the circle. If the configuration of 9 through holes being selected, the arrangement of the through holes **hp** can be arranged in a 3×3 array. According to the selected arrangement, the effect of the heat dissipation can be preferably improved.

FIG. **11K** is a plan view of a circuit layout of the LED module according to another embodiment. The layout structures of the LED module in FIGS. **11K** and **11C** correspond to the same way of connecting the LEDs **831** as those shown in FIG. **11B**, but the layout structure in FIG. **11K** comprises two conductive layers instead of only one conductive layer for forming the circuit layout as shown in FIG. **11C**. Referring to FIG. **11K**, the main difference from the layout in FIG. **11C** is that the positive conductive line **834** and the negative conductive line **835** have a lengthwise portion **834a** and a lengthwise portion **835a**, respectively, that are formed in a second conductive layer instead. The difference is elaborated as follows.

In certain embodiments, referring to FIG. **7** again at the same time, a bendable circuit sheet of the LED module includes a first conductive layer **2a** and a second conductive layer **2c** electrically insulated from each other by a dielectric layer **2b**. Of the two conductive layers, the positive conductive line **834**, the negative conductive line **835**, and the conductive parts **839** in FIG. **11E** are formed in first conductive layer **2a** by the method of etching for electrically connecting the plurality of LED components **831** e.g. in a form of a mesh, whereas the positive lengthwise portion **834a** and the negative lengthwise portion **835a** are formed in second conductive layer **2c** by etching for electrically connecting (the filtering output terminal of) the filtering

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circuit. Further, the positive conductive line **834** and the negative conductive line **835** in the first conductive layer **2a** have via points **834b** and via points **835b**, respectively, for connecting to second conductive layer **2c**. And the positive lengthwise portion **834a** and the negative lengthwise portion **835a** in second conductive layer **2c** have via points **834c** and via points **835c**, respectively. The via points **834b** are positioned corresponding to the via points **834c**, for connecting the positive conductive line **834** and the positive lengthwise portion **834a**. The via points **835b** are positioned corresponding to the via points **835c**, for connecting the negative conductive line **835** and the negative lengthwise portion **835a**. An exemplary desirable way of connecting the two conductive layers **2a** and **2c** is to form a hole connecting each via point **834b** and a corresponding via point **834c**, and to form a hole connecting each via point **835b** and a corresponding via point **835c**, with the holes extending through the two conductive layers **2a** and **2c** and the dielectric layer **2b** in-between. And the positive conductive line **834** and the positive lengthwise portion **834a** can be electrically connected by welding metallic part(s) through the connecting hole(s), and the negative conductive line **835** and the negative lengthwise portion **835a** can be electrically connected by welding metallic part(s) through the connecting hole(s). It should be noted that, electrically speaking, the positive lengthwise portion **834a** and the negative lengthwise portion **835a** in second conductive layer **2c** are part of the positive conductive line **834** and negative conductive line **835** respectively.

Similarly, the layout structure of the LED module in FIG. 11D may alternatively have the positive lengthwise portion **934a** and the negative lengthwise portion **935a** disposed in a second conductive layer to constitute a two-layered layout structure.

The positive conductive lines (**834** or **934**) may be characterized as including two end terminals at opposite ends, a plurality of pads between the two end terminals and for contacting and/or supplying power to LEDs (e.g., anodes of LEDs), and a wire portion, which may be an elongated conductive line extending along a length of an LED light strip and electrically connecting the two end terminals to the plurality of pads. Similarly, the negative conductive lines (**835** or **935**) may be characterized as including two end terminals at opposite ends, a plurality of pads between the two end terminals and for contacting and/or supplying power to LEDs (e.g., cathodes of LEDs), and a wire portion, which may be an elongated conductive line extending along a length of an LED light strip and electrically connecting the two end terminals to the plurality of pads.

The circuit layouts may be implemented for one of the exemplary LED light strips described previously, for example, to serve as a circuit board or sheet for the LED light strip on which the LED light sources are disposed.

As described herein, an LED unit may refer to a single string of LEDs arranged in series, and an LED module may refer to a single LED unit, or a plurality of LED units connected to a same two nodes (e.g., arranged in parallel). For example, the LED light strip **2** described above may be an LED module and/or LED unit.

In some embodiments, the thickness of the second conductive layer of a two-layered bendable circuit sheet is, larger than that of the first conductive layer in order to reduce the voltage drop or loss along each of the positive lengthwise portion and the negative lengthwise portion disposed in the second conductive layer. Compared to a one-layered bendable circuit sheet, since a positive lengthwise portion and a negative lengthwise portion are disposed

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in a second conductive layer in a two-layer bendable circuit sheet, the width (between two lengthwise sides) of the two-layered bendable circuit sheet is or can be reduced. On the same fixture or plate in a production process, the number of bendable circuit sheets each with a shorter width that can be laid together at most is larger than the number of bendable circuit sheets each with a longer width that can be laid together at most. Thus adopting a bendable circuit sheet with a shorter width can increase the efficiency of production of the LED module. And reliability in the production process, such as the accuracy of welding position when welding (materials on) the LED components, can also be improved, because a two-layer bendable circuit sheet can better maintain its shape.

As a variant of the above embodiments, a type of an exemplary LED tube lamp is provided that may have at least some of the electronic components of its power supply module disposed on a light strip of the LED tube lamp. For example, the technique of printed electronic circuit (PEC) can be used to print, insert, or embed at least some of the electronic components onto the LED light strip (e.g., as opposed to being on a separate circuit board connected to the LED light strip).

In one embodiment, all electronic components of the power supply module are disposed on the light strip. The production process may include or proceed with the following steps: preparation of the circuit substrate (e.g. preparation of a flexible printed circuit board); ink jet printing of metallic nano-ink; ink jet printing of active and passive components (as of the power supply module); drying/sintering; ink jet printing of interlayer bumps; spraying of insulating ink; ink jet printing of metallic nano-ink; ink jet printing of active and passive components (to sequentially form the included layers); spraying of surface bond pad(s); and spraying of solder resist against LED components. The production process may be different, however, and still result in some or all electronic components of the power supply module being disposed directly on the LED light strip.

In certain embodiments, if all electronic components of the power supply module are disposed on the LED light strip, electrical connection between the terminal pins of the LED tube lamp and the light strip may be achieved by connecting the pins to conductive lines which are welded with ends of the light strip. In this case, another substrate for supporting the power supply module is not required, thereby allowing of an improved design or arrangement in the end cap(s) of the LED tube lamp. In some embodiments, (components of) the power supply module are disposed at two ends of the light strip, in order to significantly reduce the impact of heat generated from the power supply module's operations on the LED components. Since no substrate other than the light strip is used to support the power supply module in this case, the total amount of welding or soldering can be significantly reduced, improving the general reliability of the power supply module.

Another case is that some of all electronic components of the power supply module, such as some resistors and/or smaller size capacitors, are printed onto the light strip, and some bigger size components, such as some inductors and/or electrolytic capacitors, are disposed in the end cap(s). The production process of the light strip in this case may be the same as that described above. And in this case disposing some of all electronic components on the light strip is conducive to achieving a reasonable layout of the power supply module in the LED tube lamp, which may allow of an improved design in the end cap(s).

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As a variant embodiment of the above, electronic components of the power supply module may be disposed on the LED light strip by a method of embedding or inserting, e.g. by embedding the components onto a bendable or flexible light strip. In some embodiments, this embedding may be realized by a method using copper-clad laminates (CCL) for forming a resistor or capacitor; a method using ink related to silkscreen printing; or a method of ink jet printing to embed passive components, wherein an ink jet printer is used to directly print inks to constitute passive components and related functionalities to intended positions on the light strip. Then through treatment by ultraviolet (UV) light or drying/sintering, the light strip is formed where passive components are embedded. The electronic components embedded onto the light strip include for example resistors, capacitors, and inductors. In other embodiments, active components also may be embedded. Through embedding some components onto the light strip, a reasonable layout of the power supply module can be achieved to allow of an improved design in the end cap(s), because the surface area on a printed circuit board used for carrying components of the power supply module is reduced or smaller, and as a result the size, weight, and thickness of the resulting printed circuit board for carrying components of the power supply module is also smaller or reduced. Also in this situation since welding points on the printed circuit board for welding resistors and/or capacitors if they were not to be disposed on the light strip are no longer used, the reliability of the power supply module is improved, in view of the fact that these welding points are most liable to (cause or incur) faults, malfunctions, or failures. Further, the length of conductive lines needed for connecting components on the printed circuit board is therefore also reduced, which allows of a more compact layout of components on the printed circuit board thus improving the functionalities of these components.

As mentioned above, electronic components of the power supply module **5** or **250** may be disposed either on the light strip **2** or on a circuit board (such as a printed circuit board) in the end cap(s) of one or two ends of the lamp tube. For improving benefits or advantages of embodiments of the power supply module or the general LED tube lamp, in some embodiments, capacitor(s) in the power supply module may be chip capacitor(s), such as multilayer ceramic chip capacitor(s), disposed either on the light strip **2** or on the short circuit board **253**. However, such disposed chip capacitor(s) in use is likely to produce or incur distinct noise due to piezoelectric effects, which may adversely affect the comfort level of using the LED tube lamp by consumers. To address and reduce this problem, in the LED tube lamp of this disclosure, a hole or groove may be disposed (directly) below the chip capacitor by drilling or boring, to significantly reduce the noise by changing the vibration system formed under piezoelectric effects between the chip capacitor and the circuit board carrying the chip capacitor. The shape of the circumference of the hole or groove may be substantially close to, for example, a circle or round, an oval or ellipse, or a rectangle. In some embodiments, the hole or groove is formed in a conductive or wire layer in the light strip **2**, or in the short circuit board **253** in the end cap(s), and (directly) below the chip capacitor.

Next, methods to produce embedded capacitors and resistors are explained as follows.

Usually, methods for manufacturing embedded capacitors employ or involve a concept called distributed or planar capacitance. The manufacturing process may include the following step(s). On a substrate of a copper layer a very thin insulation layer is applied or pressed, which is then generally

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disposed between a pair of layers including a power conductive layer and a ground layer. The very thin insulation layer makes the distance between the power conductive layer and the ground layer very short. A capacitance resulting from this structure can also be realized by a conventional technique of a plated-through hole. Basically, this step is used to create this structure comprising a big parallel-plate capacitor on a circuit substrate.

Of products of high electrical capacity, certain types of products employ distributed capacitances, and other types of products employ separate embedded capacitances. Through putting or adding a high dielectric-constant material, such as barium titanate, into the insulation layer, the high electrical capacity is achieved.

A usual method for manufacturing embedded resistors employ conductive or resistive adhesive. This may include, for example, a resin to which conductive carbon or graphite is added, which may be used as an additive or filler. The additive resin is silkscreen printed to an object location, and is then after treatment laminated inside the circuit board. The resulting resistor is connected to other electronic components through plated-through holes or microvias. Another method is called Ohmega-Ply, by which a two metallic layer structure of a copper layer and a thin nickel alloy layer constitutes a layer resistor relative to a substrate. Then through etching the copper layer and nickel alloy layer, different types of nickel alloy resistors with copper terminals can be formed. These types of resistor are each laminated inside the circuit board.

In an embodiment, conductive wires/lines are directly printed in a linear layout on an inner surface of the LED glass lamp tube, with LED components directly attached on the inner surface and electrically connected by the conductive wires. In some embodiments, the LED components in the form of chips are directly attached over the conductive wires on the inner surface, and connective points are at terminals of the wires for connecting the LED components and the power supply module. After being attached, the LED chips may have fluorescent powder applied or dropped thereon, for producing white light or light of other color by the operating LED tube lamp.

In some embodiments, luminous efficacy of the LED or LED component is 80 lm/W or above, and in some embodiments, it may be 120 lm/W or above. Certain more optimal embodiments may include a luminous efficacy of the LED or LED component of 160 lm/W or above. White light emitted by an LED component in the invention may be produced by mixing fluorescent powder with the monochromatic light emitted by a monochromatic LED chip. The white light in its spectrum has major wavelength ranges of 430-460 nm and 550-560 nm, or major wavelength ranges of 430-460 nm, 540-560 nm, and 620-640 nm.

FIG. 12A is a block diagram of a power supply module in an LED lamp according to an embodiment. As shown in FIG. 12A, the power supply module of the LED lamp includes a rectifying circuit **510**, a filtering circuit **520**, and may further include some parts of an LED lighting module **530**. The LED lighting module **530** in this embodiment comprises a driving circuit **1530** and an LED module **630**. The driving circuit **1530** comprises a DC-to-DC converter circuit, and is coupled to the filtering output terminals **521** and **522** to receive a filtered signal and then perform power conversion for converting the filtered signal into a driving signal at the driving output terminals **1521** and **1522**. The LED module **630** is coupled to the driving output terminals **1521** and **1522** to receive the driving signal for emitting light. In some embodiments, the current of LED module **630**

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is stabilized at an objective current value. Descriptions of this LED module **630** can be the same as those provided above with reference to FIGS. **11A-11K**.

In some embodiments, the LED lighting module **530** shown in FIG. **8D** may include the driving circuit **1530** and the LED module **630** as shown in FIG. **12A**. Thus, the power supply module for the LED lamp in the present embodiment can be applied to the single-end power supply structure, such as LED light bulbs, personal area lights (PAL), and so forth.

FIG. **12B** is a block diagram of the driving circuit according to an embodiment. Referring to FIG. **12B**, a driving circuit includes a controller **1531**, and a conversion circuit **1532** for power conversion based on a current source, for driving the LED module to emit light. The conversion circuit **1532** includes a switching circuit **1535** and an energy storage circuit **1538**. And the conversion circuit **1532** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal, under the control by the controller **1531**, into a driving signal at the driving output terminals **1521** and **1522** for driving the LED module. Under the control by the controller **1531**, the driving signal output by the conversion circuit **1532** comprises a steady current, making the LED module emitting steady light.

FIG. **12C** is a schematic diagram of the driving circuit according to an embodiment. Referring to FIG. **12C**, a driving circuit **1630** in this embodiment comprises a buck DC-to-DC converter circuit having a controller **1631** and a converter circuit. The converter circuit includes an inductor **1632**, a diode **1633** for "freewheeling" of current, a capacitor **1634**, and a switch **1635**. The driving circuit **1630** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal into a driving signal for driving an LED module connected between the driving output terminals **1521** and **1522**.

In this embodiment, the switch **1635** includes a metal-oxide-semiconductor field-effect transistor (MOSFET) and has a first terminal coupled to the anode of freewheeling diode **1633**, a second terminal coupled to the filtering output terminal **522**, and a control terminal coupled to the controller **1631** used for controlling current conduction or cutoff between the first and second terminals of switch **1635**. The driving output terminal **1521** is connected to the filtering output terminal **521**, and the driving output terminal **1522** is connected to an end of the inductor **1632**, which has another end connected to the first terminal of switch **1635**. The capacitor **1634** is coupled between the driving output terminals **1521** and **1522** to stabilize the voltage between the driving output terminals **1521** and **1522**. The freewheeling diode **1633** has a cathode connected to the driving output terminal **1521**.

Next, a description follows as to an exemplary operation of the driving circuit **1630**.

The controller **1631** is configured for determining when to turn the switch **1635** on (in a conducting state) or off (in a cutoff state) according to a current detection signal **S535** and/or a current detection signal **S531**. For example, in some embodiments, the controller **1631** is configured to control the duty cycle of switch **1635** being on and switch **1635** being off in order to adjust the size or magnitude of the driving signal. The current detection signal **S535** represents the magnitude of current through the switch **1635**. The current detection signal **S531** represents the magnitude of current through the LED module coupled between the driving output terminals **1521** and **1522**. The controller **1631** may control the duty cycle of the switch **1635** being on and off, based on, for example, a magnitude of a current detected based on current detection signal **S531** or **S535**. As such,

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when the magnitude is above a threshold, the switch may be off (cutoff state) for more time, and when magnitude goes below the threshold, the switch may be on (conducting state) for more time. According to any of current detection signal **S535** and current detection signal **S531**, the controller **1631** can obtain information on the magnitude of power converted by the converter circuit. When the switch **1635** is switched on, a current of a filtered signal is input through the filtering output terminal **521**, and then flows through the capacitor **1634**, the driving output terminal **1521**, the LED module, the inductor **1632**, and the switch **1635**, and then flows out from the filtering output terminal **522**. During this flowing of current, the capacitor **1634** and the inductor **1632** are performing storing of energy. On the other hand, when the switch **1635** is switched off, the capacitor **1634** and the inductor **1632** perform releasing of stored energy by a current flowing from the freewheeling diode **1633** to the driving output terminal **1521** to make the LED module continuing to emit light.

In some embodiments, the capacitor **1634** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **12C**. In some application environments, the natural characteristic of an inductor to oppose instantaneous change in electric current passing through the inductor may be used to achieve the effect of stabilizing the current through the LED module, thus omitting the capacitor **1634**.

As described above, because the driving circuit **1630** is configured for determining when to turn a switch **1635** on (in a conducting state) or off (in a cutoff state) according to a current detection signal **S535** and/or a current detection signal **S531**, the driving circuit **1630** can maintain a stable current flow through the LED module. Therefore, the color temperature may not change with current to some LED module, such as white, red, blue, green LED modules. For example, an LED can retain the same color temperature under different illumination conditions. In some embodiments, because the inductor **1632** playing the role of the energy-storing circuit releases the stored power when the switch **1635** cuts off, the voltage/current flowing through the LED module remains above a predetermined voltage/current level so that the LED module may continue to emit light maintaining the same color temperature. In this way, when the switch **1635** conducts again, the voltage/current flowing through the LED module does not need to be adjusted to go from a minimum value to a maximum value. Accordingly, the LED module lighting with flickering can be avoided, the entire illumination can be improved, the lowest conducting period can be smaller, and the driving frequency can be higher.

FIG. **12D** is a schematic diagram of the driving circuit according to an embodiment. Referring to FIG. **12D**, a driving circuit **1730** in this embodiment comprises a boost DC-to-DC converter circuit having a controller **1731** and a converter circuit. The converter circuit includes an inductor **1732**, a diode **1733** for "freewheeling" of current, a capacitor **1734**, and a switch **1735**. The driving circuit **1730** is configured to receive and then convert a filtered signal from the filtering output terminals **521** and **522** into a driving signal for driving an LED module coupled between the driving output terminals **1521** and **1522**.

The inductor **1732** has an end connected to the filtering output terminal **521**, and another end connected to the anode of freewheeling diode **1733** and a first terminal of the switch **1735**, which has a second terminal connected to the filtering output terminal **522** and the driving output terminal **1522**. The freewheeling diode **1733** has a cathode connected to the

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driving output terminal **1521**. And the capacitor **1734** is coupled between the driving output terminals **1521** and **1522**.

The controller **1731** is coupled to a control terminal of switch **1735**, and is configured for determining when to turn the switch **1735** on (in a conducting state) or off (in a cutoff state), according to a current detection signal **S535** and/or a current detection signal **S531**. When the switch **1735** is switched on, a current of a filtered signal is input through the filtering output terminal **521**, and then flows through the inductor **1732** and the switch **1735**, and then flows out from the filtering output terminal **522**. During this flowing of current, the current through the inductor **1732** increases with time, with the inductor **1732** being in a state of storing energy, while the capacitor **1734** enters a state of releasing energy, making the LED module continuing to emit light. On the other hand, when the switch **1735** is switched off, the inductor **1732** enters a state of releasing energy as the current through the inductor **1732** decreases with time. In this state, the current through the inductor **1732** then flows through the freewheeling diode **1733**, the capacitor **1734**, and the LED module, while the capacitor **1734** enters a state of storing energy.

In some embodiments the capacitor **1734** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **12D**. When the capacitor **1734** is omitted and the switch **1735** is switched on, the current of inductor **1732** does not flow through the LED module, making the LED module not emit light; but when the switch **1735** is switched off, the current of inductor **1732** flows through the freewheeling diode **1733** to reach the LED module, making the LED module emit light. Therefore, by controlling the time that the LED module emits light, and the magnitude of current through the LED module, the average luminance of the LED module can be stabilized to be above a defined value, thus also achieving the effect of emitting a steady light.

As described above, because the controller **1731** included in the driving circuit **1730** is coupled to the control terminal of switch **1735**, and is configured for determining when to turn a switch **1735** on (in a conducting state) or off (in a cutoff state), according to a current detection signal **S535** and/or a current detection signal **S531**, the driving circuit **1730** can maintain a stable current flow through the LED module. Therefore, the color temperature may not change with current to some LED modules, such as white, red, blue, or green LED modules. For example, an LED can retain the same color temperature under different illumination conditions. In some embodiments, because the inductor **1732** playing the role of the energy-storing circuit releases the stored power when the switch **1735** cuts off, the voltage/current flowing through the LED module remains above a predetermined voltage/current level so that the LED module may continue to emit light maintaining the same color temperature. In this way, when the switch **1735** conducts again, the voltage/current flowing through the LED module does not need to be adjusted to go from a minimum value to a maximum value. Accordingly, the LED module lighting with flickering can be avoided, the entire illumination can be improved, the lowest conducting period can be smaller, and the driving frequency can be higher.

FIG. **12E** is a schematic diagram of the driving circuit according to an exemplary embodiment. Referring to FIG. **12E**, a driving circuit **1830** in this embodiment comprises a buck DC-to-DC converter circuit having a controller **1831** and a converter circuit. The converter circuit includes an inductor **1832**, a diode **1833** for "freewheeling" of current,

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a capacitor **1834**, and a switch **1835**. The driving circuit **1830** is coupled to the filtering output terminals **521** and **522** to receive and then convert a filtered signal into a driving signal for driving an LED module connected between the driving output terminals **1521** and **1522**.

The switch **1835** has a first terminal coupled to the filtering output terminal **521**, a second terminal coupled to the cathode of freewheeling diode **1833**, and a control terminal coupled to the controller **1831** to receive a control signal from the controller **1831** for controlling current conduction or cutoff between the first and second terminals of the switch **1835**. The anode of freewheeling diode **1833** is connected to the filtering output terminal **522** and the driving output terminal **1522**. The inductor **1832** has an end connected to the second terminal of switch **1835**, and another end connected to the driving output terminal **1521**. The capacitor **1834** is coupled between the driving output terminals **1521** and **1522** to stabilize the voltage between the driving output terminals **1521** and **1522**.

The controller **1831** is configured for controlling when to turn the switch **1835** on (in a conducting state) or off (in a cutoff state) according to a current detection signal **S535** and/or a current detection signal **S531**. When the switch **1835** is switched on, a current of a filtered signal is input through the filtering output terminal **521**, and then flows through the switch **1835**, the inductor **1832**, and the driving output terminals **1521** and **1522**, and then flows out from the filtering output terminal **522**. During this flowing of current, the current through the inductor **1832** and the voltage of the capacitor **1834** both increase with time, so the inductor **1832** and the capacitor **1834** are in a state of storing energy. On the other hand, when the switch **1835** is switched off, the inductor **1832** is in a state of releasing energy and thus the current through it decreases with time. In this case, the current through the inductor **1832** circulates through the driving output terminals **1521** and **1522**, the freewheeling diode **1833**, and back to the inductor **1832**.

In some embodiments the capacitor **1834** is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. **12E**. When the capacitor **1834** is omitted, no matter whether the switch **1835** is turned on or off, the current through the inductor **1832** will flow through the driving output terminals **1521** and **1522** to drive the LED module to continue emitting light.

As described above, because the controller **1831** included in the driving circuit **1830** is configured for controlling when to turn a switch **1835** on (in a conducting state) or off (in a cutoff state) according to a current detection signal **S535** and/or a current detection signal **S531**, the driving circuit **1730** can maintain a stable current flow through the LED module. Therefore, the color temperature may not change with current to some LED modules, such as white, red, blue, or green LED modules. For example, an LED can retain the same color temperature under different illumination conditions. In some embodiments, because the inductor **1832** playing the role of the energy-storing circuit releases the stored power when the switch **1835** cuts off, the voltage/current flowing through the LED module remains above a predetermined voltage/current level so that the LED module may continue to emit light maintaining the same color temperature. In this way, when the switch **1835** conducts again, the voltage/current flowing through the LED module does not need to be adjusted to go from a minimum value to a maximum value. Accordingly, the LED module lighting with flickering can be avoided, the entire illumination can be improved, the lowest conducting period can be smaller, and the driving frequency can be higher.

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FIG. 12F is a schematic diagram of the driving circuit according to an exemplary embodiment. Referring to FIG. 12F, a driving circuit 1930 in this embodiment comprises a buck DC-to-DC converter circuit having a controller 1931 and a converter circuit. The converter circuit includes an inductor 1932, a diode 1933 for "freewheeling" of current, a capacitor 1934, and a switch 1935. The driving circuit 1930 is coupled to the filtering output terminals 521 and 522 to receive and then convert a filtered signal into a driving signal for driving an LED module connected between the driving output terminals 1521 and 1522.

The inductor 1932 has an end connected to the filtering output terminal 521 and the driving output terminal 1522, and another end connected to a first end of the switch 1935. The switch 1935 has a second end connected to the filtering output terminal 522, and a control terminal connected to controller 1931 to receive a control signal from controller 1931 for controlling current conduction or cutoff of the switch 1935. The freewheeling diode 1933 has an anode coupled to a node connecting the inductor 1932 and the switch 1935, and a cathode coupled to the driving output terminal 1521. The capacitor 1934 is coupled to the driving output terminals 1521 and 1522 to stabilize the driving of the LED module coupled between the driving output terminals 1521 and 1522.

The controller 1931 is configured for controlling when to turn the switch 1935 on (in a conducting state) or off (in a cutoff state) according to a current detection signal S531 and/or a current detection signal S535. When the switch 1935 is turned on, a current is input through the filtering output terminal 521, and then flows through the inductor 1932 and the switch 1935, and then flows out from the filtering output terminal 522. During this flowing of current, the current through the inductor 1932 increases with time, so the inductor 1932 is in a state of storing energy; but the voltage of the capacitor 1934 decreases with time, so the capacitor 1934 is in a state of releasing energy to keep the LED module continuing to emit light. On the other hand, when the switch 1935 is turned off, the inductor 1932 is in a state of releasing energy and its current decreases with time. In this case, the current through the inductor 1932 circulates through the freewheeling diode 1933, the driving output terminals 1521 and 1522, and back to the inductor 1932. During this circulation, the capacitor 1934 is in a state of storing energy and its voltage increases with time.

In some embodiments the capacitor 1934 is an optional element, so it can be omitted and is thus depicted in a dotted line in FIG. 12F. When the capacitor 1934 is omitted and the switch 1935 is turned on, the current through the inductor 1932 doesn't flow through the driving output terminals 1521 and 1522, thereby making the LED module not emit light. On the other hand, when the switch 1935 is turned off, the current through the inductor 1932 flows through the freewheeling diode 1933 and then the LED module to make the LED module emit light. Therefore, by controlling the time that the LED module emits light, and the magnitude of current through the LED module, the average luminance of the LED module can be stabilized to be above a defined value, thus also achieving the effect of emitting a steady light.

As described above, because the controller 1931 included in the driving circuit 1930 is configured for controlling when to turn a switch 1935 on (in a conducting state) or off (in a cutoff state) according to a current detection signal S535 and/or a current detection signal S531, the driving circuit 1930 can maintain a stable current flow through the LED module. Therefore, the color temperature may not change

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with current to some LED modules, such as white, red, blue, or green LED modules. For example, an LED can retain the same color temperature under different illumination conditions. In some embodiments, because the inductor 1932 playing the role of the energy-storing circuit releases the stored power when the switch 1935 cuts off, the voltage/current flowing through the LED module remains above a predetermined voltage/current level so that the LED module may continue to emit light maintaining the same color temperature. In this way, when the switch 1935 conducts again, the voltage/current flowing through the LED module does not need to be adjusted to go from a minimum value to a maximum value. Accordingly, the LED module lighting with flickering can be avoided, the entire illumination can be improved, the lowest conducting period can be smaller, and the driving frequency can be higher.

With reference back to FIGS. 5 and 6, a short circuit board 253 includes a first short circuit substrate and a second short circuit substrate respectively connected to two terminal portions of a long circuit sheet 251, and electronic components of the power supply module are respectively disposed on the first short circuit substrate and the second short circuit substrate. The first short circuit substrate and the second short circuit substrate may have roughly the same length, or different lengths. In general, the first short circuit substrate (i.e. the right circuit substrate of short circuit board 253 in FIG. 5 and the left circuit substrate of short circuit board 253 in FIG. 6) has a length that is about 30%-80% of the length of the second short circuit substrate (i.e. the left circuit substrate of short circuit board 253 in FIG. 5 and the right circuit substrate of short circuit board 253 in FIG. 6). In some embodiments the length of the first short circuit substrate is about $\frac{1}{3}$ - $\frac{2}{3}$ of the length of the second short circuit substrate. For example, in one embodiment, the length of the first short circuit substrate may be about half the length of the second short circuit substrate. The length of the second short circuit substrate may be, for example in the range of about 15 mm to about 65 mm, depending on actual application occasions. In certain embodiments, the first short circuit substrate is disposed in an end cap at an end of the LED tube lamp, and the second short circuit substrate is disposed in another end cap at the opposite end of the LED tube lamp.

For example, capacitors of the driving circuit, such as the capacitors 1634, 1734, 1834, and 1934 in FIGS. 12C-12F, in practical use may include two or more capacitors connected in parallel. Some or all capacitors of the driving circuit in the power supply module may be arranged on the first short circuit substrate of short circuit board 253, while other components such as the rectifying circuit, filtering circuit, inductor(s) of the driving circuit, controller(s), switch(es), diodes, etc. are arranged on the second short circuit substrate of short circuit board 253. Since the inductors, controllers, switches, etc. are electronic components with higher temperature, arranging some or all capacitors on a circuit substrate separate or away from the circuit substrate(s) of high-temperature components helps prevent the working life of capacitors (especially electrolytic capacitors) from being negatively affected by the high-temperature components, thus improving the reliability of the capacitors. Further, the physical separation between the capacitors and both the rectifying circuit and filtering circuit also contributes to reducing the problem of EMI.

In certain exemplary embodiments, the conversion efficiency of the driving circuits is above 80%. In some embodiments, the conversion efficiency of the driving circuits is above 90%. In still other embodiments, the conversion

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efficiency of the driving circuits is above 92%. The illumination efficiency of the LED lamps is above 120 lm/W. In some embodiments, the illumination efficiency of the LED lamps is above 160 lm/W. The illumination efficiency including the combination of the driving circuits and the LED modules is above 120 lm/W*90%=108 lm/W. In some embodiments, the illumination efficiency including the combination of the driving circuits and the LED modules is above 160 lm/W*92%=147.21 lm/W.

In some embodiments, the transmittance of the diffusion film in the LED tube lamp is above 85%. As a result, in certain embodiments, the illumination efficiency of the LED lamps is above 108 lm/W*85%=91.8 lm/W. In some embodiments, the illumination efficiency of the LED lamps is above 147.21 lm/W*85%=125.12 lm/W.

FIG. 13A is a block diagram of a power supply module in an LED tube lamp according to an exemplary embodiment. Compared to that shown in FIG. 8D, the present embodiment comprises a rectifying circuit 510, a filtering circuit 520, and a driving circuit 1530, and further comprises an over-voltage protection (OVP) circuit 1570. In this embodiment, a driving circuit 1530 and an LED module 630 compose the LED lighting module 530. The OVP circuit 1570 is coupled to the filtering output terminals 521 and 522 for detecting the filtered signal. The OVP circuit 1570 clamps the logic level of the filtered signal when determining the logic level thereof higher than a defined OVP value. Hence, the OVP circuit 1570 protects the LED lighting module 530 from damage due to an OVP condition.

FIG. 13B is a schematic diagram of an overvoltage protection (OVP) circuit according to an exemplary embodiment. An OVP circuit 1670 comprises a voltage clamping diode 1671, such as Zener diode, coupled to the filtering output terminals 521 and 522. The voltage clamping diode 1671 is conducted to clamp a voltage difference at a breakdown voltage when the voltage difference of the filtering output terminals 521 and 522 (i.e., the logic level of the filtered signal) reaches the breakdown voltage. In some embodiments, the breakdown voltage may be in a range of about 40 V to about 100 V. In certain embodiments, the breakdown voltage may be in a range of about 55 V to about 75V.

FIG. 14A is a block diagram of a power supply module in an LED tube lamp according to an exemplary embodiment. Compared to that shown in FIG. 8D, the present embodiment comprises a rectifying circuit 510, a filtering circuit 520, and a driving circuit 1530, and further comprises an auxiliary power module 2510. The auxiliary power module 2510 is coupled between the filtering output terminals 521 and 522. The auxiliary power module 2510 detects the filtered signal in the filtering output terminals 521 and 522, and determines whether to provide an auxiliary power to the filtering output terminals 521 and 522 based on the detected result. When the supply of the filtered signal is stopped or a logic level thereof is insufficient, i.e., when a drive voltage for the LED module is below a defined voltage, the auxiliary power module provides auxiliary power to keep the LED lighting module 530 continuing to emit light. The defined voltage is determined according to an auxiliary power voltage of the auxiliary power module 2510.

FIG. 14B is a block diagram of a power supply module in an LED tube lamp according to an exemplary embodiment. Compared to that shown in FIG. 14A, the present embodiment comprises a rectifying circuit 510, a filtering circuit 520, and may further include some parts of an LED lighting module 530, and an auxiliary power module 2510, and the LED lighting module 530 further comprises a driving circuit

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1530 and an LED module 630. The auxiliary power module 2510 is coupled between the driving output terminals 1521 and 1522. The auxiliary power module 2510 detects the driving signal in the driving output terminals 1521 and 1522, and determines whether to provide an auxiliary power to the driving output terminals 1521 and 1522 based on the detected result. When the driving signal is no longer being supplied or a logic level thereof is insufficient, the auxiliary power module 2510 provides the auxiliary power to keep the LED module 630 continuously light.

In an exemplary embodiment of FIG. 14A, an energy storage unit of the auxiliary power module 2510 can be implemented by a supercapacitor (e.g., electric double-layer capacitor, EDLC). In such an embodiment, since the supercapacitor provides the filtering function which is the same as the filtering circuit 520, the filtering circuit 520 can be removed in this embodiment.

In another exemplary embodiment, the LED lighting module 530 or LED module 630 can be driven merely by the auxiliary power provided by the auxiliary power module 2510, and the external driving signal is merely used for charging the auxiliary power module 2510. Since such an embodiment applies the auxiliary power provided by the auxiliary power module 2510 as the only power source for the LED lighting module 530 or the LED module 630, regardless of whether the external driving signal is provided by commercial electricity or a ballast, the external driving signal charges the energy storage unit first, and then the energy storage unit is used for supplying power to the LED module. Accordingly, the LED tube lamp applying said power architecture may be compatible with the external driving signal provided by commercial electricity or a ballast.

From the perspective of the structure, since the auxiliary power module 2510 is connected between the outputs of the filtering circuit 520 (i.e., the first filtering output 521 and the second filtering output 522) or the outputs of the driving circuit 1530 (i.e., the first driving output terminal 1521 and the second driving output terminal 1522), the circuit components of the auxiliary power module 2510 can be placed, in an exemplary embodiment, in the lamp tube (e.g., the position adjacent to the LED lighting module 530 or LED module 630 and between the two end caps), such that the power transmission loss caused by the long wiring can be avoided. In another exemplary embodiment, the circuit components of the auxiliary power can be placed in at least one of the end caps, such that the heat generated by the auxiliary power module 2510 when charging and discharging does not affect operation and illumination of the LED module.

FIG. 14C is a schematic diagram of an auxiliary power module according to an embodiment. The auxiliary power module 2610 can be applied, for example, to the configuration of the auxiliary power module 2510 illustrated in FIG. 14B. The auxiliary power module 2610 comprises an energy storage unit 2613 and a voltage detection circuit 2614. The auxiliary power module further comprises an auxiliary power positive terminal 2611 and an auxiliary power negative terminal 2612 for being respectively coupled to the filtering output terminals 521 and 522 or the driving output terminals 1521 and 1522. The voltage detection circuit 2614 detects a logic level of a signal at the auxiliary power positive terminal 2611 and the auxiliary power negative terminal 2612 to determine whether releasing outward the power of the energy storage unit 2613 through the auxiliary power positive terminal 2611 and the auxiliary power negative terminal 2612.

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In some embodiments, the energy storage unit **2613** is a battery or a supercapacitor. When a voltage difference of the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612** (the drive voltage for the LED module) is higher than the auxiliary power voltage of the energy storage unit **2613**, the voltage detection circuit **2614** charges the energy storage unit **2613** by the signal in the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**. When the drive voltage is lower than the auxiliary power voltage, the energy storage unit **2613** releases the stored energy outward through the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**.

The voltage detection circuit **2614** comprises a diode **2615**, a bipolar junction transistor (BJT) **2616** and a resistor **2617**. A positive end of the diode **2615** is coupled to a positive end of the energy storage unit **2613** and a negative end of the diode **2615** is coupled to the auxiliary power positive terminal **2611**. The negative end of the energy storage unit **2613** is coupled to the auxiliary power negative terminal **2612**. A collector of the BJT **2616** is coupled to the auxiliary power positive terminal **2611**, and an emitter thereof is coupled to the positive end of the energy storage unit **2613**. One end of the resistor **2617** is coupled to the auxiliary power positive terminal **2611** and the other end is coupled to a base of the BJT **2616**. When the collector of the BJT **2616** is a cut-in voltage higher than the emitter thereof, the resistor **2617** conducts the BJT **2616**. When the power source provides power to the LED tube lamp normally, the energy storage unit **2613** is charged by the filtered signal through the filtering output terminals **521** and **522** and the conducted BJT **2616** or by the driving signal through the driving output terminals **1521** and **1522** and the conducted BJT **2616** until that the collector-emitter voltage of the BJT **2616** is lower than or equal to the cut-in voltage. When the filtered signal or the driving signal is no longer being supplied or the logic level thereof is insufficient, the energy storage unit **2613** provides power through the diode **2615** to keep the LED lighting module **530** or the LED module **630** continuously light.

In some embodiments, the maximum voltage of the charged energy storage unit **2613** is at least one cut-in voltage of the BJT **2616** lower than the voltage difference applied between the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612**. The voltage difference provided between the auxiliary power positive terminal **2611** and the auxiliary power negative terminal **2612** is a turn-on voltage of the diode **2615** lower than the voltage of the energy storage unit **2613**. Hence, when the auxiliary power module **2610** provides power, the voltage applied at the LED module **630** is lower (about the sum of the cut-in voltage of the BJT **2616** and the turn-on voltage of the diode **2615**). In the embodiment shown in the FIG. **14B**, the brightness of the LED module **630** is reduced when the auxiliary power module supplies power thereto. Thereby, when the auxiliary power module is applied to an emergency lighting system or a constant lighting system, the user realizes the main power supply, such as commercial power, is abnormal and then performs necessary precautions therefor.

In addition to utilizing the embodiments illustrated in FIG. **14A** to FIG. **14C** in a single tube lamp architecture for emergency power supply, the embodiments also can be utilized in a lamp module including a multi tube lamp. Taking the lamp module having four parallel arranged LED tube lamps as an example, in an exemplary embodiment, one of the LED tube lamps includes the auxiliary power module.

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When the external driving signal is abnormal, the LED tube lamp including the auxiliary power module is continuously lighted up and the others LED tube lamps go off. According to the consideration of the uniformity of illumination, the LED tube lamp having the auxiliary power module can be arranged in the middle position of the lamp module.

In another exemplary embodiment, a plurality of the LED tube lamps respectively include the auxiliary power module. When the external driving signal is abnormal, the LED tube lamps including the auxiliary power module are continuously lighted up and the other LED tube lamps (if any) go off. In this way, even if the lamp module is operated in an emergency situation, a certain brightness can still be provided for the lamp module. In addition, if there are two LED lamps that have the auxiliary power module, the LED tube lamps having the auxiliary power module can be arranged, according to the consideration of the uniformity of illumination, in a staggered way with the LED tube lamps that don't have the auxiliary power module.

In still another exemplary embodiment, a plurality of the LED tube lamps respectively include the auxiliary power module. When the external driving signal is abnormal, part of the LED tube lamps including the auxiliary power module is first lighted up by the auxiliary power, and the other part of the LED tube lamps including the auxiliary power module is then lighted up by the auxiliary power after a predetermined period. In this way, the lighting time of the lamp module can be extended during the emergency situation by coordinating the auxiliary power supply sequence of the LED tube lamps.

The embodiment of coordinating the auxiliary power supply sequence of the LED tube lamps can be implemented by setting different start-up time for the auxiliary power module disposed in different tube lamp, or by disposing controllers in each tube lamp for communicating the operation state of each auxiliary power module. The present invention is not limited thereto.

FIG. **14D** is a block diagram of a power supply module in an LED tube lamp according to an exemplary embodiment. The LED tube lamp of the present embodiment includes a rectifying circuit **510**, a filtering circuit **520**, an LED lighting module **530**, and an auxiliary power module **2710**. The LED lighting module **530** of the present embodiment can only include the LED module or include the driving circuit and the LED module, the present invention is not limited thereto. Compared to the embodiment of FIG. **14B**, the auxiliary power module **2710** of the present embodiment is connected between the pins **501** and **502** to receive the external driving signal and perform a charge-discharge operation based on the external driving signal. The auxiliary power module **2710** includes an energy storage unit and a voltage detection circuit. The voltage detection circuit detects the external driving signal on the pins **501** and **502**, and determines whether the energy storage provides the auxiliary power to the input terminal of the rectifying circuit **510** according to the detection result. When the external driving signal stops providing or the AC signal level of the external driving signal is insufficient, the energy storage unit of the auxiliary power module **2710** provides the auxiliary power, such that the LED lighting module **530** continues to emit light based on the auxiliary power provided by the auxiliary power module **2710**. In the practical application, the energy storage unit for providing auxiliary power can be implemented by an energy storage assembly such as a battery or a supercapacitor, however, the present invention is not limited thereto.

In an exemplary embodiment, the brightness of the LED module on the external driving signal is different from the

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brightness of the LED module on the auxiliary power. Therefore, a user may find the external power is abnormal when observing that the brightness of LED module changed, and thus the user can eliminate the problem as soon as possible. In this manner, the operation of the auxiliary power module 2710 can be considered as an indication for indicating whether the external driving signal is normally provided, by providing the auxiliary power having the output power different from the external driving signal when the external driving signal is abnormal. For example, in some embodiments, the luminance of the LED module is 1600 to 2000 lm when being lighted up by the external driving signal; and the luminance of the LED module is 200 to 250 lm when being lighted up by the auxiliary power. From the perspective of the auxiliary power module 2710, in order to let the luminance of the LED module reach 200-250 lm, the output power of the auxiliary power module 2710 is, for example, 1 watt to 5 watts, but the present invention is not limited thereto. In addition, the electrical capacity of the energy storage unit in the auxiliary power module 2710 may be, for example, 1.5 to 7.5 Wh (watt-hour) or above, so that the LED module can be lighted up for 90 minutes under 200-250 lm based on the auxiliary power. However, the present invention is not limited thereto.

From the perspective of the structure, FIG. 14E illustrates a schematic structure of an auxiliary power module disposed in an LED tube lamp according to an exemplary embodiment. In the present embodiment, in addition, or as an alternative, to disposing the auxiliary power module 2710 in the lamp tube 1 as the embodiment mentioned above, the auxiliary power module 2710 can be disposed in the end cap 3 as well. When the auxiliary power module 2710 is disposed in the end cap 3, the auxiliary power module 2710 connects to the corresponding pins 501 and 502 via internal wiring of the end cap 3, so as to receive the external driving signal provided to the pins 501 and 502. Compared to the structure of disposing the auxiliary power module into the lamp tube 1, the auxiliary power module 2710 can be disposed far apart from the LED module since the auxiliary power module 2710 is disposed in the end cap 3 which is connected to the respective end of the lamp tube 1. Therefore, the operation and illumination of the LED module won't be affected by the charging or discharging heat generated by the auxiliary power module 2710.

In another exemplary embodiment, the auxiliary power module 2710 can be disposed in a lamp socket corresponding to the LED tube lamp as shown in FIG. 14F, which illustrates a schematic structure of an auxiliary power module disposed in a lamp socket according to an exemplary embodiment. The lamp socket 1_LH includes a base 101_LH and a connecting socket 102_LH. The base 101_LH has power line disposed inside and is adapted to lock/attach to a fixed object such as a wall or a ceiling. The connecting socket 102_LH has slot corresponding to the pin (e.g., the pins 501 and 502) on the LED tube lamp, in which the slot is electrically connected to the corresponding power line. In the present embodiment, the connecting socket 102_LH and the base 101_LH can be formed in one piece, or the connecting socket 102_LH can be removably disposed on the base 101_LH. The invention is not limited one of these embodiments.

When the LED tube lamp is installed on the lamp socket 1_LH, the pins on both end caps 3 are respectively inserted into the slot of the corresponding connecting socket 102_LH, and thus the power line can be connected to the LED tube lamp for providing the external driving signal to the corresponding pins of the LED tube lamp. Taking the

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configuration of the left end cap 3 as an example, when the pins 501 and 502 are inserted into the slots of the connecting socket 102_LH, the auxiliary power module 2710 is electrically connected to the pins 501 and 502 via the slots, so as to implement the connection configuration shown in FIG. 14D.

Compared to the embodiment of disposing the auxiliary power module 2710 in the end cap 3, the connecting socket 102_LH and the auxiliary power module 2710 can be integrated as a module since the connecting socket can be designed as a removable configuration in an exemplary embodiment. Under such configuration, when the auxiliary power module 2710 has a fault or the service life of the energy storage unit in the auxiliary power module 2710 has run out, a new auxiliary power module can be replaced for use by replacing the modularized connecting socket 102_LH, instead of replacing the entire LED tube lamp. Thus, in addition to reducing the thermal effect of the auxiliary power module, the modularized design of the auxiliary power module makes the replacement of the auxiliary power module easier. Therefore, the durability of the LED tube lamp is improved since it is no longer necessary to replace the entire LED tube lamp when a problem occurs to the auxiliary power module.

Under a lamp module architecture having multi tube lamps, which is similar with the embodiments described in FIG. 14A to FIG. 14C, the auxiliary power module can be disposed in one tube lamp, or in plural tube lamps, in which the multi tube lamps architectures based on the consideration of the uniformity of illumination are adapted to the present embodiment as well. The difference between the embodiment having multi tube lamps and the embodiments illustrated in FIG. 14A to FIG. 14C is that the auxiliary power module disposed in one of the tube lamps may supply power to the other tube lamps.

It should be noted that, although the description of the lamp module having multi tube lamps herein is taking the four parallel LED tube lamps as an example, those skilled in the art should understand, based on the description mentioned above, how to implement an auxiliary power supply by selecting and disposing the suitable energy storage unit. Therefore, any embodiments illustrated in which the auxiliary power module 2710 provides auxiliary power to one or plural tube lamps, such that the corresponding LED tube lamp has a specific illuminance in response to the auxiliary power, may be implemented according to the disclosed embodiments.

In another exemplary embodiment, the auxiliary power modules 2510, 2610, and 2710 determine whether to provide the auxiliary power to the LED tube lamp according to a lighting signal. Specifically, the lighting signal is an indication signal indicating the switching state of the lamp switch. For example, the signal level of the lighting signal can be adjusted to a first level (e.g., high logic level) or a second level different from the first level (e.g., low logic level) according to the switching of the lamp switch. When a user toggles the lamp switch to an on-position, the lighting signal is adjusted to the first level; and when the user toggles the lamp switch to an off-position, the lighting signal is adjusted to the second level. For example, the lamp switch may be switched to the on-position when the lighting signal is at the first level and to the off-position when the lighting signal is at the second level. The generation of the lighting signal can be implemented by a circuit capable of detecting the switching state of the lamp switch.

In still another exemplary embodiment, the auxiliary power module 2510/2610/2710 further includes a lighting

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determination circuit for receiving the lighting signal and determining whether the energy storage unit provides the auxiliary power to the end of the LED tube lamp (e.g., to provide the auxiliary power to the LED module) according to the signal level of the lighting signal and the detection result of the voltage detection circuit. Specifically, based on the signal level of the lighting signal and the detection result, there are three different states as follows: (1) the lighting signal is at the first level and the external driving signal is normally provided; (2) the lighting signal is at the first level and the external driving signal stops being provided or the AC signal level of the external driving signal is insufficient; and (3) the lighting signal is at the second level and the external driving signal stops being provided. Herein, state (1) is the situation where a user turns on the lamp switch and the external driving signal is normally provided, state (2) is the situation where a user turns on the lamp switch however a problem occurs to the external power supply, and state (3) is the situation where a user turns off the lamp switch so that the external power supply is stopped.

In the present exemplary embodiment, states (1) and (3) belong to normal states, which means the external power is normally provided or stops in accordance with the user's control. Therefore, under states (1) and (3), the auxiliary power module does not provide auxiliary power to the end of the LED tube lamp (e.g., to the LED module). More specifically, the lighting determination circuit controls the energy storage unit not to provide the auxiliary power to the end of the LED tube lamp according to the determination result of states (1) and (3). In state (1), the external driving signal is directly input to the rectifying circuit 510 and charges the energy storage unit. In state (3), the external driving signal stops being provided so that the energy unit is not charged by the external driving signal.

State (2) represents the external power is not provided to the tube lamp when the user turns on the light, therefore, the lighting determination circuit controls the energy storage unit to provide the auxiliary power to the rear end according to the determination result indicating state (2), so that the LED lighting module 530 emits light based on the auxiliary power provided by the energy storage unit.

Accordingly, based on the application of the lighting determination circuit, the LED lighting module 530 may have three different luminance variations. The LED lighting module 530 has a first luminance (e.g., 1600 to 2200 lm) when the external power is normally supplied; the lighting module 530 has a second luminance (e.g., 200 to 250 lm) when the external power is abnormal and the power supply is changed to the auxiliary power; and the lighting module 530 has a third luminance (e.g., does not light up the LED module) when the user turns off the power on their own such that the external power is not provided to the LED tube lamp.

More specifically, in accordance with the embodiment of FIG. 14C, the lighting determination circuit is, for example, a switch circuit (not shown) connected between the auxiliary power positive terminal 2611 and the auxiliary power negative terminal 2612 in series. The control terminal of the switch circuit receives the lighting signal. When the lighting signal is at the first level, the switch circuit is conducted in response to the lighting signal, such that the external driving signal charges the energy storage unit 2613 via the auxiliary power positive terminal 2611 and the auxiliary power negative terminal 2612 when the external driving signal is normally supplied (state (1)), or makes the energy storage unit 2613 discharge to the LED lighting module 530 or LED module 630 via the auxiliary power positive terminal 2611

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and the auxiliary power negative terminal 2612 when the external driving signal stops providing or the AC signal level of the external driving signal is insufficient (state (2)). On the other hand, when the lighting signal is at the second level, the switch circuit is cut off in response to the lighting signal (state (3)). At this time, even though the external driving signal stops being provided or the AC signal level is insufficient, the energy storage unit 2613 won't provide the auxiliary power to the rear end.

FIG. 14G is a block diagram of a power supply module in an LED tube lamp according to an exemplary embodiment. Referring to FIG. 14G, the LED tube lamp of the present embodiment includes a rectifying circuit 510', a filtering circuit 520, an LED lighting module 530, and an auxiliary power module 2810. The LED lighting module 530 of the present embodiment can only include the LED module or can only include the driving circuit and the LED module, but the present invention is not limited thereto. The rectifying circuit 510' can be implemented by the rectifying circuit 910 having three bridge arms shown in FIG. 9D, in which the rectifying circuit 510' has three input signal receiving terminals P1, P2, and P3. The input signal receiving terminal P1 is connected to the pin 501, the input signal receiving terminal P2 is connected to the pin 502 and one output end of the auxiliary power module 2810, and the input signal receiving terminal P3 is connected to another output end of the auxiliary power module. The auxiliary power module 2810 is, for example, an emergency ballast.

In the present embodiment, input signal receiving terminal P2 can be regarded as a common terminal shared by the external driving signal and the auxiliary power module 2810, in which the external driving signal can be provided to the rectifying circuit 510' via the input signal receiving terminals P1 and P2 and the auxiliary power of the auxiliary power module 2810 can be provided to the rectifying circuit 510' via the input signal receiving terminals P3 and P2. According to the configuration of the present embodiment, when the external driving signal is normally supplied, the rectifying circuit 510' performs full-wave rectification by the bridge arms corresponding to the input signal receiving terminals P1 and P2, so as to provide power to the LED lighting module 530 for use. When the external driving signal is abnormal, the rectifying circuit 510' receives the auxiliary power via the input signal receiving terminals P3 and P2, so as to provide the power to the LED lighting module 530 for use. The unidirectional conduction characteristics of the diodes disposed in the rectifying circuit 510' isolate the external driving signal from the auxiliary power, so that the two inputs cannot influence each other, and the effect of providing the auxiliary power when the external driving signal is abnormal can be achieved. In practical applications, the rectifying circuit 510' can be implemented by fast recovery diodes, so as to deal with the high-frequency current characteristic of the emergency ballast.

It should be noted that, the hardware architecture of the auxiliary power module 2810 can be implemented using the architectures illustrated in FIG. 14E and FIG. 14F. The similar benefits can be achieved by utilizing the similar architecture.

Referring to FIG. 15A, a block diagram of an LED tube lamp including a power supply module in accordance with certain embodiments is illustrated. Compared to the LED lamp shown in FIG. 8D, the LED tube lamp of FIG. 15A includes a rectifying circuit 510, a filtering circuit 520, and an LED lighting module 530, and further includes an installation detection module 2520. The installation detection module 2520 is coupled to the rectifying circuit 510 via an

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installation detection terminal **2521** and is coupled to the filtering circuit **520** via an installation detection terminal **2522**. The installation detection module **2520** detects the signal passing through the installation detection terminals **2521** and **2522** and determines whether to cut off an LED driving signal (e.g., an external driving signal) passing through the LED tube lamp based on the detected result. The installation detection module **2520** includes circuitry configured to perform the steps of detecting the signal passing through the installation detection terminals **2521** and **2522** and determining whether to cut off an LED driving signal, and thus may be referred to as an installation detection circuit, or more generally as a detection circuit or cut-off circuit. When an LED tube lamp is not yet installed on a lamp socket or holder, or in some cases if it is not installed properly or is only partly installed (e.g., one side is connected to a lamp socket, but not the other side yet), the installation detection module **2520** detects a smaller current compared to a predetermined current (or current value) and determines the signal is passing through a high impedance through the installation detection terminals **2521** and **2522**. In this case, in certain embodiments, the installation detection circuit **2520** is in a cut-off state to make the LED tube lamp stop working. Otherwise, the installation detection module **2520** determines that the LED tube lamp has already been installed on the lamp socket or holder (e.g., when the installation detection module **2520** detects a current equal to or larger than a predetermined current and determines the signal is passing through a low impedance through the installation detection terminals **2521** and **2522**), and maintains conducting state to make the LED tube lamp working normally.

For example, in some embodiments, when a current passing through the installation detection terminals **2521** and **2522** is greater than or equal to a specific, defined installation current (or a current value), which may indicate that the current supplied to the LED lighting module **530** is greater than or equal to a specific, defined operating current, the installation detection module **2520** is conducting to make the LED tube lamp operate in a conducting state. For example, a current greater than or equal to the specific current value may indicate that the LED tube lamp has correctly been installed in the lamp socket or holder. When the current passing through the installation detection terminals **2521** and **2522** is smaller than the specific, defined installation current (or the current value), which may indicate that the current supplied to the LED lighting module **530** is less than a specific, defined operating current, the installation detection module **2520** cuts off current to make the LED tube lamp enter in a non-conducting state based on determining that the LED tube lamp has been not installed in, or does not properly connect to, the lamp socket or holder. In certain embodiments, the installation detection module **2520** determines conducting or cutting off based on the impedance detection to make the LED tube lamp operate in a conducting state or enter non-conducting state. The LED tube lamp operating in a conducting state may refer to the LED tube lamp including a sufficient current passing through the LED module to cause the LED light sources to emit light. The LED tube lamp operating in a cut-off state may refer to the LED tube lamp including an insufficient current or no current passing through the LED module so that the LED light sources do not emit light. Accordingly, the occurrence of electric shock caused by touching the conductive part of the LED tube lamp which is incorrectly installed on the lamp socket or holder can be efficiently avoided.

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Referring to FIG. **15B**, a block diagram of an installation detection module in accordance with certain embodiments is illustrated. The installation detection module includes a switch circuit **2580**, a detection pulse generating module **2540**, a detection result latching circuit **2560**, and a detection determining circuit **2570**. Certain of these circuits or modules may be referred to as first, second, third, etc., circuits as a naming convention to differentiate them from each other.

The detection determining circuit **2570** is coupled to and detects the signal between the installation detection terminals **2521** (through a switch circuit coupling terminal **2581** and the switch circuit **2580**) and **2522**. The detection determining circuit **2570** is also coupled to the detection result latching circuit **2560** via a detection result terminal **2571** to transmit the detection result signal to the detection result latching circuit **2560**. The detection determining circuit **2570** may be configured to detect a current passing through terminals **2521** and **2522** (e.g., to detect whether the current is above or below a specific current value).

The detection pulse generating module **2540** is coupled to the detection result latching circuit **2560** via a pulse signal output terminal **2541**, and generates a pulse signal to inform the detection result latching circuit **2560** of a time point for latching (storing) the detection result. For example, the detection pulse generating module **2540** may be a circuit configured to generate a signal that causes a latching circuit, such as the detection result latching circuit **2560** to enter and remain in a state that corresponds to one of a conducting state or a cut-off state for the LED tube lamp. The detection result latching circuit **2560** stores the detection result according to the detection result signal (or detection result signal and pulse signal), and transmits or provides the detection result to the switch circuit **2580** coupled to the detection result latching circuit **2560** via a detection result latching terminal **2561**. The switch circuit **2580** controls the state between conducting or cut off between the installation detection terminals **2521** and **2522** according to the detection result.

In some embodiments, the detection pulse generating module **2540** may be referred to as a first circuit **2540**, the detection result latching circuit **2560** may be referred to as a second circuit **2560**, the switch circuit **2580** may be referred to as a third circuit **2580**, the detection determining circuit **2570** may be referred to as a fourth circuit **2570**, the switch circuit coupling terminal **2581** may be referred to as a first terminal **2581** and the detection result terminal **2571** may be referred to as a second terminal **2571**, the pulse signal output terminal **2541** may be referred to as a third terminal **2541**, the detection result latching terminal **2561** may be referred to as a fourth terminal **2561**, the installation detection terminal **2521** may be referred to as a first installation detection terminal **2521**, and the installation detection terminal **2522** may be referred to as a second installation detection terminal **2522**. In this exemplary embodiment, the fourth circuit **2570** is coupled to the third circuit **2580** and the second circuit **2560** via the first terminal **2581** and the second terminal **2571**, respectively, the second circuit **2560** is also coupled to the first circuit **2540** and the third circuit **2580** via the third terminal **2541** and the fourth terminal **2561**, respectively.

In some embodiments, the fourth circuit **2570** is configured for detecting a signal between the first installation detection terminal **2521** and the second installation detection terminal **2522** through the first terminal **2581** and the fourth circuit **2580**. For example, because of the above configuration, the fourth circuit **2570** is capable of detecting and determining whether a current passing through the first

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installation detection terminal **2521** and the second installation detection terminal **2522** is below or above a predetermined current value and transmitting or providing a detection result signal to the second circuit **2560** via the second terminal **2571**.

In some embodiments, the first circuit **2540** generates a pulse signal through the second circuit **2560** to make the third circuit **2580** working in a conducting state during the pulse signal. Meanwhile, as a result, the power loop of the LED tube lamp between the installation detection terminals **2521** and **2522** is thus conducting as well. The fourth circuit **2570** detects a sample signal on the power loop and generates a signal based on a detection result to inform the second circuit **2560** of a time point for latching (storing) the detection result received by the second circuit **2560** from the fourth circuit **2570**. For example, the fourth circuit **2570** may be a circuit configured to generate a signal that causes a latching circuit, such as the second circuit **2560** to enter and remain in a state that corresponds to one of a conducting state or a cut-off state for the LED tube lamp. The second circuit **2560** stores the detection result according to the detection result signal (or detection result signal and pulse signal), and transmits or provides the detection result to the third circuit **2580** coupled to the second circuit **2560** via the fourth terminal **2561**. The third circuit **2580** receives the detection result transmitted from the second circuit **2560** and controls the state between conducting or cut off between the installation detection terminals **2521** and **2522** according to the detection result. It should be noted that the labels "first," "second," "third," etc., described in connection with these embodiments can be interchangeable and are merely used here in order to more easily differentiate the different circuits, nodes, and other components from each other.

Referring to FIG. 15C, a block diagram of a detection pulse generating module in accordance with certain embodiments is illustrated. A detection pulse generating module **2640** may be a circuit that includes multiple capacitors **2642**, **2645**, and **2646**, multiple resistors **2643**, **2647**, and **2648**, two buffers **2644** and **2651**, an inverter **2650**, a diode **2649**, and an OR gate **2652**. The capacitor **2642** may be referred to as a first capacitor **2642**, the capacitor **2645** may be referred to as a second capacitor **2645**, and the capacitor **2646** may be referred to as a third capacitor **2646**. The resistor **2643** may be referred to as a first resistor **2643**, the resistor **2647** may be referred to as a second resistor **2647**, and the resistor **2648** may be referred to as a third resistor **2648**. The buffer **2644** may be referred to as a first buffer **2644** and the buffer **2651** may be referred to as a second buffer **2651**. The diode **2649** may be referred to as a first diode **2649** and the OR gate **2652** may be referred to as a first OR gate **2652**. With use or operation, the capacitor **2642** and the resistor **2643** connect in series between a driving voltage (e.g., a driving voltage source, which may be a node of a power supply), such as VCC usually defined as a high logic level voltage, and a reference voltage (or potential), such as ground potential in this embodiment. The connection node between the capacitor **2642** and the resistor **2643** is coupled to an input terminal of the buffer **2644**. In this exemplary embodiment, the buffer **2644** includes two inverters connected in series between an input terminal and an output terminal of the buffer **2644**. The resistor **2647** is coupled between the driving voltage, e.g., VCC, and an input terminal of the inverter **2650**. The resistor **2648** is coupled between an input terminal of the buffer **2651** and the reference voltage, e.g. ground potential in this embodiment. An anode of the diode **2649** is grounded and a cathode of the diode **2649** is coupled to the input terminal of the buffer

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2651. First ends of the capacitors **2645** and **2646** are jointly coupled to an output terminal of the buffer **2644**, and second, opposite ends of the capacitors **2645** and **2646** are respectively coupled to the input terminal of the inverter **2650** and the input terminal of the buffer **2651**. In this exemplary embodiment, the buffer **2651** includes two inverters connected in series between an input terminal and an output terminal of the buffer **2651**. An output terminal of the inverter **2650** and an output terminal of the buffer **2651** are coupled to two input terminals of the OR gate **2652**. According to certain embodiments, the voltage (or potential) for "high logic level" and "low logic level" mentioned in this specification are all relative to another voltage (or potential) or a certain reference voltage (or potential) in circuits, and further may be described as "logic high logic level" and "logic low logic level."

When an end cap of an LED tube lamp is inserted into a lamp socket and the other end cap thereof is electrically coupled to a human body, or when both end caps of the LED tube lamp are inserted into the lamp socket, the LED tube lamp is conductive with electricity. At this moment, the installation detection module (e.g., the installation detection module **2520** as illustrated in FIG. 15A) enters a detection stage. The voltage on the connection node of the capacitor **2642** and the resistor **2643** is high initially (equals to the driving voltage, VCC) and decreases with time to zero finally. The input terminal of the buffer **2644** is coupled to the connection node of the capacitor **2642** and the resistor **2643**, so the buffer **2644** outputs a high logic level signal at the beginning and changes to output a low logic level signal when the voltage on the connection node of the capacitor **2642** and the resistor **2643** decreases to a low logic trigger logic level. As a result, the buffer **2644** is configured to produce an input pulse signal and then remain in a low logic level thereafter (stops outputting the input pulse signal.) The width for the input pulse signal may be described as equal to one (initial setting) time period, which is determined by the capacitance value of the capacitor **2642** and the resistance value of the resistor **2643**.

Next, the operations for the buffer **2644** to produce the pulse signal with the initial setting time period will be described below. Since the voltage on a first end of the capacitor **2645** and on a first end of the resistor **2647** is equal to the driving voltage VCC, the voltage on the connection node of both of them is also a high logic level. The first end of the resistor **2648** is grounded and the first end of the capacitor **2646** receives the input pulse signal from the buffer **2644**, so the connection node of the capacitor **2646** and the resistor **2648** has a high logic level voltage at the beginning but this voltage decreases with time to zero (in the meantime, the capacitor stores the voltage being equal to or approaching the driving voltage VCC.) Accordingly, initially the inverter **2650** outputs a low logic level signal and the buffer **2651** outputs a high logic level signal, and hence the OR gate **2652** outputs a high logic level signal (a first pulse signal) at the pulse signal output terminal **2541**. At this moment, the detection result latching circuit **2560** (as illustrated in FIG. 15B) stores the detection result for the first time according to the detection result signal received from the detection determining circuit **2570** (as illustrated in FIG. 15B) and the pulse signal generated at the pulse signal output terminal **2541**. During that initial pulse time period, as illustrated in FIG. 15B, the detection pulse generating module **2540** outputs a high logic level signal, which results in the detection result latching circuit **2560** outputting the result of that high logic level signal.

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When the voltage on the connection node of the capacitor **2646** and the resistor **2648** decreases to the low logic trigger logic level, the buffer **2651** changes to output a low logic level signal to make the OR gate **2652** output a low logic level signal at the pulse signal output terminal **2541** (stops outputting the first pulse signal.) The width of the first pulse signal output from the OR gate **2652** is determined by the capacitance value of the capacitor **2646** and the resistance value of the resistor **2648**.

The operation after the buffer **2644** stops outputting the pulse signal is described as below. For example, the operation may be initially in an operating stage. Since the capacitor **2646** stores the voltage being almost equal to the driving voltage VCC, and when the buffer **2644** instantaneously changes its output from a high logic level signal to a low logic level signal, the voltage on the connection node of the capacitor **2646** and the resistor **2648** is below zero but will be pulled up to zero by the diode **2649** rapidly charging the capacitor **2646**. Therefore, the buffer **2651** still outputs a low logic level signal.

In some embodiments, when the buffer **2644** instantaneously changes its output from a high logic level signal to a low logic level signal, the voltage on the one end of the capacitor **2645** also changes from the driving voltage VCC to zero instantly. This makes the connection node of the capacitor **2645** and the resistor **2647** have a low logic level signal. At this moment, the output of the inverter **2650** changes to a high logic level signal to make the OR gate output a high logic level signal (a second pulse signal) at the pulse signal output terminal **2541**. The detection result latching circuit **2560** as illustrated in FIG. 15B stores the detection result for a second time according to the detection result signal received from the detection determining circuit **2570** (as illustrated in FIG. 15B) and the pulse signal generated at the pulse signal output terminal **2541**. Next, the driving voltage VCC charges the capacitor **2645** through the resistor **2647** to make the voltage on the connection node of the capacitor **2645** and the resistor **2647** increase with time to the driving voltage VCC. When the voltage on the connection node of the capacitor **2645** and the resistor **2647** increases to reach a high logic trigger logic level, the inverter **2650** outputs a low logic level signal again to make the OR gate **2652** stop outputting the second pulse signal. The width of the second pulse signal is determined by the capacitance value of the capacitor **2645** and the resistance value of the resistor **2647**.

As those mentioned above, in certain embodiments, the detection pulse generating module **2640** generates two high logic level pulse signals in the detection stage, which are the first pulse signal and the second pulse signal. These pulse signals are output from the pulse signal output terminal **2541**. Moreover, there is an interval with a defined time between the first and second pulse signals (e.g., an opposite-logic signal, which may have a low logic level when the pulse signals have a high logic level), and the defined time is determined by the capacitance value of the capacitor **2642** and the resistance value of the resistor **2643**.

From the detection stage entering the operating stage, the detection pulse generating module **2640** does not produce the pulse signal any more, and keeps the pulse signal output terminal **2541** on a low logic level potential. As described herein, the operating stage is the stage following the detection stage (e.g., following the time after the second pulse signal ends). The operating stage occurs when the LED tube lamp is at least partly connected to a power source, such as provided in a lamp socket. For example, the operating stage may occur when part of the LED tube lamp, such as only one

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side of the LED tube lamp, is properly connected to one side of a lamp socket, and part of the LED tube lamp is either connected to a high impedance, such as a person, and/or is improperly connected to the other side of the lamp socket (e.g., is misaligned so that the metal contacts in the socket do not contact metal contacts in the LED tube lamp). The operating stage may also occur when the entire LED tube lamp is properly connected to the lamp socket.

Referring to FIG. 15D, a detection determining circuit in accordance with certain embodiments is illustrated. An exemplary detection determining circuit **2670** includes a comparator **2671** and a resistor **2672**. The comparator **2671** may also be referred to as a first comparator **2671** and the resistor **2672** may also be referred to as a fifth resistor **2672**. A negative input terminal of the comparator **2671** receives a reference logic level signal (or a reference voltage) Vref, a positive input terminal thereof is grounded through the resistor **2672** and is also coupled to a switch circuit coupling terminal **2581**. Referring to FIGS. 15B and 15D, the signal flowing into the switch circuit **2580** from the installation detection terminal **2521** outputs to the switch circuit coupling terminal **2581** to the resistor **2672**. When the current of the signal passing through the resistor **2672** reaches a certain level (for example, bigger than or equal to a defined current for installation, (e.g. 2 A) and this makes the voltage on the resistor **2672** higher than the reference voltage Vref (referring to two end caps inserted into the lamp socket,) the comparator **2671** produces a high logic level detection result signal and outputs it to the detection result terminal **2571**. For example, when an LED tube lamp is correctly installed on a lamp socket, the comparator **2671** outputs a high logic level detection result signal at the detection result terminal **2571**, whereas the comparator **2671** generates a low logic level detection result signal and outputs it to the detection result terminal **2571** when a current passing through the resistor **2672** is insufficient to make the voltage on the resistor **2672** higher than the reference voltage Vref (referring to only one end cap inserted into the lamp socket.) Therefore, in some embodiments, when the LED tube lamp is incorrectly installed on the lamp socket or one end cap thereof is inserted into the lamp socket but the other one is grounded by an object such as a human body, the current will be too small to make the comparator **2671** output a high logic level detection result signal to the detection result terminal **2571**.

Referring to FIG. 15E, a schematic detection result latching circuit according to some embodiments of the present invention is illustrated. A detection result latching circuit **2660** includes a D flip-flop **2661**, a resistor **2662**, and an OR gate **2663**. The D flip-flop **2661** may also be referred to as a first D flip-flop **2661**, the resistor **2662** may also be referred to as a fourth resistor **2662**, and the OR gate **2663** may also be referred to as a second OR gate **2663**. The D flip-flop **2661** has a CLK input terminal coupled to a detection result terminal **2571**, and a D input terminal coupled to a driving voltage VCC. When the detection result terminal **2571** first outputs a low logic level detection result signal, the D flip-flop **2661** initially outputs a low logic level signal at a Q output terminal thereof, but the D flip-flop **2661** outputs a high logic level signal at the Q output terminal thereof when the detection result terminal **2571** outputs a high logic level detection result signal. The resistor **2662** is coupled between the Q output terminal of the D flip-flop **2661** and a reference voltage, such as ground potential. When the OR gate **2663** receives the first or second pulse signals from the pulse signal output terminal **2541** or receives a high logic level signal from the Q output terminal of the D flip-flop

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2661, the OR gate 2663 outputs a high logic level detection result latching signal at a detection result latching terminal 2561. The detection pulse generating module 2640 only in the detection stage outputs the first and the second pulse signals to make the OR gate 2663 output the high logic level detection result latching signal, and thus the D flip-flop 2661 decides the detection result latching signal to be the high logic level or the low logic level the rest of the time, e.g., including the operating stage after the detection stage. Accordingly, when the detection result terminal 2571 has no high logic level detection result signal, the D flip-flop 2661 keeps a low logic level signal at the Q output terminal to make the detection result latching terminal 2561 also keep a low logic level detection result latching signal in the detection stage. On the contrary, once the detection result terminal 2571 has a high logic level detection result signal, the D flip-flop 2661 outputs and keeps a high logic level signal (e.g., based on VCC) at the Q output terminal. In this way, the detection result latching terminal 2561 keeps a high logic level detection result latching signal in the operating stage as well.

Referring to FIG. 15F, a schematic switch circuit according to some embodiments is illustrated. A switch circuit 2680 includes a transistor, such as a bipolar junction transistor (BJT) 2681, as being a power transistor, which has the ability of dealing with high current/power and is suitable for the switch circuit. The BJT 2681 may also be referred to as a first transistor 2681. The BJT 2681 has a collector coupled to an installation detection terminal 2521, a base coupled to a detection result latching terminal 2561, and an emitter coupled to a switch circuit coupling terminal 2581. When the detection pulse generating module 2640 produces the first and second pulse signals, the BJT 2681 is in a transient conduction state. This allows the detection determining circuit 2670 to perform the detection for determining the detection result latching signal to be a high logic level or a low logic level. When the detection result latching circuit 2660 outputs a high logic level detection result latching signal at the detection result latching terminal 2561, the BJT 2681 is in the conducting state to make the installation detection terminals 2521 and 2522 conducting. In contrast, when the detection result latching circuit 2660 outputs a low logic level detection result latching signal at the detection result latching terminal 2561 and the output from detection pulse generating module 2640 is a low logic level, the BJT 2681 is cut-off or in the blocking state to make the installation detection terminals 2521 and 2522 cut-off or blocking.

Since the external driving signal is an AC signal and in order to avoid the detection error resulting from the logic level of the external driving signal being just around zero when the detection determining circuit 2670 detects, the detection pulse generating module 2640 generates the first and second pulse signals to let the detection determining circuit 2670 perform two detections. So the issue of the logic level of the external driving signal being just around zero in a single detection can be avoided. In some cases, the time difference between the productions of the first and second pulse signals is not multiple times of half one cycle of the external driving signal. For example, it does not correspond to the multiple phase differences of 180 degrees of the external driving signal. In this way, when one of the first and second pulse signals is generated and unfortunately the external driving signal is around zero, it can be avoided that the external driving signal is again around zero when the other pulse signal is generated.

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The time difference between the productions of the first and second pulse signals, for example, an interval with a defined time between both of them can be represented as following:

$$\text{the interval}=(X+Y)(T/2),$$

where T represents the cycle of an external driving signal, X is a natural number, $0<Y<1$, with Y in some embodiments in the range of 0.05-0.95, and in some embodiments in the range of 0.15-0.85.

Furthermore, in order to avoid the installation detection module entering the detection stage from misjudgment resulting from the logic level of the driving voltage VCC being too small, the first pulse signal can be set to be produced when the driving voltage VCC reaches or is higher than a defined logic level. For example, in some embodiments, the detection determining circuit 2670 works after the driving voltage VCC reaching a high enough logic level in order to prevent the installation detection module from misjudgment due to an insufficient logic level.

According to the examples mentioned above, when one end cap of an LED tube lamp is inserted into a lamp socket and the other one floats or electrically couples to a human body or other grounded object, the detection determining circuit outputs a low logic level detection result signal because of high impedance. The detection result latching circuit stores the low logic level detection result signal based on the pulse signal of the detection pulse generating module, making it as the low logic level detection result latching signal, and keeps the detection result in the operating stage, without changing the logic value. In this way, the switch circuit keeps cutting-off or blocking instead of conducting continually. And further, the electric shock situation can be prevented and the requirement of safety standard can also be met. On the other hand, when two end caps of the LED tube lamp are correctly inserted into the lamp socket, the detection determining circuit outputs a high logic level detection result signal because the impedance of the circuit for the LED tube lamp itself is small. The detection result latching circuit stores the high logic level detection result signal based on the pulse signal of the detection pulse generating module, making it as the high logic level detection result latching signal, and keeps the detection result in the operating stage. So the switch circuit keeps conducting to make the LED tube lamp work normally in the operating stage.

In some embodiments, when one end cap of the LED tube lamp is inserted into the lamp socket and the other one floats or electrically couples to a human body, the detection determining circuit outputs a low logic level detection result signal to the detection result latching circuit, and then the detection pulse generating module outputs a low logic level signal to the detection result latching circuit to make the detection result latching circuit output a low logic level detection result latching signal to make the switch circuit cutting-off or blocking. As such, the switch circuit blocking makes the installation detection terminals, e.g. the first and second installation detection terminals, blocking. As a result, the LED tube lamp is in non-conducting or blocking state.

However, in some embodiments, when two end caps of the LED tube lamp are correctly inserted into the lamp socket, the detection determining circuit outputs a high logic level detection result signal to the detection result latching circuit to make the detection result latching circuit output a high logic level detection result latching signal to make the switch circuit conducting. As such, the switch circuit conducting makes the installation detection terminals, e.g. the

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first and second installation detection terminals, conducting. As a result, the LED tube lamp operates in a conducting state.

Thus, according to the operation of the installation detection module, a first circuit, upon connection of at least one end of the LED tube lamp to a lamp socket, generates and outputs two pulses, each having a pulse width, with a time period between the pulses. The first circuit may include various of the elements described above configured to output the pulses to a base of a transistor (e.g., a BJT transistor) that serves as a switch. The pulses occur during a detection stage for detecting whether the LED tube lamp is properly connected to a lamp socket. The timing of the pulses may be controlled based on the timing of various parts of the first circuit changing from high to low logic levels, or vice versa.

The pulses can be timed such that, during that detection stage time, if the LED tube lamp is properly connected to the lamp socket (e.g., both ends of the LED tube lamp are correctly connected to conductive terminals of the lamp socket), at least one of the pulse signals occurs when an AC current from a driving signal is at a non-zero level. For example, the pulse signals can occur at intervals that are different from half of the period of the AC signal. For example, respective start points or mid points of the pulse signals, or a time between an end of the first pulse signal and a beginning of the second pulse signal may be separated by an amount of time that is different from half of the period of the AC signal (e.g., it may be between 0.05 and 0.95 percent of a multiple of half of the period of the AC signal). During a pulse that occurs when the AC signal is at a non-zero level, a switch that receives the AC signal at the non-zero level may be turned on, causing a latch circuit to change states such that the switch remains permanently on so long as the LED tube lamp remains properly connected to the lamp socket. For example, the switch may be configured to turn on when each pulse is output from the first circuit. The latch circuit may be configured to change state only when the switch is on and the current output from the switch is above a threshold value, which may indicate a proper connection to a light socket. As a result, the LED tube lamp operates in a conducting state.

On the other hand, if both pulses occur when a driving signal at the LED tube lamp has a near-zero current level, or a current level below a particular threshold, then the state of the latch circuit is not changed, and so the switch is only on during the two pulses, but then remains permanently off after the pulses and after the detection mode is over. For example, the latch circuit can be configured to remain in its present state if the current output from the switch is below the threshold value. In this manner, the LED tube lamp remains in a non-conducting state, which prevents electric shock, even though part of the LED tube lamp is connected to an electrical power source.

It is worth noting that according to certain embodiments, the width of the pulse signal generated by the detection pulse generating module is between 10 ps to 1 ms, and it is used to make the switch circuit conducting for a short period when the LED tube lamp conducts instantaneously. In some embodiments, a pulse current is generated to pass through the detection determining circuit for detecting and determining. Since the pulse is for a short time and not for a long time, the electric shock situation will not occur. Furthermore, the detection result latching circuit also keeps the detection result during the operating stage (e.g., the operating stage being the period after the detection stage and during which part of the LED tube lamp is still connected to a power source), and no longer changes the detection result

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stored previously complying with the circuit state changing. A situation resulting from changing the detection result can thus be avoided. In some embodiments, the installation detection module, such as the switch circuit, the detection pulse generating module, the detection result latching circuit, and the detection determining circuit, could be integrated into a chip and then embedded in circuits for saving the circuit cost and layout space.

As discussed in the above examples, in some embodiments, an LED tube lamp includes an installation detection circuit comprising a first circuit configured to output two pulse signals, the first pulse signal output at a first time and the second pulse signal output at a second time after the first time, and a switch configured to receive an LED driving signal and to receive the two pulse signals, wherein the two pulse signals control turning on and off of the switch. The installation detection circuit may be configured to, during a detection stage, detect during each of the two pulse signals whether the LED tube lamp is properly connected to a lamp socket. When it is not detected during either pulse signal that the LED tube lamp is properly connected to the lamp socket, the switch may remain in an off state after the detection stage. When it is detected during at least one of the pulse signals that the LED tube lamp is properly connected to the lamp socket, the switch may remain in an on state after the detection stage. The two pulse signals may occur such that they are separated by a time different from a multiple of half of a period of the LED driving signal, and such that at least one of them does not occur when the LED driving signal has a current value of substantially zero. It should be noted that although a circuit for producing two pulse signals is described, the disclosure is not intended to be limiting as such. For example, a circuit may be implemented such that a plurality of pulse signals may occur, wherein at least two of the plurality of pulse signals are separated by a time different from a multiple of half of a period of the LED driving signal, and such that at least one of the plurality of pulse signals does not occur when the LED driving signal has a current value of substantially zero.

Referring to FIG. 15G, an installation detection module according to an exemplary embodiment is illustrated. The installation detection module includes a detection pulse generating module 2740 (which may also be referred to as a detection pulse generating circuit or a first circuit), a detection result latching circuit 2760 (which may also be referred to as a second circuit), a switch circuit 2780 (which may also be referred to as a third circuit), and a detection determining circuit 2770 (which may also be referred to as a fourth circuit). The detection pulse generating module 2740 is coupled (e.g., electrically connected) to the detection result latching circuit 2760 via a path 2741, and is configured to generate at least one pulse signal. A path as described herein may include a conductive line connecting between two components, circuits, or modules, and may include opposite ends of the conductive line connected to the respective components, circuits or modules. The detection result latching circuit 2760 is coupled (e.g., electrically connected) to the switch circuit 2780 via a path 2761, and is configured to receive and output the pulse signal(s) from the detection pulse generating module 2740. The switch circuit 2780 is coupled (e.g., electrically connected) to one end (e.g., a first installation detection terminal 2521) of a power loop of an LED tube lamp and the detection determining circuit 2770, and is configured to receive the pulse signal(s) output from the detection result latching circuit 2760, and configured to conduct (or turn on) during the pulse signal(s) so as to cause the power loop of the LED tube lamp to be

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conducting. The detection determining circuit 2770 is coupled (e.g., electrically connected) to the switch circuit 2780, the other end (e.g., a second installation detection terminal 2522) of the power loop of the LED tube lamp and the detection result latching circuit 2760, and is configured to detect at least one sample signal on the power loop when the switch circuit 2780 and the power loop are conductive, so as to determine an installation state between the LED tube lamp and a lamp socket. The power loop of the present embodiment can be regarded as a detection path of the installation detection module. The detection determining circuit 2770 is further configured to transmit detection result(s) to the detection result latching circuit 2760 for next control. In some embodiments, the detection pulse generating module 2740 is further coupled (e.g., electrically connected) to the output of the detection result latching circuit 2760 to control the time of the pulse signal(s).

In some embodiments, one end of a first path 2781 is coupled to a first node of the detection determining circuit 2770 and the opposite end of the first path 2781 is coupled to a first node of the switch circuit 2780. In some embodiments, a second node of the detection determining circuit 2770 is coupled to the second installation detection terminal 2522 of the power loop and a second node of the switch circuit 2780 is coupled to the first installation detection terminal 2521 of the power loop. In some embodiments, one end of a second path 2771 is coupled to a third node of the detection determining circuit 2770 and the opposite end of the second path 2771 is coupled to a first node of the detection result latching circuit 2760, one end of a third path 2741 is coupled to a second node of the detection result latching circuit 2760 and the opposite end of the third path 2741 is coupled to a first node of the detection pulse generating circuit 2740. In some embodiments, one end of a fourth path 2761 is coupled to a third node of the switch circuit 2780 and the opposite end of the fourth path 2761 is coupled to a third node of the detection result latching circuit 2760. In some embodiments, the fourth path 2761 is also coupled to a second node of the detection pulse generating circuit 2740.

In some embodiments, the detection determining circuit 2770 is configured for detecting a signal between the first installation detection terminal 2521 and the second installation detection terminal 2522 through the first path 2781 and the switch circuit 2780. For example, because of the above configuration, the detection determining circuit 2770 is capable of detecting and determining whether a current passing through the first installation detection terminal 2521 and the second installation detection terminal 2522 is below or above a predetermined current value and transmitting or providing a detection result signal to the detection result latching circuit 2760 via the second path 2771.

In some embodiments, the detection pulse generating circuit 2740, also referred to generally as a pulse generating circuit, generates a pulse signal through the detection result latching circuit 2760 to make the switch circuit 2780 remain in a conducting state during the pulse signal. For example, the pulse signal generated by the detection pulse generating circuit 2740 controls turning on the switch circuit 2780 which is coupled to the detection pulse generating circuit 2740. As a result of maintaining a conducting state of the switch circuit 2780, the power loop of the LED tube lamp between the installation detection terminals 2521 and 2522 is also maintained in a conducting state. The detection determining circuit 2770 detects a sample signal on the power loop and generates a signal based on a detection result to inform the detection result latching circuit 2760 of a time

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point for latching (storing) the detection result received by the detection result latching circuit 2760 from the detection determining circuit 2770. For example, the detection determining circuit 2770 may be a circuit configured to generate a signal that causes a latching circuit, such as the detection result latching circuit 2760 to enter and remain in a state that corresponds to one of a conducting state (e.g., "on" state) or a cut-off state for the LED tube lamp. The detection result latching circuit 2760 stores the detection result according to the detection result signal (or detection result signal and pulse signal), and transmits or provides the detection result to the switch circuit 2780 coupled to the third node of the detection result latching circuit 2760 via the fourth path 2761. The switch circuit 2780 receives the detection result transmitted from the detection result latching circuit 2760 via the third node of the switch circuit 2780 and controls the state between conducting or cut off between the installation detection terminals 2521 and 2522 according to the detection result. For example, when the detection determining circuit 2770 detects during the pulse signal that the LED tube lamp is not properly installed on the lamp socket, the pulse signal controls the switch circuit to remain in an off state to cause a power loop of the LED tube lamp to be open, and when the detection determining circuit 2770 detects during the pulse signal that the LED tube lamp is properly installed on the lamp socket, the pulse signal controls the switch circuit to remain in a conducting state to cause the power loop of the LED tube lamp to maintain a conducting state.

The detailed circuit architecture and the entire operation thereof of each of the detection pulse generating module 2740 (or circuit), the detection result latching circuit 2760, the switch circuit 2780, and the detection determining circuit 2770 will be described below.

Referring to FIG. 15H, a detection pulse generating module according to an exemplary embodiment is illustrated. The detection pulse generating module 2740 includes: a resistor 2742 (which also may be referred to as a sixth resistor), a capacitor 2743 (which also may be referred to as a fourth capacitor), a Schmitt trigger 2744, a resistor 2745 (which also may be referred to as a seventh resistor), a transistor 2746 (which also may be referred to as a second transistor), and a resistor 2747 (which also may be referred to as an eighth resistor).

In some embodiments, one end of the resistor 2742 is connected to a driving signal, for example, Vcc, and the other end of the resistor 2742 is connected to one end of the capacitor 2743. The other end of the capacitor 2743 is connected to a ground node. In some embodiments, the Schmitt trigger 2744 has an input end and an output end, the input end connected to a connection node of the resistor 2742 and the capacitor 2743, the output end connected to the detection result latching circuit 2760 via the third path 2741 (FIG. 15G). In some embodiments, one end of the resistor 2745 is connected to the connection node of the resistor 2742 and the capacitor 2743 and the other end of the resistor 2745 is connected to a collector of the transistor 2746. An emitter of the transistor 2746 is connected to a ground node. In some embodiments, one end of the resistor 2747 is connected to a base of the transistor 2746 and the other end of the resistor 2747 is connected to the detection result latching circuit 2760 (FIG. 15G) and the switch circuit 2780 (FIG. 15G) via the fourth path 2761. In certain embodiments, the detection pulse generating module 2740 further includes: a Zener diode 2748, having an anode and a cathode, the anode connected to the other end of the capaci-

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tor 2743 to the ground, the cathode connected to the end of the capacitor 2743 (the connection node of the resistor 2742 and the capacitor 2743).

Referring to FIG. 15I, a detection result latching circuit according to an exemplary embodiment is illustrated. The detection result latching circuit 2760 includes: a D flip-flop 2762 (which also may be referred to as a second D flip-flop), having a data input end D, a clock input end CLK, and an output end Q, the data input end D connected to the driving signal mentioned above (e.g., Vcc), the clock input end CLK connected to the detection determining circuit 2770 (FIG. 15G); and an OR gate 2763 (which also may be referred to as a third OR gate), having a first input end, a second input end, and an output end, the first input end connected to the output end of the Schmitt trigger 2744 (FIG. 15H), the second input end connected to the output end Q of the D flip-flop 2762, the output end of the OR gate 2763 connected to the other end of the resistor 2747 (FIG. 15H) and the switch circuit 2780 (FIG. 15G).

Referring to FIG. 15J, a switch circuit according to an exemplary embodiment is illustrated. The switch circuit 2780 includes: a transistor 2782 (which also may be referred to as a third transistor), having a base, a collector, and an emitter, the base connected to the output of the OR gate 2763 via the fourth path 2761 (FIG. 15I), the collector connected to one end of the power loop, such as the first installation detection terminal 2521, the emitter connected to the detection determining circuit 2770 (FIG. 15G). In some embodiments, the transistor 2782 may be replaced by other equivalently electronic parts, e.g., a MOSFET.

Referring to FIG. 15K, a detection determining circuit according to an exemplary embodiment is illustrated. The detection determining circuit 2770 includes: a resistor 2774 (which also may be referred to as a ninth resistor), one end of the resistor 2774 connected to the emitter of the transistor 2782 (FIG. 15J), the other end of the resistor 2774 connected to the other end of the power loop, such as the second installation detection terminal 2522; a diode 2775 (which also may be referred to as a second diode), having an anode and a cathode, the anode connected to an end of the resistor 2744 that is not connected to a ground node; a comparator 2772 (which also may be referred to as a second comparator), having a first input end, a second input end, and an output end; a comparator 2773 (which also may be referred to as a third comparator), having a first input end, a second input end, and an output end; a resistor 2776 (which also may be referred to as a tenth resistor); a resistor 2777 (which also may be referred to as an eleventh resistor); and a capacitor 2778 (which also may be referred to as a fifth capacitor).

In some embodiments, the first input end of the comparator 2772 is connected to a predefined signal, for example, a reference voltage, $V_{ref}=1.3V$, but the reference voltage value is not limited thereto, the second input end of the comparator 2772 is connected to the cathode of the diode 2775, and the output end of the comparator 2772 is connected to the clock input end of the D flip-flop 2762 (FIG. 15I). In some embodiments, the first input end of the comparator 2773 is connected to the cathode of the diode 2775, the second input end of the comparator 2773 is connected to another predefined signal, for example, a reference voltage, $V_{ref}=0.3V$, but the reference voltage value is not limited thereto, and the output end of the comparator 2773 is connected to the clock input end of the D flip-flop 2762 (FIG. 15I). In some embodiments, one end of the resistor 2776 is connected to the driving signal mentioned above (e.g., Vcc) and the other end of the resistor

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2776 is connected to the second input end of the comparator 2772 and one end of the resistor 2777 that is not connected to a ground node and the other end of the resistor 2777 is connected to the ground node. In some embodiments, the capacitor 2778 is connected to the resistor 2777 in parallel. In certain embodiments, the diode 2775, the comparator 2773, the resistors 2776 and 2777, and the capacitor 2778 may be omitted, and the second input end of the comparator 2772 may be directly connected to the end of the resistor 2774 (e.g., the end of the resistor 2774 that is not connected to the ground node) when the diode 2775 is omitted. In certain embodiments, the resistor 2774 may include two resistors connected in parallel based on the consideration of power consumption having an equivalent resistance value ranging from about 0.1 ohm to about 5 ohm.

In some embodiments, some parts of the installation detection module may be integrated into an integrated circuit (IC) in order to provide reduced circuit layout space resulting in reduced manufacturing cost of the circuit. For example, the Schmitt trigger 2744 of the detection pulse generating module 2740, the detection result latching circuit 2760, and the two comparators 2772 and 2773 of the detection determining circuit 2770 may be integrated into an IC, but the disclosure is not limited thereto.

An operation of the installation detection module will be described in more detail in accordance with some example embodiments. In one exemplary embodiment, the capacitor voltage may not mutate; the voltage of the capacitor in the power loop of the LED tube lamp before the power loop is conductive is zero and the capacitor's transient response may appear to have a short-circuit condition; when the LED tube lamp is correctly installed to the lamp socket, the power loop of the LED tube lamp in a transient response may have a smaller current-limiting resistance and a bigger peak current; and when the LED tube lamp is incorrectly installed to the lamp socket, the power loop of the LED tube lamp in transient response may have a bigger current-limiting resistance and a smaller peak current. This embodiment may also meet the UL standard to make the leakage current of the LED tube lamp less than 5 MIU. The following table illustrates the current comparison in a case when the LED tube lamp works normally (e.g., when the two end caps of the LED tube lamp are correctly installed to the lamp socket) and in a case when the LED tube lamp is incorrectly installed to the lamp socket (e.g., when one end cap of the LED tube lamp is installed to the lamp socket but the other one is touched by a human body).

	Correct installation	Incorrect installation
Maximum transient current		$i_{pk_max} = \frac{V_{in_pk}}{R_{fuse} + 500}$ $= \frac{305 \times 1.414}{10 + 500} = 845 \text{ mA}$
Minimum transient current	$i_{pk_min} = \frac{\Delta V_{in}}{R_{fuse}}$ $= \frac{50}{10} = 5 \text{ A}$	

As illustrated in the above table, in the part of the denominator: R_{fuse} represents the resistance of the fuse of the LED tube lamp. For example, 10 ohm may be used, but the disclosure is not limited thereto, as resistance value for R_{fuse} in calculating the minimum transient current i_{pk_min} and 510 ohm may be used as resistance value for R_{fuse} in

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calculating the maximum transient current ipk_max (an additional 500 ohms is used to emulate the conductive resistance of human body in transient response). In the part of the numerator: maximum voltage from the root-mean-square voltage ($V_{max}=V_{rms}*1.414=305*1.414$) is used in calculating the maximum transient current ipk_max and minimum voltage difference, for example, 50V (but the disclosure is not limited thereto) is used in calculating the minimum transient current ipk_min . Accordingly, when the LED tube lamp is correctly installed to the lamp socket (e.g., when two end caps of the LED tube lamp are installed to the lamp socket correctly) and works normally, its minimum transient current is 5 A. But, when the LED tube lamp is incorrectly installed to the lamp socket (e.g., when one end cap is installed to the lamp socket but the other one is touched by human body), its maximum transient current is only 845 mA. Therefore, certain examples of the disclosed embodiments use the current which passes transient response and flows through the capacitor in the LED power loop, such as the capacitor of the filtering circuit, to detect and determine the installation state between the LED tube lamp and the lamp socket. For example, such embodiments may detect whether the LED tube lamp is correctly installed to the lamp socket. Certain examples of the disclosed embodiments further provide a protection mechanism to protect the user from electric shock caused by touching the conductive part of the LED tube lamp which is incorrectly installed to the lamp socket. The embodiments mentioned above are used to illustrate certain aspects of the disclosed invention but the disclosure is not limited thereto.

Further, referring to FIG. 15G again, in some embodiments, when an LED tube lamp is being installed to a lamp socket, after a period (e.g., the period utilized to determine the cycle of a pulse signal), the detection pulse generating module 2740 outputs a first high level voltage rising from a first low level voltage to the detection result latching circuit 2760 through a path 2741 (also referred to as a third path). The detection result latching circuit 2760 receives the first high level voltage, and then simultaneously outputs a second high level voltage to the switch circuit 2780 and the detection pulse generating module 2740 through a path 2761 (also referred to as a fourth path). In some embodiments, when the switch circuit 2780 receives the second high level voltage, the switch circuit 2780 conducts to cause the power loop of the LED tube lamp to be conducting as well. In this exemplary embodiment, the power loop at least includes the first installation detection terminal 2521, the switch circuit 2780, the path 2781 (also referred to as a first path), the detection determining circuit 2770, and the second installation detection terminal 2522. In the meantime, the detection pulse generating module 2740 receives the second high level voltage from the detection result latching circuit 2760, and after a period (e.g., the period utilized to determine the width (or period) of pulse signal), its output from the first high level voltage falls back to the first low level voltage (the first time of the first low level voltage, the first high level voltage, and the second time of the first low level voltage form a first pulse signal). In some embodiments, when the power loop of the LED tube lamp is conductive, the detection determining circuit 2770 detects a first sample signal, such as a voltage signal, on the power loop. When the first sample signal is greater than or equal to a predefined signal, such as a reference voltage, the installation detection module determines that the LED tube lamp is correctly installed to the lamp socket according to the application principle of this disclosed embodiments described above. Therefore, the detection determining circuit 2770 included in the installa-

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tion detection module outputs a third high level voltage (also referred to as a first high level signal) to the detection result latching circuit 2760 through a path 2771 (also referred to as a second path). The detection result latching circuit 2760 receives the third high level voltage (also referred to as the first high level signal) and continues to output a second high level voltage (also referred to as a second high level signal) to the switch circuit 2780. The switch circuit 2780 receives the second high level voltage (also referred to as the second high level signal) and maintains conducting state to cause the power loop to remain conducting. The detection pulse generating module 2740 does not generate any pulse signal while the power loop remains conductive.

However, in some embodiments, when the first sample signal is smaller than the predefined signal, the installation detection module, according to certain exemplary embodiments as described above, determines that the LED tube lamp has not been correctly installed to the lamp socket. Therefore, the detection determining circuit 2770 outputs a third low level voltage (also referred to as a first low level signal) to the detection result latching circuit 2760. The detection result latching circuit 2760 receives the third low level voltage (also referred to as the first low level signal) and continues to output a second low level voltage (also referred to as a second low level signal) to the switch circuit 2780. The switch circuit 2780 receives the second low level voltage (also referred to as the second low level signal) and then keeps blocking to cause the power loop to remain open. Accordingly, the occurrence of electric shock caused by touching the conductive part of the LED tube lamp which is incorrectly installed on the lamp socket can be sufficiently avoided.

In some embodiments, when the power loop of the LED tube lamp remains open for a period (a period that represents the cycle of pulse signal), the detection pulse generating module 2740 outputs the first high level voltage rising from the first low level voltage to the detection result latching circuit 2760 through the path 2741 once more. The detection result latching circuit 2760 receives the first high level voltage, and then simultaneously outputs a second high level voltage to the switch circuit 2780 and the detection pulse generating module 2740. In some embodiments, when the switch circuit 2780 receives the second high level voltage, the switch circuit 2780 conducts again to cause the power loop of the LED tube lamp (in this exemplary embodiment, the power loop at least includes the first installation detection terminal 2521, the switch circuit 2780, the path 2781, the detection determining circuit 2770, and the second installation detection terminal 2522) to be conducting as well. In the meantime, the detection pulse generating module 2740 receives the second high level voltage from the detection result latching circuit 2760, and after a period (a period that is utilized to determine the width (or period) of pulse signal), its output from the first high level voltage falls back to the first low level voltage (the third time of the first low level voltage, the second time of the first high level voltage, and the fourth time of the first low level voltage form a second pulse signal). In some embodiments, when the power loop of the LED tube lamp is conductive again, the detection determining circuit 2770 also detects a second sample signal, such as a voltage signal, on the power loop yet again. When the second sample signal is greater than or equal to the predefined signal, the installation detection module determines, according to certain exemplary embodiments described above, that the LED tube lamp is correctly installed to the lamp socket. Therefore, the detection determining circuit 2770 outputs a third high level voltage (also

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referred to as a first high level signal) to the detection result latching circuit 2760 through the path 2771. The detection result latching circuit 2760 receives the third high level voltage (also referred to as the first high level signal) and continues to output a second high level voltage (also referred to as a second high level signal) to the switch circuit 2780. The switch circuit 2780 receives the second high level voltage (also referred to as the second high level signal) and maintains a conducting state to cause the power loop to remain conducting. The detection pulse generating module 2740 does not generate any pulse signal while the power loop remains conductive.

In some embodiments, when the second sample signal is smaller than the predefined signal, the installation detection module determines, according to certain exemplary embodiments described above, that the LED tube lamp has not been correctly installed to the lamp socket. Therefore, the detection determining circuit 2770 outputs the third low level voltage (also referred to as the first low level signal) to the detection result latching circuit 2760. The detection result latching circuit 2760 receives the third low level voltage (also referred to as the first low level signal) and continues to output the second low level voltage (also referred to as the second low level signal) to the switch circuit 2780. The switch circuit 2780 receives the second low level voltage (also referred to as the second low level signal) and then keeps blocking to cause the power loop to remain open. According to the disclosure mentioned above, the pulse width (i.e., pulse on-time) and the pulse period are dominated by the pulse signal provided by the detection pulse generating module 2740 during the detection stage; and the signal level of the control signal is determined according to the detection result signal provided by the detection determining circuit 2770 after the detection stage.

Next, referring to FIG. 15H to FIG. 15K at the same time, in some embodiments when an LED tube lamp is being installed to a lamp socket, the capacitor 2743 is charged by the driving signal, for example, Vcc, through the resistor 2742. And when the voltage of the capacitor 2743 rises enough to trigger the Schmitt trigger 2744, the Schmitt trigger 2744 outputs a first high level voltage rising from a first low level voltage in an initial state to an input end of the OR gate 2763. After the OR gate 2763 receives the first high level voltage from the Schmitt trigger 2744, the OR gate 2763 outputs a second high level voltage to the base of the transistor 2782 and the resistor 2747. When the base of the transistor 2782 receives the second high level voltage from the OR gate 2763, the collector and the emitter of the transistor 2782 are conducting to further cause the power loop of the LED tube lamp (in this exemplary embodiment, the power loop at least includes the first installation detection terminal 2521, the transistor 2782, the resistor 2744, and the second installation detection terminal 2522) to be conducting as well. In the meantime, the base of the transistor 2746 receives the second high level voltage from the OR gate 2763 through the resistor 2747, and then the collector and the emitter of the transistor 2746 are conductive and grounded to cause the voltage of the capacitor 2743 to be discharged to the ground through the resistor 2745. In some embodiments, when the voltage of the capacitor 2743 is not enough to trigger the Schmitt trigger 2744, the Schmitt trigger 2744 outputs the first low level voltage falling from the first high level voltage (a first instance of a first low level voltage at a first time, followed by a first high level voltage, followed by a second instance of the first low level voltage at a second time form a first pulse signal). When the power loop of the LED tube lamp is conductive, the current passing

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through the capacitor in the power loop, such as, the capacitor of the filtering circuit, by transient response flows through the transistor 2782 and the resistor 2774 and forms a voltage signal on the resistor 2774. The voltage signal is compared to a reference voltage, for example, 1.3V, but the reference voltage is not limited thereto, by the comparator 2772. When the voltage signal is greater than and/or equal to the reference voltage, the comparator 2772 outputs a third high level voltage to the clock input end CLK of the D flip-flop 2762. In the meantime, since the data input end D of the D flip-flop 2762 is connected to the driving signal, the D flip-flop 2762 outputs a high level voltage (at its output end Q) to another input end of the OR gate 2763. This causes the OR gate 2763 to keep outputting the second high level voltage to the base of the transistor 2782, and further results in the transistor 2782 and the power loop of the LED tube lamp remaining in a conducting state. Besides, since the OR gate 2763 keeps outputting the second high level voltage to cause the transistor 2746 to be conducting to the ground, the capacitor 2743 is unable to reach an enough voltage to trigger the Schmitt trigger 2744.

However, when the voltage signal on the resistor 2774 is smaller than the reference voltage, the comparator 2772 outputs a third low level voltage to the clock input end CLK of the D flip-flop 2762. In the meantime, since the initial output of the D flip-flop 2762 is a low level voltage (e.g., zero voltage), the D flip-flop 2762 outputs a low level voltage (at its output end Q) to the other input end of the OR gate 2763. Moreover, the Schmitt trigger 2744 connected by the input end of the OR gate 2763 also restores outputting the first low level voltage, the OR gate 2763 thus keeps outputting the second low level voltage to the base of the transistor 2782, and further results in the transistor 2782 to remain in a blocking state (or an off state) and the power loop of the LED tube lamp to remain in an open state. Still, since the OR gate 2763 keeps outputting the second low level voltage to cause the transistor 2764 to remain in a blocking state (or an off state), the capacitor 2743 is charged by the driving signal through the resistor 2742 once again for next (pulse signal) detection.

In some embodiments, the cycle (or interval) of the pulse signal is determined by the values of the resistor 2742 and the capacitor 2743. In certain cases, the cycle of the pulse signal may include a value ranging from about 3 milliseconds to about 500 milliseconds or may be ranging from about 20 milliseconds to about 50 milliseconds. In some embodiments, the width (or period) of the pulse signal is determined by the values of the resistor 2745 and the capacitor 2743. In certain cases, the width of the pulse signal may include a value ranging from about 1 microsecond to about 100 microseconds or may be ranging from about 10 microseconds to about 20 microseconds. The Zener diode 2748 provides a protection function but it may be omitted in certain cases. The resistor 2744 may include two resistors connected in parallel based on the consideration of power consumption in certain cases, and its equivalent resistance may include a value ranging from about 0.1 ohm to about 5 ohm. The resistors 2776 and 2777 provides the function of voltage division to make the input of the comparator 2773 bigger than the reference voltage, such as 0.3V, but the value of the reference voltage is not limited thereto. The capacitor 2778 provides the functions of regulation and filtering. The diode 2775 limits the signal to be transmitted in one way. In addition, the installation detection module disclosed by the example embodiments may also be adapted to other types of LED lighting equipment with dual-end power supply, e.g., the LED lamp directly using commercial power as its

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external driving signal, the LED lamp using the signal outputted from the ballast as its external driving signal, etc. However, the invention is not limited to the above example embodiments.

Based on the embodiments illustrated in FIG. 15G to FIG. 15K, compared to the installation detection module of FIG. 15B, the installation detection module illustrated in FIG. 15G uses the control signal output by the detection result latching circuit 2760 for the reference of determining the end of the pulse or resetting the pulse signal by feeding back the control signal to the detection pulse generating module 2740. Since the pulse on-time is not merely determined by the detection pulse generating module 2740, the circuit design of the detection pulse generating module can be simplified. Compared to the detection pulse generating module illustrated in FIG. 15C, the number of the components of the detection pulse generating module illustrated in FIG. 15H is less than the detection pulse generating module 2640, and thus the detection pulse generating module 2740 may have lower power consumption and may be more suitable for integrated design.

Referring to FIG. 15L, a block diagram of an installation detection module according to an exemplary embodiment is illustrated. The installation detection module 2520 includes a pulse generating auxiliary circuit 2840, an integrated control module 2860, a switch circuit 2880, and a detection determining auxiliary circuit 2870. The integrated control module 2860 includes at least three pins such as two input terminals IN1 and IN2 and an output terminal OT. The pulse generating auxiliary circuit 2840 is connected to the input terminal IN1 and the output terminal OT of the integrated control module 2860 and configured to assist the integrated control module 2860 for generating a control signal. The detection determining auxiliary circuit 2870 is connected to the input terminal IN2 of the integrated control module 2860 and the switch circuit 2880 and configured to transmit a sample signal related to the signal passing through the LED power loop to the input terminal IN2 of the integrated control module 2860 when the switch circuit 2880 and the LED power loop are conducting, such that the integrated control module 2860 may determine an installation state between the LED tube lamp and the lamp socket according to the sample signal. For example, the sample signal may be based on an electrical signal passing through the power loop during the pulse-on time of the pulse signal (e.g., the rising portion of the pulse signal). Switch circuit 2880 is connected between one end of the LED power loop and the detection determining auxiliary circuit 2870 and configured to receive the control signal, outputted by the integrated control module 2860, in which the LED power loop is conducting during an enable period of the control signal.

Specifically, under the detection stage, the integrated control module 2860 temporarily causes the switch circuit 2880 to conduct, according to the signal received from the input terminal IN1, by outputting the control signal having at least one pulse. During the detection stage, the integrated control module 2860 may detect whether the LED tube lamp is properly connected to the lamp socket and latch the detection result according to the signal on the input terminal IN2. The detection result is regarded as the basis of whether to cause the switch circuit 2880 to conduct after the detection stage (i.e., it determines whether to provide power to LED module). The detail circuit structure and operations of the present embodiment will be described below.

Referring to FIG. 15M, an inner circuit diagram of an integrated control module according to some exemplary embodiments is illustrated. The integrated control module

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includes a pulse generating unit 2862, a detection result latching unit 2863, and a detection unit 2864. The pulse generating unit 2862 receives the signal provided by the pulse generating auxiliary circuit 2840 from the input terminal IN1 and accordingly generates a pulse signal. The generated pulse signal will be provided to the detection result latching unit 2863. In an exemplary embodiment, the pulse generating unit 2862 can be implemented by a Schmitt trigger (not shown, it can use a Schmitt trigger such as 2744 illustrated in FIG. 15H). According to the exemplary embodiment mentioned above, the Schmitt trigger has an input end coupled to the input terminal IN1 of the integrated control module 2860 and an output terminal coupled to the output terminal OT of the integrated control module 2860 (e.g., through the detection result latching unit 2863). It should be noted that, the pulse generating unit 2862 is not limited to be implemented by the Schmitt trigger, any analog/digital circuit capable of implementing the function of generating the pulse signal having at least one pulse may be utilized in the disclosed embodiments.

The detection result latching unit 2863 is connected to the pulse generating unit 2862 and the detection unit 2864. During the detection stage, the detection result latching unit 2863 outputs the pulse signal generated by the pulse generating unit 2862 as the control signal to the output terminal OT. On the other hand, the detection result latching unit 2863 further stores the detection result signal provided by the detection unit 2864 and outputs the stored detection result signal to the output terminal OT after the detection stage, so as to determine whether to cause the switch circuit 2880 to conduct according to the installation state of the LED tube lamp. In an exemplary embodiment, the detection latching unit 2863 can be implemented by a circuit structure constituted by a D flip-flop and an OR gate (not shown, for example it can use the D flip-flop 2762 and OR gate 2763 illustrated in FIG. 15I). According to the exemplary embodiment mentioned above, the D flip-flop has a data input end connected to the driving voltage VCC, a clock input end connected to the detection unit 2864, and an output end. The OR gate has a first input end connected to the pulse generating unit 2862, a second input end connected to the output end of the D flip-flop, and an output end connected to the output terminal OT. It should be noted that, the detection result latching unit 2863 is not limited to be implemented by the aforementioned circuit structure, any analog/digital circuit capable of implementing the function of latching and outputting the control signal to control the switching of the switch circuit may be utilized in the present invention.

The detection unit 2864 is coupled to the detection result latching unit 2863. The detection unit 2864 receives the signal provided by the detection determining auxiliary circuit 2870 from the input terminal IN2 and accordingly generates the detection result signal indicating the installation state of the LED tube lamp, in which the generated detection result signal will be provided to the detection result latching unit 2863. In an exemplary embodiment, detection unit 2864 can be implemented by a comparator (not shown, it can be, for example, the comparator 2772 illustrated in FIG. 15K). According to the exemplary embodiment mentioned above, the comparator has a first input end receiving a setting signal, a second input end connected to the input terminal IN2, and an output end connected to the detection result latching unit 2863. It should be noted that, the detection unit 2864 is not limited to be implemented by the comparator, any analog/digital circuit capable of implementing the function of determining

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the installation state based on the signal on the input terminal IN2 may be utilized in the disclosed embodiments.

Referring to FIG. 15N, a circuit diagram of a pulse generating auxiliary circuit according to some exemplary embodiments is illustrated. The pulse generating auxiliary circuit 2840 includes resistors 2842, 2844, and 2846, a capacitor 2843, and a transistor 2845. The resistor 2842 has an end connected to a driving voltage (e.g., VCC). The capacitor 2843 has an end connected to another end of the resistor 2842, and another end connected to ground. The resistor 2844 has an end connected to the connection node of the resistor 2842 and the capacitor 2843. The transistor 2845 has a base, a collector connected to another end of the resistor 2844, and an emitter connected to the ground. The resistor 2846 has an end connected to the base of the transistor 2845, and another end connected to the output terminal OT of the integrated control module 2840 and the control terminal of the switch circuit 2880 via the path 2841. The pulse generating auxiliary circuit 2840 further includes a Zener diode 2847. The Zener diode 2847 has an anode connected to another end of the capacitor 2843 and the ground and a cathode connected to the end connecting the capacitor 2843 and the resistor 2842.

Referring to FIG. 15O, a circuit diagram of a detection determining auxiliary circuit according to some exemplary embodiments is illustrated. The detection determining auxiliary circuit 2870 includes resistors 2872, 2873 and 2874, a capacitor 2875 and diode 2876. The resistor 2872 has an end connected to the switch circuit 2880, and another end connected to another end of the LED power loop (e.g., the second installation detection terminal 2522). The resistor 2873 has an end connected to the driving voltage (e.g., VCC). The resistor 2874 has an end connected to another end of the resistor 2873 and the input terminal IN2 of the integrated control module 2860 via the path 2871, and another end connected to the ground. The capacitor 2875 is connected to the resistor 2874 in parallel. The diode 2876 has an anode connected to the end of the resistor 2872 and a cathode connected to the connection node of the resistors 2873 and 2874. In one exemplary embodiment, the resistors 2873 and 2874, the capacitor 2875, and the diode 2876 can be omitted. When the diode 2876 is omitted, one end of the resistor 2872 is directly connected to the input terminal IN2 of the integrated control module 2860 via the path 2871. In another one exemplary embodiment, the resistor 2872 can be implemented by two paralleled resistors based on the power consideration, in which the equivalent resistance of each resistors can be 0.1 ohm to 5 ohm.

Referring to FIG. 15P, a circuit diagram of a switch circuit according to some exemplary embodiments is illustrated. The switch circuit 2880 includes a transistor 2882. The transistor 2882 has a base connected to the output terminal OT of the integrated control module 2860 via the path 2861, a collector connected to one end of the LED power loop (e.g., the first installation detection terminal 2521), and an emitter connected to the detection determining auxiliary circuit. In some embodiments, the transistor 2882 may be replaced by other equivalently electronic parts, e.g., a MOS-FET.

It should be noted that, the installation detection module of the present embodiment utilizes the same installation detection principle as the aforementioned embodiment. For example, the capacitor voltage may not mutate; the voltage of the capacitor in the power loop of the LED tube lamp before the power loop being conductive is zero and the capacitor's transient response may appear to have a short-circuit condition; when the LED tube lamp is correctly

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installed to the lamp socket, the power loop of the LED tube lamp in transient response may have a smaller current-limiting resistance and a bigger peak current; and when the LED tube lamp is incorrectly installed to the lamp socket, the power loop of the LED tube lamp in transient response may have a bigger current-limiting resistance and a smaller peak current. This embodiment may also meet the UL standard to make the leakage current of the LED tube lamp less than 5 MIU. For example, the present embodiment may determine whether the LED tube lamp is correctly/properly connected to the lamp socket by detecting the transient response of the peak current. Therefore, the detail operation of the transient current under the correct installation state and the incorrect installation state may be seen by referring to the aforementioned embodiment, and it will not be repeated herein. The following disclosure will focus on describing the entire circuit operation of the installation detection module illustrated in FIG. 15L to 15P.

Referring to FIG. 15L again, when an LED tube lamp is being installed to a lamp socket, the driving voltage may be provided to modules/circuits within the installation detection module 2520 when power is provided to at least one end cap of the LED tube lamp. The pulse generating auxiliary circuit 2840 starts charging in response to the driving voltage. The output voltage (referred to "first output voltage" hereinafter) of the pulse generating auxiliary circuit 2840 rises from a first low level voltage to a voltage level greater than a forward threshold voltage after a period (e.g., the period utilized to determine the cycle of a pulse signal), in which the first output voltage may output to the input terminal of the integrated control module 2860 via the path 2841. After receiving the first output voltage from the input terminal IN1, the integrated control module 2860 outputs an enabled control signal (e.g., a high level voltage) to the switch circuit 2880 and the pulse generating auxiliary circuit 2840. When the switch circuit 2880 receives the enabled control signal, the switch circuit 2880 is turned on so that a power loop of the LED tube lamp is conducted as well. Herein, at least the first installation detection terminal 2521, the switch circuit 2880, the path 2881, the detection determining auxiliary circuit 2870 and the second installation detection terminal 2522 are included in the power loop. In the meantime, the pulse generating auxiliary circuit 2840 conducts a discharge path for discharging in response to the enabled control signal. The first output voltage falls down to the first low level voltage from the voltage greater than the forward threshold voltage. When the first output voltage is less than a reverse threshold voltage (which can be defined based on the circuit design), the integrated control module 2860 pulls the enabled control signal down to a disable level in response to the first output voltage (i.e., the integrated control module 2860 outputs a disabled control signal, in which the disabled control signal is, for example, a low level voltage), and thus the control signal has a pulse-type signal waveform (i.e., the first time of the first low level voltage, the first high level voltage, and the second time of the first low level voltage form a first pulse signal). When the power loop is conducting, the detection determining auxiliary circuit 2870 detects a first sample signal (e.g., voltage signal) on the power loop and provides the first sample signal to the integrated control module 2860 via the input terminal IN2. When the integrated control module 2860 determines the first sample signal is greater than or equal to a setting signal (e.g., a reference voltage), which may represent the LED tube lamp has been properly installed on the lamp socket, the integrated control module 2860 outputs and keeps the enabled control signal to the switch circuit

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2880. Since receiving the enabled control signal, the switch circuit **2880** remains in the conductive state so that the power loop of the LED tube lamp is kept on the conductive state as well. During the period when the switch circuit **2880** receives the enabled control signal, the integrated control module **2860** does not output the pulses anymore.

On the contrary, when the integrated control module **2860** determines the first sample signal is less than the setting signal, which may represent the LED tube lamp has not been properly installed on the lamp socket yet, the integrated control module **2860** outputs and keeps the disabled control signal to the switch circuit **2880**. As a result of receiving the disabled control signal, the switch circuit **2880** remains in the non-conducting state so that the power loop of the LED tube lamp is kept on the non-conducting state as well.

Since the discharge path of the pulse generating auxiliary circuit **2840** is cut off, the pulse generating auxiliary circuit **2840** starts to charge again. Therefore, after the power loop of the LED tube lamp remains in a non-conducting state for a period (i.e., pulse on-time), the first output voltage of the pulse generating auxiliary circuit **2840** rises from the first low level voltage to the voltage greater than the forward threshold voltage again, in which the first output voltage may output to the input terminal of the integrated control module **2860** via the path **2841**. After receiving the first output voltage from the input terminal IN1, the integrated control module **2860** pulls up the control signal from the disable level to an enable level (i.e., the integrated control module **2860** outputs the enabled control signal) and provides the enabled control signal to the switch circuit **2880** and the pulse generating auxiliary circuit **2840**. When the switch circuit **2880** receives the enabled control signal, the switch circuit **2880** is turned on so that the power loop of the LED tube lamp is conducted as well. Herein, at least the first installation detection terminal **2521**, the switch circuit **2880**, the path **2881**, the detection determining auxiliary circuit **2870** and the second installation detection terminal **2522** are included in the power loop. In the meantime, the pulse generating auxiliary circuit **2840** conducts, in response to the enabled control signal, a discharge path again for discharging. The first output voltage gradually falls down to the first low level voltage from the voltage greater than the forward threshold voltage again. When the first output voltage is less than a reverse threshold voltage (which can be defined based on the circuit design), the integrated control module **2860** pulls the enabled control signal down to a disable level in response to the first output voltage (i.e., the integrated control module **2860** outputs a disabled control signal, in which the disabled control signal is, for example, a low level voltage), and thus the control signal has a pulse-type signal waveform (i.e., the third time of the first low level voltage, the second time of the high level voltage, and the fourth time of the first low level voltage form a second pulse signal). When the power loop is conducted again, the detection determining auxiliary circuit **2870** detects a second sample signal (e.g., voltage signal) on the power loop and provides the second sample signal to the integrated control module **2860** via the input terminal IN2. When the integrated control module **2860** determines the second sample signal is greater than or equal to a setting signal (e.g., a reference voltage), which may represent the LED tube lamp has been properly installed on the lamp socket, the integrated control module **2860** outputs and keeps the enabled control signal to the switch circuit **2880**. Since receiving the enabled control signal, the switch circuit **2880** remains in the conductive state so that the power loop of the LED tube lamp is kept on the conductive state as well.

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During the period when the switch circuit **2880** receives the enabled control signal, the integrated control module **2860** does not output the pulses anymore.

When the integrated control module **2860** determines the second sample signal is less than the setting signal, which may represent the LED tube lamp has not been properly installed on the lamp socket yet, the integrated control module **2860** outputs and keeps the disabled control signal to the switch circuit **2880**. Since receiving the disabled control signal, the switch circuit **2880** remains in the non-conducting state so that the power loop of the LED tube lamp is kept on the non-conducting state as well. Based on the above operation, when the LED tube lamp has not been properly installed on the lamp socket, the problem in which users may get an electric shock caused by touching the conductive part of the LED tube lamp can be prevented.

Operation of circuits/modules within the installation detection module is further described below. Referring to FIG. **15M** to **15P**, when the LED tube lamp is installed in the lamp socket, the capacitor **2843** is charged by a driving voltage VCC via resistor **2842**. When the voltage of the capacitor **2843** is raised to trigger the pulse generating unit **2862** (i.e., the voltage of the capacitor **2843** is raised greater than the forward threshold voltage), the output of the pulse generating unit **2862** changes to a first high level voltage from an initial first low level voltage and provides to the detection result latching unit **2863**. After receiving the first high level voltage outputted by the pulse generating unit **2862**, the detection result latching unit **2863** outputs a second high level voltage to the base of the transistor **2882** and the resistor **2846** via the output terminal OT. After the second high level voltage outputted from the detection result latching unit **2863** is received by the base of the transistor **2882**, the collector and the emitter of the transistor are conducted so as to conduct the power loop of the LED tube lamp. Herein, at least the first installation detection terminal **2521**, the transistor **2882**, the resistor **2872**, and the second installation detection terminal **2522** are included in the power loop.

In the meantime, the base of the transistor **2845** receives the second high level voltage on the output terminal OT via the resistor **2846**. The collector and the emitter of the transistor **2845** are conducting and connected to the ground, such that the capacitor **2843** is discharged to the ground via the resistor **2844**. When the voltage of the capacitor **2843** is insufficient so that the pulse generating unit **2862** cannot be triggered, the output of the pulse generating unit **2862** is pulled down to the first low level voltage from the first high level voltage (i.e., the first time of the first low level voltage, the first high level voltage, and the second time of the first low level voltage form a first pulse signal). When the power loop is conducting, the current, generated by the transient response, passing through a capacitor (e.g., filtering capacitor in the filtering circuit) in the LED power loop flows through the transistor **2882** and the resistor **2872** so as to build a voltage signal on the resistor **2872**. The voltage signal is provided to the input terminal IN2, and thus the detection unit **2864** may compare the voltage signal on the input terminal IN2 (i.e., the voltage on the resistor **2872**) with a reference voltage.

When the detection unit **2864** determines the voltage signal on the resistor **2872** is greater than or equal to the reference voltage, the detection unit outputs a third high level voltage to the detection result latching unit **2863**. On the contrary, when the detection unit **2864** determines the voltage signal on the resistor **2872** is less than the reference

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voltage, the detection unit **2864** outputs a third low level voltage to the detection result latching unit **2863**.

The detection result latching unit **2863** latches/stores the third high level voltage/third low level voltage provided by the detection unit **2864** and performs a logic operation based on the latched/stored signal and the signal provided by the pulse generating unit **2862**, such that the detection result latching unit **2863** outputs the control signal. Herein, the result of the logic operation determines whether the signal level of the outputted control signal is the second high level voltage or the second low level voltage.

More specifically, when the detection unit **2864** determines that the voltage signal on the resistor is greater than or equal to the reference voltage, the detection result latching unit **2863** may latch the third high level voltage outputted by the detection unit **2864**, and the second high level voltage is maintained to be output to the base of the transistor **2882**, so that the transistor **2882** and the power loop of the LED tube lamp maintain the conductive state. Since the detection result latching unit **2863** may continuously output the second high level voltage, the transistor **2845** is conducted to the ground as well, so that the voltage of the capacitor **2843** cannot rise enough to trigger the pulse generating unit **2862**. When the detection unit **2864** determines that the voltage signal on the resistor **2872** is less than the reference voltage, both the detection unit **2864** and the pulse generation unit **2862** provide a low level voltage, and thus the detection result latching unit **2863** continuously outputs, after performing the OR logical operation, the second low level voltage to the base of the transistor **2882**. Therefore, the transistor **2882** is maintained to be cut off and the power loop of the LED tube lamp is maintained to be at the non-conducting state. However, since the control signal on the output terminal OT is maintained at a second low level voltage, the transistor **2845** is thus maintained in a cut-off state as well, and repeatedly performs the next (pulse) detection until the capacitor **2843** is charged by the driving voltage VCC via the resistor **2842** again.

It should be noted that, the detection stage described in this embodiment can be defined as the period that the driving voltage VCC is provided to the installation detection module **2520**, however, the detection unit **2864** has not yet determined that the voltage signal on the resistor **2872** is greater than or equal to the reference voltage. During the detection stage, since the control signal outputted by the detection result latching unit **2863** alternatively conducts and cuts off the transistor **2845**, the discharge path is periodically conducted and cut off, correspondingly. Thus, the capacitor **2843** is periodically charged and discharged in response to the conduction state of the transistor **2845**, so that the detection result latching unit **2863** outputs the control signal having a periodic pulse waveform during the detection stage. The detection stage ends when the detection unit **2864** determines that the voltage signal on the resistor **2872** is greater than or equal to the reference voltage or the driving voltage VCC is stopped. The detection result latching unit **2863** is maintained to output the control signal having the second high level voltage or the second low level voltage after the detection stage.

In one embodiment, compared to the exemplary embodiment illustrated in FIG. **15G**, the integrated control module **2860** is constituted by integrating part of the circuit components in the detection pulse generating module **2740**, the detection result latching circuit **2760**, and the detection determining circuit **2770** (e.g., as part of an integrated circuit). Another part of the circuit components which are not integrated in the integrated control module **2860** con-

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stitutes the pulse generating auxiliary circuit **2840** and the detection determining auxiliary circuit **2870** of the embodiment illustrated in FIG. **15L**. In some embodiments, the function/circuit configuration of the combination of the pulse generating unit **2862** in the integrated control module **2860** and the pulse generating auxiliary circuit **2840** can be equivalent to the detection pulse generating module **2740**. The function/circuit configuration of the detection result latching unit **2863** in the integrated control module **2860** can be equivalent to the detection result latching module **2760**. The function/circuit configuration of the combination of the detection unit **2864** in the integrated control module **2860** and the detection determining auxiliary circuit **2870** can be equivalent to the detection determining circuit **2770**. However, in these embodiments, the circuit elements included in the pulse generating unit **2862**, the detection result latching unit **2863**, and the detection unit **2864** are included in an integrated circuit (e.g., formed on a die or chip).

Referring to FIG. **15Q**, an internal circuit block diagram of a three-terminal switch device according to an exemplary embodiment is illustrated. The installation detection module according to one embodiment is, for example, a three-terminal switch device **2920** including a power terminal VP1, a first switching terminal SP1, and a second switching terminal SP2. The power terminal VP1 of the three-terminal switch device **2920** is adapted to receive a driving voltage VCC. The first switching terminal SP1 is adapted to connect one of the first installation detection terminal **2521** and the second installation detection terminal **2522** (the first switching terminal SP1 is illustrated as being connected to the first installation detection terminal **2521** in FIG. **15Q**, but the invention is not limited thereto), and the second switching terminal SP2 is adapted to connect to the other one of the first installation detection terminal **2521** and the second installation detection terminal **2522** (the second switching terminal SP2 is illustrated as being connected to the second installation detection terminal **2522** in FIG. **15Q**, but the invention is not limited thereto).

The three-terminal switch device **2920** includes a signal processing unit **2930**, a signal generating unit **2940**, a signal capturing unit **2950**, and a switch unit **2960**. In addition, the three-terminal switch device **2920** further includes an internal power detection unit **2970**. The signal processing unit **2930** outputs a control signal having a pulse or multi-pulse waveform during a detection stage, according to the signal provided by the signal generating unit **2940** and the signal capturing unit **2950**. The signal processing unit **2930** outputs the control signal, in which the signal level of the control signal remains at a high voltage level or a low voltage level, after the detection stage, so as to control the conduction state of the switch unit **2960** and determine whether to conduct the power loop of the LED tube lamp. The pulse signal generated by the signal generating unit **2940** can be generated according to a reference signal received from outside, or by itself, and the present invention is not limited thereto. The term "outside" described in this paragraph is relative to the signal generating unit **2940**, which means the reference signal is not generated by the signal generating unit **2940**. As such, whether the reference signal is generated by any of the other circuits within the three-terminal switch device **2920**, or by an external circuit of the three-terminal switch device **2920**, those embodiments belong to the scope of "the reference signal received from the outside" as described in this paragraph. The signal capturing unit **2950** samples an electrical signal passing through the power loop of the LED tube lamp to generate a sample signal and detects an installation state of the LED tube lamp according to the sample signal, so as

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to transmit a detection result signal indicating the detection result to the signal processing unit 2930 for processing.

In an exemplary embodiment, the three-terminal switch device 2920 can be implemented by an integrated circuit. For example, the three-terminal switch device 2920 can be a three-terminal switch control chip, which can be utilized in any type of the LED tube lamp having two end caps for receiving power so as to provide the function of preventing electric shock. It should be noted that, the three-terminal switch device 2920 is not limited to merely include three pins/connection terminals. For example, a multi-pins switch device (with more than three pins) having at least three pins having the same configuration and function as the embodiment illustrated in FIG. 15Q can include additional pins for other purposes, even though those pins may be not described in detail herein. It should be noted that the various "units" described herein, in some embodiments, are circuits, and will be described as circuits.

In an exemplary embodiment, the signal processing unit 2930, the signal generating unit 2940, the signal capturing unit 2950, the switch unit 2960, and the internal power detection unit 2970 can be respectively implemented the circuit configurations illustrated in FIG. 15R to 15V, but the present invention is not limited thereto. Detail exemplary operation of each of the units in the three-terminal control chip are described below.

Referring to FIG. 15R, a block diagram of a signal processing unit according to an exemplary embodiment is illustrated. The signal processing unit 2930, which in one embodiment is a circuit, includes a driver 2932, an OR gate 2933, and a D flip-flop 2934. The driver 2932 has an input end, and has an output end connected to the switch unit 2960 via the path 2931, in which the driver 2932 provides the control signal to the switch unit 2960 via the output end and the path 2931. The OR gate 2933 has a first input end connected to the signal generating unit 2940 via the path 2941, a second input end, and an output end connected to the input end of the driver 2932. The D flip-flop 2934 has a data input end (D) receiving a driving voltage VCC, a clock input end (CK) connected to the signal capturing unit 2950 via the path 2951, and an output connected to the second input terminal of the OR gate 2933.

Referring to FIG. 15S, a block diagram of a signal generating unit according to an exemplary embodiment is illustrated. The signal generating unit 2940 includes resistors 2942 and 2943, a capacitor 2944, a switch 2945, and a comparator 2946. One end of the resistor 2942 receives the driving voltage VCC, and the resistors 2942 and 2943 and the capacitor 2944 are serial connected between the driving voltage VCC and the ground. The switch 2945 is connected to the capacitor 2944 in parallel. The comparator 2946 has a first input end connected to the connection node of the resistors 2942 and 2943, a second input end receives a reference voltage Vref, and an output end connected to the control terminal of the switch 2945.

Referring to FIG. 15T, a block diagram of a signal capturing unit according to an exemplary embodiment is illustrated. The signal capturing unit 2950 includes an OR gate and comparators 2953 and 2954. The OR gate 2952 has a first input end and a second input end, and an output end connected to the signal processing unit 2930 via the path 2951. The comparator 2953 has a first input end connected to one end of the switch unit 2960 (i.e., a node on the power loop of the LED tube lamp) via the path 2962, a second input end receiving a first reference voltage (e.g., 1.25V, but not limited thereto), and an output end connected to the first input end of the OR gate 2952. The comparator 2954 has a

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first input end connected to a second reference voltage (e.g., 0.15V, but not limited thereto), a second input end connected to the first input end of the comparator 2953, and an output end connected to the second input end of the OR gate 2952.

Referring to FIG. 15U, a block diagram of a switch unit according to an exemplary embodiment is illustrated. The switch unit 2960 includes a transistor 2963. The transistor 2963 has a gate connected to the signal processing unit 2930 via the path 2931, a drain connected to the first switch terminal SP1 via the path 2961, and a source connected to the second switch terminal SP2, the first input end of the comparator 2953, and the second input end of the comparator via the path 2962. In one embodiment, for example, the transistor 2963 is an NMOS transistor.

Referring to FIG. 15V, a block diagram of an internal power detection unit according to an exemplary embodiment is illustrated. The internal power detection unit 2970 includes a clamp circuit 2972, a reference voltage generating unit 2973, a voltage adjustment circuit 2974, and a Schmitt trigger 2975. The clamp circuit 2972 and the voltage adjustment circuit 2974 are respectively connected to the power terminal VP1 for receiving the driving voltage, so as to perform a voltage clamp operation and a voltage level adjustment operation, respectively. The reference voltage generating unit 2973 is coupled to the voltage adjustment circuit 2974 and is configured to generate a reference voltage to the voltage adjustment circuit 2974. The Schmitt trigger 2975 has an input end coupled to the clamp circuit 2972 and the voltage adjustment circuit 2974, and an output end to output a power confirmation signal for indicating whether the driving voltage VCC is normally supplied. If the driving voltage VCC is normally supplied, the Schmitt trigger 2975 outputs the enabled power confirmation signal, such that the driving voltage VCC is allowed to be provided to the component/circuit within the three-terminal switch device 2920. On the contrary, if the driving voltage VCC is abnormal, the Schmitt trigger 2975 outputs the disabled power confirmation signal, such that the component/circuit within the three-terminal switch device 2920 won't be damaged based on working under the abnormal driving voltage VCC.

Referring to FIG. 15Q to 15V, under the circuit operation of the present embodiment, when the LED tube lamp is installed on the lamp socket, the driving voltage VCC is provided to the three-terminal switch device 2920 via the power terminal VP1. At this time, the driving voltage VCC charges the capacitor 2944 via the resistors 2942 and 2943. When the capacitor voltage is raised greater than the reference voltage Vref, the comparator 2946 switches to output a high level voltage to the first input end of the OR gate 2933 and the control terminal of the switch 2945. The switch 2945 is conducted in response to the received high level voltage, such that the capacitor starts to discharge to the ground. The comparator 2946 outputs an output signal having pulse-type waveform through this charge and discharge process.

During the period when the comparator 2946 outputs the high level voltage, the OR gate 2952 correspondingly outputs the high level voltage to conduct the transistor 2963, such that the current flows through the power loop of the LED tube lamp. When the current passes the power loop, a voltage signal corresponding to the current size can be established on the path 2962. The comparator 2953 samples the voltage signal and compares the signal level of the voltage signal with the first reference voltage (e.g., 1.25V).

When the signal level of the sampled voltage signal is greater than the first reference voltage, the comparator 2953 outputs the high level voltage. The OR gate 2952 generates

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another high level voltage to the clock input end of the D flip-flop 2934 in response to the high level voltage outputted by the comparator 2953. The D flip-flop 2934 continuously outputs the high level voltage based on the output of the OR gate 2952. Driver 2932 generates an enabled control signal to conduct the transistor 2963 in response to the high level voltage on the input terminal. At this time, even if the capacitor 2944 has been discharged to below the reference voltage Vref and thus the output of the comparator 2946 is pulled down to the low level voltage, the transistor 2963 still remains in the conductive state since the output of the D flip-flop 2934 is kept on the high level voltage.

When the sampled voltage signal is less than the first reference voltage (e.g., 1.25V), the comparator 2953 outputs the low level voltage. The OR gate 2952 generates another low level voltage in response to the low level voltage outputted by the comparator, and provides the generated low level voltage to the clock input end of the D flip-flop 2934. The output end of the D flip-flop 2934 remains on the low level voltage based on the output of the OR gate 2952. At this time, once the capacitor 2944 is discharged to the capacitor voltage below the reference voltage Vref, the output of comparator 2946 is pulled down to the low level voltage which represents the end of the pulse on-time (i.e., the fallen edge of the pulse). Since the two input ends of the OR gate 2933 are at the low level voltage, the output end of the OR gate 2933 also outputs the low level voltage, therefore, the driver 2932 generates the disabled control signal to cut off the transistor 2963 in response to the received low level voltage, so as to cut off the power loop of the LED tube lamp.

As noted above, the operation of the signal processing unit 2930 of the present embodiment is similar to that of the detection result latching circuit 2760 illustrated in FIG. 15I, the operation of the signal generating unit 2940 is similar to that of the detection pulse generating module 2740 illustrated in FIG. 15H, the operation of the signal capturing unit 2950 is similar to that of the detection determining circuit 2770 illustrated in FIG. 15K, and the operation of the switch unit 2960 is similar to that of the switch circuit 2780 illustrated in 15J.

Referring to FIG. 15W, a block diagram of an installation detection module according to an exemplary embodiment is illustrated. The installation detection module 2520 includes a switch circuit 3080, a detection pulse generating module 3040, a control circuit 3060, a detection determining circuit 3070, and a detection path circuit 3090. The detection determining circuit 3070 is coupled to the detection path circuit 3090 via the path 3081 for detecting the signal on the detection path circuit 3090. The detection determining circuit 3070 is coupled to the control circuit 3060 via the path 3071 for transmitting the detection result signal to the control circuit 3060 via the path 3071. The detection pulse generating module 3040 is coupled to the detection path circuit 3090 via the path 3041 and generates a pulse signal to inform the detection path circuit 3090 of a time point for conducting the detection path. The control circuit 3060 outputs a control signal according to the detection result signal and is coupled to the switch circuit 3080 via the path 3061, so as to transmit the control signal to the switch circuit 3080. The switch circuit 3080 determines whether to conduct the current path between the installation detection terminals 2521 and 2522 (i.e., part of the power loop).

In the present embodiment, the configuration of the detection pulse generating module 3040 can correspond to the configurations of the detection pulse generating module 2640 shown in FIG. 15C or the detection pulse generating

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module 2740 shown in FIG. 15H. Referring to FIG. 15C, when the detection pulse generating module 2640 is applied to implement the detection pulse generating module 3040, the path 3041 of the present embodiment can correspond to the path 2541, which means the OR gate 265 is connected to the detection path circuit 3090 via the path 3041. Referring to FIG. 15H, when the detection pulse generating module 2740 is applied to implement the detection pulse generating module 3040, the path 3041 can correspond to the path 2741. In one embodiment, the detection pulse generating module is also connected to the output terminal of the control circuit 3060 via the path 3061, so that the path 3061 can correspond to the path 2761.

The control circuit 3060 can be implemented by a control chip or any circuit capable of performing signal processing. When the control circuit 3060 determines the tube lamp is properly installed (e.g., a user is not touching the pins on one end of the tube lamp with the other end plugged in) according to the detection result signal, the control circuit 3060 may control the switch state of the switch circuit 3080 so that the external power can be normally provided to the LED module when the tube lamp is properly installed into the lamp socket. In this case, the detection path will be cut off by the control circuit 3060. On the contrary, when the control circuit 3060 determines the tube lamp is not properly installed (e.g., a user is touching the pins on one end of the tube lamp with the other end plugged in) according to the detection result signal, the control circuit 3060 keeps the switch circuit 3080 at the off-state since the user has the risk from getting electric shock.

In an exemplary embodiment, the control circuit 3060 and the switch circuit 3080 can be part of the driving circuit in the power supply module. For example, if the driving circuit is a switch-type DC-to-DC converter, the switch circuit 3080 can be the power switch of the converter, and the control circuit 3060 can be the controller of the power switch.

An example of the configuration of the detection determining circuit 3070 can be seen referring to the configurations of the detection determining circuit 2670 shown in FIG. 15D or the detection determining circuit 2770 shown in FIG. 15K. Referring to FIG. 15D, when the detection determining circuit 2670 is applied to implement the detection determining circuit 3070, the resistor 2672 can be omitted. The path 3081 of the present embodiment can correspond to the path 2581, which means the positive input terminal of the comparator 2671 is connected to the detection path circuit 3090. The path 3071 of the present embodiment can correspond to the path 2571, which means the output terminal of the comparator 2671 is connected to the detection result latching circuit 3060. Referring to FIG. 15K, when the detection determining circuit 2770 is applied to implement the detection determining circuit 3070, the resistor 2774 can be omitted. The path of the present embodiment can correspond to the path 2771, which means the output terminal of the comparators 2772 and 2773 are connected to the detection result latching circuit 3060.

The configuration of the switch circuit 3080 can correspond to the configurations of the switch circuit 2680 shown in FIG. 15F or the switch circuit 2780 shown in FIG. 15J. Since the switch circuit in both embodiments of FIG. 15F and FIG. 15J are similar to each other, the following description discusses the switch circuit 2680 shown in FIG. 15F as an example. Referring to FIG. 15F, when the switch circuit 2680 is applied to implement the switch circuit 3080, the path 3061 of the present embodiment can correspond to the path 2561. The path 2581 is not connected to the

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detection determining circuit 2570, but directly connected to the installation detection terminal 2522.

An exemplary configuration of the detection path circuit 3090 is shown in FIG. 15X. The detection path circuit 3090 includes a transistor 3092 and resistors 3093 and 3094. The transistor 3092 has a base, a collector, and an emitter. The base of the transistor 3092 is connected to the detection pulse generating module 3040 via the path 3041. The resistor 3092 is serially connected between the emitter of the transistor 3092 and the ground. The resistor 3093 is serially connected between the collector of the transistor 3092 and the installation detection terminal 2521.

In the present embodiment, the transistor 3092 is conducting during a pulse-on time when receiving the pulse signal provided by the detection pulse generating module 3040. Under the situation where at least one end of the tube lamp is inserted in the lamp socket, a detection path is built from the installation detection terminal 2521 to the ground (via the resistor 3094, the transistor 3092, and the resistor 3093) in response to the conducted transistor 3092, so as to establish a voltage signal on the node X of the detection path. In one embodiment, the detection path is built from one of the rectifying circuit input terminals to another one of the rectifying circuit input terminals (via the rectifying diodes, the resistors 3093 and 3094, and the transistor 3092). When the user does not touch the tube lamp (e.g., but one end of the tube lamp is plugged in), the signal level of the voltage signal is determined by the voltage division of the resistors 3093 and 3094. When the user touches the tube lamp, an impedance of human body is equivalent to connect between the resistor 3094 and the ground, which means it is connected to the resistors 3093 and 3094 in series. At this time, the signal level of the voltage signal is determined by the voltage division of the resistor 3093, the resistor 3094, and the impedance of human body. Accordingly, by setting the resistors 3093 and 3094 having reasonable resistance, the voltage signal on the node X may reflect the state of whether the user touches the tube lamp, and thus the detection determining circuit 3070 may generate the corresponding detection result signal according to the voltage signal on the node X.

As noted above, the present embodiment may determine whether a user has a chance to get the electric shock by conducting a detection path and detecting a voltage signal on the detection path. Compared to the embodiment mentioned above, the detection path of the present embodiment is additionally built, but does not use the power loop as the detection path. Since the configuration of the components on the additional detection path is much simpler than the power loop, the voltage signal on the detection path may reflect a user's touching state more accurately.

Furthermore, similar to the above embodiment, part or all of the circuit/module can be integrated as a chip, as illustrated in the embodiments in FIG. 15L to FIG. 15V, and it will not be repeated herein.

Further, according to the embodiments illustrated in FIG. 15G to 15X, one skilled in the art should understand that the installation detection module illustrated in FIG. 15G can not only be designed as a distributed circuit applied in the LED tube lamp, but rather some components of the installation detection module can be integrated into an integrated circuit in an exemplary embodiment (e.g., the embodiment illustrated in FIG. 15L). Alternatively, all circuit components of the installation detection module can be integrated into an integrated circuit in another exemplary embodiment (e.g., the embodiment illustrated in FIG. 15Q). Therefore, the circuit cost and the size of the installation detection module

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can be saved. In addition, by integrating/modularizing the installation detection module, the installation detection module can be more easily utilized in different types of the LED tube lamps so that the design compatibility of the LED tube lamp can be improved. Also, under the application of utilizing the integrated installation detection module in the LED tube lamp, the light emitting area of the LED tube lamp can be significantly improved since the circuit size within the tube lamp is reduced. For example, the integrated circuit design may reduce the working current (reduced by about 50%) and enhance the power efficiency of the integrated components. As a result, the saved power can be used for being supplied to the LED module for emitting light, so that the luminous efficiency of the LED tube lamp can be further improved.

The embodiments of the installation detection module illustrated in FIG. 15B, FIG. 15G, FIG. 15L, and FIG. 15Q teach the installation detection module includes a pulse generating mechanism such as the detection pulse generating modules 2540 and 2740, the pulse generating auxiliary circuit 2840, and the signal generating unit 2940 for generating a pulse signal, however, the present invention is not limited thereto. In an exemplary embodiment, the installation detection module can use the original clock signal in the power supply module to replace the function of the pulse generating mechanism in the above embodiments. For example, in order to generate a PWM signal, the driving circuit (e.g., DC-to-DC converter) in the power supply module has a reference clock, originally. The function of the pulse generating mechanism can be implemented by using the reference clock of the PWM signal as a reference, so that the hardware of the detection pulse generating module 2540, 2740/pulse generating auxiliary module 2840/signal generating unit 2940 can be omitted. In this case, the installation detection module can share the circuit configuration with another part of the circuit in the power supply module, so as to realize the function of generating the pulse signal.

Although the modules/circuits are named by their functionality in the embodiments described in the present disclosure, it should be understood by those skilled in the art that the same circuit component may be considered to have different functions based on the circuit design. That is, different modules/circuits may share the same circuit component to implement their respective circuit functions. Thus, the functional naming of the present disclosure is not intended to limit a particular unit, circuit, or module to particular circuit components.

To summarize, the embodiments illustrated in FIG. 15A to FIG. 15X teach a concept of electric-shock protection by utilizing electrical control and detection method. Compared to mechanical electric-shock protection (i.e., using the mechanical structure interaction/shifting for implementing the electric shock protection), the electrical electric-shock protection has higher reliability and durability since the mechanical fatigue issue may not occur in the electrical installation detection module.

According to some embodiments, the present invention further provides a detection method adopted by a light-emitting device (LED) tube lamp for preventing a user from electric shock when the LED tube lamp is being installed on a lamp socket. The detection method includes: generating a first pulse signal by a detection pulse generating module, wherein the detection pulse generating module is configured in the LED tube lamp; receiving the first pulse signal through a detection result latching circuit by a switch circuit, and making the switch circuit conducting during the first pulse signal to cause a power loop of the LED tube lamp to

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be conducting, wherein the switch circuit is on the power loop; and detecting a first sample signal on the power loop by a detection determining circuit as the power loop being conductive, and comparing the first sample signal with a predefined signal, wherein when the first sample signal is greater than or equal to the predefined signal, the detection method further includes: outputting a first high level signal by the detection determining circuit; receiving the first high level signal by the detection result latching circuit and outputting a second high level signal; and receiving the second high level signal by the switch circuit and conducting to cause the power loop to remain conductive.

In some embodiments, when the first sample signal is smaller than the predefined signal, the detection method further includes: outputting a first low level signal by the detection determining circuit; receiving the first low level signal by the detection result latching circuit and outputting a second low level signal; and receiving the second low level signal by the switch circuit and maintaining an off state of the switch circuit to cause the power loop to remain open.

In some embodiments, when the power loop remains open, the detection method further includes: generating a second pulse signal by the detection pulse generating module; receiving the second pulse signal through the detection result latching circuit by the switch circuit, and changing an off state of the switch circuit to a conducting state again during the second pulse signal to cause the power loop to be conducting once more; and detecting a second sample signal on the power loop by the detection determining circuit as the power loop being conductive once more, and comparing the second sample signal with the predefined signal, wherein when the second sample signal is greater than or equal to the predefined signal, the detection method further includes: outputting the first high level signal by the detection determining circuit; receiving the first high level signal by the detection result latching circuit and outputting the second high level signal; and receiving the second high level signal by the switch circuit and maintaining a conducting state of the switch circuit to cause the power loop to remain conducting.

In some embodiments, when the second sample signal is smaller than the predefined signal, the detection method further includes: outputting the first low level signal by the detection determining circuit; receiving the first low level signal by the detection result latching circuit and outputting the second low level signal; and receiving the second low level signal by the switch circuit and maintaining an off state of the switch circuit to cause the power loop to remain open.

In some embodiments, a period (or a width) of the first pulse signal is between 10 microseconds-1 millisecond, a period (or a width) of the second pulse signal is between 10 microseconds-1 millisecond.

In some embodiments, a time interval between the first and the second pulse signals (or a cycle of the pulse signal) includes $(X+Y)(T/2)$, where T is the cycle of the driving signal, X is an integer which is bigger than or equal to zero, $0 < Y < 1$.

In some embodiments, a period (or a width) of the first pulse signal is between 1 microsecond-100 microseconds, a period (or a width) of the second pulse signal is between 1 microsecond-100 microseconds.

In some embodiments, a time interval between the first and the second pulse signals (or a cycle of the pulse signal) is between 3 milliseconds-500 milliseconds.

In some embodiments, at least two protection elements, such as two fuses, are respectively connected between the internal circuits of the LED tube lamp and the conductive

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pins of the LED tube lamp, and which are on the power loop of the LED tube lamp. In some embodiments, four fuses are used for an LED tube lamp having power-supplied at its both end caps respectively having two conductive pins. In this case, for example, two fuses are respectively connected between two conductive pins of one end cap and between one of the two conductive pins of this end cap and the internal circuits of the LED tube lamp; and the other two fuses are respectively connected between two conductive pins of the other end cap and between one of the two conductive pins of the other end cap and the internal circuits of the LED tube lamp. In some embodiment, the capacitance between a power supply (or an external driving source) and the rectifying circuit of the LED tube lamp may be ranging from 0 to about 100 pF. In some embodiments, the above-mentioned installation detection module may be configured to use an external power supply.

According to the design of the power supply module, the external driving signal may be a low frequency AC signal (e.g., commercial power), a high frequency AC signal (e.g., that provided by an electronic ballast), or a DC signal (e.g., that provided by a battery or external configured driving source), input into the LED tube lamp through a drive architecture of dual-end power supply. For the drive architecture of dual-end power supply, the external driving signal may be input by using only one end thereof as single-end power supply.

The LED tube lamp may omit the rectifying circuit in the power supply module when the external driving signal is a DC signal.

According to the design of the rectifying circuit in the power supply module, there may be a dual rectifying circuit. First and second rectifying circuits of the dual rectifying circuit are respectively coupled to the two end caps disposed on two ends of the LED tube lamp. The dual rectifying circuit is applicable to the drive architecture of dual-end power supply. Furthermore, the LED tube lamp having at least one rectifying circuit is applicable to the drive architecture of a low frequency AC signal, high frequency AC signal or DC signal.

The dual rectifying circuit may comprise, for example, two half-wave rectifier circuits, two full-wave bridge rectifying circuits or one half-wave rectifier circuit and one full-wave bridge rectifying circuit.

According to the design of the pin in the LED tube lamp, there may be two pins in single end (the other end has no pin), two pins in corresponding ends of two ends, or four pins in corresponding ends of two ends. The designs of two pins in single end and two pins in corresponding ends of two ends are applicable to a signal rectifying circuit design of the rectifying circuit. The design of four pins in corresponding ends of two ends is applicable to a dual rectifying circuit design of the rectifying circuit, and the external driving signal can be received by two pins in only one end or any pin in each of two ends.

According to the design of the filtering circuit of the power supply module, there may be a single capacitor, or π filter circuit. The filtering circuit filters the high frequency component of the rectified signal for providing a DC signal with a low ripple voltage as the filtered signal. The filtering circuit also further comprises the LC filtering circuit having a high impedance for a specific frequency for conforming to current limitations in specific frequencies of the UL standard. Moreover, the filtering circuit according to some embodiments further comprises a filtering unit coupled between a rectifying circuit and the pin(s) for reducing the EMI resulted from the circuit(s) of the LED tube lamp. The

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LED tube lamp may omit the filtering circuit in the power supply module when the external driving signal is a DC signal.

According to the design of the LED lighting module in some embodiments, the LED lighting module may comprise the LED module and the driving circuit or only the LED module. The LED module may be connected with a voltage stabilization circuit in parallel for preventing the LED module from over-voltage. The voltage stabilization circuit may be a voltage clamping circuit, such as Zener diode, DIAC and so on. When the rectifying circuit has a capacitive circuit, in some embodiments, two capacitors are respectively coupled between two corresponding pins in two end caps and so the two capacitors and the capacitive circuit as a voltage stabilization circuit perform a capacitive voltage divider.

If there are only the LED module in the LED lighting module and the external driving signal is a high frequency AC signal, a capacitive circuit (e.g., having at least one capacitor) is in at least one rectifying circuit and the capacitive circuit is connected in series with a half-wave rectifier circuit or a full-wave bridge rectifying circuit of the rectifying circuit and serves as a current modulation circuit (or a current regulator) to modulate or to regulate the current of the LED module due to that the capacitor equates a resistor for a high frequency signal. Thereby, even different ballasts provide high frequency signals with different voltage logic levels, the current of the LED module can be modulated into a defined current range for preventing overcurrent. In addition, an energy-releasing circuit is connected in parallel with the LED module. When the external driving signal is no longer supplied, the energy-releasing circuit releases the energy stored in the filtering circuit to lower a resonance effect of the filtering circuit and other circuits for restraining the flicker of the LED module. In some embodiments, if there are the LED module and the driving circuit in the LED lighting module, the driving circuit may be a buck converter, a boost converter, or a buck-boost converter. The driving circuit stabilizes the current of the LED module at a defined current value, and the defined current value may be modulated based on the external driving signal. For example, the defined current value may be increased with the increasing of the logic level of the external driving signal and reduced with the reducing of the logic level of the external driving signal. Moreover, a mode switching circuit may be added between the LED module and the driving circuit for switching the current from the filtering circuit directly or through the driving circuit inputting into the LED module.

A protection circuit may be additionally added to protect the LED module. The protection circuit detects the current and/or the voltage of the LED module to determine whether to enable corresponding over current and/or over-voltage protection.

According to the design of the auxiliary power module of the power supply module, the energy storage unit may be a battery or a supercapacitor, connected in parallel with the LED module. The auxiliary power module is applicable to the LED lighting module having the driving circuit.

According to the design of the LED module of the power supply module, the LED module comprises plural strings of LEDs connected in parallel with each other, wherein each LED may have a single LED chip or plural LED chips emitting different spectrums. Each LEDs in different LED strings may be connected with each other to form a mesh connection.

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In other words, the abovementioned features can be implemented in any combination to improve the LED tube lamp.

The above-mentioned exemplary features of the present invention can be accomplished in any combination to improve the LED tube lamp, and the above embodiments are described by way of example only. The present invention is not herein limited, and many variations are possible without departing from the spirit of the present invention and the scope as defined in the appended claims.

What is claimed is:

1. A ballast bypass LED tube lamp adapted to install on a lamp socket, comprising:

a lamp tube;

two end caps, each having a first external connection terminal, and each coupled to a respective end of the lamp tube, the first external connection terminals of the two end caps for receiving an AC signal without the AC signal passing through a ballast on the lamp socket;

an LED module, disposed in a power loop formed between the first external connection terminals and configured to be driven based on a driving signal for emitting light; and

a power supply module, coupled to the first external connection terminals and the LED module and configured to drive the LED module by converting a received signal into the driving signal, wherein the power supply module comprises:

a rectifying circuit, coupled to the first external connection terminals of the end caps, for rectifying the received signal to produce a rectified signal;

a filtering circuit, coupled to the rectifying circuit, for filtering the rectified signal to produce a filtered signal;

a driving circuit, coupled to the filtering circuit, for performing power conversion to the filtered signal and producing the driving signal; and

an installation detection module, configured to determine whether to limit a current on the power loop to less than a predefined value according to an installation detection result,

wherein the installation detection module causes a current to be conducted in a detection path for detecting an installation state between the LED tube lamp and the lamp socket and generates the installation detection result.

2. The ballast bypass LED tube lamp according to claim 1, wherein at least one of the end caps further has a second external connection terminal, and the first and the second external connection terminals on the same end cap are electrically connected to each other.

3. The ballast bypass LED tube lamp according to claim 2, wherein when the AC signal is applied to the first external connection terminals, a voltage difference between the first and the second external connection terminals on the same end cap does not vary with a phase of the AC signal.

4. The ballast bypass LED tube lamp according to claim 3, wherein the voltage difference between the first and the second external connection terminals on the same end cap substantially equals zero.

5. The ballast bypass LED tube lamp according to claim 2, wherein the first and the second external connection terminals on the same end cap are electrically connected via a fuse.

6. The ballast bypass LED tube lamp according to claim 1, wherein at least one of the end caps further has a second external connection terminal, and the first and the second

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external connection terminals on the same end cap are electrically independent of each other.

7. The ballast bypass LED tube lamp according to claim 6, wherein the second external connection terminal is set to a floating state.

8. The ballast bypass LED tube lamp according to claim 1, further comprising:

a light strip, disposed on an inner circumferential surface of the lamp tube, wherein the LED module is disposed on the light strip, wherein the power supply module further comprises:

a printed circuit board (PCB), coupled to the light strip and configured to carry and connect electronic components of the power supply module,

wherein the electronic components of the power supply module are coupled to the LED module via the light strip and the PCB.

9. The ballast bypass LED tube lamp according to claim 8, wherein the light strip is made from one of a bendable circuit sheet, a flexible circuit board, a flexible tape, and a flexible ribbon.

10. The ballast bypass LED tube lamp according to claim 8, wherein the printed circuit board comprises:

a first sub-PCB, disposed in one of the end caps, wherein at least part of electronic components of the power supply module are disposed on the first sub-PCB; and a second sub-PCB, disposed in the other one of the end caps and coupled to the first sub-PCB, wherein at least another part of electronic components of the power supply module are disposed on the second sub-PCB.

11. The ballast bypass LED tube lamp according to claim 8, wherein the LED module comprises a plurality of LED light sources, and each of the LED light sources has a body and a first electrode and a second electrode formed at a respective end in a length direction of the body, and wherein the light strip comprises a positive conductive line and a negative conductive line disposed in the lamp tube, each of the positive conductive line and negative conductive line extending along a lead extension direction.

12. The ballast bypass LED tube lamp according to claim 11, wherein the first electrodes of a first set of the LED light sources are connected to the positive conductive line, the second electrodes of the first set of the LED light sources are connected to the negative conductive line, and the length direction of the first set of the LED light sources is parallel to the lead extension direction.

13. The ballast bypass LED tube lamp according to claim 11, wherein the first electrodes of a first set of the LED light sources are connected to the positive conductive line, the second electrodes of the first set of the LED light sources are connected to the negative conductive line, and the length direction of the first set of the LED light sources is perpendicular to the lead extension direction.

14. The ballast bypass LED tube lamp according to claim 11, wherein the positive conductive line and the negative conductive line are formed in a right-angled Z shape or a non right-angled Z shape.

15. The ballast bypass LED tube lamp according to claim 8, wherein the PCB comprises:

a plurality of power pads, configured to be an interface for connecting the light strip, wherein at least one of the power pads has a through hole.

16. The ballast bypass LED tube lamp according to claim 1, wherein the installation detection module comprises:

a switch circuit, serially connected to the power loop and configured to be switched according to a control signal; and

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a control circuit, configured to produce the control signal according to a detection result signal indicating the installation state.

17. The ballast bypass LED tube lamp according to claim 16, wherein when the detection result signal indicates the LED tube lamp is properly installed into the lamp socket, the control circuit produces the control signal such that the switch circuit is switched on and the current on the power loop is not limited by the installation detection module.

18. The ballast bypass LED tube lamp according to claim 16, wherein when the detection result signal indicates a risk of electric shock exists, the control circuit produces the control signal such that the switch circuit is switched off and the current on the power loop is limited to less than the predefined value.

19. The ballast bypass LED tube lamp according to claim 16, wherein the installation detection module further comprises:

a detection path circuit, configured to form the detection path; and

a detection determining circuit, coupled to the detection path circuit and the control circuit and configured to detect a signal feature on the detection path and produce the detection result signal.

20. The ballast bypass LED tube lamp according to claim 19, wherein the detection path circuit consists of electronic components included in the power loop.

21. The ballast bypass LED tube lamp according to claim 19, wherein at least one electronic element of the detection path circuit is different from electronic elements included in the power loop.

22. The ballast bypass LED tube lamp according to claim 19, wherein the detection path circuit comprises:

a first resistor, having an end connected to the power loop; a second resistor, having an end connected to a ground terminal; and

a transistor, having a first terminal connected to another end of the first resistor via a first node, a second terminal coupled to another end of the second resistor via a second node, and a control terminal receiving a detection control signal, wherein the detection determining circuit detects the signal feature on at least one of the first and the second nodes.

23. The ballast bypass LED tube lamp according to claim 22, wherein the first resistor, the second resistor and the transistor are not included in the power loop.

24. The ballast bypass LED tube lamp according to claim 22, wherein the detection control signal is a pulse signal.

25. The ballast bypass LED tube lamp according to claim 1, further comprising:

an auxiliary power module, coupled to an input side of the power supply module and configured to provide an auxiliary power signal to the input side of the rectifying circuit based on the AC signal.

26. The ballast bypass LED tube lamp according to claim 25, wherein the auxiliary power module comprises:

an energy storage unit, coupled to the rectifying circuit and configured to provide the auxiliary power signal; and

a power detection circuit, configured to detect the AC signal and generating a power supply detection result, wherein the energy storage unit determines whether to provide the auxiliary power signal to the rectifying circuit according to the power supply detection result.

27. The ballast bypass LED tube lamp according to claim 26, wherein:

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when the power supply detection result indicates the AC signal is abnormal, the energy storage unit provides the auxiliary power signal to the rectifying circuit, such that the power supply module produces the driving signal based on the auxiliary power signal; and

when the power supply detection result indicates the AC signal is normally provided, the energy storage unit stops providing the auxiliary power signal to the rectifying circuit, such that the power module produces the driving signal based on the AC signal.

28. The ballast bypass LED tube lamp according to claim **25**, wherein the auxiliary power module is disposed inside of a space defined by the lamp tube and the end caps.

29. The ballast bypass LED tube lamp according to claim **25**, wherein one of the end caps further has a second external connection terminal, the auxiliary power module provides the auxiliary power signal to the power supply module via one of the first external connection terminal and the second external connection terminal.

30. The ballast bypass LED tube lamp according to claim **29**, wherein the rectifying circuit comprises:

a first bridge arm, having a first input signal receiving terminal connected to the first external connection terminal on one of the end caps;

a second bridge arm, having a second input signal receiving terminal connected to the first external connection terminal on the other one of the end caps; and

a third bridge arm, having a third input signal receiving terminal connected to the second external connection terminal,

wherein the first, the second, and the third bridge arms are connected in parallel, and

wherein any two of the bridge arms form a full-wave rectifier.

31. A power supply module for a dual-ended ballast bypass LED tube lamp, comprising:

a rectifying circuit, configured to receive an AC signal without the AC signal passing through a ballast, and to rectify the AC signal to produce a rectified signal;

a filtering circuit, coupled to the rectifying circuit and configured to filter the rectified signal to produce a filtered signal;

a driving circuit, coupled to the filtering circuit and configured to perform power conversion on the filtered signal and produce a driving signal; and

an installation detection module, configured to determine whether to limit a current on a current path of the power supply module to less than a predefined value according to an installation detection result,

wherein the installation detection module causes a current to be conducted in a detection path for detecting whether a risk of electric shock exists and generates the installation detection result.

32. The power supply module for the dual-ended ballast bypass LED tube lamp according to claim **31**, further comprising:

a printed circuit board (PCB), configured to carry and connect electronic components of the power supply module, and comprising a plurality of power pads configured to be an interface for connecting a load, wherein at least one of the power pads has a through hole.

33. The power supply module for the dual-ended ballast bypass LED tube lamp according to claim **31**, wherein the installation detection module comprises:

a detection path circuit, configured to form the detection path; and

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a detection determining circuit, coupled to the detection path circuit and configured to detect a signal feature on the detection path and produce a detection result signal indicating the risk of electric shock.

34. The power supply module for the dual-ended ballast bypass LED tube lamp according to claim **33**, wherein the detection path circuit consists of electronic components included in the current path.

35. The power supply module for the dual-ended ballast bypass LED tube lamp according to claim **33**, wherein at least one electronic element of the detection path circuit is different from electronic elements included in the current path.

36. The power supply module for the dual-ended ballast bypass LED tube lamp according to claim **33**, wherein the installation detection module comprises:

a switch circuit, serially coupled to the current path and configured to be switched according to a control signal; and

a control circuit, coupled to the detection determining circuit and configured to produce the control signal according to the detection result signal.

37. The power supply module for the dual-ended ballast bypass LED tube lamp according to claim **36**, wherein when the detection result signal indicates the risk of electric shock exists, the control circuit produces the control signal such that the switch circuit is switched off and the current on the current path is limited to less than the predefined value.

38. The power supply module for the dual-ended ballast bypass LED tube lamp according to claim **31**, wherein the AC signal is provided from one of a first power source and a second power source, and the rectifying circuit comprises:

a first bridge arm, having a first input signal receiving terminal;

a second bridge arm, having a second input signal receiving terminal; and

a third bridge arm, having a third input signal receiving terminal,

wherein the first, the second, and the third bridge arms are connected in parallel,

wherein the first and the second input signal receiving terminals are connected to the first power source, and the second and the third input signal receiving terminals are connected to the second power source.

39. The power supply module for the dual-ended ballast bypass LED tube lamp according to claim **38**, wherein:

when the AC signal is provided from the first power source, the first and the second bridge arms perform a full-wave rectification to the AC signal, and

when the AC signal is provided from the second power source, the second and the third bridge arms perform the full-wave rectification to the AC signal.

40. The power supply module according to claim **31**, further comprising:

an auxiliary power module, coupled to an input side of the power supply module and configured to provide an auxiliary power signal to the input side of the rectifying circuit based on the AC signal.

41. The power supply module according to claim **40**, wherein the auxiliary power module is disposed inside of a space defined by a lamp tube and end caps of the LED tube lamp.

42. The power supply module according to claim **40**, wherein the auxiliary power module is disposed outside of a space defined by a lamp tube and end caps of the LED tube lamp.

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43. The power supply module according to claim **40**, wherein the auxiliary power module is disposed on a lamp socket for the LED tube lamp.

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