LED Lighting Solutions

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

As the technology and light output of LEDs have continued to improve, applications for color and white high-brightness LEDs have expanded 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 desired intensity and color. 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.
The LIGHTING-1-GEVK Connected Lighting Platform is a modular development kit for prototyping cost-effective, industrial LED lighting solutions. The platform is extremely energy efficient and features wireless control (on/off, dimming, etc.) and two independently controlled LED channels that provide a maximum brightness of 7000 lumens.

The base platform consists of four components:

- LED module, supporting 2 strings (warm white and cool white) of 16 LEDs
- Bluetooth® Low Energy connectivity board featuring RSL10 SIP
- AC-DC power board (Vin AC: 90 – 270 V, Vout DC: 55 V, Pout electrical: 70 W, Power Factor >0.99 at full load)
- LED driver board featuring FL7760 (dimming down to 0.6%, telemetry data, 12-bit PWM)

The platform provides several LED control functionalities using the RSL10 Sense and Control mobile app (iOS, Google Play) or web client. The platform is supported by a comprehensive development environment, including a CMSIS-Pack featuring customizable firmware, free RTOS, and various use cases. The PoE Power Module is available separately for Power Over Ethernet (PoE) connectivity up to 90 W.

Features

- High-power lighting
- Up to 2 strings of 16 LEDs (7000 Lumen)
- Dual independent LED Channel
- White balance control (12-bit dimmer from 0 to Max)
- Multiple connectivity options
  - Bluetooth® Low Energy
  - Power Over Ethernet (PoE)
  - Zigbee™ GreenPower (Pending 2Q20)
- Compliant with multiple industry standards
- High efficiency power conversion (>90% at full load)
ON Semiconductor offers a complete portfolio of interface controllers for emerging PoE applications. The front-end PD device is compliant with IEEE802.3af, IEEE802.3at, and the new IEEE802.3bt standards, and power is provided using two-pair and four-pair configurations to meet all requirements. The portfolio includes ASSPs PD chips with (NCP108x) and without (NCP109x) integrated PWM controllers, which can convert PoE input power to one or more output voltages in a Powered Device.

Features – NCP1095, NCP1096

- Fully compliant with new IEEE 802.3bt for high power up to 90 W PoE
- Supports Autoclass
- Integrated low RDS(ON) pass-switch (NCP1096)
- Support for Short MPS
- Pass Switch disabling input for rear auxiliary supply operation
- 135 mA typical inrush current limiting
- Full backward compatibility with IEEE 802.3af/at

Complete building blocks for a highly efficient PoE Powered Device

- PoE-PD Interface controller – NCP1095, NCP1096
- Active MOSFET bridge – Greenbridge™2 FDMQ8205A
- Downstream DC-DC controller – NCP1566 Active Clamp Forward Converter
- Supplementary discrete components

---

**Table: Power-Over-Ethernet (PoE) Controllers**

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
<th>Topology</th>
<th>Control Mode</th>
<th>Vcc Min (V)</th>
<th>Vcc Max (V)</th>
<th>Pe Typ (W)</th>
<th>Ron Typ (Ω)</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCP1080</td>
<td>PoE PD Controller and DC-DC Converter</td>
<td>Flyback</td>
<td>Current</td>
<td>0</td>
<td>57</td>
<td>15</td>
<td>0.6</td>
<td>TSSOP-20</td>
</tr>
<tr>
<td>NCP1081</td>
<td>PoE PD Controller and DC-DC Converter</td>
<td>Flyback</td>
<td>Current</td>
<td>0</td>
<td>57</td>
<td>40</td>
<td>0.6</td>
<td>TSSOP-20</td>
</tr>
<tr>
<td>NCP1082</td>
<td>PoE PD Controller and DC-DC Converter, with Auxiliary Supply Support</td>
<td>Flyback</td>
<td>Current</td>
<td>0</td>
<td>57</td>
<td>15</td>
<td>0.6</td>
<td>TSSOP-20</td>
</tr>
<tr>
<td>NCP1083</td>
<td>PoE PD Controller and DC-DC Converter, with Auxiliary Supply Support</td>
<td>Flyback</td>
<td>Current</td>
<td>0</td>
<td>57</td>
<td>40</td>
<td>0.6</td>
<td>TSSOP-20</td>
</tr>
<tr>
<td>NCP1090</td>
<td>PoE PD Interface Controller</td>
<td>–</td>
<td>–</td>
<td>0</td>
<td>57</td>
<td>15</td>
<td>0.5</td>
<td>SOIC-8, TSSOP-8</td>
</tr>
<tr>
<td>NCP1091</td>
<td>PoE PD Interface Controller with Programmable UVLO</td>
<td>–</td>
<td>–</td>
<td>0</td>
<td>57</td>
<td>15</td>
<td>0.5</td>
<td>SOIC-8, TSSOP-8</td>
</tr>
<tr>
<td>NCP1092</td>
<td>PoE PD Interface Controller with Vaux Support</td>
<td>–</td>
<td>–</td>
<td>0</td>
<td>57</td>
<td>15</td>
<td>0.5</td>
<td>SOIC-8, TSSOP-8</td>
</tr>
<tr>
<td>NCP1093</td>
<td>PoE PD Interface Controller</td>
<td>–</td>
<td>–</td>
<td>0</td>
<td>57</td>
<td>25</td>
<td>0.5</td>
<td>DFN-10</td>
</tr>
<tr>
<td>NCP1094</td>
<td>PoE PD Interface Controller with Vaux Support</td>
<td>–</td>
<td>–</td>
<td>0</td>
<td>57</td>
<td>25</td>
<td>0.5</td>
<td>DFN-10</td>
</tr>
<tr>
<td>NCP1095</td>
<td>802.3bt PoE PD Interface Controller with External Hot Swap Transistor</td>
<td>–</td>
<td>–</td>
<td>0</td>
<td>57</td>
<td>100</td>
<td>–</td>
<td>TSSOP-16</td>
</tr>
<tr>
<td>NCP1096</td>
<td>802.3bt PoE PD Interface Controller with Internal Hot Swap Transistor</td>
<td>–</td>
<td>–</td>
<td>0</td>
<td>57</td>
<td>100</td>
<td>0.07</td>
<td>TSSOP-16 EP</td>
</tr>
</tbody>
</table>
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: the European Home Systems Protocol (EHS), BatiBUS, and the 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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**RF AX8052F143**
- Multi/Ready
- High Sensitivity
- Ultra Low Receive and Standby Current
- PHY + MAC

**Twisted Pair AXN5121 AXN5110 AXN5130**
- Efficiency Increase
- 10/20 mA Bus Current Consumption
- 5 to 40 mA Bus Current Consumption
- KNX Bus Current Limitation
- PHY + MAC Layer (TUART Compatible)
- PHY Layer (Analog Only)
- 3.3 V Fixed DC/DC
- Adjustable DC/DC
- 20 V LDO
- Analog Monitor Output
### PLC Modems/Power Line Driver

**Smart Grid Modem**
- **Device**: NCN49599
  - Function: PLC S-FSK Modem; A - D Band
  - Features:
    - 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
  - Package: QFN-5s

- **Device**: NCN49597
  - Function: PLC S-FSK Modem; A - D Band
  - Features:
    - ARM Cortex M0
    - Baud rate: 4800 Bauds
    - S-FSK modulation
    - Hardware embedded MAC + PHY
  - Package: QFN-52

**Power Amplifier**
- **Device**: NCS5651
  - Function: Power Line Driver; Class AB
  - Features:
    - 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
  - Package: QFN-20 EP
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 Circuit](image)

Old Solution

NCS36000 Solution
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 (tSE) over device lifetime
- Industry’s fastest WRITE performance minimizes system risk during field firmware upgrades

![Smart LED Block Diagram](image)

<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 @ TθA = 25°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>
</tr>
</tbody>
</table>
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 back lighting
- 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</td>
<td>Low to medium volume applications, reduces safety</td>
<td>Common voltages of 12, 24, 36, 48 Vdc, regulation to ±5%</td>
</tr>
<tr>
<td>Regulated Adapter</td>
<td></td>
<td></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>
### Wide Input Voltage LED Driver Selector

Vin < 40 V

- **SEPIC/Buck-Boost**
  - Vout > Vin
  - NCP3065/6

- **Step-Up (Boost)**
  - Vout > Vin
  - NCP3065/6

- **Step-Down (Buck)**
  - Vout < Vin
  - NCP3065/6

**What is the Switch Current**
- Switching
- *Switching Frequency* (kHz)
- *Vin Range* (V)
- *Switch Current* (A)
- *Automotive Qualified Device*

<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>Automotive Qualified Device</th>
<th>Packages</th>
<th>Resources</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>**</td>
<td>NCV3065</td>
<td>SOIC-8, DFN-8, PDIP-8</td>
</tr>
<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>**</td>
<td>NCV3066</td>
<td>SOIC-8, DFN-8, PDIP-8</td>
</tr>
<tr>
<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>NCV3163</td>
<td>SOIC-16W, DFN-18</td>
<td>Boost 700 mA</td>
</tr>
<tr>
<td>MC33163</td>
<td>Up to 50</td>
<td>Buck, Boost, Buck/Boost</td>
<td>2.5 to 40</td>
<td>3.4</td>
<td>—</td>
<td>SOIC-16</td>
<td>Boost &lt; 1 A</td>
</tr>
<tr>
<td>NCP1034</td>
<td>Up to 500</td>
<td>Buck</td>
<td>8 to 100</td>
<td>—</td>
<td>✔</td>
<td>—</td>
<td>SOIC-16</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>NCV5171/3</td>
<td>SOIC-8</td>
<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>—</td>
<td>TSSOP-16, SOIC-16</td>
</tr>
<tr>
<td>NCL30105</td>
<td>Up to 500</td>
<td>Buck</td>
<td>Up to 22</td>
<td>—</td>
<td>✔</td>
<td>—</td>
<td>SOIC-8</td>
</tr>
<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>Up to 40 V, 1 A Buck LED Driver</td>
</tr>
<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>—</td>
<td>DFN-10</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.
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

Resources
- Evaluation Board: NCL30160GEVB
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

![Reference Design Demo Board](image)

Reference Design Demo Board
0.457" x 1.148" (11 mm x 29 mm)

![MR16 LED Module](image)

MR16 LED Module

![Reference Design Block Diagram](image)

Reference Design Block Diagram

![I\text{out} versus Vac Input](image)

<table>
<thead>
<tr>
<th>Vac (Volts)</th>
<th>I\text{out} (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.8</td>
<td>0.300</td>
</tr>
<tr>
<td>10.8</td>
<td>0.325</td>
</tr>
<tr>
<td>11.8</td>
<td>0.350</td>
</tr>
<tr>
<td>12.8</td>
<td>0.375</td>
</tr>
<tr>
<td>13.8</td>
<td>0.400</td>
</tr>
</tbody>
</table>
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**

- **Low startup voltage**
- **Tight current regulation regardless of Vf variation**
- **Negative temperature coefficient protects LEDs**

**Resources**
- **Sample Kit: CCR2KIT/S**

---

**Linear LED Driver Solutions**

- **Features**
  - Low startup voltage
  - Tight current regulation regardless of Vf variation
  - Negative temperature coefficient protects LEDs

- **Resources**
  - Sample Kit: CCR2KIT/S

---

**Constant Current Regulators – Dimming with External BRT**

<table>
<thead>
<tr>
<th>Device</th>
<th>Max Anode-to-Cathode Voltage (VAK) (V)</th>
<th>Voltage Overhead (Vf, V LEDs) (V)</th>
<th>Constant Current Ireg (@ VAK = 7.5 V) (mA)</th>
<th>Current Tolerance Over Voltage ±15%, ±10%</th>
<th>Max Junction Temperature (°C)</th>
<th>Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSI45xxx</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>NSI50xxx</td>
<td>50</td>
<td>1.8</td>
<td>Fixed: 10, 350</td>
<td>±10%</td>
<td>175</td>
<td>SMC, DPAK</td>
</tr>
<tr>
<td>NSIC20xx</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>NSI45xxxJ</td>
<td>45</td>
<td>1.8</td>
<td>Adjustable 20 to 40, 35 to 70, 60 to 100, 90 to 160</td>
<td>±15%</td>
<td>175</td>
<td>SOT-223, DPAK</td>
</tr>
<tr>
<td>NSI50150AD</td>
<td>50</td>
<td>1.8</td>
<td>150 to 350</td>
<td>±10%</td>
<td>175</td>
<td>DPAK</td>
</tr>
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</table>

**NOTE:** xxx in the device number represents the current level.
## Linear LED Driver Solutions (continued)

### 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>
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<tbody>
<tr>
<td>N51S3505AS</td>
<td>350</td>
<td>1.8 to 50</td>
<td>±10%</td>
<td>1</td>
<td>Ext</td>
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<td>-40 to +125</td>
<td>SMC</td>
<td>AEC-Q101 qualified</td>
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<tr>
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<td>±10%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</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 120</td>
<td>±15%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
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<td>AEC-Q101 qualified</td>
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<td>NSI4530JZ</td>
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<td>±15%</td>
<td>1</td>
<td>Ext</td>
<td>1.8</td>
<td>-40 to +125</td>
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<td>AEC-Q101 qualified</td>
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<td>±15%</td>
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<td>Ext</td>
<td>1.8</td>
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<td>-40 to +125</td>
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<td>AEC-Q101 qualified</td>
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<td>±15%</td>
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<td>Ext</td>
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<td>±15%</td>
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<td>-40 to +125</td>
<td>SOT-223</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NSI4520AZ</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>NSI4520A</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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<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>NSI4501SW</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>
<tr>
<td>N51S05040D</td>
<td>150 to 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>
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<tr>
<td>N51S0500JD</td>
<td>90 to 160</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>DPAK</td>
<td>AEC-Q101 qualified</td>
</tr>
<tr>
<td>N51S0506JD</td>
<td>60 to 100</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>DPAK</td>
<td>AEC-Q101 qualified</td>
</tr>
<tr>
<td>N51S0503ZJ</td>
<td>35 to 70</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>DPAK</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>N51S0502ZJ</td>
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<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>DPAK</td>
<td>AEC-Q101 qualified</td>
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<tr>
<td>NSM4002MR6</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>
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<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>
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<tr>
<td>LV5237JA</td>
<td>Constant mode 5 to 100</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</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</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</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</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
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.
### AC Line Powered LED Driver Line Up

<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><strong>AC-DC</strong></td>
<td><strong>Buck</strong></td>
<td>FL701</td>
<td>A/P</td>
<td>HV JFET</td>
<td>✓</td>
<td>CCM</td>
<td>CCM</td>
<td>SOIC-8</td>
<td>Low eBOM counts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FLS0116</td>
<td>A/P</td>
<td>HV JFET</td>
<td>✓</td>
<td>CCM</td>
<td>CCM</td>
<td>SOIC-7</td>
<td>600 V switcher</td>
</tr>
<tr>
<td></td>
<td><strong>Boost</strong></td>
<td>NCL30167</td>
<td>PC</td>
<td>Cascade</td>
<td>✓</td>
<td>CRM</td>
<td>CRM</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>
<td>CRM</td>
<td>CRM</td>
<td>SOIC-14</td>
<td>400 V switcher</td>
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<td></td>
<td><strong>Buck-Boost</strong></td>
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<td>PC</td>
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<td>CRM</td>
<td>TSOP-6</td>
<td>Low eBOM counts</td>
</tr>
<tr>
<td></td>
<td><strong>SEPIC Flyback</strong></td>
<td>FL7734</td>
<td>PC</td>
<td>CC</td>
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<td>DCM</td>
<td>DCM</td>
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<td>Professional phase-cut dimming</td>
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<td>CC</td>
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<td>QR</td>
<td>QR</td>
<td>SOIC-8</td>
<td>Conventional switch dimming</td>
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<td>A/P</td>
<td>CC</td>
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<td>QR</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>
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<td>✓</td>
<td>QR</td>
<td>QR</td>
<td>SOIC-8</td>
<td>CC tolerance &lt;±3%</td>
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<td>HV JFET</td>
<td>CC</td>
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<td>DCM</td>
<td>DCM</td>
<td>SOIC-8</td>
<td>CC tolerance &lt;±3%, good THD</td>
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<td>HV JFET</td>
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<td>DCM</td>
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<td>CC/CC</td>
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<td>CC/CV (&lt;±2%), low THD, smart lighting</td>
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<td>HV JFET</td>
<td>CV/CC</td>
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<td>QR</td>
<td>SOIC-8</td>
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<td>CC/CV (&lt;±2%), low Pstdby, smart lighting</td>
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<td>HV JFET</td>
<td>CV/CC</td>
<td>✓</td>
<td>QR</td>
<td>SOIC-8</td>
<td>CC/CV (&lt;±2%), low Pstdby</td>
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<td>SOIC-8</td>
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<td>CCM</td>
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<td>SOIC-8</td>
<td>Current mode, optional frequency</td>
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<td><strong>2SW Forward</strong></td>
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<td>HV JFET</td>
<td>CV/CC</td>
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<td></td>
<td>DCM</td>
<td>SOIC-16</td>
<td>Current mode, integrated high side gate driver</td>
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<td>FLS1600</td>
<td>Voltage</td>
<td>SIP-9</td>
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<td><strong>Half-Bridge</strong></td>
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<td>HV JFET</td>
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<td>NCL30059</td>
<td>HV JFET</td>
<td>Current</td>
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<td>SOIC-8</td>
<td>Wide Vout simple LLC resonant half bridge</td>
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<tr>
<td></td>
<td><strong>2 Stage Combo</strong></td>
<td>NCL30030</td>
<td>HV JFET</td>
<td>✓</td>
<td>CRM+QR</td>
<td></td>
<td></td>
<td>SOIC-16 NB</td>
<td>Pstdby &lt;0.3 W</td>
</tr>
</tbody>
</table>

**Gate Driver**

| Low Side | FL3100 | P | SOT-23 | Easy PWM dimming interface |
| High Side Only | FAN73611 | SOIC-8 | 600 V floating switch driver |
| Half Bridge  | FAN7380/2 | SOIC-8 | 600 V half bridge gate driver |
|            | FL73282 | SOIC-8 | 900 V half bridge gate driver |

**Phase-Cut Dimmer Control**

| Back to Back AC Switches | FL5150 | 50 Hz | SOIC-10L NB | Self bias universal phase-cut dimmer control |
| Back to Back AC Switches | FL5160 | 60 Hz | SOIC-10L NB | Self bias universal phase-cut dimmer control |

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

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

Market & Applications
- Phase-Cut Dimming LED driver
- Phase-Cut Dimming LED retrofit

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>
</tr>
</thead>
<tbody>
<tr>
<td>NCL30167</td>
<td>SOIC-10</td>
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<td>NCL30095A</td>
<td>SOIC-14</td>
</tr>
</tbody>
</table>

AC-DC

Energy Efficient Innovations

LED Lighting Solutions
Step-Down Phase-Cut Dimmable Solution

FL7734 Universal Input Phase-Cut Dimming Single Stage PSR Controller

Features
• Universal Input \( \Phi \)-cut dimmable
• Controllable \( I_{IN} \) minimum
• Controllable dimming curve
• \(< \pm 1\% \) line regulation PSR control
• RCS short and open protection

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

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

Ordering and Package Information

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL7734MX</td>
<td>SOIC-16</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Device</th>
<th>Protections</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCL30185A</td>
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</tr>
<tr>
<td>NCL30185B</td>
<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

Features

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

Other Features

• Current control insensitive to normal transformer variation
• Wide Vcc range (9.4-26 Vdc) to support extended 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

Benefits

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

Ordering and Package Information

<table>
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<th>Protections</th>
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<td>NCL30186B</td>
<td>Auto Recoverable</td>
<td>SOIC-8</td>
</tr>
</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*

**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>
<th>Package</th>
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<tbody>
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<tr>
<td>NCL30386B1</td>
<td>DSS-OFF</td>
<td>SOIC-10</td>
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60 W 0-10/PWM Dimming Driver

Evaluation Boards Available
Analog Dimming Single Stage Solution

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

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>
<thead>
<tr>
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<tr>
<td>NCL30388B1</td>
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60 W LED Lighting Driver
Evaluation Boards Available
**Features**

- Integrated 700 V HV Startup
- Precise current regulation accuracy (<±2% typical)
- Precise voltage regulation accuracy (<±1% typical)
- PF(>0.95)/THD(<10%) @ Univ.
- Quasi-resonant control
- Standby Mode
- Optional PSR/SSR mode
- Excellent Dimming features
  - Dimming curve: Linear/Quadratic
  - ADIM: Analog I\text{OUT} with V\text{DC}
  - PWM I\text{OUT} with VPWM
  - PDIM: Analog I\text{OUT} with PWM duty
  - Optional Min. Dim. Clamping (0/1/5/8%)
  - Deeper dim. w ADIM & PDIM simultaneously
  - DIM CV Mode
- Protections
  - Brown Out/Line OVP/VCC OVP
  - LED open/short protection
  - Winding /diode short protection
  - Thermal Shutdown

**Market & Applications**

- Analog/PWM Dimmable LED driver

**Benefits**

- Fast startup, low Pstdby
- Constant brightness
- Auxiliary power supply for MCU & cold start up
- Exceeds global standards
- Higher efficiency
- P\text{IN}: < 150 mW
- Design flexibility
- Supports smart lighting
- Uses optoelectronics instead of pulse transformer
- Deep dimming features
- Vcc supply for smart lighting MCU
- High system reliability

---

**Ordering and Package Information**

<table>
<thead>
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<td>NCL30486B1*</td>
<td>Standby Mode OFF, Line OVP OFF</td>
<td>SOIC-9</td>
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* Pending 1Q20.
### Single Stage Solution

**NCL30488 HV CC/CV PFC PSR/SSR PWM Controller for LED Lighting**

#### Features
- Integrated 700 V HV Startup
- Precise current regulation accuracy (<±2% typical)
- Precise voltage regulation accuracy (<±2% typical)
- PF(>0.95)/THD(<10%) @ Univ.
- Quasi-resonant control
- Standby Mode
- Optional PSR/SSR mode
- Protections
  - Brown Out/Line OVP/VCC OVP
  - LED Open/short protection
  - Winding/Diode short protection
  - Thermal Shutdown

#### Other Features
- Wide VCC range (9.3 - 25 VDC) to support extend VF range
- Optional maximum dead time
- Optional ZCD blanking time

#### Market & Applications
- High performance LED driver

#### Benefits
- Fast startup, low Pstdby
- Constant brightness
- Auxiliary power supply for MCU & cold start up
- Exceeds global standards
- Higher efficiency
- $P_{IN}$: < 150 mW
- Design flexibility
- High system reliability

### Ordering and Package Information

<table>
<thead>
<tr>
<th>Device</th>
<th>Features</th>
<th>Package</th>
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</thead>
<tbody>
<tr>
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<td>SOIC-9</td>
</tr>
<tr>
<td>NCL30488A2 *</td>
<td>Standby Mode OFF, Line OVP ON</td>
<td>SOIC-9</td>
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<tr>
<td>NCL30486B1*</td>
<td>Standby Mode OFF, Line OVP OFF</td>
<td>SOIC-9</td>
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</table>

* Pending 1Q20.

---

60 W LED Driver EVB
Low Profile Light Engine CC Solution

NCL30288 Power Factor Corrected Primary Side Controller

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

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

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

Ordering and Package Information

<table>
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<tr>
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<th>Package</th>
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Non-isolated buck-boost topology can also be supported

20 W T Lamp Driver

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

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

### 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>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
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<tbody>
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<td>NCL30030B2</td>
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</tr>
<tr>
<td>NCL30030B3</td>
<td>SOIC-16</td>
</tr>
</tbody>
</table>

**Evaluation Boards and Design Tools Available**

150 W Analog/PWM Dimmable Driver
2 Switch Forward Solution

NCL30125 – Fixed Frequency Current Mode Controller

Features

- Adjustable frequency up to 300 kHz
- Internal 700 V high side gate driver
- +0.9/-1.2 A high & low side gate driver
- Internal 700 V HV startup current source
- Dynamic Self Supply (DSS)
- Skip cycle mode
- Jittering function

Other Features

- Design Flexibility
  - 35 V wide VCC operation
  - Adjustable operating frequency & soft start duration
  - Optional features (Skip threshold, BO level, OCP timer & etc.)
  - Auto-recovery or Latch option
- Robust system operation
  - Brown-out, OCP (SCP/OLP), VCC OVP, Thermal Shutdown
  - Dedicated Fault pin for OVP or OTP detection

Market & Applications

- Lighting advertisement power board - 2SW forward converter
- Power supplies for power tool charger, PC silver boxes, game adapter

Benefits

- Fast startup, low Pstdby
- Constant brightness
- Auxiliary power supply for MCU & cold start up
- Exceeds global standards
- Higher efficiency
- $P_{IN} < 150$ mW
- Design flexibility
- Supports smart lighting
- Uses optoelectronics instead of pulse transformer
- Deep dimming features
- Vcc supply for smart lighting MCU
- High system reliability
Direct AC LED Driver Solution

NCL30170 Power Scalable Direct AC LED Controller

Features

- Accurate LED CC regulation: <±1%
- Workable for constant power regulation
- Selectable LED channel counts
- High PF & low THD: >0.99 / <10%
- Proprietary active PC dimmer control technology
- Wide analog dimming range: 5~100%
- HV startup current source

Benefits

- Excellent light uniformity
- High design flexibility
- Easy power scalability 5~300 W
- Overpass global standard
- Excellent phase-cut dimmer compatibility
- Flexible smart lighting design
- Fast start up & low eBOM

Other Features

- Protections
  - Input Over Voltage Protection
  - RCS Short Protection
  - Thermal Shutdown

Market & Applications

- LED Light - PAR, Down, Tube, Flat, Ceiling, Flood, High Bay, Street light
  - Non-Dimming, Phase-Cut Dimming
  - Analog Dimming (0-10)

Ordering and Package Information

<table>
<thead>
<tr>
<th>Device</th>
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<th>Package</th>
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<tbody>
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<td>SOIC-10</td>
</tr>
<tr>
<td>NCL30170B</td>
<td>V_DIM: 0 - 1.5 V</td>
<td>SOIC-10</td>
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</table>
PFC Boost Controller Solution

NCL2801 Ultra-low THD Current Mode CrM PFC Controller

Features
- Valley count frequency foldback
- Dynamic response enhancer
- Soft/fast OVP
- THD enhancer
- Line level feed-forward
- Protections
  - Brown Out
  - Thermal Shutdown
  - OVP
  - Over Current limitation
  - Pin open/short protection

Benefits
- Maximize efficiency over wide load range
- Lower output undershoot
- Lower output overshoot
- Improve THD performance
- Optimal loop gain in universal input
- High system reliability

Other Features
- Wide Vcc (10.5 ~ 28 V) range/ 3 Vcc startup level
- Trans-conductance error amp (OTA)
- High drive capability: +500/-800 mA

Market & Applications
- Analog/PWM Dimmable LED Drivers
- PFC front end supplies requiring excellent THDi

Ordering and Package Information

<table>
<thead>
<tr>
<th>Device</th>
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<th>Fast OVP (%)</th>
<th>Vcc Start (V)</th>
<th>DRE (After Start)</th>
<th>DRE (Before Start)</th>
<th>Brown Out</th>
<th>Line Range Detect</th>
<th>Package</th>
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</table>
High Efficiency LCC Half Bridge Solution for Ultra Wide Output Driving

NCL30059 High Voltage Half-Bridge Controller for LED Lighting Application

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

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

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

Ordering and Package Information

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
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</thead>
<tbody>
<tr>
<td>NCL30059B</td>
<td>SOIC-8</td>
</tr>
</tbody>
</table>

Under preparing 100 W low BOM PFC+LCC half bridge driver
**Smart Lighting Luminaries Light Engine Solution**

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

**FL7740 Features**
- Wide Input voltage range (80 ~ 382 V<sub>AC</sub>)
- <200 ms start up time with integrated HV startup JFET
- CV tolerance (avg.): <±2 %
- CV overshoot and undershoot under transient: <±10 %
- P<sub>Standby</sub>: <0.15 W @ no load, <0.3 W @ 10 mA I<sub>OUTMCU</sub>, <0.4 W @ 20 mA I<sub>OUTMCU</sub>
- 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 Features**
- Wide input range (8 ~ 70 V<sub>DC</sub>)
- 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 μA)
- Thermal shutdown
- Over current protection
- Small outline package (SOT-23-6L)

---

**Ordering and Package Information**

<table>
<thead>
<tr>
<th>Device</th>
<th>Features</th>
<th>Package</th>
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<td>FL7760BM6X</td>
<td>Linear Dim</td>
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</tbody>
</table>

**Evaluation Board & Design Tools available**

- **2.4 Ghz** Radio
- **Dali** Connectivity Module
- **0-10 DIM** Aux Power
- **PWM DIM** Analog/PWM Signal
Medium to Large LCD Panel Backlighting

As LED performance and cost have improved, they have displaced 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 have replaced 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

D1 Schottky Barrier Diode for DC-DC Converter

<table>
<thead>
<tr>
<th>Device</th>
<th>Vr Max (V)</th>
<th>Ig Max (A)</th>
<th>Vf Max (V)</th>
<th>Ig Max (mA)</th>
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<tr>
<td>SB80W06T</td>
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<td>8</td>
<td>0.6 @ I = 3 A</td>
<td>0.1 @ Vr = 30 V</td>
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Q2 MOSFET for DC-DC Converter

<table>
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<th>Ig (A)</th>
<th>Pd (W)</th>
<th>Rds(on)</th>
<th>Ciss (pF)</th>
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<tbody>
<tr>
<td></td>
<td>@ Vgs =</td>
<td>Typ</td>
<td>Max</td>
<td></td>
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<td>155 mΩ</td>
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<td>CPH6445</td>
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<td>60</td>
<td>4</td>
<td>9.2 mΩ</td>
<td>14 mΩ</td>
</tr>
<tr>
<td>ATP405</td>
<td>100</td>
<td>40</td>
<td>70</td>
<td>10</td>
<td>25 mΩ</td>
<td>33 mΩ</td>
</tr>
<tr>
<td>CPH3461</td>
<td>250</td>
<td>0.35</td>
<td>1</td>
<td>4.5</td>
<td>5 Ω</td>
<td>6.5 Ω</td>
</tr>
<tr>
<td>PCP1405</td>
<td>250</td>
<td>0.6</td>
<td>3.5</td>
<td>4.5</td>
<td>5 Ω</td>
<td>6.5 Ω</td>
</tr>
<tr>
<td>PCP1402</td>
<td>250</td>
<td>1.2</td>
<td>3.5</td>
<td>10</td>
<td>1.8 Ω</td>
<td>2.4 Ω</td>
</tr>
<tr>
<td>SFT1452</td>
<td>250</td>
<td>3</td>
<td>26</td>
<td>10</td>
<td>1.8 Ω</td>
<td>2.4 Ω</td>
</tr>
<tr>
<td>NDDP010N25AZ</td>
<td>250</td>
<td>10</td>
<td>52</td>
<td>10</td>
<td>320 mΩ</td>
<td>420 mΩ</td>
</tr>
</tbody>
</table>
## Discrete Devices for LED Backlighting

### Q1 Bipolar Transistor Current Balance Switch

<table>
<thead>
<tr>
<th>No of LEDs in Series</th>
<th>$V_{CEO}$ (V)</th>
<th>$I_C$ (A)</th>
<th>$V_{CE(sat)}$ (mV)</th>
<th>Polarity</th>
<th>$h_FE$</th>
<th>CPR-3/ SOT-23</th>
<th>SOT-89</th>
<th>SOT-223</th>
<th>DPAK, IPAK</th>
<th>T0-220</th>
<th>$f_T$ Typ (MHz)</th>
<th>$P_D$ @ 25°C (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>30</td>
<td>0.7</td>
<td>190</td>
<td>NPN</td>
<td>300-800</td>
<td>30C02CH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>540</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.8</td>
<td>220</td>
<td>PNP</td>
<td>200-500</td>
<td>30A02CH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>520</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400</td>
<td>NPN</td>
<td>160-320</td>
<td>KSC3265</td>
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<td></td>
<td></td>
<td></td>
<td>120</td>
<td>0.2</td>
</tr>
<tr>
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<td></td>
<td>400</td>
<td>PNP</td>
<td>100-320</td>
<td>KSA1298</td>
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<td></td>
<td>120</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
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<td>1.5</td>
<td>225</td>
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<td>200-500</td>
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<td></td>
<td></td>
<td>PCP1203</td>
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<td>500</td>
<td>1.3</td>
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<tr>
<td></td>
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<td></td>
<td>375</td>
<td>PNP</td>
<td>200-560</td>
<td></td>
<td></td>
<td></td>
<td>PCP1103</td>
<td></td>
<td>450</td>
<td>1.3</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>0.5</td>
<td>100</td>
<td>NPN</td>
<td>300-800</td>
<td>50C02CH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>120</td>
<td>PNP</td>
<td>200-500</td>
<td>50A02CH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>600</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5</td>
<td>135 - 190</td>
<td>NPN</td>
<td>200-560</td>
<td>CPH3216</td>
<td>2SC5964</td>
<td>2SC5706</td>
<td></td>
<td></td>
<td>380 - 420</td>
<td>0.8 - 1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>230 - 430</td>
<td>PNP</td>
<td>200-560</td>
<td>CPH3116</td>
<td>2SA2125</td>
<td></td>
<td></td>
<td></td>
<td>390 - 420</td>
<td>0.9 - 1.3</td>
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<tr>
<td>20</td>
<td>60</td>
<td>3.0</td>
<td>135 - 450</td>
<td>NPN</td>
<td>300-600</td>
<td>2SC6094</td>
<td>NZT650</td>
<td>NZT697</td>
<td></td>
<td></td>
<td>390</td>
<td>0.8 - 1.3</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>550</td>
<td>PNP</td>
<td>100-300</td>
<td></td>
<td></td>
<td></td>
<td>NZT660</td>
<td></td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5</td>
<td>150 - 165</td>
<td>NPN</td>
<td>300-600</td>
<td>2SC6095</td>
<td>2SC6098</td>
<td></td>
<td></td>
<td></td>
<td>350</td>
<td>0.8 - 1.3</td>
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<td>25</td>
<td>100</td>
<td>1.0</td>
<td>400</td>
<td>NPN</td>
<td>140-400</td>
<td>CPH3240</td>
<td>2SC3646</td>
<td>2SC4134</td>
<td></td>
<td></td>
<td>120</td>
<td>0.5 - 0.9</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>600</td>
<td>PNP</td>
<td>140-400</td>
<td>CPH3140</td>
<td>2SA1416</td>
<td></td>
<td></td>
<td></td>
<td>120</td>
<td>0.5 - 0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.0</td>
<td>150</td>
<td>NPN</td>
<td>300-600</td>
<td>CPH3260</td>
<td>2SC6096</td>
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<td></td>
<td></td>
<td>300</td>
<td>1.3</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>90</td>
<td>NPN</td>
<td>120-360</td>
<td>NSS1C201L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>120</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>115</td>
<td>NPN</td>
<td>120-360</td>
<td>NSS1C200L</td>
<td></td>
<td></td>
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<td></td>
<td>120</td>
<td>0.71</td>
</tr>
<tr>
<td>40</td>
<td>160</td>
<td>0.70 - 1.5</td>
<td>400 - 450</td>
<td>NPN</td>
<td>140-400</td>
<td>2SC3648</td>
<td>2SC4027</td>
<td></td>
<td></td>
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<td>120</td>
<td>0.5 - 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>PNP</td>
<td>140-400</td>
<td>2SA1418</td>
<td>2SA1552</td>
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<td></td>
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<td>0.5 - 15</td>
</tr>
<tr>
<td>50</td>
<td>200</td>
<td>0.7 - 1.0</td>
<td>200</td>
<td>NPN</td>
<td>200-560</td>
<td>PCP1208</td>
<td></td>
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<td>MJE344</td>
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<td>15 - 120</td>
<td>1.3 - 20</td>
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</tbody>
</table>

### Q1 MOSFET Current Balance Switch

<table>
<thead>
<tr>
<th>Device</th>
<th>No of LEDs in Series</th>
<th>Polarity</th>
<th>$V_{DSS}$ (V)</th>
<th>$I_D$ (A)</th>
<th>$V_{Drive}$ (V)</th>
<th>@ $V_{GS}$ =</th>
<th>$R_{DS(on)}$ (mΩ)</th>
<th>$f_T$ Typ (MHz)</th>
<th>$P_D$ @ 25°C (W)</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCH6445</td>
<td>14</td>
<td>N-Channel</td>
<td>60</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>81 mΩ</td>
<td></td>
<td></td>
<td>MCPH-6</td>
</tr>
<tr>
<td>MCH3486</td>
<td>14</td>
<td>N-Channel</td>
<td>60</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>155 mΩ</td>
<td>217 mΩ</td>
<td></td>
<td>MCPH-3</td>
</tr>
<tr>
<td>CPH6442</td>
<td>14</td>
<td>N-Channel</td>
<td>60</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>46 mΩ</td>
<td>65 mΩ</td>
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<td>CPH-6</td>
</tr>
<tr>
<td>CPH6444</td>
<td>14</td>
<td>N-Channel</td>
<td>60</td>
<td>4.5</td>
<td>4</td>
<td>4</td>
<td>81 mΩ</td>
<td>114 mΩ</td>
<td></td>
<td>CPH-6</td>
</tr>
<tr>
<td>CPH6445</td>
<td>14</td>
<td>N-Channel</td>
<td>60</td>
<td>3.5</td>
<td>4</td>
<td>4</td>
<td>132 mΩ</td>
<td>185 mΩ</td>
<td></td>
<td>CPH-6</td>
</tr>
<tr>
<td>PCP1403</td>
<td>14</td>
<td>N-Channel</td>
<td>60</td>
<td>4.5</td>
<td>4</td>
<td>4</td>
<td>132 mΩ</td>
<td>185 mΩ</td>
<td></td>
<td>SOT-89</td>
</tr>
<tr>
<td>PCP1405</td>
<td>50</td>
<td>N-Channel</td>
<td>250</td>
<td>0.6</td>
<td>4</td>
<td>4.5</td>
<td>5 Ω</td>
<td>6.5 Ω</td>
<td></td>
<td>SOT-89</td>
</tr>
<tr>
<td>CPH3461</td>
<td>50</td>
<td>N-Channel</td>
<td>250</td>
<td>0.35</td>
<td>4</td>
<td>4.5</td>
<td>5 Ω</td>
<td>6.5 Ω</td>
<td></td>
<td>SOT-89</td>
</tr>
<tr>
<td>PCP1402</td>
<td>50</td>
<td>N-Channel</td>
<td>250</td>
<td>1.2</td>
<td>10</td>
<td>10</td>
<td>1.8 Ω</td>
<td>2.4 Ω</td>
<td></td>
<td>SOT-89</td>
</tr>
<tr>
<td>SFT1452</td>
<td>50</td>
<td>N-Channel</td>
<td>250</td>
<td>3</td>
<td>10</td>
<td>10</td>
<td>1.8 Ω</td>
<td>2.4 Ω</td>
<td></td>
<td>IPAK</td>
</tr>
</tbody>
</table>
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.
## 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>
<tbody>
<tr>
<td>NCP5603</td>
<td>2.85 - 5.5</td>
<td>1</td>
<td>200 mA DC, 350 mA pulse</td>
<td>Voltage</td>
<td>1X, 1.5X, 2X</td>
<td>–</td>
<td>PWM</td>
<td>Depends on system</td>
<td>1</td>
<td>2.5 typ</td>
<td>DFN-10</td>
<td>Backlight 4.5 / 5 V output Short circuit protection</td>
</tr>
<tr>
<td>NCP5623B/C</td>
<td>2.7 - 5.5</td>
<td>3 (independent)</td>
<td>90</td>
<td>Current</td>
<td>1X, 2X</td>
<td>±0.5%</td>
<td>I2C</td>
<td>32/ quasi-log</td>
<td>0.35</td>
<td>0.8 typ</td>
<td>LLGA-12</td>
<td>RGB illumination Backlight Built-in “gradual illumination” B &amp; C versions have different I2C addresses</td>
</tr>
</tbody>
</table>

## Inductive Boost and Buck Topology

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

<table>
<thead>
<tr>
<th>Device</th>
<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>
<tbody>
<tr>
<td>NCP1422</td>
<td>1.0 - 5.0</td>
<td>800</td>
<td>1</td>
<td>Vout 3.3 V, Vin 2.5 V</td>
<td>1 for flash</td>
<td>PFM, up to 1.2 MHz</td>
<td>PWM</td>
<td>94</td>
<td>1.3 µA</td>
<td>0.05</td>
<td>DFN-10</td>
<td>Flash/Torch Internal synchronous rectification</td>
</tr>
<tr>
<td>LV52204</td>
<td>2.7 - 5.5</td>
<td>40</td>
<td>30</td>
<td>Vout 30 V, Vin 3.7 V</td>
<td>2 to 10 / Series</td>
<td>600 kHz</td>
<td>1-wire &amp; PWM</td>
<td>90</td>
<td>3</td>
<td>0.1</td>
<td>UDFN-6</td>
<td>Backlight Isw = 750 mA</td>
</tr>
<tr>
<td>LV52207</td>
<td>2.7 - 5.5</td>
<td>40</td>
<td>30</td>
<td>Vout 30 V, Vin 3.7 V</td>
<td>2 to 10 / Series</td>
<td>600 kHz/1.2 MHz</td>
<td>1-wire &amp; PWM</td>
<td>90</td>
<td>3</td>
<td>0.1</td>
<td>WLP-9</td>
<td>Backlight Isw = 750 mA</td>
</tr>
</tbody>
</table>
Automotive Lighting Systems

ON Semiconductor offers standard products and custom devices for automotive lighting applications, has developed the defacto standard stepper driver for headlight leveling and swiveling, and is a leader in LED exterior lighting solutions.

Front Lighting

Automotive designs predominantly use LED lighting, which 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, that are specifically designed for exterior 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 Demonstration Board Efficiency

NCV78763 Application Diagram
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>$I_G$ (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></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></td>
</tr>
<tr>
<td>NSVMUN5214D</td>
<td>50</td>
<td>0.1</td>
<td>0.25</td>
<td>Dual NPN BRT, $R_1 = 10k\Omega$, $R_2 = 47k\Omega$</td>
<td>SC-88 (SOT-363)</td>
</tr>
<tr>
<td>NSVBC114YDXV6</td>
<td>50</td>
<td>0.1</td>
<td>0.25</td>
<td>Dual NPN BRT, $R_1 = 10k\Omega$, $R_2 = 47k\Omega$</td>
<td>SOT-563</td>
</tr>
</tbody>
</table>
NCV7691 and NCV7692 are pre-drivers intended for linear drive of LEDs. They can operate from the car battery, and multiple LED strings can be driven by a single device.

Features

- NCV7691 Open Load detection threshold level: 9.5 V rising, 8.8 V falling
- NCV7692 Open Load detection threshold level: 5.1 V rising, 4.95 V falling
- 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
Rear Lighting — Linear Current Regulators/Controllers

For Rear Combination Lamps, Daytime Running Lights, Fog Lights, CHMSLs, Turn Signals

The NCV7683 is an 8-channel linear programmable constant current source, 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

The NCV7685 is a 12-channel linear programmable constant current source with common reference, designed for the regulation and control of LED-based lighting.

- Allow for 128 duty cycle levels, adjustable with I2C-programmable PWM
- 3.3 V voltage reference for loads up to 1 mA
- OTP bank for stand-alone operation (2 configurations)

<table>
<thead>
<tr>
<th>Device</th>
<th>Channels</th>
<th>$V_i$ Max (V)</th>
<th>$I_o$ Max (mA)</th>
<th>Max LEDs in Series</th>
<th>Max LEDs in Parallel</th>
<th>Package(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCV7683</td>
<td>8</td>
<td>40</td>
<td>200</td>
<td>4</td>
<td>24</td>
<td>SSOP-24 NB EP</td>
</tr>
<tr>
<td>NCV7685</td>
<td>12</td>
<td>40</td>
<td>60</td>
<td>4</td>
<td>12</td>
<td>SSOP-24 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

---

<table>
<thead>
<tr>
<th>Device</th>
<th>Max Anode-to-Cathode Voltage (V)</th>
<th>Voltage Overhead (V&lt;sub&gt;in&lt;/sub&gt; – V&lt;sub&gt;LEDs&lt;/sub&gt;)</th>
<th>Constant Current I&lt;sub&gt;reg&lt;/sub&gt; (@ V&lt;sub&gt;ak&lt;/sub&gt; = 7.5 V)</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>

**Constant Current Supply During Vehicle Battery Load Dump**

---

**NOTE:** xxx in the device number represents the current level.
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