Exclara Solution Overview

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HVX High Voltage LED Driver Solution Overview

Introduction

LED lighting has continued to gain market share because it offers higher energy savings, efficiency, and power factor compared to the alternate technologies such as incandescent, halogen, and CFL. However, adoption has been slow due to the higher cost of the DC Solutions available today. DC Solutions convert AC line power to DC required by the LEDs through a multi-stage process, adding many components, cost, size and reducing efficiency, power factor and life time. AC Solutions as an alternative using discrete components can address the cost and size issues, but are not commercially viable due to lower efficiency, power factor and quality.

Exclara is the first company to offer an AC solution that is the lowest cost and smallest size LED driver solution in the industry and that improves the efficiency, power factor and quality. Exclara is currently shipping the EXC100, first IC in its HVX family of products based on Exclara's high voltage drive technology.

In this document we explore key requirements for LED drivers and how Exclara's HVX product family offers competitive advantages to OEMs, including cost, efficiency, and size. HVX enables price points that are driving mass market adoption of LED lighting through its low cost and size.

LED Lighting Requirements

The energy cost and short lifetime of incandescent bulbs led to growth in adoption of fluorescent lighting. However, LED lighting evolved initially using discrete components, followed by DC Solutions that required multi-stage power conversion. Some vendors developed AC Solutions using discrete components that reduced size and cost but lowered efficiency and power factor. Now, AC LED lighting is becoming viable with new developments in driver technology for AC LEDs that dispense with the need for multi-stage power conversion and its attendant issues. They can lower overall system cost and size and enable excellent energy efficiency.

Key requirements for LED lighting:

- cost
- power and energy parameters
- certification for safety and EMI emissions
- ease of design, product development cost and time to market
- manufacturability

We will now review each of these requirements and then explore them in relation to Exclara HVX technology and product family.

Cost

In most markets cost is an important factor for new and retrofit lighting systems. This includes manufacturing cost, and ongoing costs to the user such as energy usage and maintenance costs including replacement and lifetime. For rapid adoption of LED lighting, total cost of ownership (TCO) must be better than that of alternate technologies such as incandescent, halogen and CFL. At the same time, manufacturing cost must not be too high since that drives the upfront cost of installation which can become a limiting factor.

Manufacturing cost of LED lights using DC driver solutions has been high due to the need for several components for multi-stage power conversion. Energy savings are lower due to lower efficiency and power factor. LED light life-time in these solutions is dominated by need for capacitors, which burn out in two to three years or less, versus LED life-time of five to ten years. As a result of these limitations, these solutions do not offer significant advantage over legacy technologies limiting their adoption.

AC Solutions using discrete components such as designs that are resistor-based or linear-regulator based do offer lower cost, but at the expense of lower efficiency and power factor. Exclara HVX is the only AC Solution available today that offers the lowest cost while improving efficiency and power factor.

Power and Energy Parameters

Two important parameters for lighting are efficiency and power factor. Efficiency in turn consists of two types: energy efficiency and system efficiency.

Energy Efficiency

Power Conversion Efficiency

For power supplies, power conversion efficiency is the measure of the utilization of input power compared to the net power delivered to the LEDs. For DC solutions, it is the ratio of delivered DC power to the AC input power from the line. This requires multiple stages of power conversion and with each stage comes a practical loss of power. AC solutions deliver the AC energy directly to the load (LEDs), thus requiring only one power conversion and, therefore, incur only one stage of power loss. HVX technology has been shown to achieve 90 to 96% power conversion efficiency, while the typical flyback DC system achieves from 75 to 82%.

Traditional AC Solutions use passive (resistive) ballasts or simple active linear regulation to transfer power from the AC input to the LEDs. However, a resistive approach has two problems:: the delivered power can vary widely with the input, and it is purely lossy. Active regulators improve the dynamic response to input variations but because they are linear devices, are also lossy. Exclara HVX ICs use an internal controller for optimum switching of current throughout the AC waveform to optimize the energy transfer into multiple segments of LEDS (up to 4 with one EXC100). HVX can increase power conversion efficiency by 30 to 40 points over the resistive and linear regulator solutions. In addition, its time-domain technique not only achieves the optimum transfer of energy but also limits the sensitivity to input variations compared to the two mentioned approaches.

System Efficiency

System efficiency, or efficacy, is usually expressed in lumens per watt. LED light output in this case is a function of the integrated amount of energy under the (current) waveform delivered to them. For DC systems, power conversion and system efficiency are the same (for all practical purposes) since the output is a DC waveform. That is, the power delivered to the LEDs is the (real) product of voltage and current. However, in AC systems, the integrated energy under the AC waveform is less than a DC system at a given input power. But, due to the combined effects of HVX's optimum power conversion and the inherent losses in a DC system, the efficacies are comparable.

Power Factor

Power factor (pf) is the measure of the productivity of the delivered power. It is different from energy efficiency in the sense that pf losses are incurred by reactive components (inductors, capacitors) as opposed to resistive ones. Low pf is expensive and many utility companies charge an additional fee if it is less than 0.95. Low pf also reduces the electrical system's distribution capacity by increasing current flow and causing voltage drops. A pf of one or "unity power factor" is the goal of any electric utility company since they would otherwise have to supply more current to the user for a given amount of power use. In so doing, they would incur more line losses and therefore would need larger capacity equipment than otherwise necessary.

DC systems have an inherent pf loss due to their use of reactive components. Hence, pf correction is required especially since the Energy Star requirement is 0.9 for commercially deployed LED lighting and 0.7 for the consumer market. AC Solutions that use purely resistive ballasts have high pf's (but with huge real losses). AC Solutions that employ linear regulators could also result in being outside of the Energy Star range. Like the resistive approach, Exclara HVX-based systems have high pf because there is no utilization of reactive components, and HVX achieves even higher pf because its internal controller performs pf correction.

Certification

Regulatory entities are placing high requirements on LED lighting systems in the anticipation that this technology will dominate the public domain in the foreseeable future. Strict safety measures regarding electrical isolation and fire hazards have been defined by UL (and equivalent bodies worldwide) and compliance to electromagnetic interference (EMI) is defined by the FCC in the USA. Normally, compliance to FCC Part 15 Class B will suffice worldwide. Exclara products comply with both UL/CE and FCC requirements in the USA and with the equivalent counterparts worldwide.

In regard to EMI, all switching systems including DC solutions and HVX produce some interference. To compensate, DC systems must use filtering with external components (for example, chokes) which adds to cost. However HVX does not require this because, while it does perform internal switching, it is implemented in a way that does not produce large harmonics and meets FCC without the use of external components. With respect to isolation standards, AC solutions for LED lighting are inherently non isolatable and therefore the lighting system designer must take mechanical measures to ensure safety from electrocution. Exclara provides detailed reference designs and application notes for Exclara HVX-based systems.

Need for Engineering Knowledge to Develop a Product

Vendors developing lighting products need specific engineering capability. Although designing the LED part of LED products is a matter of optics, manufacturability, and cost, the design of power supplies that can meet the previously mentioned criteria is more difficult. Skilled, experienced power supply designers for LED high voltage lighting systems are rare. Designers of conventional power supplies may not always be able to create optimal designs suitable for this market. Design of low-cost EMI-reduced supplies may require specialized knowledge.

Design of LED power supplies using DC Solutions is inherently complex due to the higher number of components. Exclara HVX-based systems are easier to design because of the high degree of functionality in the Exclara EXC100 IC which reduces complexity . Exclara further eases the design burden by providing detailed reference designs across various product categories and form factors.

Manufacturability

Manufacturability is defined as the extent to which an item can be manufactured with relative ease at minimum cost and maximum reliability. Design for Manufacturability (DFM) is designing products in such a way that they are easy to manufacture. Higher manufacturability leads to faster adoption of a product or technology as plants can be built faster, at a lower cost, and more companies can participate in the market.

Manufacturability of LED lights includes the manufacturing process complexity, equipment complexity, and cost of building and operating manufacturing plants. On all aspects, Exclara HVX product family, with its low component count and simpler system design leads to significantly higher manufacturability compared to the DC Solutions.

The Exclara HVX Solution

The Exclara HVX product family is based on Exclara's High Voltage Drive technology supporting the design of high-voltage LED systems. The Exclara HVX product family consists of integrated circuits supported by ready-to-use reference designs enabling low BOM (bill of materials) power supplies that have excellent energy efficiency, power factor rating, ease of certification, and most importantly, cost.

The EXC100 High-Voltage LED Driver IC, first in the Exclara HVX family, implements all the functions of a high-voltage LED system power supply in a single compact chip. Only a handful of supplementary components are needed, resulting in a very small system form factor, allowing it to fit into the base of a small bulb or on the LED board itself.

Exclara offers multiple forms of support for vendors adopting the HVX solution. First of all, Exclara provides reference designs which can be easily modified to suit customer requirements. Second, a design tool helps create component values for the design. Third, design support is available for making critical or difficult design decisions.

HVX Technical Details

The HVX solution's EXC100 is a highly integrated, power factor corrected LED driver optimized for small size, high performance and which enables low BOM in any LED lighting applications. It can be used with standard leading and trailing edge phase dimmers, making it suitable for all indoor lighting applications. For high-power applications (over 100W), the HVX driver architecture is scalable using external FETs or multiple EXC100 IC's.

An EXC100 chip design supports high yields in volume production, due to the system simplicity, and long operating life since electrolytic capacitors are not required.

HVX Architecture and Technology

Power Aspects of the HVX Controller and Power IC Technology

Exclara's HVX IC delivers AC line voltage to the LEDs without any of the performance issues of traditional AC LEDs solutions and yet maintains design simplicity. The EXC100 architecture segments a single string of LEDs into a maximum of 4 segments, with most applications requiring only 3 segments. The 4th segment is for systems requiring greater than 0.98 power factor (under 20% THD). Exclara's patented segmentation approach preserves a high performance combination of power factor (greater than 0.9), high power conversion efficiency (over 90%), and low EMI pollution (for example, FCC Class B). In addition, a typical 10W application only requires fewer than 15 components (see following schematic) and scaling to higher power usually only requires the addition of a low-cost FET.

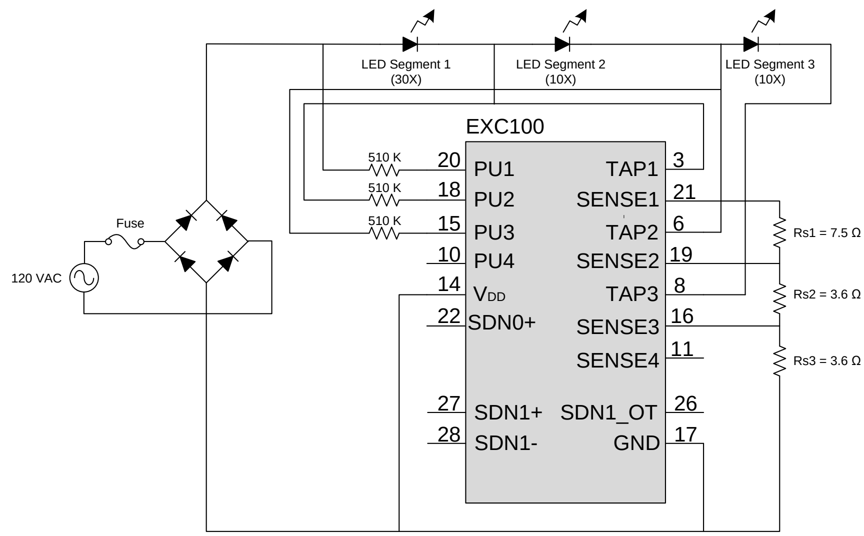
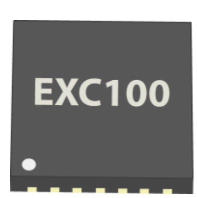


Figure 1. HVX Solution Using EXC100 Driver

The HVX architecture uses advanced time domain and AC line voltage information to control the LED current in phase with the AC line voltage. In addition, it has two user shutdown pins, both of which will shut off the controller. A typical use for one of the pins is to support thermal shutdown sensed with an external thermistor. The second shutdown pin is free to the user.

EXC100 High Voltage LED Driver

The EXC100 is an integrated high-voltage LED driver capable of direct line operation through a bridge rectifier. No capacitors are needed in a design, and only a few non-power resistors are needed. It allows integration of LEDs and the driver system on a single small printed circuit board. Benefits and features are summarized in Table 1.



7 x 7 mm QFN package enables small form factor

Table 1. Benefits and Features of the EXC100

Benefits of Exclara's EXC100	EXC100 Features
• Provides high-performance power conversion efficiency, power factor, and EMI acceptance	• High efficiency (greater than 90%) • High power factor (greater than 0.98) • FCC Class B compliance
• Stable output relative to traditional AC solutions	• Lower output sensitivity to input changes
• Multinational usability	• Universal VAC operation, 50/60 Hz operation
• Temperature protection	• Thermal sensor over-temperature shutdown
• Low number of external components reduces product cost and improves reliability	• Integrates key components

Exclara HVX Key Solution Elements

Exclara HVX Solution include several elements geared towards easing the design, development and manufacturing of LED solutions based on HVX product family and specifically using EXC100 High Voltage LED Driver IC from Exclara. These solution elements include:

1. EXC100 Reference Designs
2. EXC100 Design Tool
3. EXC100 Light Source Reference Designs

EXC100 Reference Designs

Exclara provides reference designs that cover a range of product categories and form factors to enable ease of design and rapid time-to-market for the Exclara customers. Reference designs include T8, T10 and A19 form factors, support for worldwide input VAC and a range of power output. Table 2 provides details and schedules for these reference designs.

As a part of the EXC100 Reference Design Kit, Exclara provides schematics and Gerber files for each of these reference designs.

IC Part No.	ES Available	Production
EXC100	Now	- Conditional Release: Now - Full Release: Sept 2011

Table 2. EXC100 and Reference Design Availability

Application	Input Voltage (nominal)	Power Out (W)	Length (ft)	Reference Design (1) Availability	Evaluation Kit (2) Availability
T10	220VAC	12	2	EXR100-T10-012-220-2F	
		15	3	EXR100-T10-015-220-3F	
		16	4	EXR100-T10-016-220-4F	
		20	5	EXR100-T10-020-220-4F	
		24	5	EXR100-T10-024-220-5F	
		30	6	EXR100-T10-030-220-6F	
		36	8	EXR100-T10-036-220-8F	
T10	110 VAC	16	4	EXR100-T10-016-110-4F	
T8	220VAC	12	2	EXR100-T8-012-220-2F	
		16	4	EXR100-T8-016-220-4F	EXK100-T8-016-220-4F
		17	4	EXR100-T8-017-220-4F	
		20	4	EXR100-T8-020-220-4F	
A19	220VAC	9	na	EXR100-A19-009-220	EXK100-A19-009-220
	100 VAC	9	na	EXR100-A19-009-100	EXK100-A19-009-100
	120VAC	9	na	EXR100-A19-009-120	EXK100-A19-009-120

Notes:

(1) Ref. Design comprises schematics, BOM, layout, and gerber files for EXC100 module and LED board.

(2) Evaluation Kit comprises EXC100 module, light source and qty-2 EXC100 IC's.

EXC100 Design Tool

Exclara has developed a design tool that guides the LED system designer with both the EXC100 driver as well as the light source design.

The designer inputs the following design parameters to the tool:

1. Operating temperature - ambient to EXC100
2. Rated output power to LEDs
3. Rated voltage
4. Rated current of each LED
5. Total number of LEDs
6. LED IV curve

Based on these parameters, the EXC100 Design Tool generates three types of output parameters: 1) driver-related, 2) light source related and 3) system-related.

Driver-related sense resistor values include Rsense1, Rsense2 and Rsense3 (see RS1, RS2, RS3 in Figure 1 above.

Light source-related output parameters include:

1. Number of LEDs for segment 1 in series
2. Number of LEDs for segment 2 in series
3. Number of LEDs for segment 3 in series
4. Number of LEDs Parallel Strings in segment 1
5. Number of LEDs Parallel Strings in segment 2
6. Number of LEDs Parallel Strings in segment 3

System-related output parameters include driver efficiency, power factor, THD, power and LED currents.

EXC100 Light Source Reference Designs

Exclara also provides several reference designs to aid the system designer with the light source design. These reference designs are available as schematics and Gerber files.

Exclara HVX Versus Other AC Solutions

Existing variants on AC drivers do not optimally use energy. They fall generally into two classes: 1) resistor topology, and 2) linear regulator topology, as shown in Figure 2 and 3

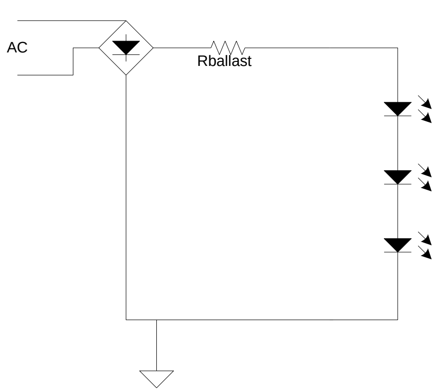


Figure 2. Resistor Topology

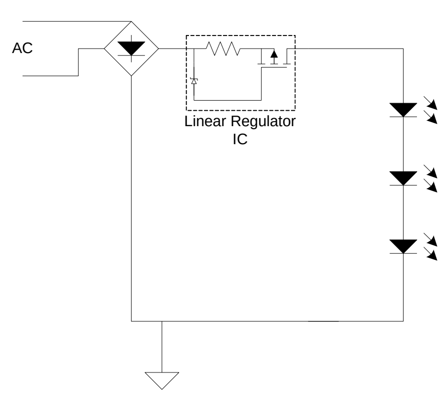


Figure 3. Linear Regulator Topology

Although the resistor topology is simple, it suffers in power conversion efficiency and the output changes dramatically with input changes.

In linear regulator-based systems, efficiency also suffers although it is better than the resistor system. Here, changes in output are more stable than in resistor-based systems, but the power factor suffers with lower input power.

The HVX technology offers a better and more efficient way to build a supply. When measured against three key metrics -- power conversion efficiency, power factor, and output sensitivity to input changes – HVX-based systems are superior as shown in the following Table 3. In addition, HVX offers a simple system structure as shown in Figure 1.

Table 3. Comparison of Resistor-Based Supplies, Linear Regulators, and the Exclara HVX Technology

	Resistor-Based Supplies			**Linear Regulator**			**Exclara HVX**		
	Pin (W)	Efficiency	PF	Pin (W)	Efficiency	PF	Pin (W)	Efficiency	PF
Min	4.89	0.52	0.904	4.6	0.64	0.87	11.15	0.839	0.912
Max	13.26	0.73	0.957	8.01	0.878	0.957	9.515	**0.929**	**0.976**
% change	172%			74%			15%		

Note that there are no energy losses due to transformers, inductors, or capacitors in an HVX design, saving energy and reducing heat generation.

Exclara HVX Versus DC Solutions

As discussed in the LED Lighting Requirements section, when compared to the DC Solutions, Exclara HVX technology dramatically reduces the number of components, system complexity, and cost while improving efficiency, power factor and life time.

The Exclara LVX product family, a DC Solution from Exclara, is the best-in-class DC Solution that offers several benefits compared to other DC Solutions in the market. These include reduced component count, higher efficiency and higher power factor. It also enables industry-leading dimming performance using Exclara Ultra-DIM™ architecture.

The Exclara LVX system design shown in Figure 4 has relatively fewer key supporting components than other DC solutions but it is more complex compared to the Exclara HVX design in Figure 1.

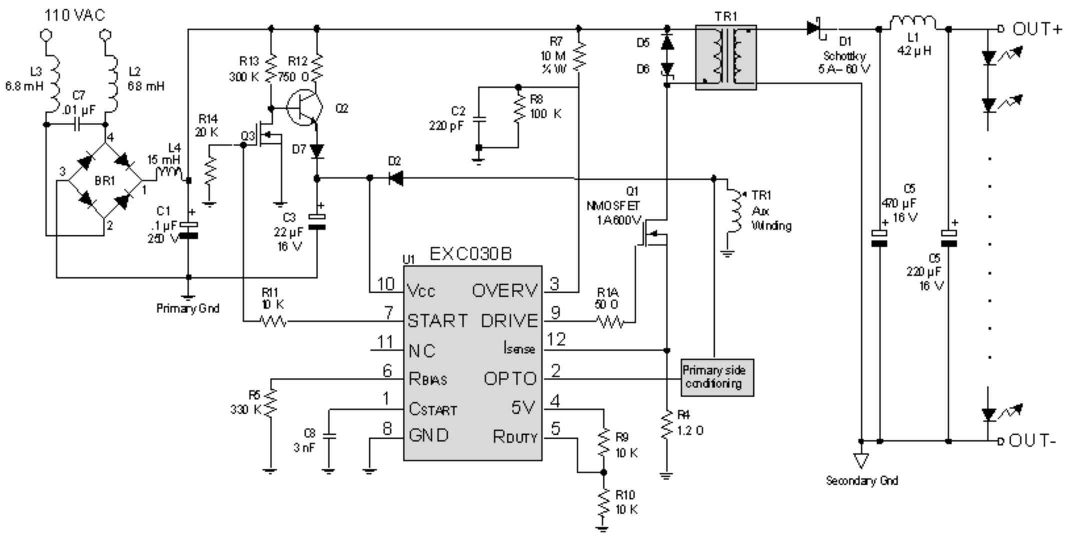


Figure 4. Exclara LVX Example System Design

The following table provides a comparison between other phase-dimmable DC Solutions, Exclara LVX and Exclara HVX product families. Exclara LVX is superior to other DC Solutions and Exclara HVX is superior to all DC Solutions in the market.

	Other Phase-Dimmable DC Solutions	LVX	HVX
Dimming Range	100:1 to 1000:1	10000:1	10:1
Power Conversion Efficiency	75 to 82%	87%	93%
Power Factor	0.8 to 0.9	0.99	0.98
FCC approval	Up to Class B	Class B	Class B
UL/CE	Yes (Class 2)	Yes (Class 2)	Yes (Class 1)
Module Size	9 to 15 cubic inches (!5W enclosed class)	Under 5 cubic inches (15W enclosed case) Under 2 cubic inches (10W open-frame)	Under 0.35 cubic inches (10W open-frame)
BOM	About 70 key components	Under 50 key components	Under 15 total components

Conclusion

Exclara HVX offers vendors significant advantages in many ways over other technologies. It can enable high-performance, very cost-effective products, opening the door to mass market penetration by LED lighting.