LED Lighting Solutions

Covering LED drivers, power management, interface, sensing, and protection solutions for solid state lighting applications from ON Semiconductor.
LED Technology

As the technology and light output of LEDs continues to improve, applications for color and white high-brightness LEDs are expanding into entirely new markets. Once primarily used as indicators, LED cost and performance levels have improved dramatically, allowing them to displace incandescent and fluorescent light sources in automotive applications, consumer electronics ranging from smart phones to LCD-TVs, architectural lighting, and general lighting. Over the next few years, LEDs will continue to transform the lighting marketplace with new and innovative solid state lighting (SSL) solutions that can take advantage of both their programmability and flexibility.

Driver Solutions

LEDs are inherently low voltage devices and depending on the color and current, the forward voltage of the LED can vary from less than 2 to 4.5 V. In addition LEDs need to be driven with a constant current to ensure the intensity and color desired. This requires power conversion and control solutions to interface to the various power sources, be it the AC line, a solar panel, a 12 V car battery, a DC power supply or low voltage AC system, or even primary Alkaline and Ni-based cells or rechargeable Li-Ion battery cells.

ON Semiconductor has focused on applying our low voltage and high voltage technologies and our expertise in power management solutions to the challenges of solid state lighting; whether in portable display products, interior automotive lighting, or ballast for LED signage. In the following pages, examples will be provided for a number of different applications of solid state lighting for architectural, industrial, automotive and portable applications.
Medium to Large LCD Panel Backlighting

As LED performance and cost have improved, they are now displacing CCFL lamps in medium and large LCD backlighting applications such as notebooks, monitors, LCD-TVs, personal navigation systems, photo frames, and medical equipment. Besides eliminating mercury, the use of LEDs allows the design of thinner displays, and improves overall power consumption and lifetime. Integrating an ambient light sensor can further contribute to energy savings while enhancing the user’s viewing experience.

High Voltage LED Driver – NCP1294

LEDs are replacing CCFL lamps as the light source of choice for large LCD panel backlighting. The circuit described in this design note provides constant current to a long string of LEDs (Vf ranging from 190 to 230 V) from a single 24 V input. A constant current regulated flyback topology was chosen over a multi-stage boost or a boost plus multiple linear driver channels to improve overall system efficiency and ensure accurate current matching of the LEDs. Beyond being mercury free, when properly driven and controlled, LEDs can offer a >10x improvement in dimming range over traditional CCFL dimming. This superior dimming range is demonstrated in the design note. This design, based on the robust, flexible NCP1294 controller includes open LED and shorted output protection for safe handling of fault conditions.

Features
- 1 MHz frequency capability
- 1 A sink/source gate drive
- Programmable pulse-by-pulse overcurrent protection
- Programmable soft start

Applications
- Monitors
- LCD-TVs
- Test equipment
- Medical instruments
- Touch panels

Resources
- Design Note DN06062/D
### Discrete Devices for LED Backlighting

#### Current Balance Switch

![Current Balance Switch Diagram](image)

**D1 Schottky Barrier Diode for DC-DC Converter**

<table>
<thead>
<tr>
<th>Device</th>
<th>( V_T ) Max (V)</th>
<th>( I_D ) Max (A)</th>
<th>( V_F ) Max (V)</th>
<th>( I_R ) Max (mA)</th>
<th>Package</th>
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<tr>
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<td>60</td>
<td>8</td>
<td>0.6 @ ( I_F ) = 3 A</td>
<td>0.1 @ ( V_R ) = 30 V</td>
<td>DPAK, IPAK</td>
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<td>SB80W10T</td>
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<td>RD0106T</td>
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**Q1 Bipolar Transistor Current Balance Switch**

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<thead>
<tr>
<th>No of LEDs in Series</th>
<th>( V_{CEO} ) (V)</th>
<th>( I_C ) (A)</th>
<th>Polarity</th>
<th>( h_{FE} )</th>
<th>( CPH-6 ) (Dual)</th>
<th>( CPR-3 )</th>
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## Discrete Devices for LED Backlighting

### Q1 MOSFET Current Balance Switch

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<tr>
<th>Device</th>
<th>No of LEDs in Series</th>
<th>Polarity</th>
<th>$V_{DDS}$ (V)</th>
<th>$I_D$ (A)</th>
<th>$V_{Drive}$ (V)</th>
<th>$R_{DS(on)}$</th>
<th>@ $V_{GS}$ = Typ</th>
<th>Max</th>
<th>Package</th>
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<tbody>
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### Q2 MOSFET for DC-DC Converter

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**Low-Voltage Portable LED Driver Topologies**

White LED and RGB tricolor LEDs are widely used for backlighting small color LCD panels and keyboards, as well as indicators. High brightness LEDs are used as flash light sources in smart phones and digital cameras. These applications require optimized solutions which can maximize battery lifetime, as well as minimize the PCB area and height. ON Semiconductor has a variety of solutions using linear, inductive, and charge pump topologies. The inductive solution offers the best overall efficiency, while the charge pump solution takes up a minimal amount of space and height due to the use of low profile ceramic capacitors as the energy transfer mechanism. Linear drivers are ideal for color indicator as well as simple backlighting applications.

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**Inductive Boost Topology**

**Charge Pump Topology**
### Charge Pump Topology

#### Charge Pump/White and RGB LED Drivers — for LCD Backlight, LED Flash/Torch and Indicator

<table>
<thead>
<tr>
<th>Device</th>
<th>Input Voltage Range (V)</th>
<th>Number of Outputs</th>
<th>Total Output Current (mA)</th>
<th>Regulation Mode</th>
<th>Charge Pump Operating Mode</th>
<th>LED-LED Current Matching, Typ</th>
<th>Dimming Method</th>
<th>Number of Current Level/Profile</th>
<th>Operating Quiescent Current, Typ (mA)</th>
<th>Shutdown Current (µA)</th>
<th>Package</th>
<th>Notes</th>
</tr>
</thead>
</table>
| NCP5603  | 2.85 - 5.5              | 1                 | 200 mA DC, 350 mA pulse   | Voltage         | 1X, 1.5X, 2X              | –                             | PWM            | Depends on system                  | 1                                    | 2.5 typ             | DFN-10  | • Backlight  
|          |                         |                   |                           |                 |                           |                               |                |                                 |                                                      |                     |          | • 4.5 / 5 V output  
|          |                         |                   |                           |                 |                           |                               |                |                                 |                                                      |                     |          | • Short circuit protection                                                           |
| NCP5623B/C | 2.7 - 5.5              | 3 (independent)   | 90                        | Current         | 1X, 2X                    | ±0.5%                         | I2C            | 32/ quasi-log                      | 0.35                                | 0.8 typ             | LLGA-12 | • RGB illumination  
|          |                         |                   |                           |                 |                           |                               |                |                                 |                                                      |                     |          | • Backlight  
|          |                         |                   |                           |                 |                           |                               |                |                                 |                                                      |                     |          | • Built-in "gradual illumination"  
|          |                         |                   |                           |                 |                           |                               |                |                                 |                                                      |                     |          | • B & C versions have different I2C addresses                                             |

### Inductive Boost and Buck Topology

#### Inductive-Boost White-LED Drivers — for Backlighting and Torch/Flash Applications

<table>
<thead>
<tr>
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<th>Input Voltage Range (V)</th>
<th>Max Output Volt, Typ (V)</th>
<th>Output Current (mA)</th>
<th>Condition</th>
<th>Number of LEDs/Configuration</th>
<th>Switching Mode/Frequency</th>
<th>Dimming Method</th>
<th>Efficiency (%)</th>
<th>Operating Quiescent Current, Typ (mA)</th>
<th>Shutdown Current, Typ (µA)</th>
<th>Package</th>
<th>Notes</th>
</tr>
</thead>
</table>
| NCP1422  | 1.0 - 5.0               | 5                        | 800                 | Vout 3.3 V, Vin 2.5 V       | 1 for flash                  | PFM, up to 1.2 MHz          | PWM            | 94             | 1.3 µA                              | 0.05                           | DFN-10   | • Flash/Torch  
|          |                         |                          |                     |                             |                             |                            |                |                |                                      |                               |          | • Internal synchronous rectification                                                    |
| NCP1529  | 2.7 - 5.5               | 3.9                      | 1                   | Vout 1.2 V, Vin 3.6 V       | 1                            | PWM/PPM 1.7 MHz             | PWM            | 96             | 28                                   | 0.3                             | TSOP-5, uDFN-6 | • Flash/Torch  
|          |                         |                          |                     |                             |                             |                            |                |                |                                      |                               |          | • Auto-switching between PWM and PPM mode at light load                              |
| NCP5005  | 2.7 - 5.5               | 24                       | 40                  | Over 5 LED, Vin 3.6 V       | 2 to 5/ series               | PFM, up to 2.25 MHz         | PWM            | 90             | –                                    | 0.3                             | TSOP-5   | • Backlight  
|          |                         |                          |                     |                             |                             |                            |                |                |                                      |                               |          | • Isw = 350 mA  
| LV52204  | 2.7 - 5.5               | 40                       | 30                  | Vout 30 V, Vin 3.7 V        | 2 to 10/ series              | 600 kHz 1-wire & PWM       | PWM            | 90             | 3                                    | 0.1                             | UDFN-6   | • Backlight  
|          |                         |                          |                     |                             |                             |                            |                |                |                                      |                               |          | • Isw = 750 mA  
| LV52207  | 2.7 - 5.5               | 40                       | 30                  | Vout 30 V, Vin 3.7 V        | 2 to 10/ series              | 600 kHz 1-wire & PWM       | PWM            | 90             | 3                                    | 0.1                             | WLP-9    | • Backlight  
|          |                         |                          |                     |                             |                             |                            |                |                |                                      |                               |          | • Isw = 750 mA  

**Notes:**
- **NCP5603:** 200 mA DC, 350 mA pulse.
- **NCP5623B/C:** 3 (independent) outputs.
- **NCP5623B/C:** Voltage levels: 1X, 1.5X, 2X - PWM.
- **NCP5623B/C:** Dimming method: PWM/PPM 1.7 MHz.
- **LV52204:** 600 kHz 1-wire & PWM.
- **LV52207:** 600 kHz 1-wire & PWM.

**Dimensions:**
- **NCP5603:** DFN-10
- **NCP5623B/C:** LLGA-12
Mid-Voltage LED Driver Topologies

Many LED applications are powered from an offline AC-DC supply, a battery, or an electronic transformer with a low voltage AC output. In addition, some of these power sources, such as lead acid batteries, are loosely regulated. As a result, there is a need for LED driver solutions that can operate over a broad range of input voltage and can be configured in various topologies to support the LED load requirements. Depending on the LED current and operating conditions, this could involve either a linear or switching regulator LED driver solution.

Applications
- Landscape lighting
- Low voltage track lighting
- Solar powered lighting
- Automotive
- Emergency vehicles
- Marine applications
- 12 Vac/Vdc MR16
- Airplane interiors
- Sign backlighting
- Channel letters and signs

<table>
<thead>
<tr>
<th>Power</th>
<th>Application</th>
<th>Voltage &amp; Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offline AC Regulated Adapter</td>
<td>Low to medium volume applications, reduces safety requirements</td>
<td>Common voltages of 12, 24, 36, 48 Vdc, regulation to ±5%</td>
</tr>
<tr>
<td>(Sealed) Lead Acid Battery</td>
<td>Automotive, solar powered, marine</td>
<td>Loose regulation, 8-14 Vdc; Wider for automotive, 7-27 Vdc</td>
</tr>
<tr>
<td>12 Vdc &amp; 12 Vac</td>
<td>Common in interior, track lighting, outdoor, landscaping applications</td>
<td>Loose if magnetic ballast, tight to ±5% if electronic ballast, minimum load may be required; plus cable losses</td>
</tr>
</tbody>
</table>

Boost (Step-Up) Topology

Linear Topology

PWM Control Logic

Mid-Voltage LED Driver Topologies

Applications
- Landscape lighting
- Low voltage track lighting
- Solar powered lighting
- Automotive
- Emergency vehicles
- Marine applications
- 12 Vac/Vdc MR16
- Airplane interiors
- Sign backlighting
- Channel letters and signs

<table>
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<td>Loose if magnetic ballast, tight to ±5% if electronic ballast, minimum load may be required; plus cable losses</td>
</tr>
</tbody>
</table>
## Wide Input Voltage LED Driver Selector

Vin < 40 V

**SEPIC/Buck-Boost**

- Vout < V Vin
- Step-Up (Boost) Vout > Vin
- **STEP-UP (Boost) Vout > Vin**
- **STEP-DOWN (Buck) Vout < Vin**

- **STEP-DOWN (Buck) Vout < Vin**
- Step-Up (Boost) Vout > Vin
- NCP3065/6 Boost Controller
- NCP3065/6 Boost Converter
- NCP30163 Boost Converter
- NCP3065/6 Buck Controller
- NCL30160 Buck Converter
- NCL30100 Buck Controller
- NCL30161 Buck Controller

### Resources

<table>
<thead>
<tr>
<th>Device</th>
<th>Switching Frequency Typ. (kHz)</th>
<th>Topology</th>
<th>Vin Range (V)</th>
<th>Switch Current (A)</th>
<th>Controller</th>
<th>Automotive Qualified Device</th>
<th>Packages</th>
<th>Application</th>
<th>Evaluation Board</th>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCP3065</td>
<td>Up to 200</td>
<td>Buck, Boost, Buck/Boost</td>
<td>3 to 40</td>
<td>1.5 **</td>
<td>NCY3065</td>
<td>SOIC-8, DFN-8, PDIP-6</td>
<td>NCP30653ABCKGEVB</td>
<td>Buck 3 A</td>
<td>NCP3065SOBCKGEVB</td>
<td>Application Note: AND8298/D</td>
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<td>Buck-Boost 350 mA, 550 mA MR16 LED bulb</td>
<td>Design Note: DN06047/D</td>
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<td>SEPIC 350 mA, 700 mA, 1 A MR16 LED bulb</td>
<td>Design Note: DN06033/D</td>
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<td>SEPIC 350 mA &amp; 700 mA</td>
<td>Design Note: DN06031/D</td>
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<td>Buck with external P-channel MOSFET</td>
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<td>NCP3066</td>
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<td>Buck, Boost, Buck/Boost</td>
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<td>1.5 **</td>
<td>NCY3066</td>
<td>SOIC-8, DFN-8, PDIP-8</td>
<td>NCP3066DFSEPGEVB</td>
<td>SEPIC 350 mA, 700 mA, 1 A</td>
<td>NCP3066SOBCKGEVB</td>
<td>Application Note: AND8298/D</td>
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<td>Buck 3 A</td>
<td>Application Note: AND8298/D</td>
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<td>Boost &lt;1 A</td>
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<td>NCP3163</td>
<td>Up to 200</td>
<td>Buck, Boost, Buck/Boost</td>
<td>2.5 to 40</td>
<td>3.4</td>
<td>NCY3163</td>
<td>SOIC-16W, DFN-18</td>
<td>NCP3163BUCKGEVB</td>
<td>Buck 3 A</td>
<td>NCP3163BUCKGEVB</td>
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<td>Boost 700 mA</td>
<td>Application Note: AND8298/D</td>
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<td>Boost 3 A</td>
<td>Application Note: AND8298/D</td>
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<td>Inverter 500 mA</td>
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<td>MC33163</td>
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<td>2.5 to 40</td>
<td>3.4</td>
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<td>SOIC-16</td>
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<tr>
<td>NCP1034</td>
<td>Up to 500</td>
<td>Buck</td>
<td>8 to 100</td>
<td>– ✔</td>
<td>–</td>
<td>SOIC-16</td>
<td>NCP3065SOBCKGEVB</td>
<td>Buck 3 A, 5 Vout</td>
<td>NCP3065SOBCKGEVB</td>
<td>Design Note: DN06047/D</td>
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<tr>
<td>CS5171/3</td>
<td>280 / 560</td>
<td>Boost or SEPIC</td>
<td>2.7 to 30</td>
<td>1.5</td>
<td>NCY5171/3</td>
<td>SOIC-8</td>
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<td>Boost 400 mA, 5 Vout</td>
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<tr>
<td>NCP1294</td>
<td>1000</td>
<td>Buck, Boost, Buck/Boost</td>
<td>4.7 to 100</td>
<td>– ✔</td>
<td>–</td>
<td>TSSOP-16, SOIC-16</td>
<td>NCP3065SOBCKGEVB</td>
<td>High Voltage LED Driver</td>
<td>Design Note: DN06062/D</td>
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<td></td>
<td>(24 Vin to 110 Vout @ 100 mA)</td>
<td>Design Note: DN06062/D</td>
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<tr>
<td>NCL30100</td>
<td>Up to 700</td>
<td>Buck</td>
<td>6.35 to 18</td>
<td>– ✔</td>
<td>–</td>
<td>TSSOP-6</td>
<td>NCL30100AOLMGEVB</td>
<td>Buck 700 mA MR16 LED bulb</td>
<td>NCL30100AOLMGEVB</td>
<td>Design Note: DN06062/D</td>
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<td></td>
<td>Buck 700 mA PWM dimmable LED driver</td>
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<tr>
<td>NCL30105</td>
<td>Up to 500</td>
<td>Buck</td>
<td>Up to 22</td>
<td>– ✔</td>
<td>–</td>
<td>SOIC-8</td>
<td>NCL30105GEVB</td>
<td>High Voltage Input, 350 mA Buck LED Driver</td>
<td>NCL30105GEVB</td>
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<tr>
<td>NCL30160</td>
<td>Up to 1.4 MHz</td>
<td>Buck</td>
<td>6.5 to 40</td>
<td>1</td>
<td>–</td>
<td>SOIC-8</td>
<td>–</td>
<td>–</td>
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<td>Up to 40 V, 1 A Buck LED Driver</td>
<td>NCL30160GEVB</td>
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<tr>
<td>NCL30161</td>
<td>Up to 2.4 MHz</td>
<td>Buck</td>
<td>6.3 to 40</td>
<td>– ✔</td>
<td>–</td>
<td>DFN-10</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

1 For switching regulators, this current is used to calculate LED current based on Vin conditions.  ** Can be configured as a controller.
Linear solutions are the preferred approach for many lighting applications, as they are simple, straightforward to design, and allow the LEDs to be driven with a tightly regulated current, regardless of LED forward voltage or input supply variation. Because the LED drivers are linear, they must be matched to the power dissipation requirements of the application. ON Semiconductor offers a wide range of constant current linear LED drivers whose current levels span from 10 mA to 1 A.

**Constant Current Regulators – Dimming with External BRT**
## Fixed Linear LED Drivers

<table>
<thead>
<tr>
<th>Device</th>
<th>Channel Output Current (mA)</th>
<th>Operating Voltage Range (V)</th>
<th>Typical Current Tolerance (%)</th>
<th>Number of Channels</th>
<th>Dimming Control</th>
<th>Typical Dropout (V)</th>
<th>Operating Temperature Range (°C)</th>
<th>Package(s)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>NISI0350AS</td>
<td>350</td>
<td>1.8 to 50</td>
<td>±10%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
<td>SMC</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NISI0350AD</td>
<td>350</td>
<td>1.8 to 50</td>
<td>±10%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
<td>DPAK</td>
<td>AEC-Q101 qualified</td>
</tr>
<tr>
<td>NISIC2050JB</td>
<td>50</td>
<td>1.8 to 120</td>
<td>±15%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
<td>SMB</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NISIC2030JB</td>
<td>30</td>
<td>1.8 to 120</td>
<td>±15%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
<td>SMB</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NISI45030Z</td>
<td>30</td>
<td>1.8 to 45</td>
<td>±15%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
<td>SOT-223</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NISI45030AZ</td>
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<td>1.8 to 45</td>
<td>±15%</td>
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<td>Ext</td>
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<td>-40 to +125</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NISI45030A</td>
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<td>-40 to +125</td>
<td>SOD-123</td>
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<td>±15%</td>
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<td>Ext</td>
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<td>-40 to +125</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NISI45025Z</td>
<td>25</td>
<td>1.8 to 45</td>
<td>±15%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
<td>SOT-223</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NISI45025AZ</td>
<td>25</td>
<td>1.8 to 45</td>
<td>±15%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NISI45025A</td>
<td>25</td>
<td>1.8 to 45</td>
<td>±15%</td>
<td>1</td>
<td>Ext</td>
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<td>-40 to +125</td>
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<td>NISI45025</td>
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<td>1.8 to 45</td>
<td>±15%</td>
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<td>Ext</td>
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<td>-40 to +125</td>
<td>AEC-Q101 qualified</td>
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<td>NISI45020</td>
<td>20</td>
<td>1.8 to 45</td>
<td>±15%</td>
<td>1</td>
<td>Ext</td>
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<td>-40 to +125</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NISI45020A</td>
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<td>1.8 to 45</td>
<td>±15%</td>
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<td>Ext</td>
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<td>-40 to +125</td>
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<tr>
<td>NISIC2020JB</td>
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<td>1.8 to 120</td>
<td>±15%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
<td>SMB</td>
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<td>1.8 to 45</td>
<td>±20%</td>
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<td>SOD-123</td>
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<td>NISI50010Y</td>
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<td>±30%</td>
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<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
<td>SOD-123</td>
<td>AEC-Q101 qualified</td>
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## Adjustable Linear LED Drivers

<table>
<thead>
<tr>
<th>Device</th>
<th>Channel Output Current (mA)</th>
<th>Operating Voltage Range (V)</th>
<th>Typical Current Tolerance (%)</th>
<th>Number of Channels</th>
<th>Dimming Control</th>
<th>Typical Dropout (V)</th>
<th>Operating Temperature Range (°C)</th>
<th>Package(s)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
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<td>NISI50050AD</td>
<td>150 to 350</td>
<td>1.8 to 50</td>
<td>±10%</td>
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<td>DPAK</td>
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<td>NISI45090JD</td>
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<td>±15%</td>
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<td>Ext</td>
<td>1.8</td>
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<td>DPAK</td>
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<td>±15%</td>
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<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
<td>SOT-223</td>
<td>AEC-Q101 qualified</td>
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<td>-40 to +125</td>
<td>AEC-Q101 qualified</td>
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<td>NISI45020Z</td>
<td>20 to 40</td>
<td>1.8 to 45</td>
<td>±15%</td>
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<td>NISM4002MR6</td>
<td>1 to 200</td>
<td>1.4 to 45</td>
<td>±3%</td>
<td>1</td>
<td>Ext</td>
<td>1.4</td>
<td>-40 to +125</td>
<td>SC-74</td>
<td>Can be used with an external transistor</td>
</tr>
<tr>
<td>NUD4001</td>
<td>500</td>
<td>2.0 to 30 (60 V Surge)</td>
<td>±3%</td>
<td>1</td>
<td>Ext</td>
<td>1.4</td>
<td>-40 to +125</td>
<td>SOIC-8</td>
<td>Can be used with an external transistor</td>
</tr>
<tr>
<td>NUD4011</td>
<td>70</td>
<td>5 to 200</td>
<td>±3%</td>
<td>1</td>
<td>Ext</td>
<td>5</td>
<td>-40 to +125</td>
<td>SOIC-8</td>
<td>Can be used with an external transistor</td>
</tr>
<tr>
<td>NCV7680</td>
<td>35</td>
<td>6 to 16</td>
<td>±10% @ 35 mA</td>
<td>8</td>
<td>Ext</td>
<td>1</td>
<td>-40 to +125</td>
<td>SOIC-16 EP</td>
<td>AEC-Q101 qualified</td>
</tr>
<tr>
<td>LV5237JA</td>
<td>Constant mode 5 to 100 Open</td>
<td>VDD 3.3 – 12.8 LED 0.7 – 42</td>
<td>≥7%</td>
<td>9</td>
<td>PWM 256 steps</td>
<td>0.7</td>
<td>-25 to +85</td>
<td>SSOP-24</td>
<td>General purpose</td>
</tr>
<tr>
<td>LV5239TA</td>
<td>Constant mode 5 to 50 Open</td>
<td>VDD 3.3 – 12.8 LED 0.7 – 42</td>
<td>≥7%</td>
<td>24</td>
<td>PWM 256 steps</td>
<td>0.7</td>
<td>-25 to +85</td>
<td>TQFP-48</td>
<td>General purpose</td>
</tr>
<tr>
<td>LV5234</td>
<td>Constant mode 5 to 100 Open</td>
<td>VDD 4.5 – 5.5 LED 0.7 – 42</td>
<td>≥5.5%</td>
<td>9</td>
<td>PWM 256 steps</td>
<td>0.7</td>
<td>-25 to +75</td>
<td>SSOP-30</td>
<td>General purpose</td>
</tr>
<tr>
<td>LV5235</td>
<td>Constant mode 5 to 50 Open</td>
<td>VDD 4.5 – 5.5 LED 0.7 – 42</td>
<td>≥5.5%</td>
<td>16</td>
<td>PWM 256 steps</td>
<td>0.7</td>
<td>-25 to +75</td>
<td>SSOP-44J</td>
<td>General purpose</td>
</tr>
<tr>
<td>LV5236</td>
<td>Constant mode 5 to 50 Open</td>
<td>VDD 4.5 – 5.5 LED 0.7 – 42</td>
<td>≥5.5%</td>
<td>24</td>
<td>PWM 256 steps</td>
<td>0.7</td>
<td>-25 to +75</td>
<td>SSOP-44J</td>
<td>General purpose</td>
</tr>
</tbody>
</table>
Lamp Drivers Based on Constant Current Regulators

- Compact universal input for low power
- Constant LED current from 80 to 280 Vac
- Requires only 48 V of LEDs

- 120 Vac low cost CCR circuit
- Dimmable
- THD below 20%
- All surface mount components
- Passes EMI without filter

- Dusk-to-dawn dimming module
- Compatible with all CCR circuits
- Uses all surface mount components
- Provides 30 second hysteresis
LED MR16 Light Bulb

NCL30100, Fixed Off-Time Step-Down LED Driver Controller
- Quasi-fixed OFF time, peak current hysteretic control method thus requiring no compensation components
- Low Side N-FET switch topology
- Intended for continuous conduction mode operation, thus no output capacitor is needed
- >500 kHz operation
- ±5% typical current regulation tolerance
- \( V_{CC} \) operation from 6.35 to 18 V

Solar-Powered LED Street Sign

NCL30160 — Constant Current Step-Down LED Driver for High Power LEDs
- 30 mΩ integrated MOSFET
- 100% duty cycle for high efficiency
- Input voltage: 6.3 V to 40 V
- Switching frequency: Up to 1.4 MHz
- Dedicated PWM dimming pin/low power shutdown
- No control loop compensation required
- 1.5 A average current capability

Resources
- Evaluation Board: NCL30160GEVB

Solar Panel → MPPT Charge Controller → Battery → LED Driver (Buck) → LEDs Are Connected to Vin

Resources
- Evaluation Boards
  - NCL30100ADLMGEVB: MR16 form factor
  - NCL30100ASLDGEVB: PWM dimmable
12 V AC-DC Design for 3 and 4 LED Modules

The circuit described in the DN06048/D Design Note is intended for driving multi-die LED modules like the Sharp mini-ZENIGATA™, 12 V Cree XLamp® XT-E, and other LEDs in low voltage 12 Vac/Vdc applications. The forward voltage of the modules overlaps the input voltage range, so a single switch buck-boost configuration is used.

**Features**
- Small size
- Wide input and output operation voltage
- Regulated output current
- Open LED protection
- Output short circuit protection

**Applications**
- MR16 bulbs
- Landscape lighting
- Transportation lighting

**Resources**
- Design Note DN06048/D
- Reference Design: TND373/D
- Evaluation board: NCP3065BBGEVB, buck-boost MR16

![Sharp mini-ZENIGATA LED Module](image1)

![12 V Cree XLamp XT-E LED](image2)

![Reference Design Demo Board](image3)

![Reference Design Block Diagram](image4)

![Iout versus Vac Input](image5)

![MR16 LED Module](image6)
**Automotive Lighting Systems**

ON Semiconductor offers standard products and custom devices for automotive lighting applications. The company plays a prominent role in the market for Xenon driver ASICs, developed the defacto standard stepper driver for headlight leveling and swiveling, and is a leader in LED exterior lighting solutions.

**Front Lighting**

The majority of automobiles on the road today are equipped with halogen lights for the high-beam (HB) and low-beam (LB) functions - the main front lighting functions. Halogen LB typically consumes 55 W, and provides ~1,000 lumen. HID technology - introduced over ten years ago - consumes 35 W, and provides ~3,500 lumen. Because of the high intensity and risk of glare to approaching traffic, some countries require automatic leveling of the LB, plus a high pressure cleaning device. Over time, HID lights will integrate the HB function into bi-xenon solutions.

While halogen technology continues to be viable for front lighting, automotive designs increasingly use LED lighting. LED lighting offers enhanced styling options, enables 'instant-on' lighting, and allows brightness control from 0% to 100% power.

Another important aspect for automotive front lighting is beam swiveling for Advanced Frontlighting Systems (AFS), to optimize the visibility in curves, and Adaptive Driving Beam (ADB), to adapt the beam to real-time situations. Stepper motors provide the primary controls for AFS and ADB.

ON Semiconductor offers a full range of products, from generic bulb driver solutions to stepper drivers, LED drivers, and Xenon drivers, that are specifically designed for front lighting.
Front Lighting – Power Ballast and Dual LED Driver for Advanced LED

The NCV78763 single-chip, intelligent LED driver for front lighting enables single-module control of high beams, low beams, daytime running lights, position lights, cornering lights, turn indicators, and fog lights. With integrated digital dimming, SPI programmable settings, and build-in diagnostics, the NCV78763 offers integrated, energy efficient solutions for comprehensive front lighting control.

**Features - NCV78763**
- System integrated solution with few external components.
- Buck-boost topology
- LED current regulator
  - Constant average current
  - Efficient integrated buck switches (high-side)
  - Current per output up to 1.6 A
  - Extended diagnostics: detection of open circuit or failing driver, short, over-current protection, single LED failures
- Thermal protection
- System customization by SPI interface
  - Multiple system configurations with one device
  - Fewer module versions for OEM
- Better EMC behavior, without extra filtering
  - Low EMC from battery
  - Low EMC to LED string
- High overall efficiency (>90%)

---

**NCV78763 Application Diagram**

**NCV78763 Demonstration Board Efficiency**

**Demonstration Kit**
Front Lighting – Leveling and Swiveling

The NCV70628 is a single-chip micro-stepping motor driver with position controller and control/diagnostic interface, making it ideal for dedicated mechatronics solutions, connected remotely through a LIN master.

The NCV70514 is a micro-stepping motor driver that is fully compatible with automotive voltage requirements, and is especially well-suited for use in applications with fluctuating battery supplies.
Front Lighting – Small Signal Solutions for Pixel (Matrix) Control

Today's adaptive front lighting systems (AFLS) utilize a combination of sensors, motors, and a LED matrix to adjust the direction and intensity of the light beam. One AFLS method involves blanking of certain LED strings within the matrix, which can be controlled by a combination of small signal components such as Low $V_{CE(sat)}$ bipolar transistors and digital transistors (BRT – bias resistor transistor).

The collector of the NPN digital transistor is connected to the base of the Low $V_{CE(sat)}$ PNP transistor, thereby forming an ultra-low saturation voltage ($V_{CE(sat)}$) and high current gain capability of the combination. The high current gain allows this combination to be driven directly from an MCU or PMU’s control outputs, reducing overall system complexity and cost.

**Features**
- AEC-Q101 discrete & Mixed Element Array (MEA) components
- Low $V_{CE(sat)}$ ensures shunting of LED
- Simplifies circuit design & reduces component count
- PCB space saving with 2 mm x 2 mm wettable flank DFN packaging

<table>
<thead>
<tr>
<th>Device</th>
<th>$V_{CEO}$ (V)</th>
<th>$I_C$ (A)</th>
<th>$V_{CE(sat)}$ (V)</th>
<th>Description</th>
<th>Package(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSV60100DMTW</td>
<td>-60</td>
<td>1.0</td>
<td>-0.35</td>
<td>60 V, 1 A Dual PNP Low $V_{CE(sat)}$ BJT</td>
<td>WDFN-6 WF</td>
</tr>
<tr>
<td>NSV60200DMTW*</td>
<td>-60</td>
<td>2.0</td>
<td>-0.45</td>
<td>60 V, 2 A Dual PNP Low $V_{CE(sat)}$ BJT</td>
<td>WDFN-6 WF</td>
</tr>
<tr>
<td>NSV20200DMTW*</td>
<td>-20</td>
<td>2.0</td>
<td>-0.39</td>
<td>20 V, 2 A Dual PNP Low $V_{CE(sat)}$ BJT</td>
<td>WDFN-6 WF</td>
</tr>
<tr>
<td>NSVMUN5214D</td>
<td>50</td>
<td>0.1</td>
<td>0.25</td>
<td>Dual NPN BRT, R1 = 10kΩ, R2 = 47kΩ</td>
<td>SC-88 (SOT-363)</td>
</tr>
<tr>
<td>NSVM602002214DMTW*</td>
<td>-60</td>
<td>2.0</td>
<td>-0.45</td>
<td>60 V, 2 A MEA - Dual (NPN BRT + PNP Low $V_{CE(sat)}$ BJT)</td>
<td>WDFN-6 WF</td>
</tr>
<tr>
<td>NSVM202002214DMTW*</td>
<td>-20</td>
<td>2.0</td>
<td>-0.39</td>
<td>20 V, 2 A MEA - Dual (NPN BRT + PNP Low $V_{CE(sat)}$ BJT)</td>
<td>WDFN-6 WF</td>
</tr>
</tbody>
</table>

* Pending 2Q18.
**Rear Lighting – Linear LED Pre-Driver**

NCV7691 is a pre-driver intended for linear drive of LEDs. It can operate from the car battery and multiple LED strings can be driven by a single NCV7691 device.

**Features – NCV7691**

- Constant Current Output for LED String Drive External Programming Current Resistor
- Wide Current Range using External Bipolar Device
- Multiple LED String Control
- Pulse Width Modulation (PWM) Control
- Negative Temperature Coefficient (NTC) Current Control
- Open LED String & Short−Circuit LED String Diagnostic
- Overvoltage Set Back Power Limitation
- SOIC−8 Package
- AEC−Q100 Qualified and PPAP Capable

Reference “Short Circuit Detection with 4 or more channels” Figure for circuit details
The NCV7680, NCV7681, and NCV7683 are 8-channel linear programmable constant current sources, designed for the regulation and control of LED-based lighting.

- Allow for two programmed levels for Stop and Tail illumination, or optional external PWM
- Slew rate control to eliminate EMI concerns
- Sequencing functionality (NCV7683)

The NCV7684 is a 12-channel linear programmable constant current sources, designed for the regulation and control of LED-based lighting.

- Allow for 128 current levels, adjustable with I2C-programmable PWM
- 3.3 V voltage reference for loads up to  mA
- OTP back for stand-alone operation (2 configurations)

<table>
<thead>
<tr>
<th>Device</th>
<th>Channels</th>
<th>V&lt;sub&gt;I&lt;/sub&gt; Max (V)</th>
<th>I&lt;sub&gt;G&lt;/sub&gt; Max (mA)</th>
<th>Max LEDs in Series</th>
<th>Max LEDs in Parallel</th>
<th>Package(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCV7680</td>
<td>8</td>
<td>45</td>
<td>75</td>
<td>1</td>
<td>16</td>
<td>SOIC-16 WB EP</td>
</tr>
<tr>
<td>NCV7681</td>
<td>8</td>
<td>40</td>
<td>100</td>
<td>3</td>
<td>8</td>
<td>SOIC-16 WB EP</td>
</tr>
<tr>
<td>NCV7683</td>
<td>8</td>
<td>40</td>
<td>200</td>
<td>4</td>
<td>24</td>
<td>SSOP24 NB EP</td>
</tr>
<tr>
<td>NCV7684</td>
<td>12</td>
<td>40</td>
<td>60</td>
<td>3</td>
<td>12</td>
<td>SSOP24 NB EP</td>
</tr>
</tbody>
</table>
Interior Lighting — LIN RGB LED Driver

The LIN Bus (Local Interconnect Network) is an inexpensive serial communications protocol, which is used within current automotive network architectures. It is a relatively slow communication system intended to monitor sensor devices or actuators in today’s cars.

The NCV7430, LIN RGB LED Driver, combines a LIN transceiver together with a RGB LED driver and memory. It is a single-chip RGB driver intended to monitor for dedicated multicolor LED applications in automotive interior lighting. It contains a LIN interface (slave) for parametric programming of LED color and intensity. The device receives instructions through the LIN bus and subsequently drives the LEDs independently.

The NCV7430 acts as a slave on the LIN bus and the master can request specific status information (parameter values and error flags). The LIN address of the NCV7430 can be programmed in the internal memory of the device.

The NCV7430 is fully compatible with automotive requirements.

Features — NCV7430

RGB LED Driver
- 3 independent LED current regulators
- LED currents programmable with external resistors
- Power dissipation option with external ballast transistor
- LED temperature compensation with external sense circuit
- Modulation control for 3 LEDs (with calibration)

LIN Interface
- LIN physical layer according to LIN 2.1/SAE J2602
- OTP-programmable device node number and group address
- Diagnostics and status information about LEDs
- Supports auto-addressing

Protection and Diagnostics Over-Current Detection
- Short circuit detection to GND and VBB
- Open LED detection
- High temperature warning and shutdown
- Retry mode on error detection

Power Saving
- Sleep mode supply current 20 μA
- Compliant with 14 V automotive systems

EMI Compatibility
- LIN Bus integrated slope control
- EMC reduced LED modulation mode
Interior Lighting and Center High Mount Stop Lamp (CHMSL) — Constant Current Regulators

The two-terminal linear constant current regulators (CCRs) are simple, economical, and robust devices that provide an effective solution for regulating current in cost-sensitive LED applications. The devices require no external components, allowing them to be implemented as high or low-side regulators. These devices regulate output current over a wide range of input voltage, and are designed with a negative temperature coefficient to protect LEDs from thermal runaway at extreme voltage and operating temperature.

Features
- Regulated current provides constant brightness over wide voltage range
- Negative temperature coefficient protects LEDs in high ambient conditions
- Available with multiple maximum operating voltages (45 V, 50 V, and 120 V) to withstand battery load dump

Resources
- Sample Kit: CCR2KIT/S

<table>
<thead>
<tr>
<th>Device</th>
<th>Max Anode-to-Cathode Voltage (V)</th>
<th>Voltage Overhead (V_{in} – V_{LEDs}) (V)</th>
<th>Constant Current I_{reg} (@ V_{ak} = 7.5 V) (mA)</th>
<th>Current Tolerance Over Voltage</th>
<th>Max Junction Temperature (°C)</th>
<th>Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSV45xxx</td>
<td>45</td>
<td>1.8</td>
<td>Fixed: 15, 20, 25, 30</td>
<td>±15%, ±10%</td>
<td>150</td>
<td>SOD-123, SOT-223</td>
</tr>
<tr>
<td>NSV50xxx</td>
<td>50</td>
<td>2.0</td>
<td>Fixed: 10, 350</td>
<td>±10%</td>
<td>175</td>
<td>SMC, DPAK</td>
</tr>
<tr>
<td>NSVC20xx</td>
<td>120</td>
<td>1.8</td>
<td>Fixed: 20, 30, 50</td>
<td>±15%</td>
<td>175</td>
<td>SMB</td>
</tr>
<tr>
<td>NSV45xxxJ</td>
<td>45</td>
<td>1.8</td>
<td>Adjustable 20 to 40 35 to 70 60 to 100 90 to 160 150 to 350</td>
<td>±15%</td>
<td>150</td>
<td>SOT-223, DPAK</td>
</tr>
</tbody>
</table>

NOTE: xxx in the device number represents the current level.
AC Line Powered LED Driver Topologies

There are numerous topologies for driving LEDs off the AC mains, depending on the requirements of the application (size, efficiency, power factor, power delivered, drive current). Fortunately, ON Semiconductor provides a wide range of power solutions, whether the application is a 5 W LED under-cabinet light or a 150 W LED streetlight.
<table>
<thead>
<tr>
<th>Category</th>
<th>Topology</th>
<th>Device</th>
<th>Dimming</th>
<th>Startup</th>
<th>PSR</th>
<th>PFC</th>
<th>Mode</th>
<th>Package</th>
<th>Key Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC-DC</td>
<td>Low Voltage Buck</td>
<td>NCL30100</td>
<td>CCM</td>
<td></td>
<td></td>
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<td>TSOP-6</td>
<td>MR16</td>
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<td></td>
<td></td>
<td>NCL30160</td>
<td>P</td>
<td>CCM</td>
<td></td>
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<td>SOIC-8</td>
<td>40 V switcher</td>
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<tr>
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<td></td>
<td>NCL30161</td>
<td>P</td>
<td>CCM</td>
<td></td>
<td></td>
<td></td>
<td>DFN-10</td>
<td>Controller</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FL7760</td>
<td>A/P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CCM</td>
<td>Wide analog dimming, 60 V</td>
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<tr>
<td>AC-DC</td>
<td>Direct AC Driver</td>
<td>FL7704/05/44</td>
<td>A/P</td>
<td>HV JFET</td>
<td>✓</td>
<td></td>
<td></td>
<td>SOIC-8/16L</td>
<td>Shunt type switcher</td>
</tr>
<tr>
<td></td>
<td>Buck</td>
<td>FL7701</td>
<td>A/P</td>
<td>HV JFET</td>
<td>✓</td>
<td></td>
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<td>SOIC-8</td>
<td>Low eBOM counts</td>
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<td>FLS0116</td>
<td>A/P</td>
<td>HV JFET</td>
<td>✓</td>
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<td>SOIC-7/14</td>
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<td></td>
<td>Boost</td>
<td>NCL30167</td>
<td>PC</td>
<td>Cascade</td>
<td>✓</td>
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<td></td>
<td>SOIC-10 NB</td>
<td>Professional phase-cut dimming</td>
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<tr>
<td></td>
<td></td>
<td>NCL30095</td>
<td>PC</td>
<td>Cascade</td>
<td>✓</td>
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<td>SOIC-14</td>
<td>400 V switcher</td>
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<td></td>
<td>Buck-Boost</td>
<td>NCL30185</td>
<td>Step</td>
<td>CC</td>
<td>✓</td>
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<td>QR</td>
<td>SOIC-8</td>
<td>Conventional switch dimming</td>
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<td>SEPIC Flyback</td>
<td>NCL30186</td>
<td>A/P</td>
<td>CC</td>
<td>✓</td>
<td></td>
<td>QR</td>
<td>SOIC-10 NB</td>
<td>Non-phase-cut dimming</td>
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<tr>
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<td>NCL30188</td>
<td>CC</td>
<td>✓</td>
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<td>QR</td>
<td>SOIC-8</td>
<td>CC tolerance ±3%</td>
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<td>NCL30288</td>
<td>CC</td>
<td>✓</td>
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<td>QR</td>
<td>TSOP-6</td>
<td>Small form factor</td>
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<td>FL7733A</td>
<td>HV JFET</td>
<td>CC</td>
<td>✓</td>
<td></td>
<td>DCM</td>
<td>SOIC-8/16L</td>
<td>CC tolerance ±3%, good THD</td>
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<td>NCL30060</td>
<td>HV JFET</td>
<td>✓</td>
<td></td>
<td></td>
<td>QR</td>
<td>SOIC-7</td>
<td>SSR, protections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FL7740</td>
<td>HV JFET</td>
<td>CV</td>
<td>✓</td>
<td></td>
<td>DCM</td>
<td>SOIC-10</td>
<td>CV ±3%/PF, Pstdby &lt;0.3 W, smart lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NCL30386*</td>
<td>A/P</td>
<td>HV JFET</td>
<td>✓</td>
<td></td>
<td>QR</td>
<td>SOIC-10 NB</td>
<td>CC/CV (&lt;±2%), low THD, smart lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NCL30388*</td>
<td>HV JFET</td>
<td>CV/CC</td>
<td>✓</td>
<td></td>
<td>QR</td>
<td>SOIC-8</td>
<td>CC/CV (&lt;±2%), low THD</td>
</tr>
<tr>
<td></td>
<td>Boost PFC</td>
<td>NCP1622</td>
<td>✓</td>
<td>CRM</td>
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<td></td>
<td></td>
<td>SOIC-8</td>
<td>Voltage mode, no ZCD winding</td>
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<td></td>
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<td>NCP1607/8</td>
<td>✓</td>
<td>CRM</td>
<td></td>
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<td></td>
<td>SOIC-8</td>
<td>Voltage mode, wide dynamic power range</td>
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<td></td>
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<td>NCP1654</td>
<td>✓</td>
<td>CCM</td>
<td></td>
<td></td>
<td></td>
<td>SOIC-8</td>
<td>Current mode, optional frequency</td>
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<tr>
<td></td>
<td>Half-Bridge</td>
<td>FLS1600</td>
<td>Voltage</td>
<td>SIP-9</td>
<td></td>
<td></td>
<td></td>
<td>SOIC-8</td>
<td>500 V switcher</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLS1700</td>
<td>Voltage</td>
<td>SIP-9</td>
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<td>Wide Vout simple LLC resonant half bridge</td>
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<td>NCL30030</td>
<td>HV JFET</td>
<td>✓</td>
<td>CRM+QR</td>
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<td>FL3100</td>
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<td>SOT-23</td>
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<td></td>
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<td>Self bias universal phase-cut dimmer control</td>
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</tbody>
</table>

Direct AC LED Driver Solution

**Key Features**
- HV start up
- 3/4 channel internal MOSFET
- Active channel communication
- Self valley fill external IP

**Benefits**
- Self bias without Vdd supply circuit
- Low BOM counts
- High PF/low THD performance
- Low ripple index without degradation of PF/THD

**Other Features**
- FL77904: 4 channel, <9 W @ 120 VAC, <17 W @ 220 VAC
- FL77905: 3 channel, <9 W @ 120 VAC, <17 W @ 220 VAC
  Analog/PWM dimming
- FL77944: 4 channel, <18 W @ 120 VAC, <33 W @ 220 VAC
  Analog/PWM dimming
- Easy current setting: control with RCS
- Power scalability with multiple drivers

**Market & Applications**
- Phase-Cut Dimming LED light
- Non Dimming LED light
- Non-Phase-Cut Dimming LED lighting

**Ordering and Package Information**

<table>
<thead>
<tr>
<th>Device</th>
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<tr>
<td>FL77944MX</td>
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**Evaluation Boards and Design Tools Available**

8~35 W Retrofit/Down Light Drivers
Non-Isolated Step-up Phase-Cut Dimmable Solution

NCL30167 PFC Boost Switching Regulator for Phase-Cut Dimming LED Lighting Driver
NCL30095 PFC Boost Switching Regulator Switcher for Phase-Cut Dimming LED Retrofit

Key Features
- Cascade architecture
- Integrated ZCD detection
- Direct phase angle detection monitoring
- NTC based thermal foldback
- Internal 400 V MOSFET (only NCL30095)

Other Features
- Near-unity power factor
- Crm constant on-time control architecture
- Accurate current regulation ±2% typical
- Cycle-by-cycle current limiting
- Open LED string protection
- Shorted winding protection
- Vcc overvoltage protection
- –40 to +125°C operation

Benefits
- Fast start up & self bias without Vdd supply circuit
- No auxiliary winding needed
- SSL7A compliant
- Extends product lifetime
- Low BOM counts

Ordering and Package Information

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
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</thead>
<tbody>
<tr>
<td>NCL30167DR2G</td>
<td>SOIC-10</td>
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<td>NCL30095AR2G</td>
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</table>

AC – DC
Step-Down Phase-Cut Dimmable Solution

**FL7734 Universal Input Phase-Cut Dimming Single Stage PSR Controller**

**Key Features**
- Universal Input Φ-cut dimmable
- Controllable \( I_{IN} \) minimum
- Controllable dimming curve
- \(<\pm1\% \text{ line regulation} \) PSR control
- RCS short and open protection

**Other Features**
- High PF, Low THD : >0.9/\(<20
- Fast < 0.3 s start-up (@ Small phase angle)
- LED Short Protection (SCP)
- LED Open Protection (OVP-VS, OVP-VDD)
- Output Diode Short Protection (OCP)
- Over Temperature Protection (TSD)

**Market & Applications**
- Phase-Cut Dimming LED Light
  - A19, PAR30/38, Down Light
  - Indoor Flat, Ceiling light

**Benefits**
- Universal input design
- Meets SSL7A & ENERGY STAR®
- Good light uniformity and low BOM
- High system reliability

---

**Ordering and Package Information**

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL7734MX</td>
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</tbody>
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---

**8 ~ 60 W Universal Input Drivers**

**Evaluation Boards and Design Tools Available**
Step Dimming Driver with Mechanical Wall Switch

NCL30185 Step Dimmable QR PSR Current Mode Controller for LED Lighting

**Key Features**
- Precise current regulation accuracy (±2% typical)
- Quasi-resonant control
- Adjustable thermal foldback
- 3 step dimmable (70/25/5%)
- Programmable OVP

**Other Features**
- Current control insensitive to normal transformer variation
- Wide Vcc range (9.4-26 Vdc) to support extend Vf range
- Output diode and shorted winding protection
- Cycle-by-cycle current limiting
- Open LED and shorted output protection
- Built-in Vcc overvoltage protection
- 12 V nominal gate drive clamp
- –40 to +125°C operation

**Market & Applications**
- LED bulbs and tubes
- LED drivers
- LED luminaires

**Benefits**
- Avoids over specifying LEDs to achieve lumen output
- Higher efficiency
- Improved driver reliability
- Dimming with conventional on/off wall switch
- User can set over voltage protection level

**Ordering and Package Information**

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<thead>
<tr>
<th>Device</th>
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<td>Auto Recoverable</td>
<td>SOIC-8</td>
</tr>
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</table>

**Evaluation Boards and Design Tools Available**
Analog Dimming Single Stage Solution

NCL30186 QR PSR Current Mode Controller for LED Lighting with Smart Analog/Dimming Capability

**Key Features**
- Precise current regulation accuracy (±2% typical)
- Quasi-resonant control
- Adjustable thermal foldback
- Analog or PWM dimming
- Wide Vcc range

**Benefits**
- Avoids over specifying LEDs to achieve lumen output
- Higher efficiency
- Improved driver reliability
- Supports smart lighting
- Supports wide LED forward voltage range

**Other Features**
- Current control insensitive to normal transformer variation
- Wide Vcc range (9.4-26 Vdc) to support extend VF range
- Output diode and shorted winding protection
- Cycle-by-cycle current limiting
- Open LED and shorted output protection
- Vcc overvoltage protection
- 12 V nominal gate drive clamp
- -40 to +125°C operation

**Market & Applications**
- Non-Phase-Cut Dimming LED Lighting
  - A19, PAR30/38, Down Light
  - Indoor Flat, Ceiling light

**Ordering and Package Information**

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<thead>
<tr>
<th>Device</th>
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</tbody>
</table>

Evaluation Boards and Design Tools Available:
- 8 W Smart Light Driver
- 60 W 0-10 Dimming Driver
Analog Dimming Single Stage Solution

NCL30386* HV CC/CV PFC PSR PWM Controller for LED Lighting with Analog/PWM Dimming Capability

Key Features
- Precise current regulation accuracy (±2% typical)
- Precise voltage regulation accuracy (±2% typical)
- Integrated HV startup current source
- Analog and PWM signal input for analog dimming

Other Features
- High PF (>0.95) and Low THD (<10%) at universal input
- Wide VCC range (9.2 - 26 VDC) to support extend VF range
- Dynamic Self Supply for wide operation range
- Quasi-resonant control for high efficiency
- Abundant protections – brown-out, OVP, RCS-, Output-, Diode-, Winding- short Protection & TSD

Market & Applications
- Non-Phase-Cut Dimming LED Lighting
  - A19, PAR30/38, Down Light
  - Indoor Flat, Ceiling light

Benefits
- Avoids over specifying LEDs to achieve lumen output
- Stable startup at cold temperature
- Fast startup & low standby power
- Precise CC control at dimming condition
- Wide dimming operation range
- Selectable dimming curve – linear & quadratic

Ordering and Package Information

<table>
<thead>
<tr>
<th>Device</th>
<th>Features</th>
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</table>

* Pending 2Q18
Analog Dimming Single Stage Solution

NCL30388* HV CC/CV PFC PSR PWM Controller for LED Lighting

Key Features
- Precise current regulation accuracy (±2% typical)
- Precise voltage regulation accuracy (±2% typical)
- Integrated HV startup current source
- High PF (>0.95) and low THD (<10%) at universal input

Other Features
- Wide VCC range (9.2 - 26 VDC) to support extend VF range
- Dynamic Self Supply for wide operation range
- Quasi-resonant control for high efficiency
- Abundant protections – brown-Out, OVP, RCS-, Output-, Diode-, Winding- short Protection & TSD

Market & Applications
- Non-Phase-Cut Dimming LED Lighting
  - A19, PAR30/38, Down Light
  - Indoor Flat, Ceiling light

Benefits
- Avoids over specifying LEDs to achieve lumen output
- Stable startup at cold temperature
- Fast startup & Low standby power
- Easy to overpass global standard

Ordering and Package Information

<table>
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<tr>
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<td>NCL30388B1DR2G</td>
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<td>SOIC-10</td>
</tr>
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</table>

* Pending 2Q18

60 W LED Lighting Driver
Evaluation Boards Available
Low Profile Light Engine CC Solution

NCL30288 Power Factor Corrected Primary Side Controller

**Key Features**
- Precise current regulation accuracy (±3% typical)
- Quasi-resonant control
- Active Power Factor Correction
- Robust protection suite
- Universal mains (90-305 V)
- <22 BOM components

**Benefits**
- Avoids over specifying LEDs to achieve lumen output
- Higher efficiency
- Exceeds global power quality standards for lighting
- Eases safety testing
- Wide operating coverage
- Low profile design

**Other Features**
- <10% THD @ 230 Vac
- <500 ms Start Up Time
- Output Ripple <40% Pk to Pk
- Dual OVP protection
- No optocoupler needed for isolated topology
- Wide Vcc range (9.4-26 Vdc) to support extend VF range
- –40 to +125°C operation

**Market & Applications**
- Non Dimming LED light
- Non-Phase-Cut Dimming LED lighting

**Ordering and Package Information**

<table>
<thead>
<tr>
<th>Device</th>
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</table>

20 W T Lamp Driver

Evaluation Boards and Design Tools Available
PFC+QR PWM Combo Solution for General Light Engine

FL7921 Voltage Mode CRM PFC+QR PWM Combo

Key Features
- HV start up
- THD optimizer
- Over power compensation

Benefits
- Fast start up
- High PF/low THD
- Wide input/output operating range

Other Features
- PFC function always ON regardless of PWM load condition for high PF at light load
- Internal minimum tOFF 8 µs for QR PWM stage
- Internal 9.5 ms Soft-Start time for PWM
- Brown-out protection
- Auto-recovery OCP, OLP, OTP & OVP
- Adjustable OTP with external NTC through RT pin

Market & Applications
- Non Dimming LED light driver
- Analog Dimming LED light driver

Ordering and Package Information

<table>
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Evaluation Boards and Design Tools Available

100 W Analog Dimmable Driver
**PFC+QR PWM Combo Solution for General Light Engine**

**NCL30030 Current Mode CRM PFC+QR PWM Combo IC**

**Key Features**
- Multiplier
- Digital boost follower
- Programmable thermal shutdown

**Benefits**
- Improved THD performance
- Improved efficiency for wide mains applications
- Protects supply from overheating

**Other Features**
- High voltage pin for fast startup time and line sensing
- 4 ms Soft-Start timer
- Feed-forward for improved operation across line/load
- PFC off control for smart lighting applications
- –40 to +125°C for outdoor lighting applications

**Market & Applications**
- Non Dimming LED light driver
- Analog Dimming Dimming LED light driver

**Ordering and Package Information**

<table>
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<td>NCL30130B3DR2G</td>
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</table>

**Evaluation Boards and Design Tools Available**

150 W Analog/PWM Dimmable Driver
High Efficiency LCC Half Bridge Solution for Ultra Wide Output Driving

NCL30059 High Voltage Half-Bridge Controller for LED Lighting Application

Key Features
- Minimum frequency adjust accuracy 3%
- Brown-out input
- 100 ms PFC delay timer

Other Features
- Wide operating frequency range: 25 kHz ~ 250 kHz
- Adjustable brown out protection
- Low start up current of 50 µA
- Latched input
- Thermal shut down function

Benefits
- Keeps operation in the right region & simplifies design
- Simple PFC association, design flexibility
- Allows PFC out voltage to stabilize before device operation

Evaluation Board Highlights
- 90 – 277 VAC Input, 0-50 VDC Output
- >0.95 PF, <20% THD @ Universal Input
- >90% Total Efficiency
- ±2% precise CC tolerance

Market & Applications
- High power in/out door light
- Flood light
- Street light

Under preparing 100 W low BOM PFC+LCC half bridge driver

Ordering and Package Information

<table>
<thead>
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<td>NCL30059BDR2G</td>
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</table>
Energy Efficient Innovations

Smart Lighting Luminaries Light Engine Solution

60 W Smart LED Driver

Evaluation Board Highlights

- Universal input voltage from 90 Vac to 300 Vac
- 3-Channel LED output with 20 W max per channel
- Ultra-wide dimming range from 0.05% to 100%
- Programmable via either analog or PWM dimming
- High power factor >0.9
- Excellent THD <10 %
- High efficiency >90 %
- Wide LED voltage range from 24 V to 48 V
- Meets EMI Standard FCC Part 15 Class B

Featured Products

- FL7930C – CRM PFC controller
- FAN7631 – LLC Resonant Half Bridge Controller
- FL3100T – Low Side Gate Driver with PWM Dimming

• Fully software configurable
• Communication interface to plug in and power wireless (BLE, Wi-Fi, ZBee,) or wired (DALI, DMX, 0-10V) modules
• Designed for high volume manufacturing
• Eval boards available for testing and prototyping

Under preparing evaluation board
**Smart Lighting Luminaries Light Engine Solution**

**FL7740 – Single Stage CV PSR PWM + FL7760 – Wide ADIM Buck PWM**

**FL7740 Key Features**
- Wide Input voltage range (80 ~ 382 V\text{AC})
- <200 ms start up time with integrated HV startup JFET
- CV tolerance (avg.): <±2 \%
- CV overshoot and undershoot under transient: <±10 \%
- P\text{Standby}: <0.15 W @ no load, <0.3 W @ 10 mA I\text{OUTMCU}
- <0.4 W @ 20 mA I\text{OUTMCU}
- Selectable PF optimizer
  - Without PF optimizer (PF/THD): >0.9/<10\% @ full load & universal input
  - >0.8/<10\% @ half load & universal input
  - With PF optimizer: >0.9/<10\% @ full load & universal input
  - >0.9/<20\% @ half load & universal input

**FL7760 Key Features**
- Wide input range (8 ~ 60 V\text{DC})
- Constant Current Mode operation
- Hysteresis control with fixed reference
- Wide dimming range
  - Analog dimming: 5 ~ 100 \%
  - PWM dimming: 1 ~ 100\% (@ 2 kHz)
- High switching frequency up to 1 MHz
- High source/sink current of 1.5 A/2.5 A
- Cycle-by-cycle current limit
- Low operating current (150 \mu A)
- Thermal shutdown
- Over current protection
- Small outline package (SOT-23-6L)

**Ordering and Package Information**

<table>
<thead>
<tr>
<th>Device</th>
<th>Features</th>
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<tbody>
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**Evaluation Board & Design Tools available**
Smart Lighting

Smart Lighting involves communication and sensing functions to be able to remotely control (turn on or off, dim or change color) and monitor (remote diagnostic) one or multiple light fixtures in a building, a street or simply at home. Smart Lighting also provides a light fixture with the intelligence to make adjustments based on conditions such as occupancy or ambient light.

Communication can be implemented wirelessly or by using the existing powerline infrastructure. Powerlines make up the largest copper infrastructure in the world. There are electrical outlets at every corner of a home or office building, making it an all-encompassing network. Given that all lighting fixtures connect to a powerline to convert electricity to light, Powerline Communication (PLC) has become a logical way to serve as the primary communication and control link.

For example, two-way communication between a centralized control center and street lights can be implemented to form a fully networked intelligent street light system. This enables municipalities, power utility companies and commercial entities to remotely dim the light output of their street lights, and therefore to reduce the overall energy consumption of their street light network. Two-way communication can be easily implemented on the power line by using PLC modems.

Light fixtures in an office building can be controlled by using the KNX network over an existing twisted pair wiring using KNX transceivers.

Ambient Light Sensors and PIR (Passive Infrared) Detectors such as the NCS36000 can also be used to control the light output of street lighting.
## PLC Modems/Power Line Driver

### Communication
- **Coupling**
- **PHY**
- **MAC**

### Application
- **MCU**

### PLC Modems

<table>
<thead>
<tr>
<th>Device</th>
<th>Function</th>
<th>Features</th>
<th>Package(s)</th>
</tr>
</thead>
</table>
| NCN49599       | PLC S-FSK Modem; A - D Band           | • ARM Cortex M0  
• Baud rate: 4800 Bauds  
• S-FSK modulation  
• Hardware embedded MAC + PHY  
• Embedded 1.2 A, 2-stage power amplifier with current limitation and thermal protection | QFN-56     |
| NCN49597       | PLC S-FSK Modem; A - D Band           | • ARM Cortex M0  
• Baud rate: 4800 Bauds  
• S-FSK modulation  
• Hardware embedded MAC + PHY | QFN-52     |
| AMIS49587      | PLC S-FSK Modem; A & B Band           | • ARM7TDMI, 24 MHz core  
• Baud rate: 2400 Bauds  
• S-FSK modulation  
• Hardware embedded MAC + PHY | QFN-52     |
| NCS5651        | Power Line Driver; Class AB           | • Low distortion power line driver with optimized interface for PLC modems  
• Capability to drive 2.0 A peak into reactive loads  
• Current shutdown minimizes power consumption during power down state  
• Rail-to-Rail Drop of Only ±1 V with Iout = 1.5 A | QFN-20 EP  |

### G3-PLC Alliance

**G3-PLC Reference Board**
KNX Transceivers

KNX is a standardized (EN 50090, ISO/IEC 14543), OSI-based network communications protocol for intelligent buildings. KNX is the successor to, and convergence of, three previous standards:

- European Home Systems Protocol (EHS)
- BatiBUS
- European Installation Bus (EIB or Instabus)

**KNX Open Standards**

- EN 50090: European Standard
- ISO/IEC 14543-3: International Standard
- GB/Z 20965: Chinese Standard

**Applications**

- Connects appliances and sensors, especially for climate and light control - wired or wireless - to the 9600 Baud KNX twisted pair (TP) bus inside a building

---

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<tr>
<td>High Sensitivity</td>
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<tr>
<td>Ultra Low Receive and Standby Current</td>
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<td>PHY + MAC</td>
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<tr>
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<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>PHY + MAC Layer (TPIUART Compatible)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>PHY Layer (Analog Only)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>3.3 V Fixed DC/DC</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Adjustable DC/DC</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>20 V LDO</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Analog Monitor Output</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>
Motion Detector Passive Infrared Controller (PIR) — NCS36000

- Passive infrared controller circuit for the lighting and occupancy sensing market
- Amplifies and conditions signal from PIR sensor

**Features**
- 3.0 – 5.75 V operation
- Integrated low noise 2-stage amplifiers
- Internal voltage reference to drive sensor
- Internal oscillator with external RC
- Single or dual pulse detection
- Digital filter to minimize false alarms
- Direct drive of LED and relay

**Benefits**
- Lower BOM cost than comparable discrete solutions
- Extremely flexible solution
- Customer can customize digital filtering
- Customer can customize analog processing
- Designed for wide range of occupancy sensors

![Diagram of NCS36000](image1)

Old Solution

NCS36000 Solution
Features

- Design flexibility/customization (i.e., EEPROM if desired for trimming)
- 0.0125 lux detection with customizable filtering (i.e., Photopic Light Response)
- Dark current and temperature compensation
- Lowest power consumption per resolution bit
- I2C Interface (including High Speed Mode) and no effect on bus during power down

<table>
<thead>
<tr>
<th>Device</th>
<th>Special Features</th>
<th>$I_{op} \text{ Typ @ } E_y = 100 \text{ Lux}$ $\mu$A</th>
<th>Output Interface</th>
<th>$V_{in}$ Range (V)</th>
<th>$T_a$ Range ($^\circ$C)</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA0151CS</td>
<td>2-Stage Gain Switching</td>
<td>8 (high gain)</td>
<td>Analog, linear current</td>
<td>2.2 - 5.5</td>
<td>-30 to +85</td>
<td>ODCSP-4</td>
</tr>
<tr>
<td>LV0104CS</td>
<td>Integrated Sleep Mode</td>
<td>--</td>
<td>I2C, 16-bit ADC</td>
<td>2.3 - 3.6</td>
<td>-30 to +85</td>
<td>ODCSP-4</td>
</tr>
<tr>
<td>LV0111CF</td>
<td>Standby Function</td>
<td>21</td>
<td>Analog, logarithmic current</td>
<td>2.3 - 5.5</td>
<td>-30 to +85</td>
<td>ODCSP-4I</td>
</tr>
<tr>
<td>NOA1212</td>
<td>Dark Current Compensation</td>
<td>51 (high gain)</td>
<td>Analog, linear current</td>
<td>2.0 - 5.5</td>
<td>-40 to +85</td>
<td>CUDFN-6</td>
</tr>
<tr>
<td>NOA1213</td>
<td>Dark Current Compensation</td>
<td>--</td>
<td>Analog</td>
<td>2.0 - 5.5</td>
<td>-40 to +85</td>
<td>CUDFN-6</td>
</tr>
<tr>
<td>NOA1305</td>
<td>Dark Current Compensation</td>
<td>--</td>
<td>I2C, 16-bit ADC</td>
<td>2.4 - 3.6</td>
<td>-40 to +85</td>
<td>CUDFN-6</td>
</tr>
<tr>
<td>NOA3302</td>
<td>Proximity Sensor</td>
<td>--</td>
<td>I2C, 16-bit ADC</td>
<td>2.3 - 3.6</td>
<td>-40 to +80</td>
<td>CWDFN-8</td>
</tr>
</tbody>
</table>
**Power-Over-Ethernet (PoE) Controllers**

**Features - NCP1083**

NCP1083, consisting of fully compliant PoE functionality and DC-DC controller, may be used to drive LED lamps. Additionally, lamps may be controlled remotely through PoE.

- Emits white color of ~2700°K
- LED lamp overall maximum power output 33 W
- Peak efficiency ~89%
- LED lamp powered by PSE directly over NCP1083 load switch circuitry; DC-DC controller can provide 3.3 V, 5 V or 15 V power supply

**IEEE 802.3at + Auxiliary, 40 W**

- Auxiliary input voltage range from 9.0 V to 57 V
- Integrated DC-DC converter controller implements highly efficient power conversion at low output voltages in conjunction with auxiliary voltage input
- LED drivers operate in buck operation mode, switching frequency about 1.05 MHz, PWM dimming frequency 16 kHz
- DC-DC controller working frequency up to 500 kHz, fly-back topology used
- Under-voltage startup level set to 38 V, or programmable down to 8.5 V; current limit 970 mA
- Delivers 25.5 W for PoE+ IEEE 802.3at and up to 40 W in proprietary applications
- Supports IEEE two event classification
- Best-in-class cable ESD and thermal characteristics

---

**Device** | **Description** | **Topology** | **Control Mode** | **VCC Min (V)** | **VCC Max (V)** | **PD Typ (W)** | **Ron Typ (Ω)** | **Package**
--- | --- | --- | --- | --- | --- | --- | --- | ---
NCP1080 | PoE-PD Controller and DC-DC Converter | Flyback | Current | 0 | 57 | 15 | 0.6 | TSSOP-20
NCP1081 | PoE-PD Controller and DC-DC Converter | Flyback | Current | 0 | 57 | 40 | 0.6 | TSSOP-20
NCP1082 | PoE-PD Controller and DC-DC Converter, with Auxiliary Supply Support | Flyback | Current | 0 | 57 | 15 | 0.6 | TSSOP-20
NCP1083 | PoE-PD Controller and DC-DC Converter, with Auxiliary Supply Support | Flyback | Current | 0 | 57 | 40 | 0.6 | TSSOP-20
NCP1090 | PoE-PD Interface Controller | — | — | 0 | 57 | 15 | 0.5 | SOIC-8, TSSOP-8
NCP1091 | PoE-PD Interface Controller with Programmable UVLO | — | — | 0 | 57 | 15 | 0.5 | SOIC-8, TSSOP-8
NCP1092 | PoE-PD Interface Controller with Vaux Support | — | — | 0 | 57 | 15 | 0.5 | SOIC-8, TSSOP-8
NCP1093 | PoE-PD Interface Controller | — | — | 0 | 57 | 25 | 0.5 | DFN-10
NCP1094 | PoE-PD Interface Controller with Vaux Support | — | — | 0 | 57 | 25 | 0.5 | DFN-10
Serial NOR Flash for Smart LED Lighting

Smart LED systems require NOR Flash for over-the-air firmware updates, in order to minimize risks from disconnection.

**Features**

- Faster data rewrite (Sector Erase/Page Program)
- Lower power consumption with efficient rewrite operation
- 20-year data retention with no data deterioration
- Consistent Sector Erase operation time \( t_{SE} \) over device lifetime
- Industry’s fastest WRITE performance minimizes system risk during field firmware upgrades

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**Smart LED Block Diagram**

---

<table>
<thead>
<tr>
<th>Device</th>
<th>Density</th>
<th>Power Supply (V)</th>
<th>Sector Erase Time (ms)</th>
<th>Page Program Time (ms)</th>
<th>Read/Write Current (mA)</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>LE25S20</td>
<td>2 Mb</td>
<td>1.65 - 1.95</td>
<td>80</td>
<td>3</td>
<td>6 Read; 15 Write</td>
<td>SOIC-8, VSOIC-8</td>
</tr>
<tr>
<td>LE25U20A</td>
<td>2 Mb</td>
<td>2.3 - 3.6</td>
<td>80</td>
<td>4</td>
<td>6 Read; 15 Write</td>
<td>SOIC-8, VSOIC-8, WDFN-8</td>
</tr>
<tr>
<td>LE25U40C</td>
<td>4 Mb</td>
<td>2.3 - 3.6</td>
<td>80</td>
<td>4</td>
<td>6 Read; 15 Write</td>
<td>SOIC-8, VSON-8, VDFN-8</td>
</tr>
<tr>
<td>LE25S40</td>
<td>4 Mb</td>
<td>1.65 - 1.95</td>
<td>80</td>
<td>6</td>
<td>6 Read; 15 Write</td>
<td>SOIC-8, VSOIC-8, VDFN-8, VSON-8</td>
</tr>
<tr>
<td>LE25W81</td>
<td>8 Mb</td>
<td>2.45 - 3.6</td>
<td>100</td>
<td>0.3</td>
<td>6 Read; 15 Write</td>
<td>VSON-8, VDFN-8</td>
</tr>
<tr>
<td>LE25S81A</td>
<td>8 Mb</td>
<td>1.65 - 1.95</td>
<td>15</td>
<td>0.3</td>
<td>5 Read; 4.5 Erase</td>
<td>SOIC-8, VSOIC-8</td>
</tr>
<tr>
<td>LE25S161</td>
<td>16 Mb</td>
<td>1.65 - 1.95</td>
<td>15</td>
<td>0.4</td>
<td>4.5 Read; 4.5 Erase</td>
<td>SOIC-8, VSOIC-8, UDFN-8, WLCSP-8</td>
</tr>
</tbody>
</table>
LED Bypass Shunts

A typical solid-state lighting application contains strings of LEDs. Without LED shunts in place, an open circuit failure will cause an entire string of LEDs to go dark. Many applications require high reliability in order to prevent costly early replacement or safety hazards. LED shunts ensure that despite an LED failure, the remainder of the string stays lit. When all LEDs are functioning the low leakage of an LED shunt ensures that it consumes very little power. Once an LED fails the shunt allows current to flow around the failed LED in a matter of nanoseconds. Their current range and tight voltage specifications ensure that ON Semiconductor LED shunts are compatible with all LED drivers.

**Key Requirements**
- Low ON-state resistance, high OFF-state resistance and high reliability

**Features**
- High ON-state current capability
- Low off-state leakage
- Low and repeatable response time

**Benefits**
- High reliability, enables longevity of string and fixture
- Capable of operating in high current strings
- Compatible with PWM dimming

**High Reliability Applications**
- Street lights
- Tunnel lighting
- Architectural lighting
- High-bay lighting
- Train and runway lights
- Automotive lighting

<table>
<thead>
<tr>
<th>Device</th>
<th>Current Range @ $T_A = 25^\circ$C (mA)</th>
<th>Minimum Breakdown Voltage (V)</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUD4700</td>
<td>70 to 1300</td>
<td>5.5</td>
<td>POWERMITE®</td>
</tr>
<tr>
<td>HBL5006</td>
<td>50 to 350</td>
<td>6.2</td>
<td>SOD-323, SOD-523, SOD-923</td>
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<tr>
<td>HBL1015</td>
<td>140 to 500</td>
<td>8.0</td>
<td>TSOP-5</td>
</tr>
<tr>
<td>HBL1025</td>
<td>140 to 500</td>
<td>11.5</td>
<td>TSOP-5</td>
</tr>
<tr>
<td>HBL5107*</td>
<td>200 to 2000</td>
<td>7.3</td>
<td>SOD-123 FL</td>
</tr>
</tbody>
</table>

* Pending 2Q18

HBL1015 and HBL1025 Shunts for Multiple LEDs
Power Over Ethernet (POE) Surge and ESD Protection

**Advantages**
- 24 A IEC 61000-4-2 Surge protection
- 30 kV IEC 61000-4-5 ESD protection
- Supports 802.3at Type 2 “PoE+”

**Benefits**
- Flexible design
- Space saving SOIC-8 package

---

**POE Protector**

<table>
<thead>
<tr>
<th>Device</th>
<th>Function</th>
<th>Vdc (V)</th>
<th>Clamp Voltage @ 24 A (V)</th>
<th>Surge Ipp 8/20 (μs)</th>
<th>ESD Contact/Air (kV)</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSP5804*</td>
<td>Protector</td>
<td>58</td>
<td>&lt;80</td>
<td>50</td>
<td>&gt;30</td>
<td>SOIC-8</td>
</tr>
<tr>
<td>DF10S2</td>
<td>Full Bridge</td>
<td>70</td>
<td>&gt;1000</td>
<td>85</td>
<td>Protected by NSP5804</td>
<td>PDIP-4 GW</td>
</tr>
</tbody>
</table>

* Pending 2Q18