US010383187B2

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

(10) **Patent No.: US 10,383,187 B2**
(45) **Date of Patent: *Aug. 13, 2019**

(54) **SYSTEMS AND METHODS FOR INTELLIGENT CONTROL RELATED TO TRIAC DIMMERS**

(71) Applicant: **GUANGZHOU ON-BRIGHT ELECTRONICS CO., LTD.**, Guangzhou (CN)

(72) Inventors: **Yimu Liao**, Guangzhou (CN); **Yuhao Liang**, Guangzhou (CN); **Zhiliang Chen**, Shanghai (CN); **Lieyi Fang**, Shanghai (CN)

(73) Assignee: **Guangzhou On-Bright Electronics Co., Ltd.**, Guangzhou (CN)

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

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/263,080**

(22) Filed: **Sep. 12, 2016**

(65) **Prior Publication Data**

US 2017/0064787 A1 Mar. 2, 2017

Related U.S. Application Data

(63) Continuation of application No. 14/593,734, filed on Jan. 9, 2015, now Pat. No. 9,480,118.

(30) **Foreign Application Priority Data**

Apr. 25, 2014 (CN) 2014 1 0172086

(51) **Int. Cl.**
H05B 33/08 (2006.01)

(52) **U.S. Cl.**
CPC ***H05B 33/0845*** (2013.01); ***H05B 33/0815*** (2013.01); *Y02B 20/347* (2013.01)

(58) **Field of Classification Search**
CPC H05B 33/0815; H05B 33/0818; H05B 33/0809; H05B 37/029; H05B 37/02;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,803,452 A 4/1974 Goldschmied
3,899,713 A 8/1975 Barkan et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 1448005 A 10/2003
CN 101657057 A 2/2010
(Continued)

OTHER PUBLICATIONS

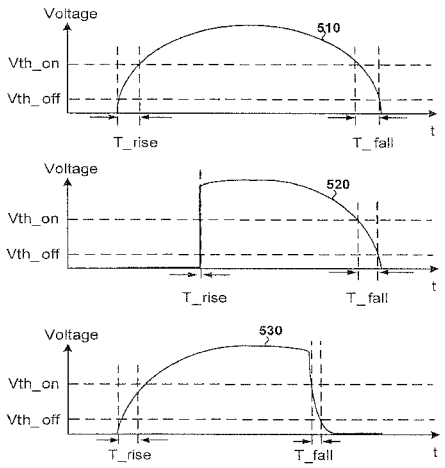
China Patent Office, Office Action dated Aug. 28, 2015, in Application No. 201410322602.9.
(Continued)

Primary Examiner — Douglas W Owens
Assistant Examiner — Syed M Kaiser
(74) *Attorney, Agent, or Firm* — Faegre Baker Daniels LLP

(57) **ABSTRACT**

System controller and method for a lighting system. The system controller includes a first controller terminal configured to receive a first signal, and a second controller terminal configured to output a second signal to a diver component. The driver component is configured to receive a first current and provide one or more drive currents to one or more light emitting diodes in response to the second signal. Additionally, the system controller is configured to process information associated with the first signal, determine a first time period for the first signal to increase from a first threshold to a second threshold, and determine a second time period for the first signal to decrease from the second threshold to the first threshold.

4 Claims, 9 Drawing Sheets



(58) **Field of Classification Search**
CPC H05B 41/3925; H05B 41/391; H05B 41/2828; H05B 33/0803
USPC ..... 315/224, 119, 200 R, 291, 307
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,253,045	A	2/1981	Weber	
5,144,205	A	9/1992	Motto et al.	
5,249,298	A	9/1993	Bolan et al.	
5,504,398	A	4/1996	Rothenbuhler	
5,949,197	A	9/1999	Kastner	
6,218,788	B1	4/2001	Chen et al.	
6,229,271	B1	5/2001	Liu	
6,278,245	B1	8/2001	Li et al.	
7,038,399	B2	5/2006	Lys et al.	
7,649,327	B2	1/2010	Peng	
7,825,715	B1	11/2010	Greenberg	
7,880,400	B2	2/2011	Zhou et al.	
7,944,153	B2	5/2011	Greenfeld	
8,134,302	B2	3/2012	Yang et al.	
8,278,832	B2	10/2012	Hung et al.	
8,378,583	B2	2/2013	Hying et al.	
8,378,588	B2	2/2013	Kuo et al.	
8,378,589	B2	2/2013	Kuo et al.	
8,415,901	B2	4/2013	Recker et al.	
8,432,438	B2	4/2013	Ryan et al.	
8,497,637	B2	7/2013	Liu	
8,569,956	B2	10/2013	Shteynberg et al.	
8,644,041	B2	2/2014	Pansier	
8,698,419	B2	4/2014	Yan et al.	
8,716,882	B2	5/2014	Pettler et al.	
8,890,440	B2	11/2014	Yan et al.	
8,941,324	B2	1/2015	Zhou et al.	
9,030,122	B2	5/2015	Yan et al.	
9,084,316	B2	7/2015	Melanson et al.	
9,148,050	B2	9/2015	Chiang	
9,220,133	B2	12/2015	Salvestrini et al.	
9,220,136	B2	12/2015	Zhang	
9,247,623	B2	1/2016	Recker et al.	
9,247,625	B2	1/2016	Recker et al.	
9,301,349	B2	3/2016	Zhu et al.	
9,332,609	B1	5/2016	Rhodes et al.	
9,402,293	B2	7/2016	Vaughan et al.	
9,408,269	B2	8/2016	Zhu et al.	
9,414,455	B2	8/2016	Zhou et al.	
9,467,137	B2	10/2016	Eum et al.	
9,480,118	B2	10/2016	Liao et al.	
9,554,432	B2	1/2017	Zhu et al.	
9,585,222	B2	2/2017	Zhu et al.	
9,655,188	B1	5/2017	Lewis et al.	
9,723,676	B2	8/2017	Ganick et al.	
9,750,107	B2	8/2017	Zhu et al.	
9,820,344	B1	11/2017	Papanicolaou	
9,883,561	B1	1/2018	Liang et al.	
9,883,562	B2	1/2018	Zhu et al.	
9,961,734	B2	6/2018	Zhu et al.	
10,054,271	B2	8/2018	Xiong et al.	
2006/0022648	A1	2/2006	Ben-Yaakov et al.	
2007/0182338	A1	8/2007	Shteynberg et al.	
2007/0182699	A1	8/2007	Ha et al.	
2007/0267978	A1	11/2007	Shteynberg et al.	
2008/0224629	A1	9/2008	Melanson	
2008/0278092	A1	11/2008	Lys et al.	
2009/0021469	A1	1/2009	Yeo et al.	
2009/0251059	A1	10/2009	Veltman	
2010/0141153	A1	6/2010	Recker et al.	
2010/0156319	A1	6/2010	Melanson	
2010/0164406	A1	7/2010	Kost et al.	
2010/0176733	A1	7/2010	King	
2010/0207536	A1	8/2010	Burdalski	
2010/0213859	A1	8/2010	Shteynberg	
2010/0231136	A1	9/2010	Reisenauer et al.	
2011/0037399	A1	2/2011	Hung et al.	
2011/0080110	A1	4/2011	Nuhfer et al.	
2011/0080111	A1	4/2011	Nuhfer et al.	
2011/0101867	A1	5/2011	Wang et al.	
2011/0121744	A1	5/2011	Salvestrini	
2011/0121754	A1	5/2011	Shteynberg	
2011/0133662	A1	6/2011	Yan et al.	
2011/0227490	A1	9/2011	Huynh	
2011/0260619	A1	10/2011	Sadwick	
2011/0285301	A1	11/2011	Kuang et al.	
2011/0291583	A1	12/2011	Shen	
2011/0309759	A1	12/2011	Shteynberg	
2012/0001548	A1	1/2012	Recker et al.	
2012/0032604	A1	2/2012	Hontele	
2012/0069616	A1	3/2012	Kitamura et al.	
2012/0080944	A1	4/2012	Recker et al.	
2012/0081009	A1	4/2012	Shteynberg et al.	
2012/0146526	A1*	6/2012	Lam	H05B 41/2824 315/200 R
2012/0181944	A1	7/2012	Jacobs et al.	
2012/0181946	A1	7/2012	Melanson	
2012/0187857	A1	7/2012	Ulmann et al.	
2012/0242237	A1	9/2012	Chen et al.	
2012/0262093	A1	10/2012	Recker et al.	
2012/0268031	A1	10/2012	Zhou et al.	
2012/0299500	A1	11/2012	Sadwick	
2012/0299501	A1	11/2012	Kost et al.	
2012/0319604	A1	12/2012	Walters	
2012/0326616	A1*	12/2012	Sumitani	H05B 33/0815 315/201
2013/0009561	A1	1/2013	Briggs	
2013/0020965	A1	1/2013	Kang et al.	
2013/0026942	A1	1/2013	Ryan et al.	
2013/0026945	A1	1/2013	Ganick et al.	
2013/0027528	A1	1/2013	Staats et al.	
2013/0034172	A1	2/2013	Pettier et al.	
2013/0043726	A1	2/2013	Krishnamoorthy et al.	
2013/0063047	A1	3/2013	Veskovic	
2013/0154487	A1	6/2013	Kuang et al.	
2013/0162158	A1	6/2013	Pollischanshy	
2013/0175931	A1	7/2013	Sadwick	
2013/0181630	A1	7/2013	Taipale et al.	
2013/0193879	A1	8/2013	Sadwick	
2013/0194848	A1	8/2013	Bernardinis et al.	
2013/0215655	A1*	8/2013	Yang	H05B 33/0851 363/89
2013/0223107	A1	8/2013	Zhang et al.	
2013/0241427	A1	9/2013	Kesterson et al.	
2013/0241428	A1	9/2013	Takeda	
2013/0241441	A1	9/2013	Myers et al.	
2013/0242622	A1	9/2013	Peng	
2013/0307431	A1	11/2013	Zhu et al.	
2013/0307434	A1	11/2013	Zhang	
2014/0009082	A1	1/2014	King et al.	
2014/0029315	A1	1/2014	Zhang et al.	
2014/0063857	A1	3/2014	Peng	
2014/0078790	A1	3/2014	Lin et al.	
2014/0103829	A1	4/2014	Kang	
2014/0132172	A1	5/2014	Zhu et al.	
2014/0160809	A1	6/2014	Lin et al.	
2014/0176016	A1	6/2014	Li et al.	
2014/0197760	A1	7/2014	Radermacher	
2014/0265898	A1	9/2014	Del Carmen, Jr. et al.	
2014/0265935	A1	9/2014	Sadwick	
2014/0268935	A1	9/2014	Chiang	
2014/0346973	A1	11/2014	Zhu et al.	
2014/0354170	A1	12/2014	Gredler	
2015/0035450	A1	2/2015	Werner	
2015/0077009	A1*	3/2015	Kunimatsu	H05B 33/0815 315/224
2015/0091470	A1	4/2015	Zhou et al.	
2015/0312982	A1	10/2015	Melanson	
2015/0312988	A1	10/2015	Liao et al.	
2015/0333764	A1	11/2015	Pastore et al.	
2015/0357910	A1	12/2015	Murakami et al.	
2015/0359054	A1	12/2015	Lin et al.	
2015/0366010	A1	12/2015	Mao et al.	
2016/0014861	A1	1/2016	Zhu et al.	
2016/0014865	A1	1/2016	Zhu et al.	
2016/0037604	A1	2/2016	Zhu et al.	
2016/0119998	A1	4/2016	Linnartz et al.	

(56) **References Cited**

U.S. PATENT DOCUMENTS

2016/0286617	A1	9/2016	Takahashi et al.
2016/0338163	A1	11/2016	Zhu et al.
2017/0027029	A1	1/2017	Hu et al.
2017/0181235	A1	6/2017	Zhu et al.
2017/0196063	A1	7/2017	Zhu et al.
2017/0251532	A1	8/2017	Wang et al.
2017/0311409	A1	10/2017	Zhu et al.
2017/0354008	A1	12/2017	Eum et al.
2017/0359880	A1	12/2017	Zhu et al.
2018/0103520	A1	4/2018	Zhu et al.
2018/0110104	A1	4/2018	Liang et al.
2018/0288845	A1	10/2018	Zhu et al.

FOREIGN PATENT DOCUMENTS

CN	101868090		10/2010
CN	101896022	A	11/2010
CN	101917804	A	12/2010
CN	101998734	A	3/2011
CN	102014540		4/2011
CN	102014551	A	4/2011
CN	102056378	A	5/2011
CN	102209412	A	10/2011
CN	102300375	A	12/2011
CN	102347607		2/2012
CN	102387634	A	3/2012
CN	103004290		3/2012
CN	102474953		5/2012
CN	102497706		6/2012
CN	202353859	U	7/2012
CN	102695330	A	9/2012
CN	102791056	A	11/2012
CN	102843836	A	12/2012
CN	202632722	U	12/2012
CN	102870497		1/2013
CN	102946674	A	2/2013
CN	103024994	A	4/2013
CN	103260302	A	8/2013
CN	103313472		9/2013
CN	103369802	A	10/2013
CN	103379712	A	10/2013
CN	103547014		1/2014
CN	103716934		4/2014
CN	103858524		6/2014
CN	203675408	U	6/2014
CN	103945614	A	7/2014
CN	103096606	B	12/2014
CN	103781229	B	9/2015
CN	105265019		1/2016
CN	105423140	A	3/2016
CN	105591553	A	5/2016
CN	105873269		8/2016
CN	205812458	U	12/2016
CN	106358337	A	1/2017
CN	106793246	A	5/2017
CN	107046751	A	8/2017
CN	106332374	A	11/2017
EP	2403318	A1	1/2012
JP	2008-010152	A	1/2008
JP	2011-249328	A	12/2011
TW	201215228	A1	9/2010
TW	201125441	A	7/2011
TW	201132241		9/2011
TW	201143530	A	12/2011
TW	201146087	A1	12/2011
TW	201204168	A1	1/2012
TW	201208463	A1	2/2012
TW	201208481	A1	2/2012
TW	201208486		2/2012
TW	201233021	A	8/2012
TW	I 387396		2/2013
TW	201315118	A	4/2013
TW	201322825	A	6/2013
TW	201342987		10/2013
TW	I-422130		1/2014
TW	I 423732		1/2014
TW	201412189	A	3/2014
TW	201414146	A	4/2014
TW	M477115		4/2014
TW	201417626	A	5/2014
TW	201417631		5/2014
TW	201422045		6/2014
TW	201424454	A	6/2014
TW	I 448198		8/2014
TW	201503756	A	1/2015
TW	I 496502	B	8/2015
TW	201630468	A	8/2016
TW	201639415	A	11/2016

OTHER PUBLICATIONS

China Patent Office, Office Action dated Aug. 8, 2015, in Application No. 201410172086.6.

China Patent Office, Office Action dated Mar. 2, 2016, in Application No. 201410172086.6.

China Patent Office, Office Action dated Dec. 14, 2015, in Application No. 201210166672.0.

China Patent Office, Office Action dated Sep. 2, 2016, in Application No. 201510103579.9.

China Patent Office, Office Action dated Jul. 7, 2014, in Application No. 201210468505.1.

China Patent Office, Office Action dated Jun. 3, 2014, in Application No. 201110103130.4.

China Patent Office, Office Action dated Jun. 30, 2015, in Application No. 201410171893.6.

China Patent Office, Office Action dated Nov. 15, 2014, in Application No. 201210166672.0.

China Patent Office, Office Action dated Oct. 19, 2015, in Application No. 201410322612.2.

China Patent Office, Office Action dated Mar. 3, 2016, in Application No. 201410322612.2.

Taiwan Intellectual Property Office, Office Action dated Jan. 7, 2014, in Application No. 100119272.

Taiwan Intellectual Property Office, Office Action dated Jun. 9, 2014, in Application No. 101124982.

Taiwan Intellectual Property Office, Office Action dated Nov. 13, 2015, in Application No. 103141628.

Taiwan Intellectual Property Office, Office Action dated Sep. 17, 2015, in Application No. 103127108.

Taiwan Intellectual Property Office, Office Action dated Sep. 17, 2015, in Application No. 103127620.

Taiwan Intellectual Property Office, Office Action dated Sep. 25, 2014, in Application No. 101148716.

Taiwan Intellectual Property Office, Office Action dated Apr. 18, 2016, in Application No. 103140989.

United States Patent and Trademark Office, Notice of Allowance dated Apr. 9, 2015, in U.S. Appl. No. 13/527,475.

United States Patent and Trademark Office, Notice of Allowance dated May 7, 2015, in U.S. Appl. No. 13/527,475.

United States Patent and Trademark Office, Notice of Allowance dated Oct. 22, 2015, in U.S. Appl. No. 13/527,475.

United States Patent and Trademark Office, Office Action dated Dec. 2, 2014, in U.S. Appl. No. 13/527,475.

United States Patent and Trademark Office, Notice of Allowance dated Mar. 7, 2016, in U.S. Appl. No. 13/710,277.

United States Patent and Trademark Office, Notice of Allowance dated Dec. 21, 2015, in U.S. Appl. No. 13/710,277.

United States Patent and Trademark Office, Office Action dated Jun. 5, 2015, in U.S. Appl. No. 13/710,277.

United States Patent and Trademark Office, Office Action dated Jan. 13, 2016, in U.S. Appl. No. 14/451,656.

United States Patent and Trademark Office, Office Action dated Dec. 17, 2015, in U.S. Appl. No. 14/459,167.

United States Patent and Trademark Office, Office Action dated Sep. 6, 2016, in U.S. Appl. No. 14/459,167.

United States Patent and Trademark Office, Notice of Allowance dated Mar. 30, 2016, in U.S. Appl. No. 14/562,432.

(56) **References Cited**

OTHER PUBLICATIONS

United States Patent and Trademark Office, Notice of Allowance dated Jan. 21, 2016, in U.S. Appl. No. 14/562,432.
United States Patent and Trademark Office, Notice of Allowance dated Sep. 12, 2016, in U.S. Appl. No. 14/819,200.
United States Patent and Trademark Office, Office Action dated Aug. 19, 2015, in U.S. Appl. No. 14/562,432.
United States Patent and Trademark Office, Office Action dated Jan. 15, 2015, in U.S. Appl. No. 14/562,432.
United States Patent and Trademark Office, Office Action dated Dec. 30, 2015, in U.S. Appl. No. 14/593,734.
United States Patent and Trademark Office, Notice of Allowance dated Jun. 16, 2015, in U.S. Appl. No. 14/593,734.
United States Patent and Trademark Office, Office Action dated Dec. 3, 2015, in U.S. Appl. No. 14/819,200.
United States Patent and Trademark Office, Notice of Allowance dated Jun. 16, 2016, in U.S. Appl. No. 14/593,734.
United States Patent and Trademark Office, Notice of Allowance dated Oct. 20, 2016, in U.S. Appl. No. 14/451,656.
United States Patent and Trademark Office, Office Action dated Jun. 27, 2017, in U.S. Appl. No. 14/459,167.
United States Patent and Trademark Office, Notice of Allowance dated Apr. 21, 2017, in U.S. Appl. No. 15/364,100.
United States Patent and Trademark Office, Notice of Allowance dated Jul. 27, 2017, in U.S. Appl. No. 15/364,100.
United States Patent and Trademark Office, Notice of Allowance dated Apr. 21, 2017, in U.S. Appl. No. 14/532,811.
United States Patent and Trademark Office, Office Action dated Jun. 1, 2017, in U.S. Appl. No. 15/372,324.
United States Patent and Trademark Office, Notice of Allowance dated Jul. 13, 2017, in U.S. Appl. No. 15/403,520.
Taiwan Intellectual Property Office, Office Action dated Aug. 23, 2017, in Application No. 106103535.
United States Patent and Trademark Office, Office Action dated Aug. 29, 2017, in U.S. Appl. No. 15/158,237.
United States Patent and Trademark Office, Notice of Allowance dated Nov. 1, 2017, in U.S. Appl. No. 15/364,100.
United States Patent and Trademark Office, Notice of Allowance dated Oct. 10, 2017, in U.S. Appl. No. 15/403,520.
United States Patent and Trademark Office, Office Action dated Oct. 3, 2017, in U.S. Appl. No. 15/649,586.
United States Patent and Trademark Office, Office Action dated Oct. 3, 2017, in U.S. Appl. No. 15/649,566.
United States Patent and Trademark Office, Notice of Allowance dated Dec. 26, 2017, in U.S. Appl. No. 14/459,167.
United States Patent and Trademark Office, Office Action dated Dec. 13, 2017, in U.S. Appl. No. 15/372,324.
United States Patent and Trademark Office, Notice of Allowance dated Mar. 23, 2018, in U.S. Appl. No. 15/158,237.
United States Patent and Trademark Office, Office Action dated Feb. 16, 2018, in U.S. Appl. No. 15/836,478.
United States Patent and Trademark Office, Office Action dated Mar. 6, 2018, in U.S. Appl. No. 15/836,461.
United States Patent and Trademark Office, Office Action dated Jul. 30, 2018, in U.S. Appl. No. 15/836,478.
United States Patent and Trademark Office, Office Action dated Aug. 3, 2018, in U.S. Appl. No. 15/372,324.
United States Patent and Trademark Office, Notice of Allowance dated May 23, 2018, in U.S. Appl. No. 15/649,586.
United States Patent and Trademark Office, Office Action dated May 11, 2018, in U.S. Appl. No. 15/649,566.
Taiwan Intellectual Property Office, Office Action dated Feb. 27, 2018, in Application No. 106136242.
Taiwan Intellectual Property Office, Office Action dated Feb. 6, 2018, in Application No. 106130686.
United States Patent and Trademark Office, Notice of Allowance dated Oct. 19, 2018, in U.S. Appl. No. 15/158,237.
United States Patent and Trademark Office, Notice of Allowance dated Sep. 24, 2018, in U.S. Appl. No. 15/849,452.
United States Patent and Trademark Office, Notice of Allowance dated Oct. 24, 2018, in U.S. Appl. No. 15/649,586.
United States Patent and Trademark Office, Office Action dated Nov. 2, 2018, in U.S. Appl. No. 15/836,461.
United States Patent and Trademark Office, Office Action dated Oct. 3, 2018, in U.S. Appl. No. 15/934,460.
United States Patent and Trademark Office, Notice of Allowance dated Sep. 24, 2018, in U.S. Appl. No. 15/836,478.
China Patent Office, Office Action dated Nov. 29, 2018, in Application No. 201710828263.5.
China Patent Office, Office Action dated Dec. 3, 2018, in Application No. 201710557179.4.
Taiwan Intellectual Property Office, Office Action dated Jan. 14, 2019, in Application No. 107107508.
United States Patent and Trademark Office, Notice of Allowance dated Jan. 25, 2019, in U.S. Appl. No. 15/849,452.
United States Patent and Trademark Office, Notice of Allowance dated Jan. 7, 2019, in U.S. Appl. No. 15/372,324.
United States Patent and Trademark Office, Notice of Allowance dated Dec. 27, 2018, in U.S. Appl. No. 15/649,566.
United States Patent and Trademark Office, Office Action dated Jan. 11, 2019, in U.S. Appl. No. 16/009,727.
United States Patent and Trademark Office, Notice of Allowance dated Dec. 3, 2018, in U.S. Appl. No. 15/836,478.
China Patent Office, Office Action dated Mar. 22, 2019, in Application No. 201711464007.9.
United States Patent and Trademark Office, Notice of Allowance dated Apr. 4, 2019, in U.S. Appl. No. 15/836,461.
United States Patent and Trademark Office, Office Action dated Apr. 17, 2019, in U.S. Appl. No. 16/119,952.

* cited by examiner

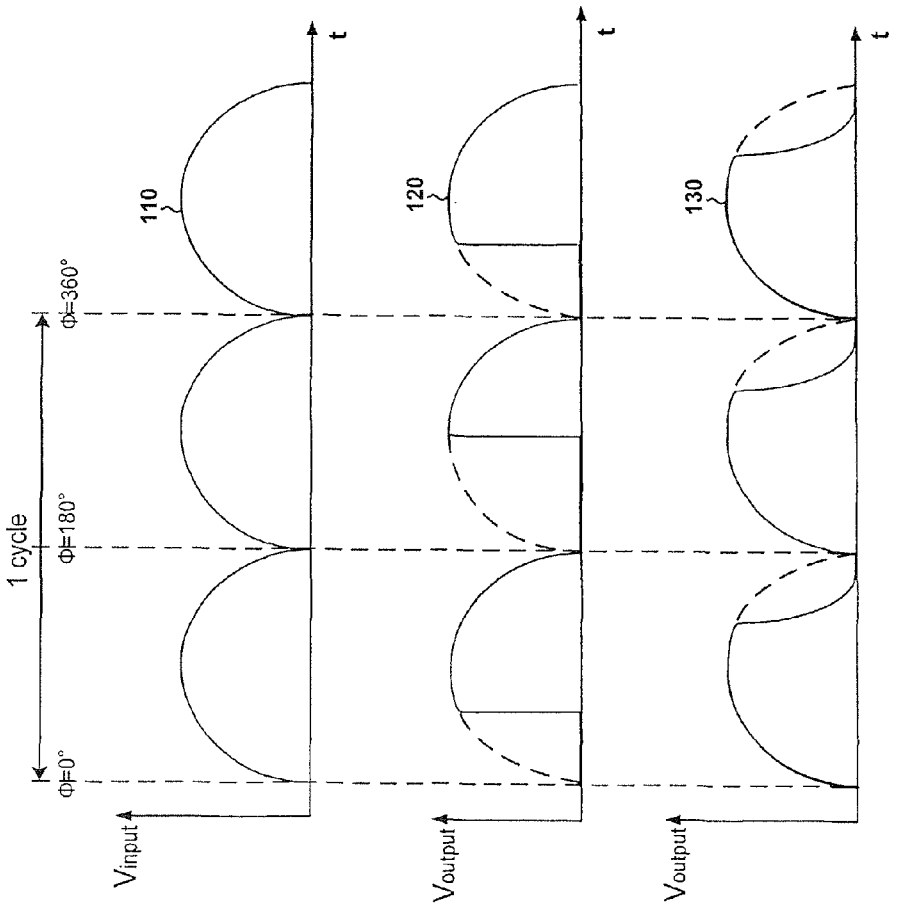


Figure 1
Prior Art

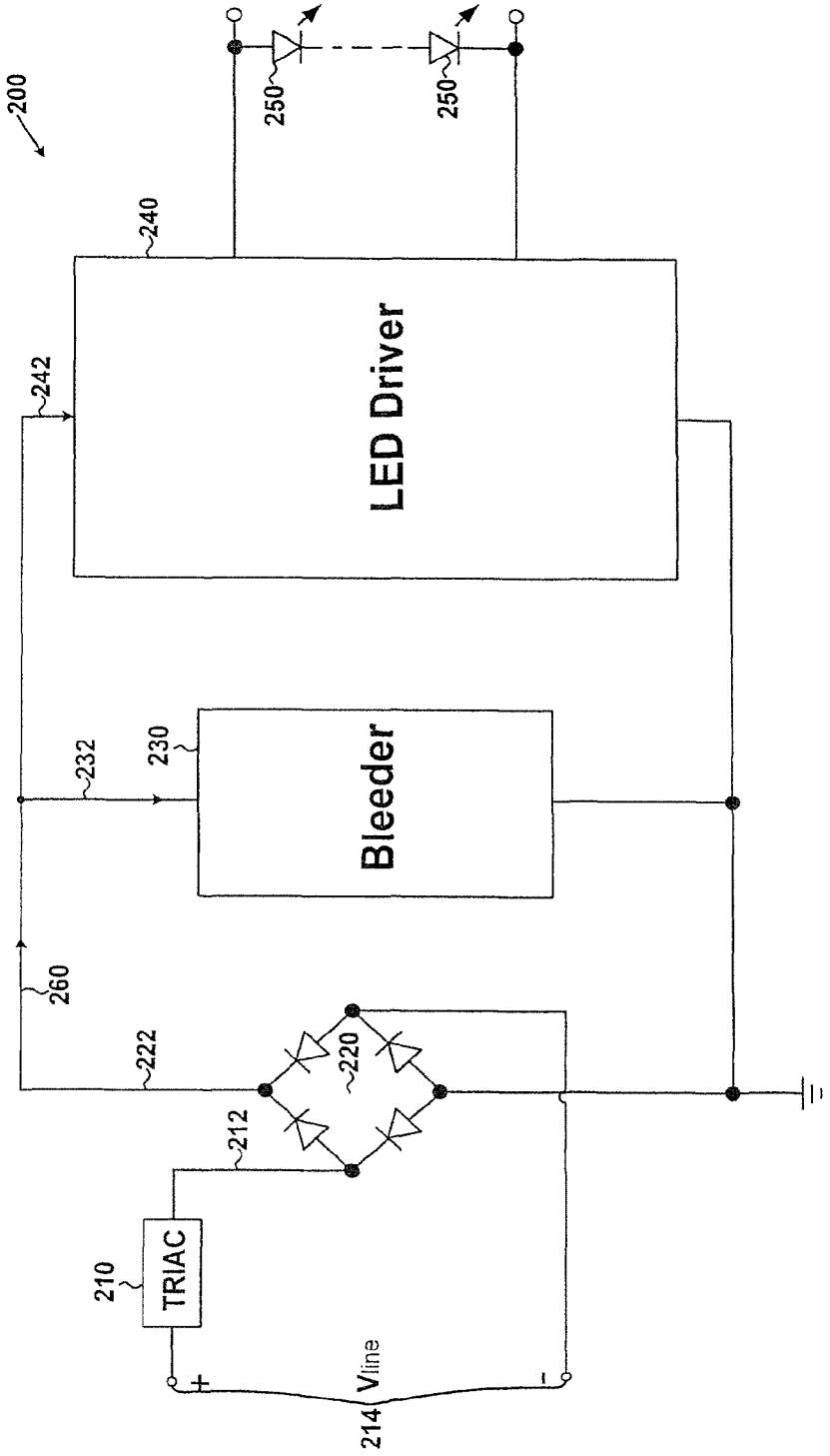


Figure 2
Prior Art

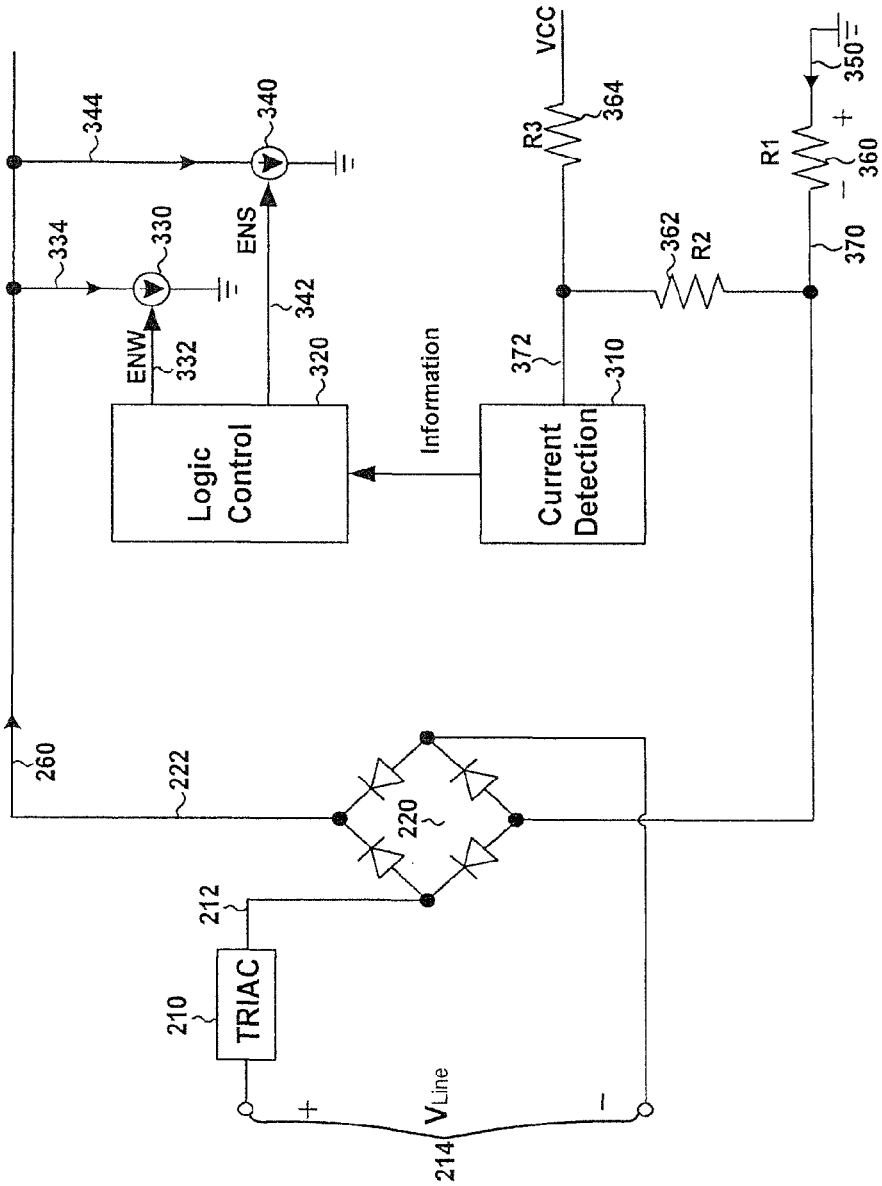


Figure 3
Prior Art

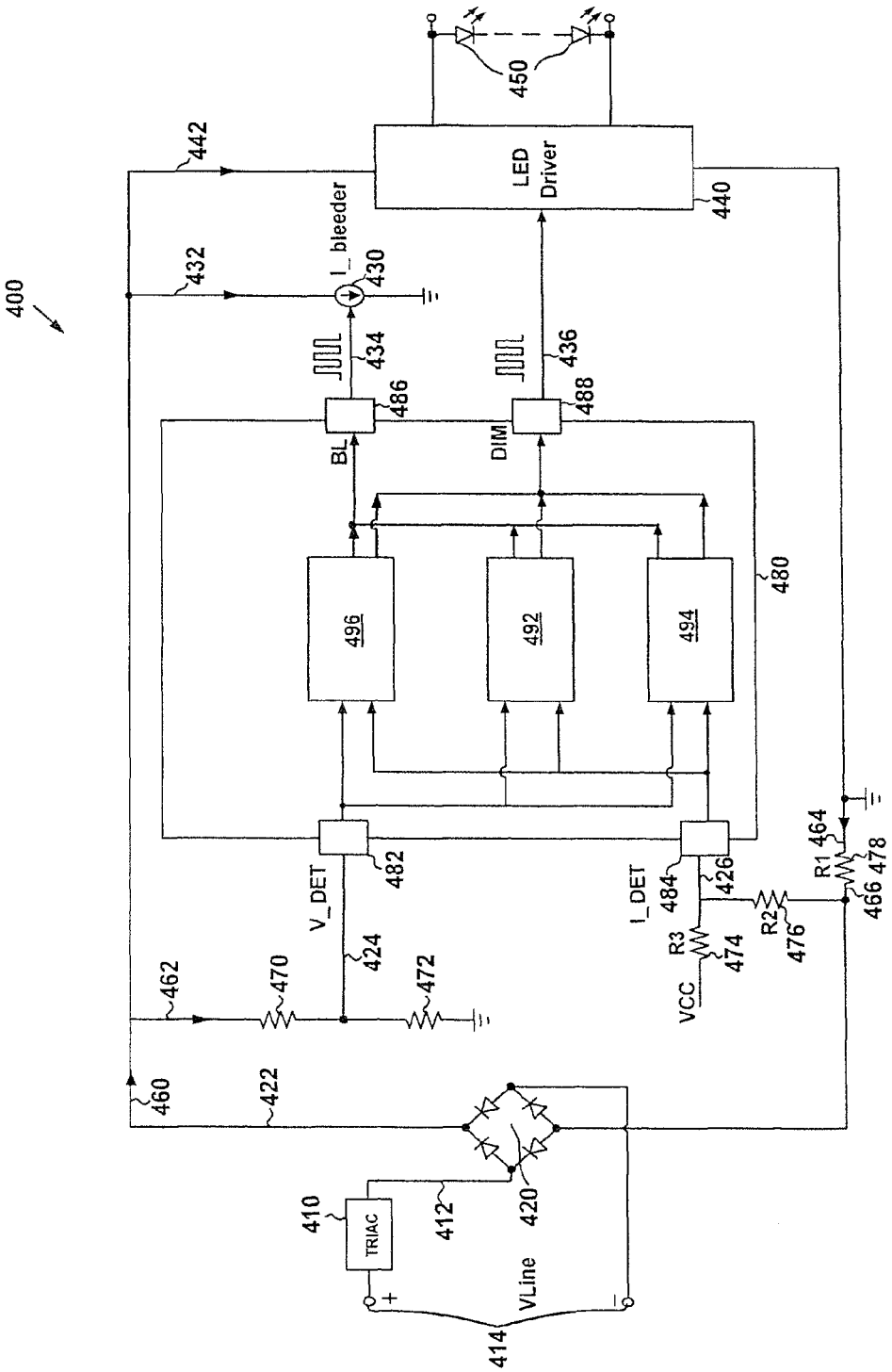

400
450
442
LED Driver
440
I_ bleeder
430
432
434
436
486
488
BL
DIM
496
492
494
480
V_DET
482
I_DET
484
426
R1
464
478
466
R2
476
R3
474
VCC
424
462
470
472
460
422
410
TRIAC
412
420
VLine
414

Figure 4

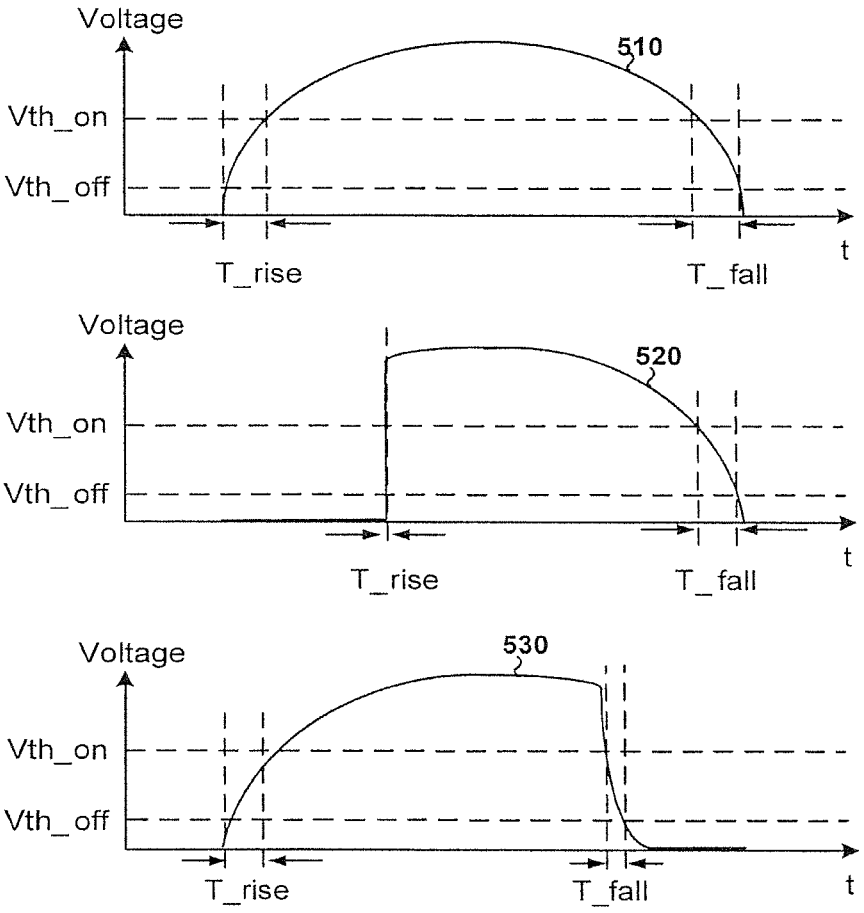

Voltage
510
Vth_on
Vth_off
t
T_rise
T_fall
Voltage
520
Vth_on
Vth_off
t
T_rise
T_fall
Voltage
530
Vth_on
Vth_off
t
T_rise
T_fall

Figure 5

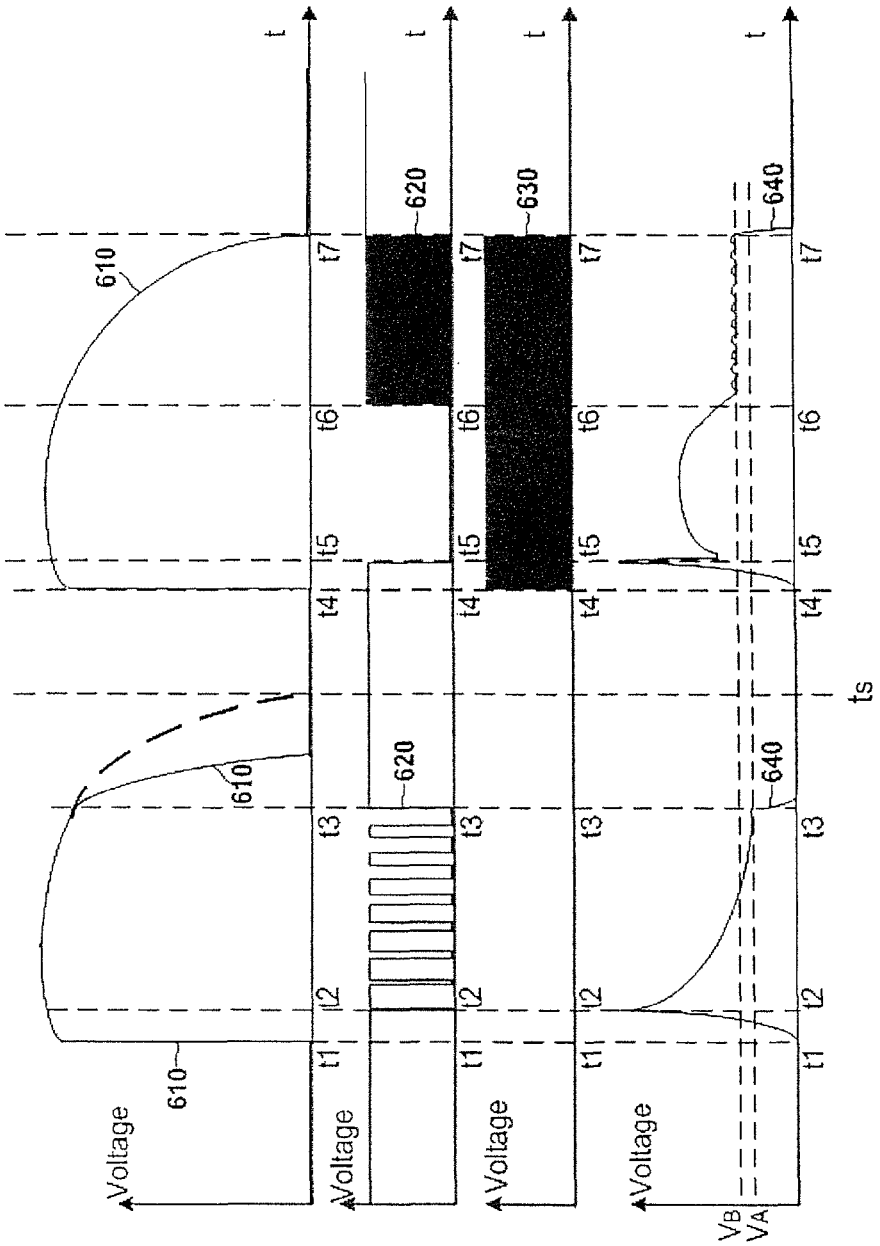


Figure 6

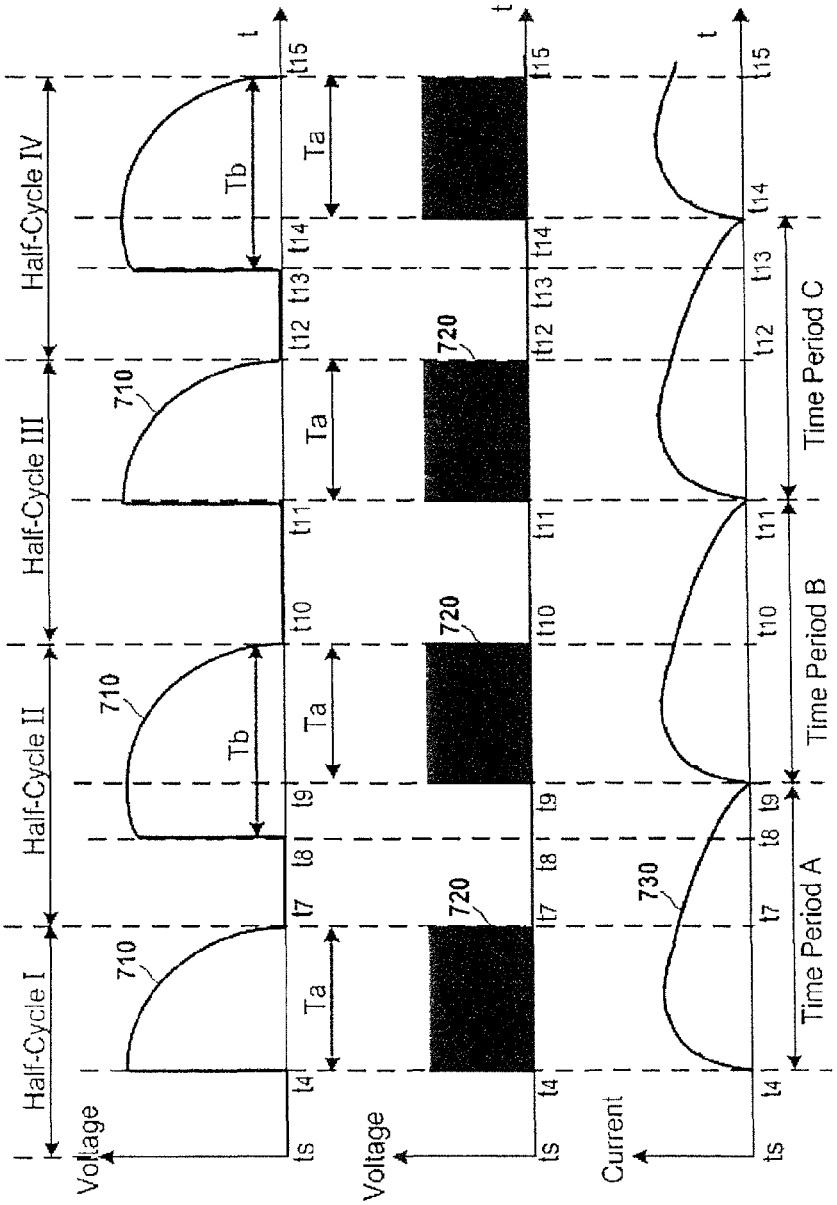

Half-Cycle I
Half-Cycle II
Half-Cycle III
Half-Cycle IV
Voltage
Voltage
Current
t
ts
t4
t7
t8
t9
t10
t11
t12
t13
t14
t15
Ta
Tb
710
720
730
Time Period A
Time Period B
Time Period C

Figure 7

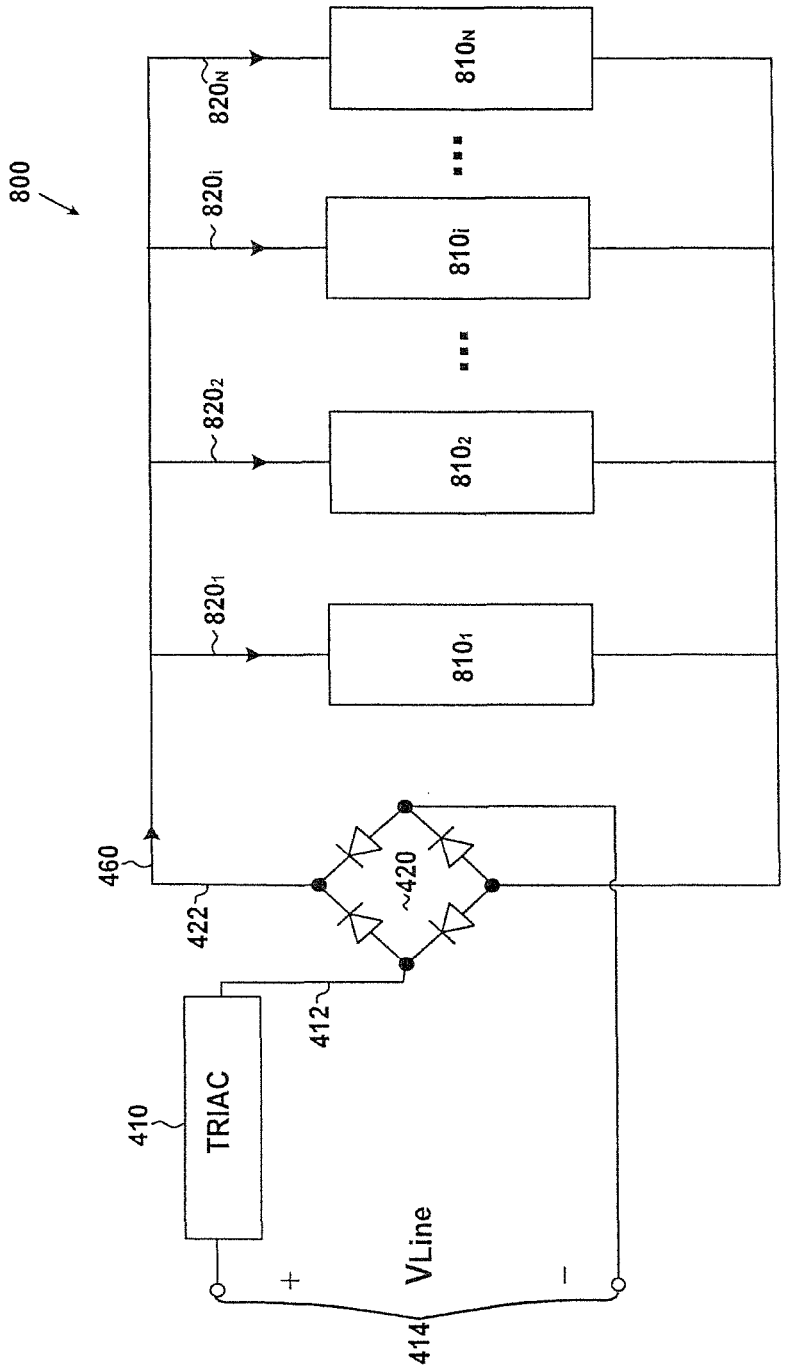

800
820N
810N
820i
810i
820₂
810₂
820₁
810₁
460
422
420
412
410
TRIAC
VLine
+
−
414

Figure 8

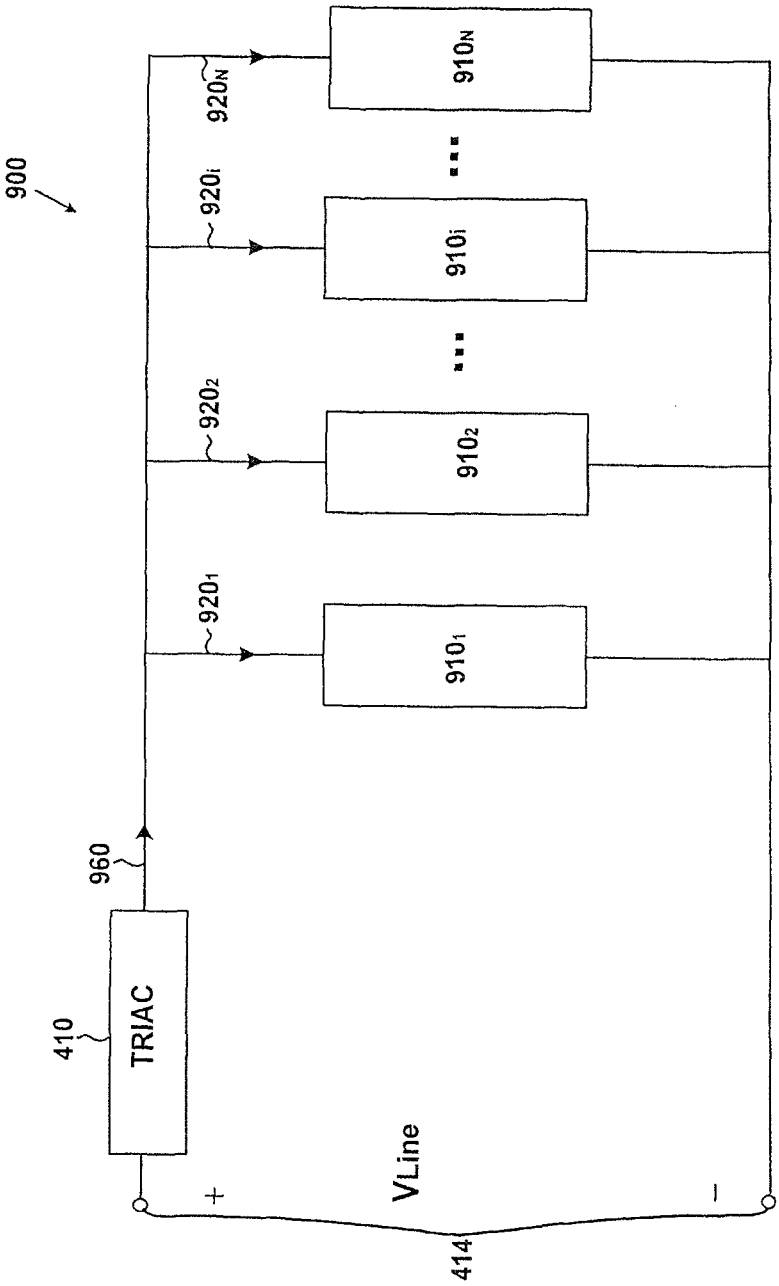

900
920N
910N
920i
910i
920₂
910₂
920₁
910₁
960
410
TRIAC
+
VLine
-
414

Figure 9

SYSTEMS AND METHODS FOR INTELLIGENT CONTROL RELATED TO TRIAC DIMMERS

1. CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/593,734, filed Jan. 9, 2015, which claims priority to Chinese Patent Application No. 201410172086.6, filed Apr. 25, 2014, both of the above-referenced applications being commonly assigned and incorporated by reference herein for all purposes.

Additionally, this application is related to U.S. patent application Ser. No. 14/451,656, which is incorporated by reference herein for all purposes.

2. BACKGROUND OF THE INVENTION

Certain embodiments of the present invention are directed to integrated circuits. More particularly, some embodiments of the invention provide a system and method for intelligent control related to TRIAC dimmers. Merely by way of example, some embodiments of the invention have been applied to driving light emitting diodes (LEDs). But it would be recognized that the invention has a much broader range of applicability.

A conventional lighting system may include or may not include a TRIAC dimmer that is a dimmer including a Triode for Alternating Current (TRIAC). For example, the TRIAC dimmer is either a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer. Often, the leading-edge TRIAC dimmer and the trailing-edge TRIAC dimmer are configured to receive an alternating-current (AC) input voltage, process the AC input voltage by clipping part of the waveform of the AC input voltage, and generate an voltage that is then received by a rectifier (e.g., a full wave rectifying bridge) in order to generate a rectified output voltage.

FIG. **1** shows certain conventional timing diagrams for a leading-edge TRIAC dimmer and a trailing-edge TRIAC dimmer. The waveforms **110**, **120**, and **130** are merely examples. Each of the waveforms **110**, **120**, and **130** represents a rectified output voltage as a function of time that is generated by a rectifier. For the waveform **110**, the rectifier receives an AC input voltage without any processing by a TRIAC dimmer. For the waveform **120**, an AC input voltage is received by a leading-edge TRIAC dimmer, and the voltage generated by the leading-edge TRIAC dimmer is received by the rectifier, which then generates the rectified output voltage. For the waveform **130**, an AC input voltage is received by a trailing-edge TRIAC dimmer, and the voltage generated by the trailing-edge TRIAC dimmer is received by the rectifier, which then generates the rectified output voltage.

As shown by the waveform **110**, each cycle of the rectified output voltage has, for example, a phase angel (e.g., ϕ) that changes from 0° to 180° and then from 180° to 360°. As shown by the waveform **120**, the leading-edge TRIAC dimmer usually processes the AC input voltage by clipping part of the waveform that corresponds to the phase angel starting at 0° or starting at 180°. As shown by the waveform **130**, the trailing-edge TRIAC dimmer often processes the AC input voltage by clipping part of the waveform that corresponds to the phase angel ending at 180° or ending at 360°.

Various conventional technologies have been used to detect whether or not a TRIAC dimmer has been included in a lighting system, and if a TRIAC dimmer is detected to be included in the lighting system, whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer. In one conventional technology, a rectified output voltage generated by a rectifier is compared with a threshold voltage V_{th_on} in order to determine a turn-on time period T_{on}. If the turn-on time period T_{on} is equal to the duration of a half cycle of the AC input voltage, no TRIAC dimmer is determined to be included in the lighting system; if the turn-on time period T_{on} is smaller than the duration of a half cycle of the AC input voltage, a TRIAC dimmer is determined to be included in the lighting system. If a TRIAC dimmer is determined to be included in the lighting system, a turn-on voltage V_{on} is compared with the threshold voltage V_{th_on}. If the turn-on voltage V_{on} is larger than the threshold voltage V_{th_on}, the TRIAC dimmer is determined to be a leading-edge TRIAC dimmer; if the turn-on voltage V_{on} is smaller than the threshold voltage V_{th_on}, the TRIAC dimmer is determined to be a trailing-edge TRIAC dimmer.

In another conventional technology, a rate of change of a rectified output voltage is used. The rectified output voltage is generated by a rectifier, and its rate of change is determined by quickly sampling the rectified voltage twice. Depending on the phase angles at which these two sampling actions are taken, a predetermined range for the rate of change is used. If the rate of change falls within this predetermined range, no TRIAC dimmer is determined to be included in the lighting system; if the rate of change falls outside this predetermined range, a TRIAC dimmer is determined to be included in the lighting system. If a TRIAC dimmer is determined to be included in the lighting system, whether the rate of change is positive or negative is used to determine the type of the TRIAC dimmer. If the rate of change is positive, the TRIAC dimmer is determined to be a leading-edge TRIAC dimmer; if the rate of change is negative, the TRIAC dimmer is determined to be a trailing-edge TRIAC dimmer.

If a conventional lighting system includes a TRIAC dimmer and light emitting diodes (LEDs), the light emitting diodes may flicker if the current that flows through the TRIAC dimmer falls below a holding current that is, for example, required by the TRIAC dimmer. As an example, if the current that flows through the TRIAC dimmer falls below the holding current, the TRIAC dimmer may turn on and off repeatedly, thus causing the LEDs to flicker. As another example, the various TRIAC dimmers made by different manufacturers have different holding currents ranging from 5 mA to 50 mA.

In order to solve this flickering problem, certain conventional technology uses a bleeder for the conventional lighting system. FIG. **2** is a simplified diagram of a conventional lighting system that includes a bleeder. As shown, the lighting system **200** includes a TRIAC dimmer **210**, a rectifier **220**, a bleeder **230**, an LED driver **240**, and LEDs **250**. The TRIAC dimmer **210** receives an AC input voltage **214** (e.g., V_{line}) and generate a voltage **212**. The voltage **212** is received by the rectifier **220** (e.g., a full wave rectifying bridge), which then generates a rectified output voltage **222** and a rectified output current **260**. The rectified output current **260** is equal to the current that flows through the TRIAC dimmer **210**, and is also equal to the sum of currents **232** and **242**. The current **232** is received by the bleeder **230**, and the current **242** is received by the LED driver **240**. The magnitude of the current **232** may have a fixed magnitude or may change between two different predetermined magnitudes.

FIG. **3** is a simplified diagram showing certain conventional components of the bleeder as part of the lighting system **200** as shown in FIG. **2**. The bleeder **230** includes a current detection circuit **310**, a logic control circuit **320**, and current sinks **330** and **340**. As shown in FIG. **3**, a current **350** is configured to follow through a resistor **360** in order to generate a voltage **370** (e.g., V_1). The current **350** equals the rectified output current **260** in magnitude, and the voltage **370** represents the magnitude of the current **350**. The voltage **370** is divided by resistors **362** and **364** to generate a voltage **372** (e.g., V_2). The voltage **372** is received by the current detection circuit **310**, which sends detected information to the logic control circuit **320**. In response, the logic control circuit **320** either enables the current sink **330** with a control signal **332** or enables the current sink **340** with a control signal **342**. The control signals **332** and **342** are generated by the logic control circuit **320** and are complementary to each other. If the current sink **330** is enabled, the current **232** received by the bleeder **230** is equal to a current **334**; if the current sink **340** is enabled, the current **232** is equal to a current **344**. The current **344** is larger than the current **334** in magnitude.

Returning to FIG. **2**, the voltage **212** generated by the TRIAC dimmer **210** may have waveforms that are not symmetric between a positive half cycle and a negative half cycle of the AC input voltage **214**. This lack of symmetry can cause the current that flows through the LEDs **250** to vary with time; therefore, the LEDs **250** can flicker at a fixed frequency (e.g., 50 Hz or 60 Hz). Also, according to certain conventional technology, a single TRIAC dimmer (e.g., the TRIAC dimmer **210**) and a single rectifier (e.g., the rectifier **220**) are used to support multiple lamp subsystems that are connected in parallel. Each lamp subsystem includes a bleeder (e.g., the bleeder **230**), an LED driver (e.g., the LED driver **240**), and LEDs (e.g., LEDs **250**), and is associated with a rectified output current (e.g., the rectified output current **260**) that provides currents to the bleeder (e.g., the bleeder **230**) and the LED driver (e.g., the LED driver **240**). The sum of these rectified output currents of multiple lamp subsystems is equal to the current that flows through the TRIAC dimmer (e.g., the TRIAC dimmer **210**). Often, each rectified output current for each lamp subsystem is made larger than the holding current of the TRIAC dimmer (e.g., the TRIAC dimmer **210**); hence the sum of these rectified output currents become much larger than the holding current of the TRIAC dimmer (e.g., the TRIAC dimmer **210**), wasting of energy and thus lowering efficiency of the system.

Hence it is highly desirable to improve the techniques of dimming control.

3. BRIEF SUMMARY OF THE INVENTION

Certain embodiments of the present invention are directed to integrated circuits. More particularly, some embodiments of the invention provide a system and method for intelligent control related to TRIAC dimmers. Merely by way of example, some embodiments of the invention have been applied to driving light emitting diodes (LEDs). But it would be recognized that the invention has a much broader range of applicability.

According to one embodiment, a system controller for a lighting system includes a first controller terminal configured to receive a first signal, and a second controller terminal configured to output a second signal to a diver component. The driver component is configured to receive a first current and provide one or more drive currents to one or more light emitting diodes in response to the second signal. Additionally, the system controller is configured to process information associated with the first signal, determine a first time period for the first signal to increase from a first threshold to a second threshold, and determine a second time period for the first signal to decrease from the second threshold to the first threshold. Moreover, the system controller is further configured to, in response to the second time period minus the first time period being larger than a predetermined positive value, determine the first signal to be associate with a leading-edge TRIAC dimmer, and in response to the first time period minus the second time period being larger than the predetermined positive value, determine the first signal to be associate with a trailing-edge TRIAC dimmer. Also, the system controller is further configured to, in response to an absolute value of the first time period minus the second time period being smaller than the predetermined positive value, determine the first signal not to be associated with any TRIAC dimmer.

According to another embodiment, a system controller for a lighting system includes a first controller terminal configured to receive a first signal associated with a TRIAC dimmer, and a second controller terminal configured to output a second signal to a current sink. The current sink is configured to receive a first current in response to the second signal. Additionally, the system controller includes a third controller terminal configured to output a third signal to a driver component. The driver component is configured to receive a second current and provide one or more drive currents to one or more light emitting diodes in response to the third signal. Moreover, the system controller includes a fourth controller terminal configured to receive a fourth signal. The fourth signal is related to a third current that flows through the TRIAC dimmer. Also, the system controller is configured to process information associated with the first signal, and determine the TRIAC dimmer is turned on at a first time based at least in part on the first signal. Additionally, the system controller is configured to, after the first time, with a first delay, decrease a duty cycle of the second signal from a first predetermined value until the fourth signal indicates that the TRIAC dimmer is turned off at a second time, and in response to the fourth signal indicating that the TRIAC dimmer is turned off at the second time, set a first threshold for the fourth signal, the first threshold being related to a holding current of the TRIAC dimmer. Moreover, the system controller is further configured to process information associated with the first signal, and determine the TRIAC dimmer is turned on at a third time based at least in part on the first signal. Also, the system controller is further configured to, after the third time, with a second delay, change the second signal from a first logic level to a second logic level and keep the second signal at the second logic level until a fourth time, and at the fourth time, change the second signal to a modulation signal to regulate the fourth signal at a second threshold in order to keep the fourth signal larger than the first threshold and keep the third current larger than the holding current of the TRIAC dimmer. The second threshold is larger than the first threshold, and the modulation signal changes between the first logic level and the second logic level.

According to yet another embodiment, a method for a lighting system includes receiving a first signal, processing information associated with the first signal, determining a first time period for the first signal to increase from a first threshold to a second threshold, determining a second time period for the first signal to decrease from the second threshold to the first threshold, and processing information

associated with the first time period and the second time period. Additionally, the method includes, in response to the second time period minus the first time period being larger than a predetermined positive value, determining the first signal to be associate with a leading-edge TRIAC dimmer, and in response to the first time period minus the second time period being larger than the predetermined positive value, determining the first signal to be associate with a trailing-edge TRIAC dimmer. Moreover, the method includes, in response to an absolute value of the first time period minus the second time period being smaller than the predetermined positive value, determining the first signal not to be associated with any TRIAC dimmer.

According to yet another embodiment, a method for a lighting system includes receiving a first signal associated with a TRIAC dimmer, receiving a second signal related to a first current that flows through the TRIAC dimmer, processing information associated with the first signal, and determining the TRIAC dimmer is turned on at a first time based at least in part on the first signal. Additionally, the method includes, after the first time, with a first delay, decreasing a duty cycle of a third signal from a first predetermined value until the second signal indicates that the TRIAC dimmer is turned off at a second time, and setting a first threshold for the second signal in response to the second signal indicating that the TRIAC dimmer is turned off at the second time, the first threshold being related to a holding current of the TRIAC dimmer. Moreover, the method includes determining that the TRIAC dimmer is turned on at a third time based at least in part on the first signal, and after the third time, with a second delay, changing the third signal from a first logic level to a second logic level and keep the third signal at the second logic level until a fourth time. Also, the method includes at the fourth time, changing the third signal to a modulation signal to regulate the second signal at a second threshold in order to keep the second signal larger than the first threshold and keep the first current larger than the holding current of the TRIAC dimmer. The second threshold is larger than the first threshold, and the modulation signal changes between the first logic level and the second logic level.

Depending upon embodiment, one or more benefits may be achieved. These benefits and various additional objects, features and advantages of the present invention can be fully appreciated with reference to the detailed description and accompanying drawings that follow.

4. BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows certain conventional timing diagrams for a leading-edge TRIAC dimmer and a trailing-edge TRIAC dimmer.

FIG. **2** is a simplified diagram of a conventional lighting system that includes a bleeder.

FIG. **3** is a simplified diagram showing certain conventional components of the bleeder as part of the lighting system as shown in FIG. **2**.

FIG. **4** is a simplified diagram of a lighting system according to an embodiment of the present invention.

FIG. **5** shows certain timing diagrams for a processing component of a system controller as part of the lighting system as shown in FIG. **4** according to an embodiment of the present invention.

FIG. **6** shows certain timing diagrams for another processing component of the system controller as part of the lighting system as shown in FIG. **4** if a TRIAC dimmer is includes in the lighting system and the TRIAC dimmer is a leading-edge TRIAC dimmer according to an embodiment of the present invention.

FIG. **7** shows certain timing diagrams for yet another processing component of the system controller as part of the lighting system as shown in FIG. **4** if a TRIAC dimmer is includes in the lighting system and the TRIAC dimmer is a leading-edge TRIAC dimmer according to an embodiment of the present invention.

FIG. **8** is a simplified diagram of a lighting system that includes multiple lamp subsystems according to an embodiment of the present invention.

FIG. **9** is a simplified diagram of a lighting system that includes multiple lamp subsystems according to another embodiment of the present invention.

5. DETAILED DESCRIPTION OF THE INVENTION

Certain embodiments of the present invention are directed to integrated circuits. More particularly, some embodiments of the invention provide a system and method for intelligent control related to TRIAC dimmers. Merely by way of example, some embodiments of the invention have been applied to driving light emitting diodes (LEDs). But it would be recognized that the invention has a much broader range of applicability.

As discussed earlier, various conventional technologies have been used to detect whether or not a TRIAC dimmer has been included in a lighting system, and if a TRIAC dimmer is detected to be included in the lighting system, whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer. These conventional technologies have various weaknesses.

In one conventional technology, a rectified output voltage generated by a rectifier is compared with a threshold voltage V_{th_on} in order to determine a turn-on time period T_{on}. This conventional technology, however, often cannot effectively distinguish the situation where no TRIAC dimmer is included in a lighting system from the situation where a trailing-edge TRIAC dimmer is included in a lighting system. In the situation where a trailing-edge TRIAC dimmer is included in a lighting system, the voltage generated by the trailing-edge TRIAC dimmer after the dimmer is turned off decreases slowly to the threshold voltage V_{th_on} due to charging and/or discharging of one or more capacitors. This slow reduction of the voltage makes it difficult to compare the turn-on time period T_{on} and the duration of a half cycle of the AC input voltage; hence the determination about whether a TRIAC dimmer has been included in a lighting system and/or whether a trailing-edge TRIAC dimmer has been included in a lighting system becomes unreliable.

In another conventional technology, a rate of change of a rectified output voltage is used. The rectified output voltage is generated by a rectifier, and its rate of change is determined by quickly sampling the rectified voltage twice. Hence this conventional technology needs real-time fast calculation of rate of change between two successively sampled rectified voltage values, and also needs storage of various predetermined ranges for the rate of change that correspond to various phase angles at which these two sampling actions are taken. Such computation and storage often impose significant demand on bit depth of an analog-to-digital converter, computational capability of the system, and storage capacity of the system.

Additionally, referring to FIG. **2**, the current **232** is received by the bleeder **230**. As shown in FIG. **3**, the

magnitude of the current **232** can change between two different predetermined magnitudes. The current **232** equals the current **334** or the current **344**, and the current **344** is larger than the current **334** in magnitude. One weakness of this conventional technology as shown in FIGS. **2** and **3** is that the currents **334** and **344** each have a fixed magnitude. If the holding current of the TRIAC dimmer **210** is higher than both the currents **334** and **344** in magnitude, the LEDs **250** may flicker. If the holding current of the TRIAC dimmer **210** is lower than the current **344** but higher than the current **334** in magnitude, setting the current **232** equal to the current **334** may cause the LEDs **250** to flicker, but setting the current **232** equal to the current **344** may waster energy and thus lower efficiency of the system.

Moreover as discussed above, as shown in FIG. **2**, the voltage **212** generated by the TRIAC dimmer **210** may have waveforms that are not symmetric between a positive half cycle and a negative half cycle of the AC input voltage **214**. This lack of symmetry can cause the LEDs **250** to flicker at a fixed frequency (e.g., 50 Hz or 60 Hz). To resolve this issue, two turn-on time periods for the waveforms can be detected in real time. One of the two turn-on time periods corresponds to a positive half cycle, and the other of the two turn-on time periods corresponds to a negative half cycle that is neighboring to the positive half cycle. The waveform with the longer turn-on time period can, for example, be delayed in providing a current to the LEDs **250**, so that the current received by the LEDs **250** is symmetric between the positive half cycle and the negative half cycle of the AC input voltage **214**.

Additionally as discussed above, according to certain conventional technology, a single TRIAC dimmer (e.g., the TRIAC dimmer **210**) and a single rectifier (e.g., the rectifier **220**) are used to support multiple lamp subsystems that are connected in parallel. The sum of the rectified output currents of multiple lamp subsystems is equal to the current that flows through the TRIAC dimmer (e.g., the TRIAC dimmer **210**), and often is much larger than the holding current of the TRIAC dimmer (e.g., the TRIAC dimmer **210**). Such large magnitude for the sum of the rectified output currents of multiple lamp subsystems not only lowers efficiency of the system but also reduces the number of lamp subsystems that can be supported by the single TRIAC dimmer (e.g., the TRIAC dimmer **210**) and the single rectifier (e.g., the rectifier **220**).

Certain embodiments of the present invention provide an intelligent mechanism to match and control a TRIAC dimmer. According to one embodiment, the intelligent mechanism can reliably and automatically detect whether or not a TRIAC dimmer has been included in a lighting system, and if a TRIAC dimmer is detected to be included in the lighting system, whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer. For example, this reliable and automatic detection can help to select appropriate method of dimming control in order to improve energy efficiency of the system. According to another embodiment, the intelligent mechanism can automatically detect the holding current of the TRIAC dimmer, and use the closed-loop control to ensure the current that flows through the TRIAC dimmer is not lower than the holding current of the TRIAC dimmer.

According to another embodiment, the intelligent mechanism can provide to LEDs a current that is symmetric between the positive half cycle and the negative half cycle of an AC input voltage in order to prevent flickering of the LEDs that can be caused by an asymmetric current between the positive half cycle and the negative half cycle of the AC input voltage. According to yet another embodiment, if multiple lamp subsystems are connected in parallel, the intelligent mechanism can optimize each rectified output current for each lamp subsystem so that the sum of these rectified output currents is larger than but not too much larger than the holding current of the TRIAC dimmer in order to avoid flickering of LEDs that is caused by insufficient current flowing through the TRIAC dimmer. For example, such optimization of each rectified output current can help improve energy efficiency of the system. In another example, such optimization of each rectified output current can increase the number of lamp subsystems that can be supported by the system.

FIG. **4** is a simplified diagram of a lighting system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The lighting system **400** includes a TRIAC dimmer **410**, a rectifier **420**, a current sink **430**, an LED driver **440**, one or more LEDs **450**, resistors **470**, **472**, **474**, **476**, and **478**, and a system controller **480**.

Although the above has been shown using a selected group of components for the lighting system **400**, there can be many alternatives, modifications, and variations. In one embodiment, the TRIAC dimmer **410** is removed from the lighting system **400** so that the lighting system **400** does not include the TRIAC dimmer **410**. In another embodiment, the TRIAC dimmer **410** and the rectifier **420** are used to support multiple lamp subsystems that are connected in parallel.

For example, each lamp subsystem includes a system controller (e.g., the system controller **480**), and resistors (e.g., the resistors **470**, **472**, **474**, **476**, and **478**), a current sink (e.g., the current sink **430**), an LED driver (e.g., the LED driver **440**), and one or more LEDs (e.g., the one or more LEDs **450**). In another example, each lamp subsystem includes a rectifier (e.g., the rectifier **420**), a system controller (e.g., the system controller **480**), and resistors (e.g., the resistors **470**, **472**, **474**, **476**, and **478**), a current sink (e.g., the current sink **430**), an LED driver (e.g., the LED driver **440**), and one or more LEDs (e.g., the one or more LEDs **450**).

As shown in FIG. **4**, the TRIAC dimmer **410** receives an AC input voltage **414** (e.g., V_{line}) and generates a voltage **412**. For example, the voltage **412** is received by the rectifier **420** (e.g., a full wave rectifying bridge), which generates a rectified output voltage **422** and a rectified output current **460**. In another example, the rectified output voltage **422** is received by a voltage divider including the resistors **470** and **472**, and the voltage divider outputs a voltage **424**.

In one embodiment, a current **464** flows through the resistor **478**, which generates a voltage **466**. For example, the current **464** is equal to the rectified output current **460** in magnitude. In another example, the voltage **466** is received by a voltage divider including the resistors **474** and **476**, and the voltage divider outputs a voltage **426**. In yet another example, the voltage **426** represents the rectified output current **460**, which is equal to the current that flows through the TRIAC dimmer **410**.

In another embodiment, the system controller **480** includes terminals **482**, **484**, **486**, and **488**, and processing components **492**, **494**, and **496**. For example, the terminal **482** (e.g., the terminal "V_DET") receives the voltage **424**. In another example, the terminal **484** (e.g., the terminal "I_DET") receives the voltage **426**. In yet another example, the terminal **486** (e.g., the terminal "BL") outputs a control signal **434** (e.g., a pulse-width-modulation signal or an

analog voltage signal) to the current sink **430**. In yet another example, the terminal **488** (e.g., the terminal "DIM") outputs a control signal **436** (e.g., a pulse-width-modulation signal or an analog voltage signal) to the LED driver **440**.

In yet another embodiment, the current sink **430**, in response to the received signal **434**, generates a current **432**. For example, the signal **434** is an analog voltage signal that controls the magnitude of the current **432**. In another example, the received signal **434** is a logic signal, which changes between a logic high level and a logic low level. According to one embodiment, if the received signal **434** is at the logic high level, the current sink **430** is turned on and the current **432** is equal to a predetermined current level that is larger than zero, and if the received signal **434** is at the logic low level, the current sink **430** is turned off and the current **432** is equal to zero. According to another embodiment, the ratio between the time period when the received signal **434** is at the logic high level and the time period when the received signal **434** is at the logic low level is used by the current sink **430** to determine the magnitude of the current **432**. For example, if the ratio becomes smaller, the current **432** also becomes smaller in magnitude.

In yet another embodiment, the LED driver **440** is configured to receive the signal **436** and a current **442**, and provide one or more drive currents to drive the one or more LEDs **450** in response to the signal **436**. For example, the control signal **436** is a logic signal. In another example, if the control signal **436** is at the logic high level, the LED driver in response receives the current **442** and provides one or more drive currents to drive the one or more LEDs **450**. In yet another example, if the control signal **436** is at the logic low level, in response, the current **442** is equal to zero and the one or more drive currents are also equal to zero. In yet another example, the control signal **436** is an analog signal, and the LED driver in response receives the current **442** and provides one or more drive currents to drive the one or more LEDs **450**, where the one or more drive currents are proportional to the magnitude of the control signal **436**.

In yet another embodiment, the rectified output current **460** is equal to the current that flows through the TRIAC dimmer **410**, and is divided into a current **462** received by the resistor **470**, the current **432** generated and received by the current sink **430**, and the current **442** received by the LED driver **440**. For example, the rectified output current **460** is equal to the sum of the current **462**, the current **432**, and the current **442**. In another example, the rectified output current **460** is equal to the current **464** that is received by the resistor **478** in magnitude.

In yet another embodiment, the processing component **492** is configured to detect whether or not the TRIAC dimmer **410** is included in the lighting system **400**, and if the TRIAC dimmer **410** is detected to be included in the lighting system **400**, whether the TRIAC dimmer **410** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer. For example, the processing component **494** is configured to detect the holding current of the TRIAC dimmer **410**, and use the closed-loop control to control the current **432**. In another example, the processing component **496** is configured to process the voltage **424** that has waveforms not symmetric between a positive half cycle and a negative half cycle of the AC input voltage **414**, so that the system controller **480** can provide to the one or more LEDs **450** a current that is symmetric between the positive half cycle and the negative half cycle of the AC input voltage **414**. In yet another example, the processing component **492** is configured to, if the lighting system **400** includes the multiple lamp subsystems, control the current **432** for the lamp subsystem to which the system controller **480** belongs.

In yet another embodiment, the following processes (a), (b), and (c) are performed sequentially:

(a) The system controller **480** uses the processing component **492** to detect whether or not the TRIAC dimmer **410** is included in the lighting system **400**, and if the TRIAC dimmer **410** is detected to be included in the lighting system **400**, whether the TRIAC dimmer **410** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer;

(b) After the process (a) as described above, if the process (a) determines the TRIAC dimmer **410** is included in the lighting system **400**, the system controller **480** uses the processing component **494** to detect the holding current of the TRIAC dimmer **410**; and

(c) After the processes (a) and (b) as described above, the process (c) is performed. During the process (c), the system controller **480** uses the processing component **494** to rely on the closed-loop control to control the current **432**. Additionally, during the process (c), the system controller **480** uses the processing component **496** to process the voltage **424** that has waveforms not symmetric between a positive half cycle and a negative half cycle of the AC input voltage **414**, so that the system controller **480** can provide to the one or more LEDs **450** a current that is symmetric between the positive half cycle and the negative half cycle of the AC input voltage **414**.

As discussed above and further emphasized here, FIG. **4** is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. In one embodiment, the TRIAC dimmer **410** is removed from the lighting system **400**, so that the lighting system **400** does not include the TRIAC dimmer **410** and the rectifier **420** directly receives the AC input voltage **414** and generates the rectified output voltage **422** and the rectified output current **460**. In another embodiment, some (e.g., one or two) of the processing components **492**, **494**, and **496** are removed from the system controller **480**.

As shown in FIG. **4**, when the lighting system **400** is just turned on, the duty cycle of the signal **436** is equal to zero and hence the LED driver **440** does not operate according to certain embodiments. In one embodiment, immediately after the lighting system **400** is turned on, the system controller **480** uses the processing component **492** to first detect whether or not the TRIAC dimmer **410** is included in the lighting system **400**, and if the TRIAC dimmer **410** is detected to be included in the lighting system **400**, whether the TRIAC dimmer **410** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer. In another embodiment, the processing component **492** uses the received voltage **424** to detect a rising time period (e.g., T_rise) during which the voltage **424** increases from a lower threshold voltage (e.g., Vth_off) to a higher threshold voltage (e.g., Vth_on) and to detect a falling time period (e.g., T_fall) during which the voltage **424** decreases from the higher threshold voltage (e.g., Vth_on) to the lower threshold voltage (e.g., Vth_off). For example, the processing component **492** compares the detected rising time (e.g., T_rise) and the detected falling time (e.g., T_fall) to determine whether or not the TRIAC dimmer **410** is included in the lighting system **400**, and if the TRIAC dimmer **410** is determined to be included in the lighting system **400**, whether the TRIAC dimmer **410** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer.

FIG. **5** shows certain timing diagrams for the processing component **492** of the system controller **480** as part of the lighting system **400** as shown in FIG. **4** according to an embodiment of the present invention. These diagrams are merely examples, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications.

For example, the waveform **510** represents the voltage **424** as a function of time during a half cycle of the AC input voltage **414** (e.g., V_{line}) if the lighting system **400** does not include the TRIAC dimmer **410** so that the rectifier **420** directly receives the AC input voltage **414** and generates the rectified output voltage **422** and the rectified output current **460**. In another example, the waveform **520** represents the voltage **424** as a function of time during a half cycle of the AC input voltage **414** (e.g., V_{line}) if the lighting system **400** includes the TRIAC dimmer **410** and the TRIAC dimmer **410** is a leading-edge TRIAC dimmer. In yet another example, the waveform **530** represents the voltage **424** as a function of time during a half cycle of the AC input voltage **414** (e.g., V_{line}) if the lighting system **400** includes the TRIAC dimmer **410** and the TRIAC dimmer **410** is a trailing-edge TRIAC dimmer.

According to one embodiment, if the detected rising time (e.g., T_rise) is equal to or approximately equal to the detected falling time (e.g., T_fall), the processing component **492** determines that the TRIAC dimmer **410** is not included in the lighting system **400**. According to another embodiment, if the detected rising time (e.g., T_rise) is smaller than the detected falling time (e.g., T_fall), the processing component **492** determines that the TRIAC dimmer **410** is included in the lighting system **400** and the TRIAC dimmer **410** is a leading-edge TRIAC dimmer. For example, for the leading-edge TRIAC dimmer, the voltage **424** increases rapidly so that the detected rising time (e.g., T_rise) is approximately equal to zero. In another example, comparing the detected rising time (e.g., T_rise) and the detected falling time (e.g., T_fall) can reliably detect whether or not the TRIAC dimmer **410** in the lighting system **400** is a leading-edge TRIAC dimmer. According to yet another embodiment, if the detected rising time (e.g., T_rise) is larger than the detected falling time (e.g., T_fall), the processing component **492** determines that the TRIAC dimmer **410** is included in the lighting system **400** and the TRIAC dimmer **410** is a trailing-edge TRIAC dimmer. For example, for the trailing-edge TRIAC dimmer, the voltage **424** decreases slowly due to charging and/or discharging of one or more capacitors so that the detected falling time (e.g., T_fall) is not approximately equal to zero. In another example, comparing the detected rising time (e.g., T_rise) and the detected falling time (e.g., T_fall) can reliably distinguish the situation where the TRIAC dimmer **410** is not included in the lighting system **400** from the situation where the TRIAC dimmer **410** in the lighting system **400** is a trailing-edge TRIAC dimmer.

According to certain embodiments, where ΔT is a predetermined threshold,

(a) if $|T_rise - T_fall| \leq \Delta T$, the processing component **492** determines that the TRIAC dimmer **410** is not included in the lighting system **400**;

(b) if $T_fall - T_rise > \Delta T$, the processing component **492** determines that the TRIAC dimmer **410** is included in the lighting system **400** and the TRIAC dimmer **410** is a leading-edge TRIAC dimmer; and

(c) if $T_rise - T_fall > \Delta T$, the processing component **492** determines that the TRIAC dimmer **410** is included in the lighting system **400** and the TRIAC dimmer **410** is a trailing-edge TRIAC dimmer.

As shown in FIG. **4**, after the processing component **492** has detected that the TRIAC dimmer **410** is included in the lighting system **400**, and also determined whether the TRIAC dimmer **410** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer, the processing component **494** is configured to detect the holding current of the TRIAC dimmer **410**, and use the closed-loop control to control the current **432** according to certain embodiments.

FIG. **6** shows certain timing diagrams for the processing component **494** of the system controller **480** as part of the lighting system **400** as shown in FIG. **4** if the TRIAC dimmer **410** is includes in the lighting system **400** and the TRIAC dimmer **410** is a leading-edge TRIAC dimmer **410** according to an embodiment of the present invention. These diagrams are merely examples, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. According to some embodiments, the waveform **610** represents the voltage **424** as a function of time, the waveform **620** represents the signal **434** as a function of time, the waveform **630** represents the signal **436** as a function of time, and the waveform **640** represents the voltage **426** as a function of time. According to certain embodiments, the processing component **494** is configured to detect the holding current of the TRIAC dimmer **410** before time t_s, and use the closed-loop control to control the current **432** after time t_s.

In one embodiment, the processing component **494** receives the voltage **424**, and based on the received voltage **424**, determines that the TRIAC dimmer **410** is turned on at time t_1, as shown by the waveform **610**. In response, after time t_1, the system controller **480**, including the processing component **494**, generates the signal **434** so that the signal **434** is at the maximum duty cycle immediately after time t_1, but the duty cycle of the signal **434** then decreases with time from the maximum duty cycle, according to some embodiments. For example, if the signal **434** is at the maximum duty cycle, the current **432** reaches a maximum magnitude. In another example, if the current **432** reaches a maximum magnitude, the current **460** also reaches a maximum magnitude and the voltage **426** reaches a corresponding maximum magnitude at time t_2, as shown by the waveform **640**. In yet another example, the maximum magnitude of the current **460** is high than the holding current of the TRIAC dimmer **410**, so that the TRIAC dimmer **410** remains to be turned on at time t_2.

In yet another embodiment, if the duty cycle of the signal **434** decreases with time from the maximum duty cycle as shown by the waveform **610**, the voltage **426**, which represents the current **460**, also decreases with time from the maximum magnitude as shown by the waveform **640**. For example, if the current **460**, which is equal to the current flowing through the TRIAC dimmer **410**, becomes smaller than the holding current of the TRIAC dimmer **410**, the TRIAC dimmer **410** is turned off. In yet another example, in response to the TRIAC dimmer **410** being turned off, the decrease of the voltage **424** becomes steeper at time t_3 as shown by the waveform **610** and the decrease of the voltage **426** also becomes steeper at time t_3 as shown by the waveform **640**. In yet another example, the processing component **494** is configured to detect an abrupt change of slope at which the voltage **426** decreases, and set a threshold magnitude V_A for the voltage **426** based at least in part on the detected abrupt change of slope.

In yet another embodiment, the threshold magnitude V_A of the voltage **426** at time t_3 corresponds to the holding current of the TRIAC dimmer **410**. For example, V_A represents the holding current as detected by the process. In yet another embodiment, the system controller **480** sets a threshold magnitude V_B for the voltage **426**. For example, V_B is larger than V_A. In another example, $V_B=V_A+\Delta V_1$, where ΔV_1 is a predetermined threshold and is larger than zero. In yet another example, $V_B=k\times V_A$, where k is a constant that is larger than or equal to 1.05 but smaller than or equal to 1.3. In yet another example, if the voltage **426** is approximately equal to V_B, the current flowing through the TRIAC dimmer **410** is larger than the holding current of the TRIAC dimmer **410**, so long as the voltage **426** remains larger than V_A. In yet another example, the system controller **480** stores the threshold magnitude V_B.

As shown in FIG. **6**, after time t_s, the processing component **494** is configured to use the threshold magnitude V_B to perform the closed-loop control to control the voltage **426** by controlling the current **432** according to some embodiments. For example, time t_s is the beginning of the next half cycle of the AC input voltage **414**. In another example, the voltage **426** represents the current that flows through the TRIAC dimmer **410**, so the system controller **480** controls the current flowing through the TRIAC dimmer **410** by controlling the current **432** and the voltage **426**.

In one embodiment, the processing component **494** receives the voltage **424**, and based on the received voltage **424**, determines that the TRIAC dimmer **410** is turned on at time t_4, as shown by the waveform **610**. In response, the signal **436** generated by the system controller **480** becomes a modulation signal (e.g., a pulse-width-modulation signal) at time t_4, changing between a logic high level and a logic low level according to another embodiment, as shown by the waveform **630**. For example, the signal **436** remains at the logic low level from time t_1 to time t_4. In another example, the signal **436** is a modulation signal (e.g., a pulse-width-modulation signal) from time t_4 to time t_7. In yet another example, the pulse-width-modulation signal **436** has a pulse width that corresponds to the dimming control as reflected by the time duration from time t_1 to time t_s.

In yet another embodiment, the signal **434** generated by the system controller **480** remains at the logic high level from time t_3 to time t_5, and time t_5 follows time t_4. For example, at time t_5, the signal **434** changes from the logic high level to the logic low level. In another example, from time t_4 to time t_5, the current **432** increases with time and reaches a maximum magnitude at time t_5. In yet another example, at time t_5, the current **460** also reaches a maximum magnitude and the voltage **426** reaches a corresponding maximum magnitude at time t_5, as shown by the waveform **640**. In yet another example, the maximum magnitude of the current **460** is high than the holding current of the TRIAC dimmer **410**, so that the TRIAC dimmer **410** remains to be turned on at time t_5.

In yet another embodiment, from time t_5 and time t_6, the signal **434** remains at the logic low level. For example, from time t_5 and time t_6, the voltage **426** becomes smaller than the corresponding maximum magnitude that the voltage **426** reaches at time t_5. In another example, at time t_6, the voltage **426** becomes smaller than $V_B+\Delta V_2$, even though the voltage **426** is still larger than V_B, where V_B represents the threshold magnitude that is stored by the system controller **480**, and ΔV_2 represents a predetermined threshold that is larger than zero. In yet another example, at time t_6, in response to the voltage **426** becoming becomes smaller than $V_B+\Delta V_2$, even though still larger than the threshold magnitude V_B, the signal **434** generated by the system controller **480** becomes a modulation signal at time t_6, changing between a logic high level and a logic low level, as shown by the waveform **620**.

According to one embodiment, the signal **434** is a modulation signal from time t_6 to time t_7. For example, from time t_6 to time t_7, the signal **434** as a modulation signal regulates the voltage **426** at the threshold magnitude V_B, and the voltage **426** becomes approximately equal to the threshold magnitude V_B by a closed-loop regulation, so that the voltage **426** remains larger than the magnitude V_A of the voltage **426** from time t_6 to time t_7, where the magnitude V_A of the voltage **426** corresponds to the holding current of the TRIAC dimmer **410**.

In another example, from time t_6 to time t_7, the current flowing through the TRIAC dimmer **410** remains larger than the holding current of the TRIAC dimmer **410**, so that the TRIAC dimmer **410** is not turned off by the insufficient current flowing through the TRIAC dimmer **410**.

According to another embodiment, time t_7 is the end of the half cycle of the AC input voltage **414** that starts at time t_s, and time t_7 is also the beginning of another half cycle of the AC input voltage **414**. For example, as shown by the waveform **610**, the voltage **424** becomes zero at time t_7 and remains to be zero until the TRIAC dimmer **410** is turned on. In another example, as shown by the waveform **620**, the signal **434** is at the logic high level at time t_7, and remains at the logic high level until sometime after the TRIAC dimmer **410** is turned on. In yet another example, as shown by the waveform **630**, the signal **436** is at the logic low level at time t_7, and remains at the logic low level until the TRIAC dimmer **410** is turned on. In yet another example, as shown by the waveform **640**, the voltage **426** decreases to zero soon after time t_7, and remains to be zero until the TRIAC dimmer **410** is turned on.

As discussed above and further emphasized here, FIG. **6** is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. For example, the waveforms **610**, **620**, **630** and **640** are changed if the TRIAC dimmer **410** is includes in the lighting system **400** and the TRIAC dimmer **410** is a trailing-edge TRIAC dimmer, instead of a leading-edge TRIAC dimmer **410**. In another example, the waveforms **610**, **620**, **630** and **640** are changed if the TRIAC dimmer **410** is not included in the lighting system **400**. In yet another example, FIG. **6** is used to describe certain operations of FIG. **8**. In yet another example, FIG. **6** is used to describe certain operations of FIG. **9**.

As shown in FIG. **4**, the processing component **496** is configured to process the voltage **424** that has waveforms not symmetric between a positive half cycle and a negative half cycle of the AC input voltage **414**, so that the system controller **480** can provide to the one or more LEDs **450** a current that is symmetric between the positive half cycle and the negative half cycle of the AC input voltage **414** according to some embodiments.

FIG. **7** shows certain timing diagrams for the processing component **496** of the system controller **480** as part of the lighting system **400** as shown in FIG. **4** if the TRIAC dimmer **410** is includes in the lighting system **400** and the TRIAC dimmer **410** is a leading-edge TRIAC dimmer **410** according to an embodiment of the present invention. These diagrams are merely examples, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. According to some embodiments, the waveform **710**

represents the voltage **424** as a function of time, the waveform **720** represents the signal **436** as a function of time, and the waveform **730** represents the current that flows through the one or more LEDs **450** as a function of time. According to certain embodiments, the processing component **496** is configured to work with the processing component **494**, wherein the processing component **494** uses the closed-loop control to control the current **432** and the processing component **496** processes the voltage **424** that has waveforms not symmetric between a positive half cycle and a negative half cycle of the AC input voltage **414**.

In one embodiment, the processing component **494** receives the voltage **424**, and based on the received voltage **424**, determines that the TRIAC dimmer **410** is turned on at time t_4, as shown by the waveform **710**. In response, the signal **436** generated by the system controller **480** becomes a modulation signal (e.g., a pulse-width-modulation signal) at time t_4, changing between a logic high level and a logic low level according to another embodiment, as shown by the waveform **720**. For example, the signal **436** is at the logic low level before time t_4. In another example, the signal **436** is a modulation signal (e.g., a pulse-width-modulation signal) from time t_4 to time t_7. In yet another embodiment, time t_7 is the end of the half cycle of the AC input voltage **414**, during which the voltage **426** has a pulse width of T_a from time t_4 to time t_7. For example, time t_7 is also the beginning of another half cycle of the AC input voltage **414**, during which the voltage **426** has a pulse width of T_b from time t_8 to time t_{10}. In another example, the pulse width of T_b is larger than the pulse width of T_a.

According to one embodiment, the processing component **494** detects the pulse width of T_a and the pulse width of T_b, which correspond to two successive half cycles of the AC input voltage **414**, and the processing component **494** also determines that the pulse width of T_b is larger than the pulse width of T_a. For example, the processing component **494** detects the pulse width T_b during the half cycle of the AC input voltage **414** that ends at time t_s, and detects the pulse width T_a during the half cycle of the AC input voltage **414** that starts at time t_s.

According to another embodiment, the processing component **494** receives the voltage **424**, and determines that the TRIAC dimmer **410** is turned on at time t_8 with the pulse width of T_b for the voltage **424** as shown by the waveform **710**. In response, the system controller **480**, for example, keeps the signal **436** at the logic level from time t_8 to time t_9; then, at time t_9, the signal **436** becomes a modulation signal (e.g., a pulse-width-modulation signal) that changes between a logic high level and a logic low level as shown by the waveform **720**. In another example, the signal **436** is a modulation signal (e.g., a pulse-width-modulation signal) from time t_9 to time t_{10}. In yet another example, the time duration from time t_9 to time t_{10} is equal to the pulse width of T_a, the same as the time duration from time t_4 to time t_7.

According to yet another embodiment, time t_{10} is the end of the half cycle of the AC input voltage **414**, during which the voltage **426** has a pulse width of T_b from time t_8 to time t_{10}. For example, time t_{10} is also the beginning of another half cycle of the AC input voltage **414**, during which the voltage **426** has a pulse width of T_a from time t_{11} to time t_{12}. In response, for example, the signal **436** generated by the system controller **480**, at time t_{11}, becomes a modulation signal (e.g., a pulse-width-modulation signal) that changes between a logic high level and a logic low level as shown by the waveform **720**. In another example, the signal **436** is a modulation signal (e.g., a pulse-width-modulation signal) from time t_{11} to time t_{12}. In yet another example, the time duration from time t_{11} to time t_{12} is equal to the pulse width of T_a, the same as the time duration from time t_9 to time t_{10}.

According to yet another embodiment, the processing component **494** receives the voltage **424**, and determines that the TRIAC dimmer **410** is turned on at time t_{13} with the pulse width of T_b for the voltage **424** as shown by the waveform **710**. In response, the system controller **480**, for example, keeps the signal **436** at the logic level from time t_{13} to time t_{14}; then, at time t_{14}, the signal **436** becomes a modulation signal (e.g., a pulse-width-modulation signal) that changes between a logic high level and a logic low level as shown by the waveform **720**. In another example, the signal **436** is a modulation signal (e.g., a pulse-width-modulation signal) from time t_{14} to time t_{15}. In yet another example, the time duration from time t_{14} to time t_{15} is equal to the pulse width of T_a, the same as the time duration from time t_9 to time t_{10}. According to yet another embodiment, time t_{15} is the end of the half cycle of the AC input voltage **414**, during which the voltage **426** has a pulse width of T_b from time t_{13} to time t_{15}. For example, time t_{15} is also the beginning of another half cycle of the AC input voltage **414**, during which the voltage **426** has a pulse width of T_a.

As shown in FIG. **7**, even though the pulse width of the voltage **424** is equal to T_a in the half cycle I of the AC input voltage **414**, is equal to T_b in the half cycle II of the AC input voltage **414**, is equal to T_a in the half cycle III of the AC input voltage **414**, and is equal to T_b in the half cycle IV of the AC input voltage **414**, the signal **436** is a modulation signal (e.g., a pulse-width-modulation signal) for a time duration equal to the pulse width of T_a in each of the half cycle I of the AC input voltage **414**, the half cycle II of the AC input voltage **414**, the half cycle III of the AC input voltage **414**, and the half cycle IV of the AC input voltage **414**, according to certain embodiments. For example, the pulse width of T_b is larger than the pulse width of T_a. In another example, as shown by the waveform **710**, the pulse width of the voltage **424** changes from one half cycle of the AC input voltage **414** to another half cycle I of the AC input voltage **414**, but the current that flows through the one or more LEDs **450** remains periodic as shown by the waveform **730**. In yet another example, the waveform for the current that flows through the one or more LEDs **450** changes in the same way during the time period A (e.g., from time t_4 to time t_9), the time period B (e.g., from time t_9 to time t)$_{11}$, and the time period C (e.g., from time t_{11} to time t_{13}). In yet another example, the waveform for the current that flows through the one or more LEDs **450** is symmetric between a positive half cycle and a negative half cycle of the AC input voltage **414** (e.g., between the half cycle II and the half cycle III as shown in FIG. **7**).

FIG. **8** is a simplified diagram of a lighting system that includes multiple lamp subsystems according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The lighting system **800** includes a TRIAC dimmer **410**, a rectifier **420**, and multiple lamp subsystems **810**$_1$, **810**$_2$, . . . **810**$_i$, . . . and **810**$_N$, wherein N is an integer that is larger than 1, and i is an integer that is larger than or equal to 1 and is smaller than or equal to N.

In one embodiment, each of the multiple lamp subsystems includes a current sink (e.g., a current sink **430**), an LED driver (e.g., an LED driver **440**), one or more LEDs (e.g., one or more LEDs **450**), resistors (e.g., resistors **470**, **472**, **474**, **476**, and **478**), and a system controller (e.g., a system controller **480**). For example, the system controller (e.g., the

system controller **480**) of each of the multiple lamp subsystems includes terminals (e.g., terminals **482**, **484**, **486**, and **488**), and processing components (e.g., processing components **492**, **494**, and **496**). In another embodiment, the lamp subsystem $\mathbf{810}_i$ includes a current sink $\mathbf{430}_i$, an LED driver $\mathbf{440}_i$, one or more LEDs $\mathbf{450}_i$, resistors $\mathbf{470}_i$, $\mathbf{472}_i$, $\mathbf{474}_i$, $\mathbf{476}_i$, and $\mathbf{478}_i$, and a system controller $\mathbf{480}_i$.

As shown in FIG. **8**, the TRIAC dimmer **410** receives an AC input voltage **414** (e.g., V_{line}) and generates a voltage **412**. For example, the voltage **412** is received by the rectifier **420** (e.g., a full wave rectifying bridge), which generates a rectified output voltage **422** and a rectified output current **460**. In another example, the rectified output voltage **422** is received by a voltage divider including the resistors $\mathbf{470}_i$ and $\mathbf{472}_i$, and the voltage divider outputs a voltage $\mathbf{424}_i$.

For example, the system controller $\mathbf{480}_i$ includes terminals $\mathbf{482}_i$, $\mathbf{484}_i$, $\mathbf{486}_i$, and $\mathbf{488}_i$, and processing components $\mathbf{492}_i$, $\mathbf{494}_i$, and $\mathbf{496}_i$. In another example, the terminal $\mathbf{484}_i$ (e.g., the terminal "I_DET") receives a voltage $\mathbf{426}_i$. In yet another example, the terminal $\mathbf{486}_i$ (e.g., the terminal "BL") outputs a control signal $\mathbf{434}_i$ (e.g., a pulse-width-modulation signal or an analog voltage signal) to the current sink $\mathbf{430}_i$ to control a current $\mathbf{432}_i$. In yet another example, the terminal $\mathbf{488}_i$ (e.g., the terminal "DIM") outputs a control signal $\mathbf{436}_i$ (e.g., a pulse-width-modulation signal or an analog voltage signal) to the LED driver $\mathbf{440}_i$. In yet another example, the current $\mathbf{432}_i$ is smaller than or equal to a current $\mathbf{820}_i$ that flows into the lamp subsystem $\mathbf{810}_i$.

In yet another embodiment, the rectified output current **460** is equal to the current flowing through the TRIAC dimmer **410**, and is also equal to the sum of a current $\mathbf{820}_1$, a current $\mathbf{820}_2$, . . . , a current $\mathbf{820}_i$, . . . and a current $\mathbf{820}_N$. For example, the current $\mathbf{820}_1$, the current $\mathbf{820}_2$, . . . , the current $\mathbf{820}_i$, . . . and the current $\mathbf{820}_N$ are currents that flow into the lamp subsystems $\mathbf{810}_1$, $\mathbf{810}_2$, . . . $\mathbf{810}_i$, . . . and $\mathbf{810}_N$, respectively. In another example, the current $\mathbf{820}_1$, the current $\mathbf{820}_2$, . . . , the current $\mathbf{820}_i$, . . . and the current $\mathbf{820}_N$ each are a component of the rectified output current **460**, and each represent a component of the current flowing through the TRIAC dimmer **410**. In yet another example, the voltage $\mathbf{426}_i$ represents the current $\mathbf{820}_i$, and also represents a component of the current flowing through the TRIAC dimmer **410**.

In yet another embodiment, the current $\mathbf{820}_i$ is divided into a current $\mathbf{462}_i$ received by the resistor $\mathbf{470}_i$, the current $\mathbf{432}_i$ generated and received by the current sink $\mathbf{430}_i$, and a current $\mathbf{442}_i$ received by the LED driver $\mathbf{440}_i$. For example, the current $\mathbf{820}_i$ is equal to the sum of the current $\mathbf{462}_i$, the current $\mathbf{432}_i$, and the current $\mathbf{442}_i$.

According to one embodiment, after the processing component $\mathbf{492}_i$ has detected that the TRIAC dimmer **410** is included in the lighting system **800**, and after the processing component $\mathbf{492}_i$ has also determined whether the TRIAC dimmer **410** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer, the processing component $\mathbf{494}_i$ of the lamp subsystem $\mathbf{810}_i$ uses the closed-loop control to control the current $\mathbf{432}_i$. For example, the multiple lamp subsystems $\mathbf{810}_1$, $\mathbf{810}_2$, . . . $\mathbf{810}_i$, . . . and $\mathbf{810}_N$ together satisfy the following equation:

$$I_{holding} < \sum_{i=1}^{N} I_i < I_{holding} \times N \quad \text{(Equation 1)}$$

wherein $I_{holding}$ represents the magnitude of the holding current of the TRIAC dimmer **410**, and I_i represents the magnitude of the current $\mathbf{820}_i$. N is an integer that is larger than 1, and i is an integer that is larger than or equal to 1 and is smaller than or equal to N.

As discussed above and further emphasized here, FIG. **6** is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. For example, FIG. **6** is used to describe certain operations of FIG. **8**.

According to some embodiments, the waveform **610** represents the voltage $\mathbf{424}_i$ as a function of time, the waveform **620** represents the signal $\mathbf{434}_i$ as a function of time, the waveform **630** represents the signal $\mathbf{436}_i$ as a function of time, and the waveform **640** represents the voltage $\mathbf{426}_i$ as a function of time. According to certain embodiments, all of the processing components $\mathbf{494}_i$ are configured to detect the holding current of the TRIAC dimmer **410** before time t_s, and each use the closed-loop control to control the current $\mathbf{432}_i$ after time t_s.

In one embodiment, the processing component $\mathbf{494}_i$ receives the voltage $\mathbf{424}_i$, and based on the received voltage $\mathbf{424}_i$, determines that the TRIAC dimmer **410** is turned on at time t_1, as shown by the waveform **610**. In response, after time t_1, the system controller $\mathbf{480}_i$, including the processing component $\mathbf{494}_i$, generates the signal $\mathbf{434}_i$ so that the signal $\mathbf{434}_i$ is at the maximum duty cycle immediately after time t_1, but the duty cycle of the signal $\mathbf{434}_i$ then decreases with time from the maximum duty cycle, according to some embodiments. For example, if the signal $\mathbf{434}_i$ is at the maximum duty cycle, the current $\mathbf{432}_i$ reaches a maximum magnitude.

In another example, if all of the currents $\mathbf{432}_i$, where i is an integer that is larger than or equal to 1 and is smaller than or equal to N, each reach a maximum magnitude, all of the voltages $\mathbf{426}_i$ each reach a corresponding maximum magnitude at time t_2 as shown by the waveform **640**, and the current **460** also reaches a maximum magnitude. In yet another example, the maximum magnitude of the current **460** is high than the holding current of the TRIAC dimmer **410**, so that the TRIAC dimmer **410** remains to be turned on at time t_2.

In yet another embodiment, if the duty cycle of the signal $\mathbf{434}_i$ decreases with time from the maximum duty cycle as shown by the waveform **610**, the voltage $\mathbf{426}_i$, which represents the current $\mathbf{820}_i$, also decreases with time from the maximum magnitude as shown by the waveform **640**. For example, if all of the currents $\mathbf{820}_i$, where i is an integer that is larger than or equal to 1 and is smaller than or equal to N, each decrease with time from the maximum magnitude, the current **460** also decreases with time from its maximum magnitude. In another example, the current **460**, which is equal to the current flowing through the TRIAC dimmer **410**, becomes smaller than the holding current of the TRIAC dimmer **410**, the TRIAC dimmer **410** is turned off. In yet another example, in response to the TRIAC dimmer **410** being turned off, the decrease of the voltage $\mathbf{424}_i$ becomes steeper at time t_3 as shown by the waveform **610** and the decrease of the voltage $\mathbf{426}_i$ also becomes steeper at time t_3 as shown by the waveform **640**.

In yet another embodiment, the magnitude V_A of the voltage $\mathbf{426}_i$ at time t_3 corresponds to one component of multiple components of the holding current of the TRIAC dimmer **410**. For example, if all of the voltages $\mathbf{426}_i$ each are equal to their corresponding magnitudes V_A, the current **460** is equal to the holding current of the TRIAC dimmer **410**.

In yet another embodiment, the system controller $\mathbf{480}_i$ sets a threshold magnitude V_B for the voltage $\mathbf{426}_i$. For example, V_B is larger than V_A. In another example, $V_B=V_A+\Delta V_1$, where ΔV_1 is a predetermined threshold and is larger than

zero. In yet another example, V_B=k×V_A, where k is a constant that is larger than or equal to 1.05 but smaller than or equal to 1.3. In yet another example, if all of the voltages **426**$_i$ each are approximately equal to their corresponding V_B, the current flowing through the TRIAC dimmer **410** is larger than the holding current of the TRIAC dimmer **410**, so long as the voltage **426**$_i$ remains larger than V_A. In yet another example, the system controller **480**$_i$ stores the corresponding threshold magnitude V_B.

As shown in FIG. **6**, after time t_s, the processing component **494**$_i$ is configured to use the threshold magnitude V_B to perform the closed-loop control to control the voltage **426**$_i$ by controlling the current **432**$_i$ according to some embodiments. For example, time t_s is the beginning of the next half cycle of the AC input voltage **414**. In another example, the voltage **426**$_i$ represents the current **820**$_i$, and sum of all of the currents **820**$_i$ is equal to the current that flows through the TRIAC dimmer **410**, so all of the system controllers **480**$_i$ together can control the current flowing through the TRIAC dimmer **410** by each controlling the current **432**$_i$ and the voltage **426**$_i$.

In one embodiment, the processing component **494**$_i$ receives the voltage **424**$_i$, and based on the received voltage **424**$_i$, determines that the TRIAC dimmer **410** is turned on at time t_4, as shown by the waveform **610**. In response, the signal **436**$_i$ generated by the system controller **480**$_i$ becomes a modulation signal (e.g., a pulse-width-modulation signal) at time t_4, changing between a logic high level and a logic low level according to another embodiment, as shown by the waveform **630**. For example, the signal **436**$_i$ remains at the logic low level from time t_1 to time t_4. In another example, the signal **436**$_i$ is a modulation signal (e.g., a pulse-width-modulation signal) from time t_4 to time t_7. In yet another example, the pulse-width-modulation signal **436**$_i$ has a pulse width that corresponds to the dimming control as reflected by the time duration from time t_1 to time t_s.

In yet another embodiment, the signal **434**$_i$ generated by the system controller **480**$_i$ remains at the logic high level from time t_3 to time t_5, and time t_5 follows time t_4. For example, at time t_5, the signal **434**$_i$ changes from the logic high level to the logic low level. In another example, from time t_4 to time t_5, the current **432**$_i$ increases with time and reaches a maximum magnitude at time t_5, so the voltage **426**$_i$ reaches a corresponding maximum magnitude at time t_5, as shown by the waveform **640**. In yet another example, at time t_5, all of the currents **820**$_i$ each reach their corresponding maximum magnitudes, so the current **460** also reaches a maximum magnitude. In yet another example, the maximum magnitude of the current **460** is high than the holding current of the TRIAC dimmer **410**, so that the TRIAC dimmer **410** remains to be turned on at time t_5.

In yet another embodiment, from time t_5 and time t_6, the signal **434**$_i$ remains at the logic low level. For example, from time t_5 and time t_6, the voltage **426**$_i$ becomes smaller than the corresponding maximum magnitude that the voltage **426**$_i$ reaches at time t_5. In another example, at time t_6, the voltage **426**$_i$ becomes smaller than V_B+ΔV_2, even though the voltage **426**$_i$ is still larger than V_B, where V_B represents the threshold magnitude that is stored by the system controller **480**$_i$, and ΔV_2 represents a predetermined threshold that is larger than zero. In yet another example, at time t_6, in response to the voltage **426**$_i$ becoming smaller than V_B+ΔV_2, even though still larger than the threshold magnitude V_B, the signal **434**$_i$ generated by the system controller **480**$_i$ becomes a modulation signal at time t_6, changing between a logic high level and a logic low level, as shown by the waveform **620**.

According to one embodiment, the signal **434**$_i$ is a modulation signal from time t_6 to time t_7. For example, from time t_6 to time t_7, the voltage **426**$_i$ remains larger than or approximately equal to the threshold magnitude V_B by a closed-loop regulation, so that the voltage **426**$_i$ remains larger than the magnitude V_A of the voltage **426**$_i$ from time t_6 to time t_7, where the magnitude V_A of the voltage **426**$_i$ corresponds to the holding current of the TRIAC dimmer **410**. In another example, from time t_6 to time t_7, the current flowing through the TRIAC dimmer **410** remains larger than the holding current of the TRIAC dimmer **410**, so that the TRIAC dimmer **410** is not turned off by the insufficient current flowing through the TRIAC dimmer **410**.

According to another embodiment, time t_7 is the end of the half cycle of the AC input voltage **414** that starts at time t_s, and time t_7 is also the beginning of another half cycle of the AC input voltage **414**. For example, as shown by the waveform **610**, the voltage **424**$_i$ becomes zero at time t_7 and remains to be zero until the TRIAC dimmer **410** is turned on. In another example, as shown by the waveform **620**, the signal **434**$_i$ is at the logic high level at time t_7, and remains at the logic high level until sometime after the TRIAC dimmer **410** is turned on. In yet another example, as shown by the waveform **630**, the signal **436**$_i$ is at the logic low level at time t_7, and remains at the logic low level until the TRIAC dimmer **410** is turned on. In yet another example, as shown by the waveform **640**, the voltage **426**$_i$ decreases to zero soon after time t_7, and remains to be zero until the TRIAC dimmer **410** is turned on.

FIG. **9** is a simplified diagram of a lighting system that includes multiple lamp subsystems according to another embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The lighting system **900** includes a TRIAC dimmer **410** and multiple lamp subsystems **910**$_1$, **910**$_2$, . . . **910**$_i$, . . . and **910**$_N$, wherein N is an integer that is larger than 1, and i is an integer that is larger than or equal to 1 and is smaller than or equal to N.

In one embodiment, each of the multiple lamp subsystems includes a rectifier (e.g., a rectifier **420**), a current sink (e.g., a current sink **430**), an LED driver (e.g., an LED driver **440**), one or more LEDs (e.g., one or more LEDs **450**), resistors (e.g., resistors **470**, **472**, **474**, **476**, and **478**), and a system controller (e.g., a system controller **480**). For example, the system controller (e.g., the system controller **480**) of each of the multiple lamp subsystems includes terminals (e.g., terminals **482**, **484**, **486**, and **488**), and processing components (e.g., processing components **492**, **494**, **496**, and **498**). In another embodiment, the lamp subsystem **910**$_i$ includes a rectifier **420**$_i$, a current sink **430**$_i$, an LED driver **440**$_i$, one or more LEDs **450**$_i$, resistors **470**$_i$, **472**$_i$, **474**$_i$, **476**$_i$, and **478**$_i$, and a system controller **480**$_i$. For example, the system controller **480**$_i$ includes terminals **482**$_i$, **484**$_i$, **486**$_i$, and **488**$_i$, and processing components **492**$_i$, **494**$_i$, **496**$_i$, and **498**$_i$. In another example, the system controller **480**$_i$ outputs a signal **434**$_i$ to the current sink **430**$_i$ to control the current **432**$_i$. In yet another example, the current **432**$_i$ is smaller than or equal to a current **920**$_i$ that flows into the lamp subsystem **910**$_i$. In yet another embodiment, a current **960** is equal to the current flowing through the TRIAC dimmer **410**, and is also equal to the sum of a current **920**$_1$, a current **920**$_2$, . . . , a current **920**$_i$, . . . and a current **920**$_N$. For example, the currents **920**$_1$, **920**$_2$, . . . , **920**$_i$, . . . and **920**$_N$ are currents that flow into the lamp subsystems **910**$_1$, **910**$_2$, . . . **910**$_i$, . . . and **910**$_N$, respectively.

According to one embodiment, after the processing component $\mathbf{492}_i$ has detected that the TRIAC dimmer **410** is included in the lighting system **900**, and after the processing component $\mathbf{492}_i$ has also determined whether the TRIAC dimmer **410** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer, the processing component $\mathbf{498}_i$ is configured to work with the processing component $\mathbf{494}_i$ of the same lamp subsystem $\mathbf{910}_i$ and with the processing components $\mathbf{498}_j$ of each of the other lamp subsystems $\mathbf{910}_j$ to detect the holding current of the TRIAC dimmer **410**, and use the closed-loop control to control the current $\mathbf{432}_i$, wherein j is an integer that is larger than or equal to 1 and is smaller than or equal to N, and j is not equal to i. For example, the multiple lamp subsystems $\mathbf{910}_1$, $\mathbf{910}_2$, . . . $\mathbf{910}_i$, . . . and $\mathbf{910}_N$ work together, and satisfy the following equation:

$$I_{holding} < \sum_{i=1}^{N} I_i < I_{holding} \times N \quad \text{(Equation 2)}$$

wherein $I_{holding}$ represents the magnitude of the holding current of the TRIAC dimmer **410**, and I_i represents the magnitude of the current $\mathbf{920}_i$. N is an integer that is larger than 1, and i is an integer that is larger than or equal to 1 and is smaller than or equal to N.

According to certain embodiments, systems and methods are provided for intelligent control related to TRIAC dimmers. For example, the systems and methods can intelligently detect the type of a TRIAC dimmer. In another example, the type of the TRIAC dimmer can be a leading-edge TRIAC dimmer, a trailing-edge TRIAC dimmer, or the situation that no TRIAC dimmer is included in the lighting system. In yet another example, the detection of the type of a TRIAC dimmer takes into account a threshold voltage as well as rate of voltage change. In yet another example, the systems and methods also provide intelligent control that matches with the detected type of the TRIAC dimmer.

According to some embodiments of the present invention, systems and methods can provide intelligent detection of the type of a TRIAC dimmer and also provide dimming control without causing one or more LEDs to flicker. For example, the systems and methods are configured to detect whether or not a TRIAC dimmer is included in the lighting system, and if the TRIAC dimmer is detected to be included in the lighting system, whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer. In another example, the systems and methods are further configured to detect the holding current of the TRIAC dimmer, and use the closed-loop control so that the current flowing through the TRIAC dimmer exceeds, but does not exceed too much, the holding current of the TRIAC dimmer in order to reduce flickering of the one or more LEDs and also to improve efficiency of the lighting system. In yet another example, the systems and methods are further configured to process a voltage that has waveforms not symmetric between a positive half cycle and a negative half cycle of an AC input voltage in order to provide to one or more LEDs a current that is symmetric between the positive half cycle and the negative half cycle of the AC input voltage **414**. In yet another example, the systems and methods are further configured to, if the lighting system includes multiple lamp subsystems, control the current flowing through the TRIAC dimmer so that this current exceeds, but does not exceed too much, the holding current of the TRIAC dimmer in order to reduce flickering of the one or more LEDs and also to improve efficiency of the lighting system.

According to another embodiment, a system controller for a lighting system includes a first controller terminal configured to receive a first signal, and a second controller terminal configured to output a second signal to a diver component. The driver component is configured to receive a first current and provide one or more drive currents to one or more light emitting diodes in response to the second signal. Additionally, the system controller is configured to process information associated with the first signal, determine a first time period for the first signal to increase from a first threshold to a second threshold, and determine a second time period for the first signal to decrease from the second threshold to the first threshold. Moreover, the system controller is further configured to, in response to the second time period minus the first time period being larger than a predetermined positive value, determine the first signal to be associate with a leading-edge TRIAC dimmer, and in response to the first time period minus the second time period being larger than the predetermined positive value, determine the first signal to be associate with a trailing-edge TRIAC dimmer. Also, the system controller is further configured to, in response to an absolute value of the first time period minus the second time period being smaller than the predetermined positive value, determine the first signal not to be associated with any TRIAC dimmer. For example, the system controller is implemented according to at least FIG. **4**, FIG. **5**, FIG. **8**, and/or FIG. **9**.

According to another embodiment, a system controller for a lighting system includes a first controller terminal configured to receive a first signal associated with a TRIAC dimmer, and a second controller terminal configured to output a second signal to a current sink. The current sink is configured to receive a first current in response to the second signal. Additionally, the system controller includes a third controller terminal configured to output a third signal to a driver component. The driver component is configured to receive a second current and provide one or more drive currents to one or more light emitting diodes in response to the third signal. Moreover, the system controller includes a fourth controller terminal configured to receive a fourth signal. The fourth signal is related to a third current that flows through the TRIAC dimmer. Also, the system controller is configured to process information associated with the first signal, and determine the TRIAC dimmer is turned on at a first time based at least in part on the first signal. Additionally, the system controller is configured to, after the first time, with a first delay, decrease a duty cycle of the second signal from a first predetermined value until the fourth signal indicates that the TRIAC dimmer is turned off at a second time, and in response to the fourth signal indicating that the TRIAC dimmer is turned off at the second time, set a first threshold for the fourth signal, the first threshold being related to a holding current of the TRIAC dimmer. Moreover, the system controller is further configured to process information associated with the first signal, and determine the TRIAC dimmer is turned on at a third time based at least in part on the first signal. Also, the system controller is further configured to, after the third time, with a second delay, change the second signal from a first logic level to a second logic level and keep the second signal at the second logic level until a fourth time, and at the fourth time, change the second signal to a modulation signal to regulate the fourth signal at a second threshold in order to keep the fourth signal larger than the first threshold and keep the third current larger than the holding current of the TRIAC dim-

mer. The second threshold is larger than the first threshold, and the modulation signal changes between the first logic level and the second logic level. For example, the system controller is implemented according to at least FIG. **4**, FIG. **6**, FIG. **8**, and/or FIG. **9**.

According to yet another embodiment, a method for a lighting system includes receiving a first signal, processing information associated with the first signal, determining a first time period for the first signal to increase from a first threshold to a second threshold, determining a second time period for the first signal to decrease from the second threshold to the first threshold, and processing information associated with the first time period and the second time period. Additionally, the method includes, in response to the second time period minus the first time period being larger than a predetermined positive value, determining the first signal to be associate with a leading-edge TRIAC dimmer, and in response to the first time period minus the second time period being larger than the predetermined positive value, determining the first signal to be associate with a trailing-edge TRIAC dimmer. Moreover, the method includes, in response to an absolute value of the first time period minus the second time period being smaller than the predetermined positive value, determining the first signal not to be associated with any TRIAC dimmer. For example, the method is implemented according to at least FIG. **4**, FIG. **5**, FIG. **8**, and/or FIG. **9**.

According to yet another embodiment, a method for a lighting system includes receiving a first signal associated with a TRIAC dimmer, receiving a second signal related to a first current that flows through the TRIAC dimmer, processing information associated with the first signal, and determining the TRIAC dimmer is turned on at a first time based at least in part on the first signal. Additionally, the method includes, after the first time, with a first delay, decreasing a duty cycle of a third signal from a first predetermined value until the second signal indicates that the TRIAC dimmer is turned off at a second time, and setting a first threshold for the second signal in response to the second signal indicating that the TRIAC dimmer is turned off at the second time, the first threshold being related to a holding current of the TRIAC dimmer. Moreover, the method includes determining that the TRIAC dimmer is turned on at a third time based at least in part on the first signal, and after the third time, with a second delay, changing the third signal from a first logic level to a second logic level and keep the third signal at the second logic level until a fourth time. Also, the method includes at the fourth time, changing the third signal to a modulation signal to regulate the second signal at a second threshold in order to keep the second signal larger than the first threshold and keep the first current larger than the holding current of the TRIAC dimmer. The second threshold is larger than the first threshold, and the modulation signal changes between the first logic level and the second logic level. For example, the method is implemented according to at least FIG. **4**, FIG. **6**, FIG. **8**, and/or FIG. **9**.

For example, some or all components of various embodiments of the present invention each are, individually and/or in combination with at least another component, implemented using one or more software components, one or more hardware components, and/or one or more combinations of software and hardware components. In another example, some or all components of various embodiments of the present invention each are, individually and/or in combination with at least another component, implemented in one or more circuits, such as one or more analog circuits and/or one or more digital circuits. In yet another example, various embodiments and/or examples of the present invention can be combined.

Although specific embodiments of the present invention have been described, it will be understood by those of skill in the art that there are other embodiments that are equivalent to the described embodiments. Accordingly, it is to be understood that the invention is not to be limited by the specific illustrated embodiments, but only by the scope of the appended claims.

What is claimed is:

1. A system controller for a lighting system, the system controller comprising:

a first controller terminal configured to receive a first signal; and

a second controller terminal configured to output a second signal to a driver component, the driver component being configured to receive a first current and provide one or more drive currents to one or more light emitting diodes in response to the second signal;

wherein the system controller is configured to:

process information associated with the first signal;

determine a first time period for the first signal to increase from a first threshold to a second threshold; and

determine a second time period for the first signal to decrease from the second threshold to the first threshold;

wherein the system controller is further configured to:

in response to the second time period minus the first time period being larger than a predetermined positive value, determine the first signal to be associate with a leading-edge TRIAC dimmer;

in response to the first time period minus the second time period being larger than the predetermined positive value, determine the first signal to be associate with the trailing-edge TRIAC dimmer; and

in response to an absolute value of the first time period minus the second time period being smaller than the predetermined positive value, determine the first signal not to be associated with any TRIAC dimmer.

2. A method for a lighting system, the method comprising:

receiving a first signal;

processing information associated with the first signal;

determining a first time period for the first signal to increase from a first threshold to a second threshold;

determining a second time period for the first signal to decrease from the second threshold to the first threshold;

processing information associated with the first time period and the second time period;

in response to the second time period minus the first time period being larger than a predetermined positive value, determining the first signal to be associate with a leading-edge TRIAC dimmer;

in response to the first time period minus the second time period being larger than the predetermined positive value, determining the first signal to be associate with a trailing-edge TRIAC dimmer; and

in response to an absolute value of the first time period minus the second time period being smaller than the predetermined positive value, determining the first signal not to be associated with any TRIAC dimmer.

3. The method of claim **2** wherein the fourth signal represents the third current that flows through the leading-edge TRIAC dimmer or the trailing-edge TRIAC dimmer.

4. The method of claim 2 wherein the fourth signal represents one component of multiple components of the third current that flows through the leading-edge TRIAC dimmer or the trailing-edge TRIAC dimmer.

* * * * *