Diodes Incorporated is a leading global provider of Discrete, Logic and Analog semiconductors. Its global footprint includes sales offices in 5 countries and manufacturing locations in China, Europe and the USA. A focus on product innovation, cost reduction, acquisitions and customer service has made Diodes Incorporated an industry leader. Combining leading silicon and packaging technologies, Diodes provides a broad portfolio of Discrete semiconductors comprising Bipolar Transistors, MOSFETs, Schottky diodes, SBR, switching diodes and functional specific arrays to enable our customers’ next generation designs. The Diodes’ Analog IC portfolio consists of 6 main areas: Power Management ICs, Standard Linear, Lighting, Sensors, Direct Broadcast by Satellite and Applications, Specific Standard Products.

Solutions for LED Lighting Applications

Diodes’ acquisition of Zetex semiconductors expanded the companies’ Analog product portfolios. The best Analog ICs provide circuit designers with the most advantageous combination of efficiency, functionality and package size. Diodes Incorporated’s LED lighting solutions are not only recognized for their high efficiency and simplicity, but also for their flexibility and versatility. They are well suited to tackle a wide range of applications:
- General lighting
- Signage and display
- Portable lighting
- Automotive
- Signals

This selection guide covers Diodes’ range of LED drivers and their fit into these markets/applications:

Diodes’ family of LED drivers provide high efficiency constant current drive for high brightness LEDs – both high and low current. When driving multiple LEDs in a single string efficiencies greater than 95% may be achieved together with very accurate LED current matching. Diodes’ medium voltage DC-DC high brightness LED drivers combine a small footprint and high power density with operating voltage up to 6V. Integrated switch LED drivers are capable of delivering LED currents up to 1.5A. Device topologies include Buck, Boost and Buck-boost. Diodes’ low voltage DC-DC high brightness LED drivers are targeted at battery powered systems for general illumination applications. Uses range from 3W LED flashlights, to bicycle lights, to solar powered architectural lighting. Operation down to 0.8V supports 1-AA cell lamps. Diodes provides small screen display illumination with high efficiency charge pump multi-channel LED drivers and inductive boost LED drivers. High efficiency and high switching frequencies make them well suited to modern portable consumer equipment.
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## Medium Voltage DC-DC LED Drivers

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Type</th>
<th>Boost</th>
<th>Minimum Input Voltage</th>
<th>Maximum Input Voltage</th>
<th>Minimum Output Voltage</th>
<th>Maximum Output Voltage</th>
<th>Switching Frequency (min)</th>
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<td>-40 to 85</td>
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**Product Benefits**

- **Simple versatile solutions for LED driving**
  - Simple high performance solutions for driving multiple 1W and 3W LEDs in a variety of lighting applications
  - Small TSO25-5 package with standard footprint for medium voltage LEDs
  - High power density
  - Simple small solution size for high brightness LED
  - ZXLD1360/62/66, AP8802/03 and AL8801 targeted at driving 3W LEDs
  - ZXLD1150/50/56 and AP8800/81 targeted at driving 1W LEDs
  - Simple boost converters for driving LED from 1~2 cells
  - ZS5C310/310 maximize battery runtime by reducing LED current as battery voltage reduces
  - PWM and DC dimming
    - Versatile dimming, DC for thermal and PWM for brightness control
  - Hysteresis topology operates to 1000kHz
    - Inherently stable; inductor value dominates frequency setting which can be optimized for efficiency, EMI, accuracy and size
  - Green mold compound (No Bi, Sb) and Pb-free RoHS compliant
    - Better for the environment, no mercury unlike CFL

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**The DIODES Advantage**

- Simple solutions for high performance DC-DC LED driving
- Small TSO25-5 package with standard footprint for medium voltage LEDs
- High power density
- Simple small solution size for high brightness LED
- ZXLD1360/62/66, AP8802/03 and AL8801 targeted at driving 3W LEDs
- ZXLD1150/50/56 and AP8800/81 targeted at driving 1W LEDs
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Medium Voltage Applications: General Illumination

MR16 LED Lamp Solution

MR16 lamps require a high reliability small footprint solution. These lamps frequently use different combinations of LEDs, ranging from three 1W LED to one 3W LED. The AL8805 with its 1A, 5% capability provides a cost-effective simple reliable solution to MR16.

LED Lamp Solution for Refrigerators

LED lamps provide a good solution for commercial refrigerators because they provide uniform illumination, can operate from safe low voltages, and do not have start-up issues at low temperatures. The AP8802H provides a small footprint solution for commercial refrigeration - requiring a minimum of 4 external components while driving 12 LEDs in series from a 48V rail. The device CTRL pin provides lamp dimming for advanced illumination options.

AL8805 Benefits

- The AL8805 provides a simple cost-effective solution for general illumination LED lamps
- 30V 1A LED drive capability
- Drives multiple 1W and 3W LED in series, providing cost-effective solutions for MR16
- 5% initial average LED current accuracy
- Cost-effective solution meets accuracy requirements of most lighting applications and improves inter-channel matching
- High switching frequency up to 1MHz
- Small inductance value and size reduces solution size
- Small footprint SOT25 uses only 4 external components
- High power density small PCB footprint solution

AP8802H Benefits

- The AP8802H provides a simple cost effective solution for commercial refrigeration applications
- Operating voltage range up to 60V and down to -40°C
- Up to 15 LEDs can be connected in series; higher power can be delivered without reduction in lumens at low temperatures
- LED current can be up to 1A
- Drives both 1W and 3W LED systems
- Up to 500kHz switching frequency
- Small, cost-effective inductor and capacitor can be used
- 5% initial average LED current accuracy
- Meets accuracy requirements of most lighting applications at a cost-effective price and improves inter-channel matching
LED Lamp Solution for Street Lights

Many high power lamps utilize multiple serial channels of LEDs in parallel. The ZXLD1366EN8 offers 2.5% accuracy, providing a simple solution for these high power lamps by maintaining close matching between the parallel serial chains.

LED Lamp LCD Projector

LED lamp LCD projectors improve reliability, robustness and efficacy over existing solutions. The ZXLD1370 LED driver controller provides a scalable and versatile solution to this application. The fast PWM dimming feature provides the ability to do brightness control and multiplexing to allow 1 LED lamp to provide RGB color mixing.

ZXLD1366 Benefits

- Operating voltage range up to 60V and 125ºC
- Up to 15 LEDs can be connected in series such that higher output power can be delivered without reduction in lumens at low temperature
- 2.5% initial average LED current accuracy
- Meets accuracy requirement of most lighting applications and improves inter-channel matching
- Supports up to 1A LED current
- Good match for 3W LED systems
- Low thermal impedance exposed pad SO-8EP package

ZXLD1370 Benefits

- The ZXLD1370 provides the high drive current and accuracy needed for LED lamp LCD projectors
- Versatile controller
- Easily scalable LED current
- High accuracy LED control: 1% reference tolerance
- Better brightness control and matching between lamps
- Dedicated fast PWM dimming input
- Enables RGB multiplexing and brightness control
- LED thermal management via external thermistor
- Improves reliability of LED lamps
- Switching frequency up to 1MHz

LED Street Lamp Architecture

LED Lamp LCD Projector Architecture

Medium Voltage Applications: General Illumination (Continued)
Medium Voltage Applications: Automotive Lighting

Door Lighting

Door safety lamps usually use just 1 high brightness LED so a simple buck converter is typically used. The lamp operates directly off the battery, requiring the driver to withstand load dump as well as meeting AEC-Q100 automotive quality requirements. The ZXLD1362 is qualified to AEC-Q100 grade 1. Its 1A capability allows it to drive 3W LEDs while the device’s 60V operating voltage withstands most load dump conditions.

ZXLD1362ET5 delivers a simple, small footprint solution for automotive safety lighting
- 60V 1A LED drive capability
- Drives multiple 3W and 1W LEDs and withstands load dump
- 5% initial average LED current accuracy
- Meets accuracy requirements at a cost-effective price
- AEC-Q100 Grade 1 with 60V capability
- Suitable for wide range of automotive applications
- Small footprint TSOT23-5 package requires only 4 external components
- High power density small PCB footprint solution

LED Lamp Solution for Daytime Running Lights

Due to the variation in battery voltage and the number of LEDs used, buck-boost configurations are commonly used in daytime running lights. The ZXLD1374 LED driver used in buck-boost mode can deliver the accuracy, reliability and power drive needed for the large number of LEDs used in daytime running lights.

ZXLD1374 Benefits
- The ZXLD1374 provides a simple high reliability solution for driving LED daytime running lights
  - High accuracy LED control: 1% reference tolerance
  - Better brightness control and matching between lamps
  - LED thermal management via external thermistor
  - Improves reliability of LED lamps
  - Separate 1000:1 PWM dimming capability
  - Improves dynamic range of dimming at lower light levels
  - Switching frequency up to 1MHz
  - Reduces the value of the inductor, reducing the size of the solution
  - Two-pin diagnostic feedback pins
- Reports back to the system the status of the LED driver and load, increasing overall system reliability
## Low Voltage DC-DC LED Drivers

<table>
<thead>
<tr>
<th>Device</th>
<th>Topology</th>
<th>VIN (Min)</th>
<th>VIN (Max)</th>
<th>VOUT</th>
<th>ILED</th>
<th>fsw</th>
<th>Efficiency</th>
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### Product Benefits

**Versatile low voltage LED drivers**

- Simple low voltage LED drivers capable of operating from as low as 0.8V
  - Boost controllers
    - External transistor sets maximum LED current and chain voltage for increased versatility
  - Boost drivers
    - Targeted for small footprint low current LED solutions
- 0.8V minimum input voltage
- ZXL132x Buck, Boost and Buck-boost LED drivers
- Integrated 2A switch in a small footprint DFN4030 package
Low Voltage Applications: Portable Lighting

**2-Cell Flashlight**

Due to the cost-sensitive nature of flashlights, a simple low cost solution with long running time is beneficial.

The ZXSC310 low voltage boost controller provides such a solution. It operates with constant off-time and peak current switching topology. This reduces the average LED current automatically as the battery voltage is reduced, extending the flashlight run-time with only a small change in brightness.

**ZXSC310 Benefits**

- Simple solutions for 1- and 2-cell flashlights increases operating life
- 0.9V minimum operating voltage
- LED current set by input voltage and current through R1
- LED current is reduced as the battery voltage decreases, increasing lamp run-time.

**Portable LED Projector**

High efficacy LEDs enable long operating life in portable projectors. Common-anode connected RGB LEDs are used to reduce wiring and ensure low thermal impedances for the LED. This requires the use of 4 high efficiency low voltage LED drivers.

The ZXLD1320 LED driver can supply 1.5A in common anode configuration, offering a small footprint, high power-density solution to RGB common-anode portable projectors.

**ZXLD1320 Benefits**

- Simple small footprint solution for Li-ion powered 4W LED lit portable LED projectors
- 5 ~ 20V input voltage range
- Operates from 2 ~ 3 Li-ion cells
- 1.5A output current
- Drives 4W LEDs
- High efficiency Buck LED driver
- Drives one 4W LED from one Li-ion cell or two 4W LEDs from two Li-ion cells
- High power dissipation DFN4030-14 package
- Maintains high LED drive at higher ambient temperatures
Low Voltage Applications: Signage and Display

Single Cell Emergency Lighting

Emergency lighting applications require long run times from rechargeable batteries.

The ZXLD1321 boost LED driver with its low operating voltage range allows it to operate from a single and multi cell lead-acid/NiCd/Li-Ion batteries. Its 1A drive capability supports 1W and 3W LED applications.

Low Voltage Applications: General Illumination

Simple Solar Exterior Lights

Cost and run-time are important factors for solar powered exterior lamps. The ZXLD383 has been developed to meet these requirements.

Its 0.9V minimum operating voltage coupled with its 85% efficiency extends system operating life. The ZXLD383 offers a simple and elegant solution requiring only the LED, inductor, and a solar cell, eliminating one diode from the system.

ZXLD1321 Benefits

- Small footprint solution for safety-critical applications
- 1.2 ~ 12V input voltage range
- Operate from a single rechargeable cell
- 1A load current
- Drives 3W LEDs
- Boost topology
- Drives multiple 3W LEDs from one rechargeable cell
- High power dissipation DFN4030-14 package
- Maintains high LED drive at higher ambient temperatures

ZXLD383 Benefits

- Simple Boost and Buck-boost LED driver solution requiring only 1 external component plus LEDs
- Single cell operation (0.9V minimum)
- Increased battery life
- 85% Efficiency
- Increased battery life
- Simple flexible LED driving
- Requires only the inductor and LED
- Low saturation voltage switching transistor
- Improved efficiency
- Dual function enable input
- Inhibits operation and prevents discharging the rechargeable solar cell during darkness
Linear High Voltage LED Driver

DLD101 Benefits

- Small footprint 3mm x 3mm DFN package
- Saves board space
- Low thermal impedance DFN package
- Higher power dissipation than SOT23 form factor
- 1A, 100V MOSFET as LED driver
- Drives multiple 3W LEDs giving increased light intensity without bias current issues of BJT pass elements
- Incorporates bias resistors and MOSFETs into package
- Provides simple, versatile small footprint Linear LED driver solution
- Current set with one external resistor
- Lower part count and lower total cost compared to other devices

Linear Low Voltage LED Driver

AP8804 Benefits

- Operating voltage range from 1.8 to 6V
- Drives 1 LED from 1 Li-ion cell and 3 to 4 AA/AAA cells
- LED current can be up to 350mA
- Good match in 1W LED systems
- PWM and DC dimming using only 1 pin
- Simple and flexible solution that allows users to use their preferred dimming method
- DFN2020 green mold compound package
- Small footprint solution for low voltage applications
- 10% initial average LED current accuracy
- Meets accuracy requirements of most lighting applications at a cost-effective price

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<thead>
<tr>
<th>Device</th>
<th>Topology</th>
<th>$V_{IL}(\text{Min})$</th>
<th>$V_T$</th>
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# Backlighting ICs and Bias Generators

## LED Backlight Drivers

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<th>Maximum Input Voltage</th>
<th>Maximum Output Voltage</th>
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<td>-</td>
<td>0.6/1.2/1.8</td>
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<td>1.2</td>
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<td>26</td>
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## LCD and OLED Bias Generators

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<th>Maximum Input Voltage</th>
<th>Maximum Output Voltage</th>
<th>Number of LED</th>
<th>Frequency</th>
<th>Efficiency</th>
<th>Current Limit</th>
<th>OVP</th>
<th>Soft Start</th>
<th>VFB</th>
<th>Operating Temperature Range</th>
<th>Available Packages</th>
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<td>-40 to +85</td>
<td>TSOT23-5</td>
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**AL3158/9 Benefits**

- Simple small footprint solutions for small screen backlighting and biasing
- High Efficiency: up to 93% Typical
- Longer battery life
- Fast 1.2MHz Switching Frequency
- Smaller inductor and capacitor size
- Inductive Boost converters and multi-channel charge pumps
- High efficiency, cost effective solutions
- Built-in soft-start, OVP, Current limit and UVLO protection
- Extra protection for safe operation
- Small footprint and low profile (as low as 0.4mm) packages
- Reduces PCB area and meets height constraints
Small Screen Display Applications

5” PND Screen

Larger Portable Navigation Device screens require more LEDs to maintain display quality in variable background light conditions. The AL3159, with its current matching accuracy, is well-suited for this requirement. The high efficiency linear and charge-pump functionality extends the device operating life when powered from the PND’s internal Li-Ion battery.

3” Mobile Phone Screen

Large screen (>2.8”) mobile phones frequently use 6 LED to ensure uniform brightness across the screen. AP5724/5/6 boost LED drivers provide a high efficiency solution for this application. The series connection of the LED ensures uniform brightness from the LEDs. The TSOT23-6 packaged versions offer industry standard pinouts and are thinner than 1mm.

AL3159 Benefits

- High power efficiency: 93%
- 1% Current matching accuracy between channels
- Drives up to 9 Channels of LEDs
- Versatile 3-wire logic decoding of LED current control
- Small, thin solution reduces size of portable LED backlighting

AP5724/5/6 Benefits

- Simple small footprint solutions for small screen backlighting
- High efficiency: 84% Typical
- Fast 1.2MHz Switching Frequency
- Built-in OVP, Current limit and UVLO protection
- 3 choices of Vfb (0.1, 0.25 & 0.31V)
- Low profile (<1 mm) packages: TSOT23-6 and DFN2020C-6 (0.6mm)

The AL3159 provides a simple cost-effective solution for small LED backlit LCD screens.

The AP5724/5/6 boost LED drivers provide a high efficiency solution for this application. The series connection of the LED ensures uniform brightness from the LEDs. The TSOT23-6 packaged versions offer industry standard pinouts and are thinner than 1mm.
## LED Driver Evaluation Boards

<table>
<thead>
<tr>
<th>Device</th>
<th>Board Number</th>
<th>Description of Assembly</th>
<th>Package used</th>
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<tbody>
<tr>
<td>AL3158</td>
<td>AL3158FSG-EVM Rev.1</td>
<td>9-channel White LED charge pump LED driver</td>
<td>QFN3030-20</td>
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<tr>
<td>AL3158</td>
<td>AL3158FSG-EVM Rev.2</td>
<td>3 x 3-channel RGB LED charge pump LED driver</td>
<td>QFN3030-20</td>
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<tr>
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<tr>
<td>AL8805</td>
<td>AL8805EV1</td>
<td>3in1, 1A LED Driver; Buck, 600 mA, control input, no onboard LEDs</td>
<td>SOT23-3</td>
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<tr>
<td>AL8805</td>
<td>AL8805EV2</td>
<td>MR16 Replacement, external 3W LED, VIN=12VDC 50/60 Hz AC or 12VDC 600 mA</td>
<td>SOT23-3</td>
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<tr>
<td>AP3156</td>
<td>AP3156FVD-1</td>
<td>6-channel LED Driver, Charge Pump, VIN=2.7 to 5.5V</td>
<td>DFN4040-16</td>
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<tr>
<td>AP8724</td>
<td>AP8724W-1</td>
<td>Boost converter, 1.2MP to 5V Input, 100mA Feedback</td>
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<tr>
<td>AP8800</td>
<td>AP8800EV2</td>
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<td>AP8802HEV2</td>
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<td>AP8804</td>
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<td>Linear LED Driver output current 350mA max.</td>
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<td>DLD101EV1</td>
<td>High voltage linear LED driver</td>
<td>DFN4030-10</td>
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<tr>
<td>ZXLD1220</td>
<td>ZXLD1220EV1</td>
<td>Buck LED Driver, 100mA PPM, VIN=5 to 18V, 1.5A output, + External Thermostat</td>
<td>DFN4010-14</td>
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<tr>
<td>ZXLD1221</td>
<td>ZXLD1221EV1</td>
<td>Boost LED Driver, 550 kHz PWM, VIN=1.2 to 12V, 1A output, + External Thermostat</td>
<td>DFN4010-10</td>
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<td>ZXLD1222</td>
<td>ZXLD1222EV1</td>
<td>Buck-boost LED Driver, 550 kHz PWM, VIN=2.5 to 12V, 0.7A output, + Ext Thermostat</td>
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<tr>
<td>ZXLD1230</td>
<td>ZXLD1230EV1</td>
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<td>ZXLD1237EV5</td>
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# Drivers for Industry Standard LEDs

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