Guest Editorial
Special Issue on LED Drivers

When in 1907, Henry Joseph Round (1881–1966) published “A Note on Carborundum,” in Electrical World, 49, pp. 309, reporting the electroluminescence effect on a carborundum (SiC) crystal, little he knew about the huge impact that his discovery would cause in the lighting industry 100 years later. Unfortunately, carborundum proved impractical for light production, mainly due to its very low conversion efficiency. Thus, it was not until the early 1960s, when the first commercial GaAs-based light-emitting diodes (LEDs) were produced. Since then, LED technology has experienced a continuous improvement, especially intense during the 1990s, which led to the great number of applications that we can enjoy nowadays.

In this field of knowledge, a special recognition must be paid to Isamu Akasaki, Hiroshi Amano, and Shuji Nakamura, who invented the blue LED, being awarded by the Royal Swedish Academy of Sciences with the 2014 Nobel Prize in Physics. Before the invention of the blue LED, it was not possible to use LED technology for general lighting applications, because white light is required in this application. Blue light is an essential component in white-light generation, which can mainly be produced by mixing blue and yellow lights, or red, green, and blue lights. Thus, in the early 2000s and afterward, LED lighting applications blossomed, making themselves tough competitors against fluorescent lighting. Now, everyone has heard about this amazing technology and about the benefits that come with it; namely, energy saving, endurance, and the possibility of having different colors of light, also known as mood lighting. However, most people remain ignorant about the fact that LEDs, unlike incandescent lamps, require an electronic device to be properly operated: the so-called LED driver or LED power supply. And here is where our work as power electronics engineers starts, even though it will sadly remain overlooked and unrecognized in most cases, not being a “visible” part of the lighting system. Nevertheless, LED drivers are an essential component of the lighting fixture, and play a major role in taking full advantage of the LED benefits. Basically, LEDs must be supplied with a regulated dc current, and its operating temperature must be maintained within a precise range, both in order to assure their photometrical characteristics and avoid early aging. When supplying from the ac grid is required, the LED driver role becomes still more critical, being necessary to provide high input power factor and, therefore, deal with the instantaneous power unbalance between line and load. In conventional laptop and cell phone power supplies, electrolytic capacitors were gladly used to store energy and compensate for the line-to-load power unbalance. However, in offline LED applications, electrolytic capacitors are banned, and must be avoided at any cost, due to its low life expectancy compared with that of LEDs. This topic has inspired a lot of research on LED driving. Other hot topics of research are LED modeling, efficient dimming, current equalizing in multiarray LED lamps, and digital control applied to LED drivers, among others.

In this Special Issue, 37 submissions were received, from which 15 papers were finally accepted for publication. We sincerely appreciate the effort of all authors in contributing to this Special Issue in so diligent and timely manner. We have classified the accepted papers in three main sections:

1) LED modeling;
2) DC LED drivers;
3) offline LED drivers.

In the next sections, the papers are briefly introduced and summarized. In each section, an alphabetical order by the first author’s surname has been followed.

I. LED Modeling

In this section, the paper titled “Four-Parameter Taylor Series Based Light-Emitting-Diode Model,” by Lin et al., presents an LED model based on the Taylor series to describe the nonlinear V–I characteristic of the LED, including the LED junction temperature effect. One of the advantages of this model is that it can directly be obtained from the manufacturer’s datasheet, using four available parameters: 1) maximum operating point; 2) rated operating point; 3) knee point; and 4) temperature coefficient. The paper also presents how the model can be used to obtain the small-signal behavior of the LED, which can be used in the small-signal modeling of the complete LED driver. Experimental verification demonstrates the feasibility of the proposed modeling technique, obtaining a maximum error between the laboratory results and the theoretical model of 1.5%.

II. DC LED Drivers

This section starts with the paper “Multi-Channel LED Driver With CLL Resonant Converter,” by Chen et al., in which the authors present a two-stage multichannel LED driver made up by a buck converter as first stage and a multichannel CLL resonant converter as second stage. The operation of the resonant converter is maintained at the series resonant...
frequency in order to assure high efficiency. The system senses the current through one of the LED strings to perform closed-loop current regulation using PWM upon the buck converter, being the rest of the strings cross-regulated. The authors conclude that the proposed driver can achieve high efficiency within a wide load range, low dimming levels, and good current balance among LED strings.

The paper titled “Energy Efficiency Considerations for LED-Based Lighting of Multipurpose Outdoor Environments,” by Farahat et al. presents an outdoor lighting system with high energy efficiency. The work deals with energy efficiency aspects at two levels: 1) at component level, by presenting a high-performance LED driver based on a dual-phase LCC resonant converter and 2) at system level, by proposing a control strategy and associated hardware infrastructure. With this combined strategy, authors demonstrate a reduction of 34% on energy consumption in a real-life application.

In the third paper of this section, entitled “Optimal Design of LED Array Combinations for CCM Single-Loop Control LED Drivers,” Lin et al. employ the LED Taylor series model and the equivalent circuits of three LED driver topologies, to predict the optimal combination of the LED arrays, so that the requirements of critical damping and maximum efficiency can be fulfilled. Three prototypes were built and tested at the laboratory to demonstrate the feasibility of the proposed design methodology.

Pollock et al. in their contribution “High Efficiency LED Power Supplies” present a solution based on the arrangement of one or more LEDs in series with the voltage power supply and a conventional LED power supply, which acts as a series compensation module. The analysis carried out by the authors show that the efficiency of the whole circuit will always be higher than that of the series compensation block in stand-alone operation. Experimental results demonstrated an improvement in the LED driver efficiency of 5%.

The paper “DC Level Dimmable LED Driver With Primary Side On-Time Control for DC Distribution,” by Seo and Cho, proposes an LED driver that employs a dc-level dimming technique with the aim of avoiding complex communication arrangements in the lighting system. An additional system efficiency improvement is obtained by matching the dc input voltage to the LED load operating conditions. The proposed system has been implemented in a 180 LED lamp parking lot, proving an energy saving of 7% compared with a conventional lighting system.

III. OFFLINE LED DRIVERS

The first paper of this section is authored by Abramovitz et al., titled “Quasi Resonant LED Driver With Capacitive Isolation and High PF,” in which the authors present a novel topology of the LED driver based on a quasi-resonant structure, which attains safety isolation by means of a capacitive barrier. The solution is focused on reducing footprint area and cost by avoiding the use of a magnetic transformer for providing electrical isolation. The paper includes a detailed analysis of the converter, design guidelines and example, and experimental results. The authors state that the primary advantages of the proposed topology are capacitive isolation, zero-voltage-switching turn off, zero-current turn on, high-frequency operation, inherently low input-current distortion, high power factor, and high efficiency.

In “Digital Implementation of the Feedforward Loop of the Asymmetrical Half-Bridge Converter for LED Lighting Applications,” Arias et al. propose a digital feedforward algorithm to improve the low-frequency output-voltage ripple cancellation provided by the asymmetrical half-bridge converter when used as a downstream converter in offline LED drivers. The implementation of the control algorithm is based on lookup tables, and according to authors’ conclusions, ripple compensation is improved in comparison with the state-of-the-art analog-implemented feedforward control. Experimental results obtained from a 40-W laboratory prototype demonstrate the benefits of the proposed technique.

The paper “A Flicker-Free Single-Stage Offline LED Driver With High Power Factor,” by Fang et al. deals with the previously mentioned line-load power unbalance in offline LED drivers by introducing a ripple cancellation method to remove the twice line-frequency ripple in high-power-factor LED drivers. The proposed solution allows for a great reduction of the required storage capacitance, which can therefore be implemented avoiding electrolytic capacitors. In addition, high efficiency is attained, because most of the input energy is processed only once by the proposed structure.

The third contribution of this section, by Gacio et al., titled “Optimization of a Front-End DCM Buck PFP for an HPF Integrated Single-Stage LED Driver” investigates the use of the buck converter as an upstream power factor correction (PFC) stage in offline LED drivers. The work is focused on optimizing the buck converter so that the dc-link storage capacitance can be reduced to a value that makes feasible the use of nonelectrolytic capacitors. A 70-W buck-flyback laboratory prototype able to supply different LED arrangements, which also includes PWM-based dimming capability, is presented to support the conclusions of the performed study.

Lam and Kain, in their paper “Isolated AC/DC Offline High Power Factor Single Switch LED Drivers Without Electrolytic Capacitors,” propose two novel isolated offline LED driver topologies in which the energy storage capacitor is moved to the input rectifier side by employing a three-winding transformer, which additionally provides galvanic isolation. The authors state that the energy storage capacitance can significantly be reduced, allowing for the use of film or ceramic capacitors instead of electrolytic ones. The proposed converters are analyzed in detail. Experimental results from a 12-W laboratory prototype are presented to confirm the expected benefits of the converters.

The next contribution of this section is presented by Lyu et al. in their paper “A High-Efficiency Linear LED Driver With Concave Current Control for Low-Power Application,” in which the authors analyze and compare three different possibilities for the input current; namely, flat, convex, and concave shaped. The authors conclude that the concave control proposed in this paper presents the highest efficiency among the three methods. Operation principles, design considerations, and experimental results are also
presented in this work. Experimental results showed a 10% average improvement on the converter efficiency compared with the state-of-the-art solutions.

Qiu et al. in their paper titled “Bipolar Ripple Cancellation Method to Achieve Single-Stage Electrolytic-Capacitor-Less High-Power LED Driver” deal with the avoidance of electrolytic capacitors in the offline LED drivers by proposing a ripple cancellation method with two different full-bridge structures, which are used to cancel the low-frequency ac ripple in the LED current and minimize the storage capacitance requirements. According to author statements, the proposed circuit can achieve zero double-line-frequency ripple, while providing high power factor and high efficiency. A 100-W laboratory prototype was built, and experimental results are presented. Authors report that a reduction close to 1/100 in the required storage capacitance has been achieved, while maintaining an efficiency of nearly 93%.

The paper “An Average Current Modulation Method for Single Stage LED Drivers With High Power Factor and Zero Low Frequency Current Ripple,” by White and Liu, is also focused on the reduction of low-frequency ripple in LED drivers, by proposing an average current modulation method that is designed to operate in conjunction with single-stage PFC drivers. Authors state that the energy storage capacitor of the PFC stage can be reduced, so that electrolytic capacitors are not required. In addition, the proposed technique is simple to implement, and has little impact on the overall efficiency of the converter. Experimental results from two laboratory prototypes are presented to prove the benefits of the proposed control method.

Last but not least, in the paper titled “A Single-Stage LED Driver Based on Interleaved Buck-Boost Circuit and LLC Resonant Converter,” Wang et al. present a single-stage LED driver for offline applications, which is based on an interleaved buck–boost circuit and an LLC resonant converter. The two buck–boost converters operate in an interleave mode with the inductor current in discontinuous conduction mode, in order to provide PFC. The LLC resonant converter allows for reducing switching losses and improving the efficiency of the LED driver. The authors present a detailed design process for a 100-W LED street lighting system, which achieves excellent performance and efficiency as high as 92%.

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This Special Issue could have not been possible without the contributions made by all of the authors. We sincerely appreciate the effort carried out by them in preparing their first manuscripts, and in improving them out of the comments and suggestions from the reviewers. Unfortunately, some of the papers had to be rejected due to fail on achieving the high-quality standard required by Journal of Emerging and Selected Topics in Power Electronics (JESTPE). We hope this particular outcome does not discourage the authors from continuing their research work in this exciting field.

We also want to thank all the reviewers who participated in this Special Issue. Their invaluable, anonymous, and never-recognized-enough work has been essential for the success of a technical publication like the present one. Similarly, our thanks and deep recognition are due to all Guest Associate Editors who have collaborated in this Special Issue: Francisco Azcondo, Henry Chung, Marco A. Dalla Costa, Ron Hui, Ray-Lee Lin, Mor M. Peretz, Giorgio Spiazzi, and Regan Zane. Their efforts in finding reviewers, supplying additional comments, and making recommendations were a vital part of the review process. We also want to thank Ahmed Rubaai, Chair of the Industry Applications Society Publication Department, and Don Tan, JESTPE Editor in Chief, for giving us the opportunity and honor of acting as Guest Editors of this Special Issue, and for their warm help and assistance along the whole editorial process. Last but not least, we appreciate the excellent support received from JESTPE staff Michael Markowycz and Sonal Parikh, whose technical help during the review process proved to be indispensable for the timely publication of this Special Issue.

J. MARCOS ALONSO, Guest Editor
University of Oviedo,
Electrical Engineering Park
33204 Gijón, Asturias, Spain

GEORGES ZISSIS, Guest Editor
Université de Toulouse
LAPLACE (Laboratoire Plasma et Conversion d’Energie)
31062 Toulouse Cedex 9, France
J. Marcos Alonso (S’94–M’98–SM’03) received the M.Sc. and Ph.D. degrees in electrical engineering from the University of Oviedo, Asturias, Spain, in 1990 and 1994, respectively. He was a Visiting Researcher with the Federal University of Santa Maria, Santa Maria, Brazil, in 2011 and 2014, and the Center for Power Electronics Systems, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, in 2013. He has been a Full Professor with the Department of Electrical Engineering, University of Oviedo, since 2007. He has participated in more than 50 research projects and contracts with companies. He has co-authored over 350 journal and conference publications, including 80 publications in highly referenced journals. He was a Supervisor for eight Ph.D. theses. His current research interests include electronic ballasts, LED power supplies, power factor correction, dc–dc converters, soft-switching converters, resonant inverters, and high frequency switching converters in general.

Prof. Alonso is a member of the Power Electronics Technical Committee of the IEEE Industrial Electronics Society. He is also a member of the European Power Electronics Association and belongs to the International Steering Committee of the European Conference on Power Electronics and Applications. He was a recipient of the Early Career Award of the IEEE Industrial Electronics Society in 2006. He was honored with the University of Oviedo Electrical Engineering Doctorate Award in 1996. He received the National Funding for Intensification of Research Activity from 2008 to 2012. He also received three IEEE paper awards. He serves as an Associate Editor of the IEEE Transactions on Power Electronics, the IEEE Journal on Emerging and Selected Topics on Power Electronics, and the IEEE Transactions on Industry Applications. He was a Co-Guest Editor of two special issues on lighting applications in the IEEE Transactions on Power Electronics in 2007, and the IEEE Transactions on Industrial Electronics in 2012. He has organized many IEEE Conference Special Sessions on Lighting Applications. He was a Secretary of the IEEE IAS Industrial Lighting and Display Committee from 2013 to 2014, where he currently serves as the Vice Chair. He was elected as the Member-at-Large of the IEEE IAS Executive Board from 2013 to 2014, and re-elected from 2015 to 2016, where he collaborates with the Education Department activities, and as an IAS Newsletter Editor.

Georges Zissis (M’92–SM’06) was born in Athens, Greece, in 1964. He received the Degree in general physics from the Department of Physics, University of Crete, Rethimno, Greece, in 1986, and the M.Sc. and Ph.D. degrees in plasma science from Toulouse 3 University, Toulouse, France, in 1987 and 1990, respectively. He is currently pursuing the Doctor Honoris Causa degree with Saint Petersburg State University, Saint Petersburg, Russia.

He was an Advisor for 20 Ph.D. students and several master’s students. He is currently a Full Professor with Toulouse 3 University. He is the Director of the Light & Matter Research Group with Université de Toulouse, Laboratoire Plasma et Conversion d’Énergie (LAPLACE), Toulouse, France that enrolls 20 researchers. He has authored four books, 18 chapters in books, 110 papers in WoS referenced journals, 42 invited conferences, and more than 250 communications to national and international conferences. His current research interests include light sources science and technology, in particular, the physics of electrical discharges used as light sources; system and metrology issues for solid-state lighting systems; normalization and quality issues for light sources; impact of lighting to energy, environment, quality of life, health, and security; interaction between light source and associated power supply; and illumination and lighting.

Dr. Zissis received the First Award of the International Electrotechnical Committee Centenary Challenge for his work on normalization for urban lighting systems (in conjunction with the IEEE, IET, and the Observer) in 2006. He also received the Energy Globe Award for France in 2009, and the Fresnel Medal from the French Illuminating Engineering Society. From 2003 to 2008, he acted successively as a Secretary, the Vice Chair, and finally the Chairman of the IEEE Industrial Application Society (IAS) of the Industrial Lighting and Display Committee. Since 2008, he has been a member of the Editorial Board of the OSA Journal of Display Technology and the IEEE Journal of Display Technology, a journal co-sponsored by IAS, as IAS representative. He acts as a Reviewer for several international scientific journals, and in particular, the IEEE Transactions on Industry Applications, the IEEE Transactions on Industrial Electronics, the IEEE Transactions on Plasma Science. He organized several scientific conferences with the IEEE technical co-sponsorship. He acted as an IEEE-IAS MSDAD-Department Chair from 2011 to 2014. Since 2015, he has been elected as the Vice President of the IEEE IAS.