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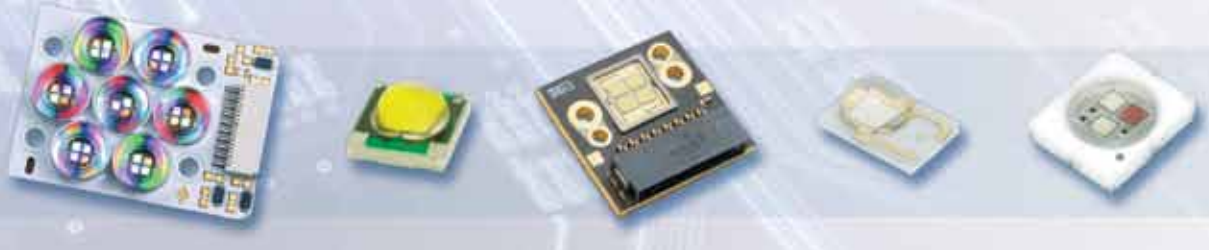
ON Semiconductor®

Enabling Energy Efficient Solutions

LED Lighting Solutions

Covering LED drivers, power management, communication and control solutions for solid state lighting applications from ON Semiconductor.



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Introduction

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 cellphones 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.

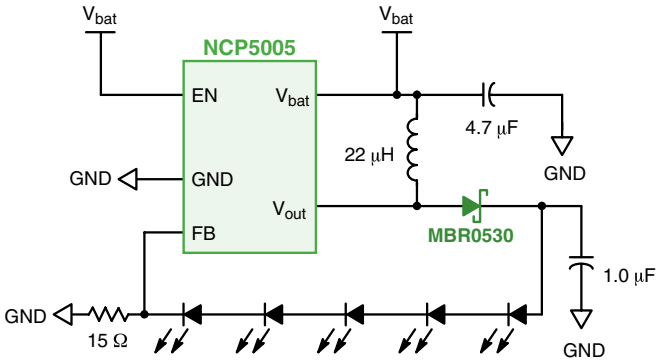
ON Semiconductor has focused on applying our low voltage and high voltage technologies and applying our expertise in power management solutions to the challenges of solid state lighting; whether in portable display products, interior automotive lighting, or ballast for LED signage. In the following pages,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

Table of Contents

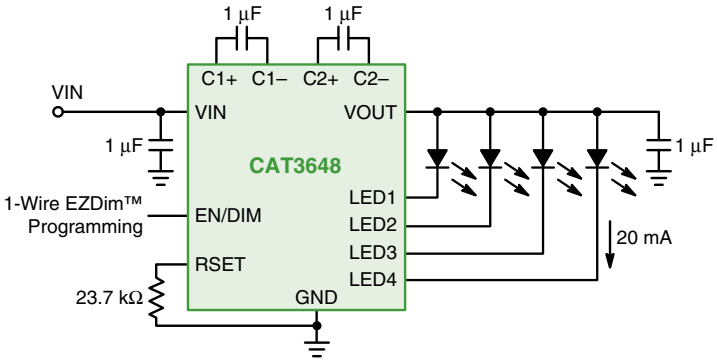
PORTABLES

Low-Voltage Portable LED Drivers

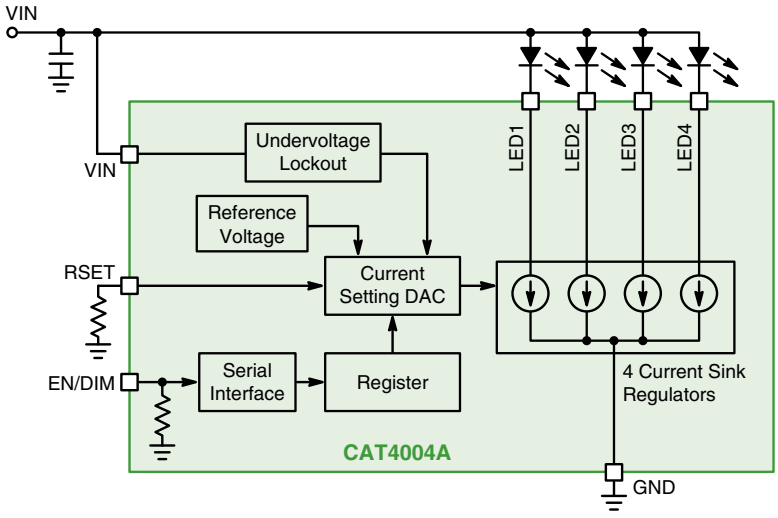
White LED and RGB tricolor LEDs are widely used for backlighting small color LCD panels and keyboards, as well as indicators. High brightness LEDs are used as flash light sources in cell phones and digital cameras. These applications require optimized solutions which can maximize battery lifetime, as 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.



Inductive Boost Topology



Charge Pump Topology

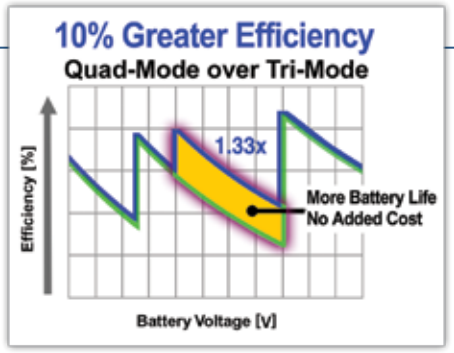


Linear Topology

Charge Pump Architecture with 10% Higher Efficiency

Patented Quad-Mode™ adaptive fractional charge pumps take LED driver performance to a new level by offering a 10% efficiency improvement and up to 65% smaller packaging, without the need for an additional capacitor.

Quad-Mode LED drivers deliver the high efficiency levels normally associated with inductor-based LED drivers, while eliminating the associated high-profile inductors and unwanted EMI. Most charge pump LED drivers offer three modes of operation corresponding to the ratio of the output voltage to the input voltage: 1x, 1.5x and 2x. The Quad-Mode architecture adds a fourth mode of operation, 1.33x, without the need for the additional capacitor required by all other four-mode charge pumps.



Features

- 4 charge pump modes: 1x, 1.33x, 1.5x, 2x
- 10% higher efficiency versus 3-mode charge pumps
- No additional capacitors
- No inductor

Charge Pump / White and RGB LED Drivers – for LCD Backlight, LED Flash/Torch

Device	Input Voltage Range (V)	Number of Outputs	Total Output Current (mA)	Reglation Mode	Charge Pump Operating Mode	LED-LED Current Matching, Typ	Dimming Method	Number of Current Level/ Profile	Operating Quiescent Current, Typ (mA)	Shutdown Current, Typ (µA)	Package	Notes
CAT3606	2.7 - 5.5	6	180	Current	1x / 1.5x	±1.5%	PWM	Depends on System	1	1 µA max	TQFN-16	–
CAT3616	2.7 - 5.5	6	186	Current	1x / 1.5x	±3%	Single Wire	32	0.5	1 µA max	TQFN-16	–
CAT3626	2.7 - 5.5	6	192	Current	1x / 1.5x	±3%	I2C	Depends on System	0.5	1 µA max	TQFN-16	–
CAT3636	2.2 - 5.5	6	192	Current	1x / 1.33x / 1.5x / 2x	±1%	Single Wire	32	0.5	1 µA max	TQFN-16	–
CAT3637	2.2 - 5.5	6	192	Current	1x / 1.33x / 1.5x / 2x	±1%	Single Wire	16	0.5	1 µA max	TQFN-16	–
CAT3604	2.7 - 5.5	4	120	Current	1x / 1.5x	±3%	PWM	Depends on System	0.3	0.05 µA typ	TQFN-16	–
CAT3614	2.7 - 5.5	4	124	Current	1x / 1.5x	±3%	Single Wire	32	0.5	1 µA max	TDFN-12	–
CAT3604V	2.7 - 5.5	4	120	Current	1x / 1.33x / 1.5x / 2x	±1.5%	PWM	Depends on System	1	1 µA max	TQFN-16	–
CAT3644	2.2 - 5.5	4	100	Current	1x / 1.33x / 1.5x / 2x	±1.5%	Single Wire	6	1	1 µA max	TQFN-16	–
CAT3648	2.2 - 5.5	4	100	Current	1x / 1.33x / 1.5x / 2x	±1.5%	Single Wire	32	1	1 µA max	TQFN-16	–
NCP5604A/ B	2.7 - 5.5	3 or 4	100	Current	1X, 1.33X, 1.5X, 2X	±0.2%	PWM	Depends on system	1	0.3 µA typ	WQFN-16	Short circuit protection; OVP
NCP5623	2.7 - 5.5	3 (Independent)	90	Current	1X, 2X	±0.5%	I2C	32/ quasi-log	0.35	0.8 µA typ	LLGA-12	Built-in “Gradual Dimming”; OVP
CAT3603	2.7 - 5.5	3	90	Current	1x / 1.5x	±3%	PWM	Depends on System	0.4	0.1 µA typ	TDFN-12	–
CAT3643	2.2 - 5.5	3	90	Current	1x / 1.33x / 1.5x / 2x	±1.5%	Single Wire	6	1	1 µA max	XQFN-12, TDFN-12, TQFN-16	–
CAT3647	2.2 - 5.5	3	100	Current	1x / 1.33x / 1.5x / 2x	±1.5%	Single Wire	32	1	1 µA max	TQFN-16	–
CAT3612	2.7 - 5.5	2	300	Current	1x / 1.5x	±3%	Single Wire	32	0.5	1 µA max	TDFN-12	–
NCP5612	2.7 - 5.5	2	60	Current	1X, 1.5X	±0.2%	S-Wire Link (Single Wire Serial Link)	16/ linear	0.6	1 µA typ	LLGA-12	Built-in “Icon” mode; OVP; short circuit protection

Charge Pump / White and RGB LED Drivers – for LCD Backlight, LED Flash/Torch (cont.)

Device	Input Voltage Range (V)	Number of Outputs	Total Output Current (mA)	Reglation Mode	Charge Pump Operating Mode	LED-LED Current Matching, Typ	Dimming Method	Number of Current Level/ Profile	Operating Quiescent Current, Typ (mA)	Shutdown Current, Typ (μA)	Package	Notes
NCP5602	2.7 - 5.5	2	60	Current	1X, 1.5X	±0.2%	I2C	16/ linear	0.75	6 μA typ	LLGA-12	Built-in "Icon" mode; OVP; short circuit protection
CAT3661*	2.0-5.5	1	10	Current	1x / 1.33x / 1.5x / 2x	–	–	–	0.13	1 μA max	TQFN–16	Optimized for coin cell applications
NCP5603	2.85 - 5.5	1	350 mA pulse	Voltage	1X, 1.5X, 2X	–	PWM	Depends on system	1	2.5 μA typ	DFN-10	4.5 / 5 V output; short circuit protection
CAT3200	2.7 -4.5	1	100	Voltage	2X	–	PWM	Depends on system	1.7	1 μA typ	TSOT-23-6	2 MHz switching; soft-start; thermal shut down
CAT3200-5	2.7 -4.5	1	100	Voltage	2X	–	PWM	Depends on system	1.7	1 μA typ	MSOP-8	2 MHz switching; soft-start; thermal shut down

* Pending 1H10

Backlighting and Torch

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

Device	Input Voltage Range (V)	Max Output Volt, Typ (V)	Output Current	Condition	Number of LEDs/ Configuration	Swiching Mode/ Frequency	Dimming Method	Efficiency (%)	Operating Quiescent Current, Typ	Shutdown Current, Typ (μA)	Package	Notes
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	Internal synchronous rectification
CAT37	2.5 - 7	20	20	Vout =10.8V	1 to 4 / Series	1.2 MHz	PWM	84	0.5	1	TSOT23–5	LT1937 pinout, Isw = 550 mA
CAT32	2.0 - 7	20	20	Vout =14V	1 to 4 / Series	1.2 MHz	PWM	84	0.5	0.05	TSOT23–6 / TDFN-8	LT1932 pinout, Isw = 550 mA
NCP5010	2.7 - 5.5	22	30	Over 5 LED, Vin 3.3 V	2 to 5/ series	PWM, 1 MHz	PWM	85	400 μA	2	Flip-Chip-8	Isw = 420 mA, Internal rectifier
NCP5050	2.7 - 5.5	22	600	Vout 10 V, Vin 4.2 V	Flash: 2 to 5 in series; Backlight: up to 120 LED in multiple branches	PWM, 1.7 MHz	PWM	88	2 mA	2	TDFN-10	Internal switch between torch & flash current; 1.2 s time-out
CAT4137	2.2 - 5.5	24	40	Vout 17 V, Vin 3.5	1 to 5 / Series	1 MHz	PWM	87	0.4	0.1	TSOT23–5	Isw = 350 mA
CAT4139	2.0 - 5.5	24	50	Vout 14 V, Vin 3.0	1 to 5 / Series	1 MHz	PWM	87	0.6	0.1	TSOT23–5	Isw = 850 mA
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	Isw = 350 mA
CAT4237	2.0 - 5.5	34	30	Vout 30 V, Vin 3.6	1 to 8 / Series	1 MHz	PWM	87	0.6	0.1	TSOT23–5	Isw = 450 mA
CAT4238	2.0 - 5.5	38	20	Vout 33 V, Vin 3.5	1 to 10 / Series	1 MHz	PWM	87	0.6	0.1	TSOT23–5	Isw = 450 mA
CAT4240	2.0 - 5.5	38	250	Vout 30 V, VL 13 V, Vin 5 V	1 to 10 / Series	1 MHz	PWM	87	0.6	0.1	TSOT23–5	Isw = 850 mA

* Typical value based on input and output voltage conditions.

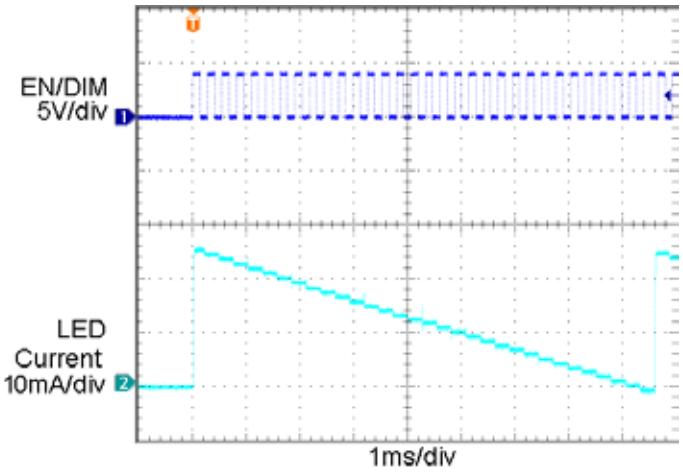
Micro Portable Linear Backlight Drivers

Features

- 32 level of dimming control
- 25 mA fixed or adjustable versions
- Zero current shutdown (< 1 μA)
- No switching supply noise
- Tightly matched current LED sinks
- Ultra-low headroom current sink
- Dropout voltage of 75 mV at 20 mA
- Low profile micro packaging

Applications

- Mobile Handsets
- Still and Video Cameras
- Portable Gaming
- Portable Medical Devices

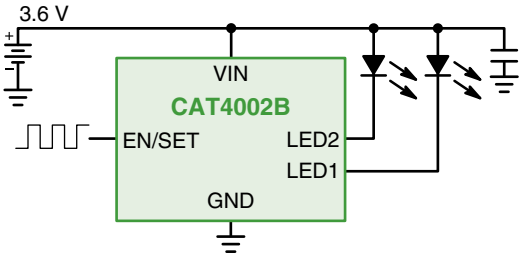


32-Step EZDIM Control

Linear Backlight Drivers

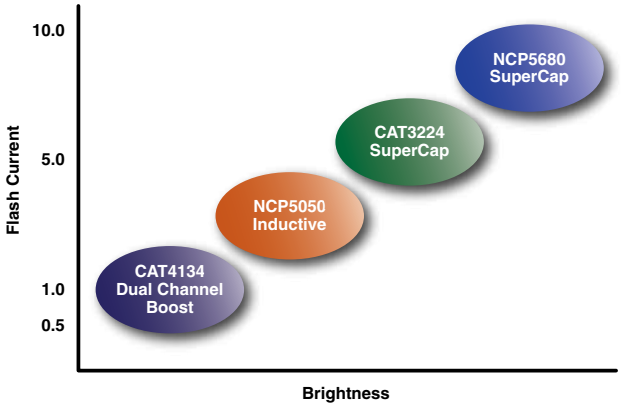
Device	No of Channels	Current		Available Packages		
		Fixed	Adjustable	SCL70-6L	TSOT23-6	UDFN-8
CAT4002A*	2	✔		✔	✔	
CAT4002B*	2		✔	✔	✔	
CAT4003B*	3		✔	✔	✔	
CAT4004A*	4	✔				✔
CAT4004B*	4		✔			✔

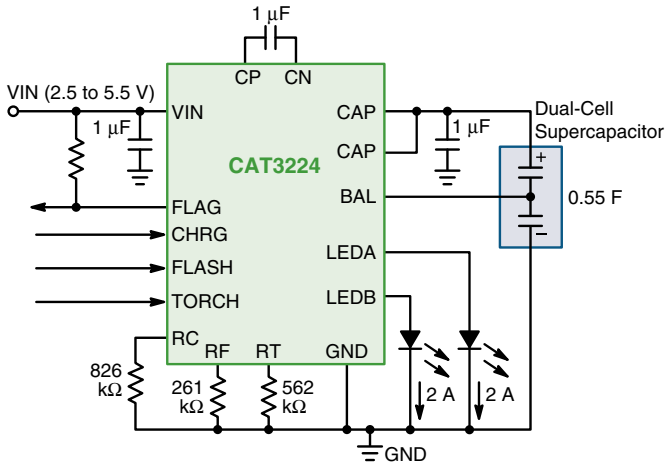
* Pending 1H10



Camera Flash and Torch

LEDs for camera phones, smart phones, and XENON bulb replacement, are scaling up in light output to meet the needs of higher performance camera imagers.





Features

- Provides charging for dual-cell supercapacitors
- Matched output channels

Camera Flash and Torch

Device	Topology	Input Voltage Range (V)	Output Current	Output	Package
NCP5680	Charge Pump	2.7 - 5.5	10 A flash, 200 mA torch	2 channels	µQFN-24
CAT3224	Charge Pump	2.5 - 5.5	4 A flash; 400 mA torch	2 channels	TQFN-16
NCP5050	Inductive Boost	2.7 - 5.5	600 mA	Flash: 2 to 5 in series	TDFN-10
CAT4134	Step-up Boost	2.0 - 5.5	500 mA	2 x 3 LEDs	TDFN-12

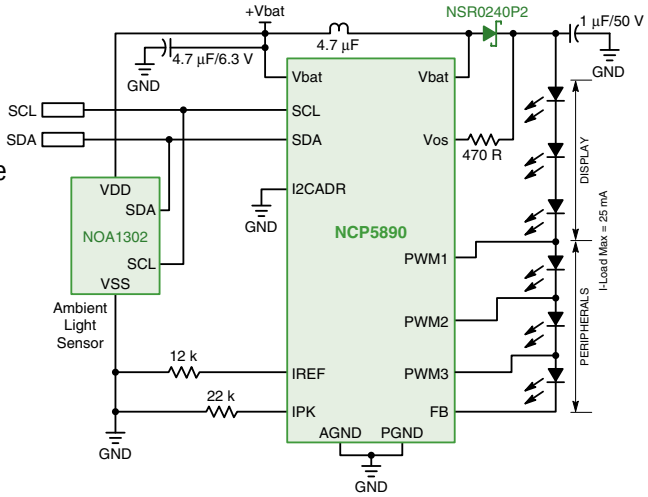
Integrated LCD Backlighting and Indicator Controller – NCP5890

Features

- I²C interface
- Gradual dimming control
- Ambient light sensor
- >90% efficiency
- ±1% current LED accuracy
- 30 V maximum string voltage
- 3 segment PWM control
- 1.3 MHz operation

Applications

- Smartphones
- Portable medical devices
- Video and still cameras
- Personal navigation systems
- Portable gaming
- Educational toys



Coin Cell Optimized LED Driver – CAT3661*

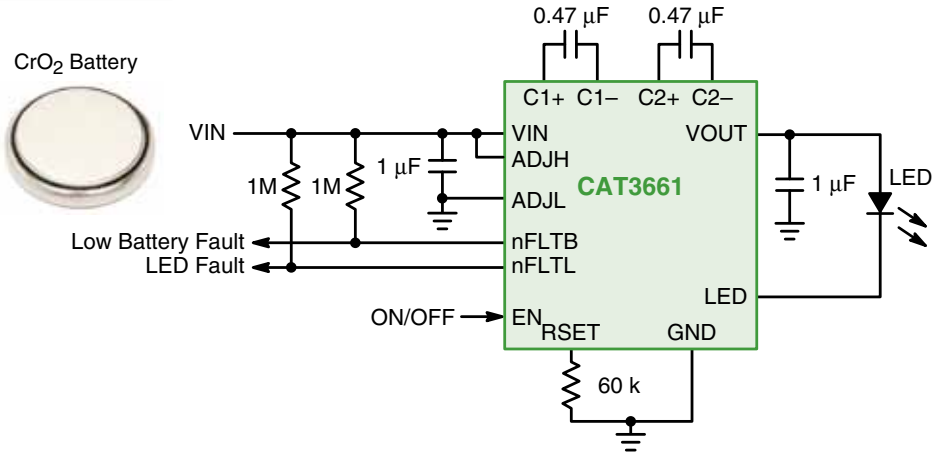
Innovative portable devices are now powered from coin cells. Due to the unique characteristics of these batteries and the need for long lifetime operation, it is important to have an LED backlight driver tailor-made for these compact applications that not only manages the backlighting but also the battery monitoring.

Features

- 2 – 5.5 V Single LED Driver
- Quad Mode Charge Pump Architecture
- Driver Efficiency up to 92%
- Low quiescent current
- Robust LED Fault Monitoring
- Soft start and short circuit limiting
- Adjustable Low Battery Detect
- Low profile 3 x 3 mm TQFN-16 package

Applications

- Glucose Meters
- Digital Thermometers
- Pulse Oximeters
- Breath Analyzers
- Biometric Monitors



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CONTROL

Intelligent LED Control for Signage and Architectural Lighting

Two widely used applications for LEDs are addressable signage and architectural lighting, which utilize the wide range of available LED colors and their long operating lifetime. In architectural lighting, the use of LEDs allows vivid colors in lighting facades and enhancement of structural details. In moving signage applications, information can be updated in real time traffic displays, video images, and advertising. ON Semiconductor offers a series of linear solutions that can accurately regulate LED current and have programmable interfaces to allow software control.

LED Controllers

Device	Vin (V)	LEDs	Iout per Channel (mA)	Dropout Voltage (mV)	Shutdown Current Max (μA)	Dimming Interface	Features	Packages	Architectural	Signage
CAT310	5.5	10	50	–	–	4-Wire	–	SOIC-20		
CAT4008	3.0 - 5.5	8	100	300 @ 30 mA	1	4-Wire	Thermal Shutdown; UVLO	SOIC-16, TSSOP-16		✔
CAT4016	3.0 - 5.5	16	100	400 @ 30 mA	1	4-Wire	Thermal Shutdown; UVLO	QSOP-24, SOIC-24, TQFN-24, TSSOP-24		✔
CAT4101	3.0 - 5.5/25	8	1000	500 @ 1 A	1	PWM	Thermal Shutdown; UVLO	TO-263-5	✔	
CAT4103	3.0 - 5.5/25	8 x 3	175	400 @ 175 mA	1	4-Wire	3 Independent Current Sinks; Cascadable	SOIC-16	✔	
CAT4104	3.0 - 5.5/25	8 x 4	175	400 @ 175 mA	1	PWM	Thermal Shutdown; UVLO	SOIC-8, TQFN-8	✔	
CAT4109	3.0 - 5.5/25	8 x 3	175	400 @ 175 mA	5	PWM	3 Independent Current Sinks	SOIC-16	✔	

8 and 16 Channel Constant Current LED Sink Drivers

Features

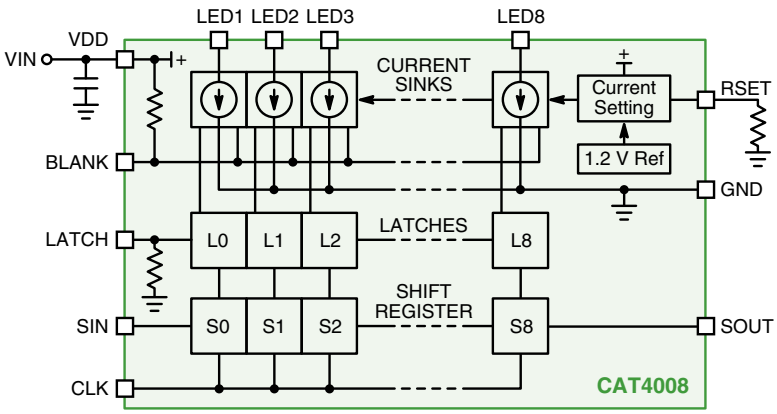
- ±1.5% typical channel matching
- Up to 100 mA drive per channel
- 300 mV dropout at 30 mA
- Robust protection (UVLO, thermal shutdown)
- Cascadable 25 MHz capable 4-wire data interface

Applications

- Intelligent vehicle signs
- Scrolling banners
- Billboard signs
- Marque signs
- Gaming and pachinko
- Sports scoreboards

Resources

- Evaluation Board



3-Channel Cascade-Capable Driver with Independent Current Control – CAT4103

Features

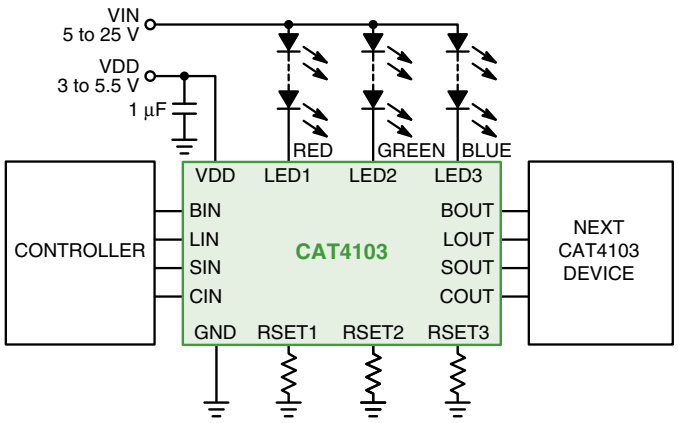
- Up to 25 V per string
- Robust protection (UVLO, thermal shutdown)
- RGB Drivers can be individually controlled or cascaded
- Drivers to support currents of up to 175 mA per channel

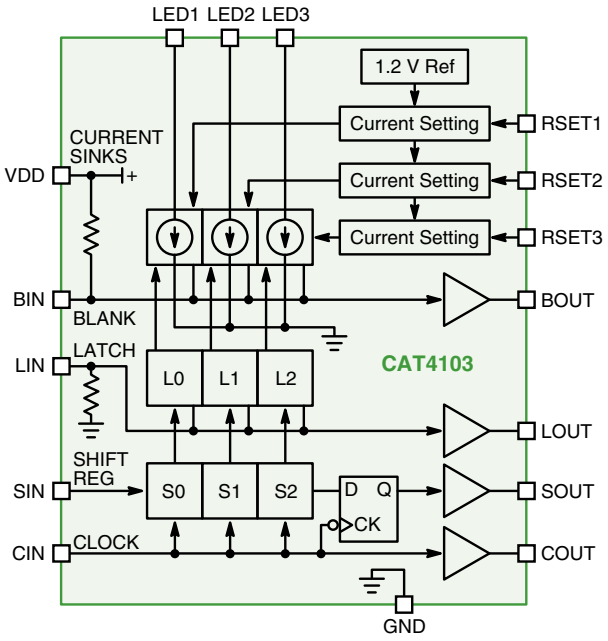
Applications

- Accent lighting
- Color mixing
- Effects lighting
- Mood lighting

Resources

- Evaluation Board

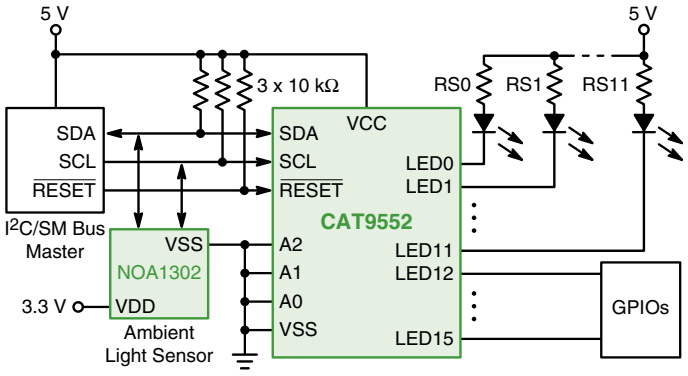




16-Channel I²C LED Indicator Driver and Port Expander – CAT9532 and CAT9552

Features

- 16 LED drivers with dimming control
- 256 brightness steps
- 16 open drain outputs drive 25 mA each
- Programmable blink rates
- I/Os can be used as general purpose I/Os
- 400 kHz I²C bus compatible
- 8 address expansion selections



Applications

- Single board computers
- Telecom equipment
- Office machines
- Appliance control panels
- Gaming
- Alarm systems
- Point of sale displays

MID-VOLTAGE

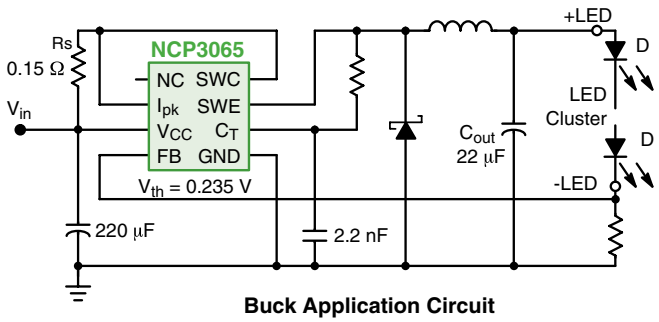
Mid-Voltage LED Drivers

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 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 driver solution.

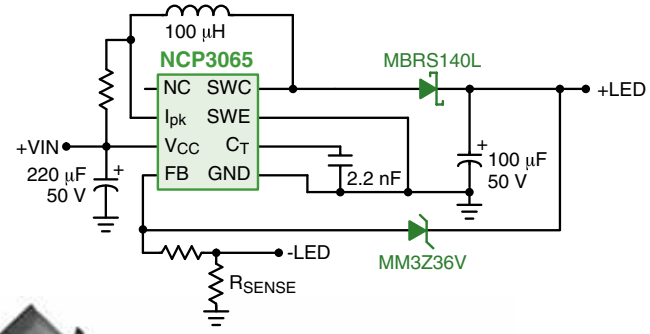
Applications

- 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

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



Buck Application Circuit

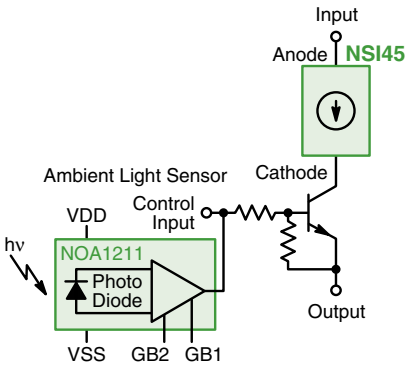


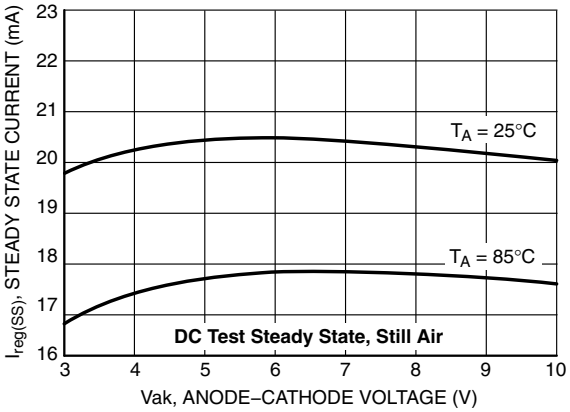
Boost Application Circuit

Linear Driver Solutions

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 drivers are linear, they must be matched to the power dissipation requirements of the application. ON Semiconductor offers a wide range of linear driver solutions that span the current range from 10 mA to 1 A.

Constant Current Regulators – Dimming with External BRT

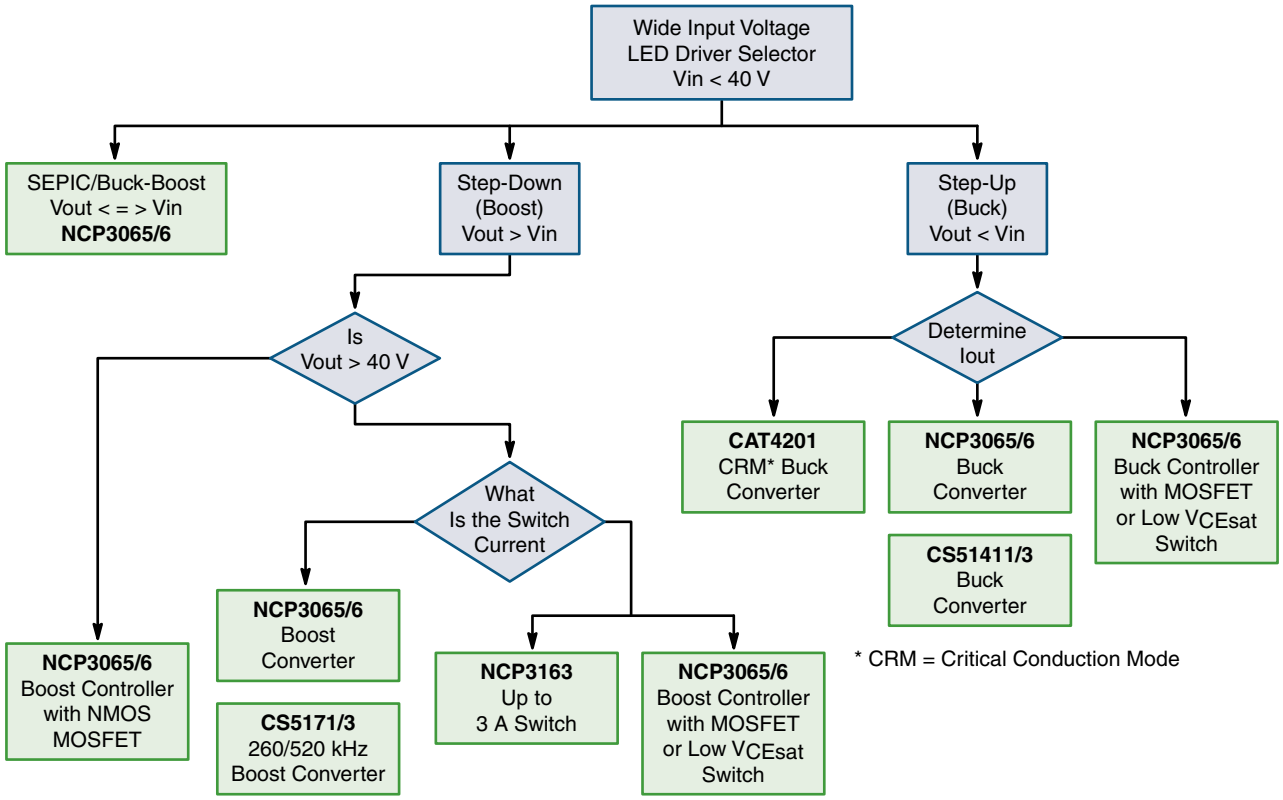




Device	Operating Voltage Range (V)	Channel Output Current (mA)	Typical Current Tolerance	Number of Channels	Adjustable	Dimming Control	Typical Dropout	Operating Temperature Range (°C)	Package(s)	Features
CAT4004	2.4 - 5.5	25	±1%	4	Y	Single-Wire	130 mV @ 30 mA	–40 to +85	TDFN-8	Thermal Shutdown, UVLO
CAT4101	3.0 - 25	1000	±2%	1	Y	PWM	500 mV @ 1000 mA	–40 to +85	D2PAK	Thermal Shutdown, UVLO
CAT4104	3.0 - 25	175	±2%	4	Y	PWM	400 mV @ 175 mA	–40 to +85	SOIC-8, TDFN-8	Thermal Shutdown, UVLO
NCV7680	6 - 16	35	±10% @ 35 mA	8	Y	Ext	1.0 V	–40 to +125	SOIC-16 EP	AEC-101 Qualified
NSI45010	1.8 - 45	10	±20%	1	N	Ext	1.8 V	–40 to +125	SOD-123	AEC-101 Qualified
NSI45020	1.8 - 45	20	±10%, ±15%	1	N	Ext	1.8 V	–40 to +125	SOD-123	AEC-101 Qualified
NSI45025	1.8 - 45	25	±10%, ±15%	1	N	Ext	1.8 V	–40 to +125	SOD-123, SOT-223	AEC-101 Qualified
NSI45030	1.8 - 45	30	±10%, ±15%	1	N	Ext	1.8 V	–40 to +125	SOD-123, SOT-223	AEC-101 Qualified
NSI45020D*	1.8 - 45	20 - 40	±10%	1	Y	Ext	1.8 V	–40 to +125	SOT-223	AEC-101 Qualified
NSI45035D*	1.8 - 45	35 - 70	±10%	1	Y	Ext	1.8 V	–40 to +125	SOT-223	AEC-101 Qualified
NSI45060D*	1.8 - 45	60 - 120	±10%	1	Y	Ext	1.8 V	–40 to +125	DPAK	AEC-101 Qualified
NSI45090D*	1.8 - 45	90 - 160	±10%	1	Y	Ext	1.8 V	–40 to +125	DPAK	AEC-101 Qualified
NUD4001	2 - 30 (60 V Surge)	500	±3%	1	Y	Ext	1.4 V	–40 to +125	SOIC-8	Linear controller
NUD4011	5 - 200	70	±3%	1	Y	Ext	5 V	–40 to +125	SOIC-8	Linear controller

* Pending 1H10

Switching Driver Solutions



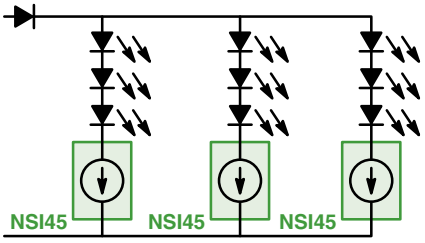
Device	f_{SW} Typ (kHz)	Topology	V_{in} Range (V)	Switch Current (A)[1]	Controller	Automotive Option	Packages
NCP3065	Up to 200	Buck, Boost, Buck/Boost	3.0 - 40	1.5	*	✔	SOIC-8, DFN-8, PDIP-8
NCP3066	250	Buck, Boost, Buck/Boost	3.0 - 40	1.5	*	✔	SOIC-8, DFN-8, PDIP-8
NCP3163	Up to 200	Buck, Boost, Buck/Boost	2.5 - 40	3.4			SOIC-16, DFN-16
MC33163	Up to 50	Buck, Boost, Buck/Boost	2.5 - 40	3.4			SOIC-16
CS51411/3	260 / 520	Buck	4.5 - 40	1.5		✔	SOIC-8, DFN-8
CAT4201	50 - 1000	Buck	7.0 - 36	0.7			TSOT-23-5
NCP1034	Up to 500	Buck	8.0 - 100	–	✔		SOIC-16
CS5171/3	280 / 560	Step-up or SEPIC	2.7 - 30	1.5			SOIC-8
NCP1294	1000	Buck, Boost, Buck/Boost	3.3 - 72	–	✔		TSSOP-16, SOIC-16

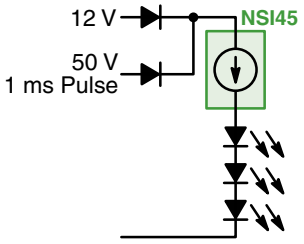
1 For switching regulators, this current is used to calculate LED current based on Vin and Vout conditions. * Can be configured as a controller.

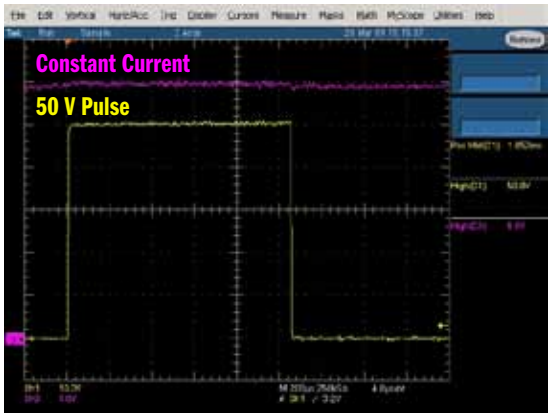
Constant Current Regulators for Automotive Center High Mount Stop Lamp – NSI45xx Series

Features

- Regulated current provides constant brightness over wide voltage range
- Negative temperature coefficient protects LEDs in high ambient conditions
- 45 V maximum operating voltage withstands battery load dump



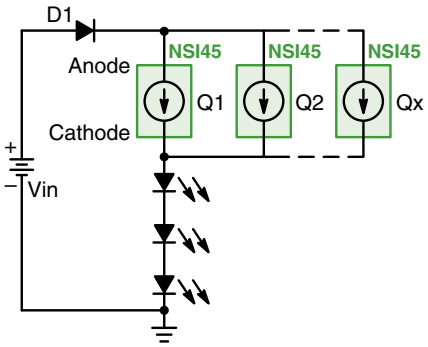


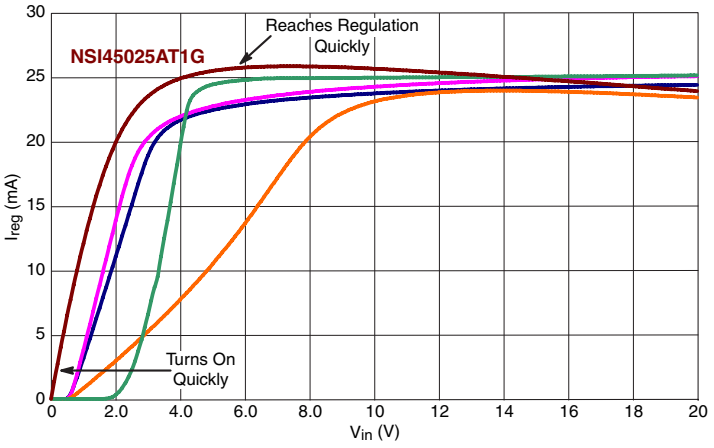


Constant Current Regulator Signage Drivers for Displays and Channel Letters – NSI45xx Series

Features

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



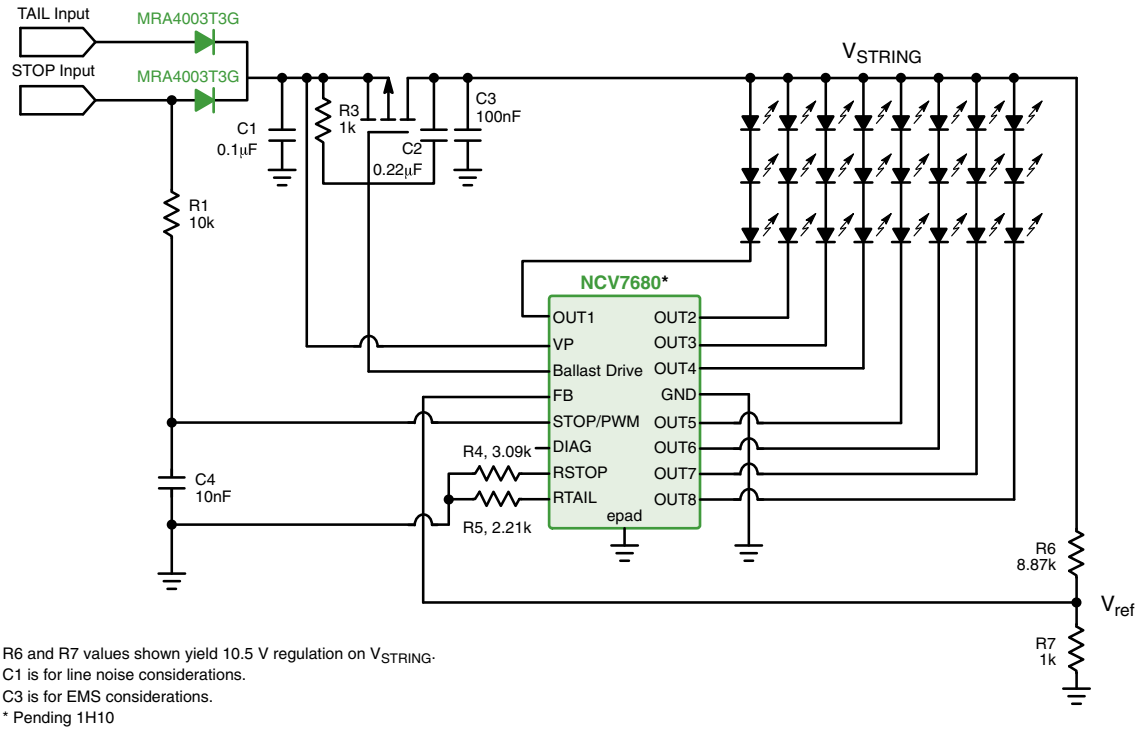


NSI45025 vs Competing Devices @ 25 mA

Linear Current Regulator and Controller for Automotive LED Rear Combination Lamps

Features

- Constant current outputs for LED string drive
- Open LED string diagnostic with open−drain output
- Slew rate control eliminates EMI concerns
- Low drop-out operation for pre−regulator applications
- External modulation capable
- On−chip 1 kHz tail PWM dimming
- Single resistor for stop current set point
- Single resistor for tail dimming set point
- Over-voltage and over-temperature set back power limitation
- SO-16 EP Package



R6 and R7 values shown yield 10.5 V regulation on V_{STRING}.
C1 is for line noise considerations.
C3 is for EMS considerations.
* Pending 1H10

Application Diagram with External FET Ballast Transistor

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 ZENIGATA™, Cree XLamp™ MC-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

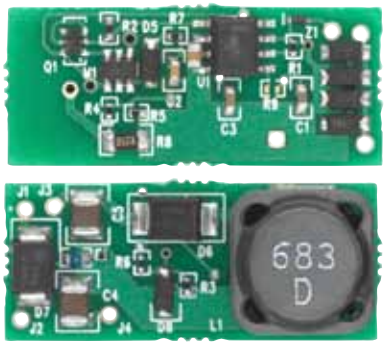
Applications

- MR16 bulbs
- Landscape lighting
- Transportation lighting

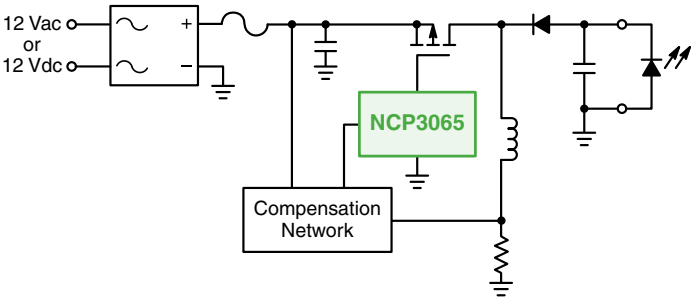
Resources

- Design Note DN06048/D

Sharp ZENIGATA LED Module

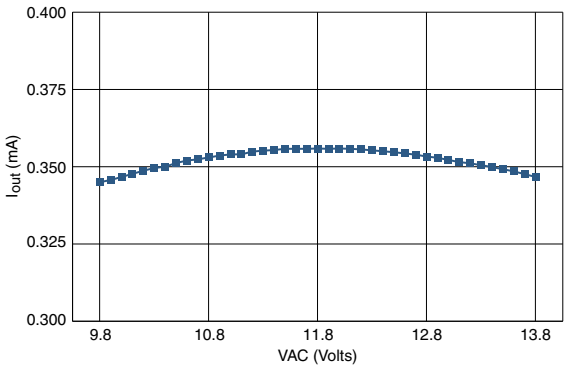


Reference Design Demo Board
0.457" x 1.148" (11 mm x 29 mm)



Reference Design Block Diagram

Cree XLamp MC-E LED



I_{out} versus Vac Input

MR16 LED Module

MID-VOLTAGE

Compact 350 mA Buck LED Driver – CAT4201

Features

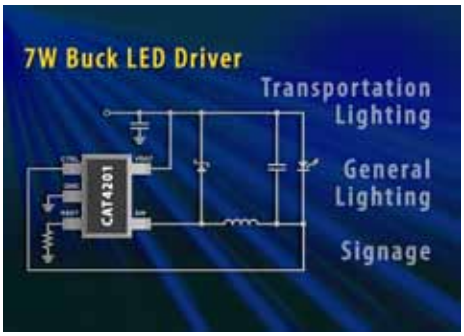
- Reduces system complexity
- Patented average current regulation architecture
- Drives up to 7 LEDs in series from 24 V
- Handles transients up to 40 V
- Power efficiency >94%
- Current limit and thermal protection
- Open LED protection
- Thin SOT-23-5

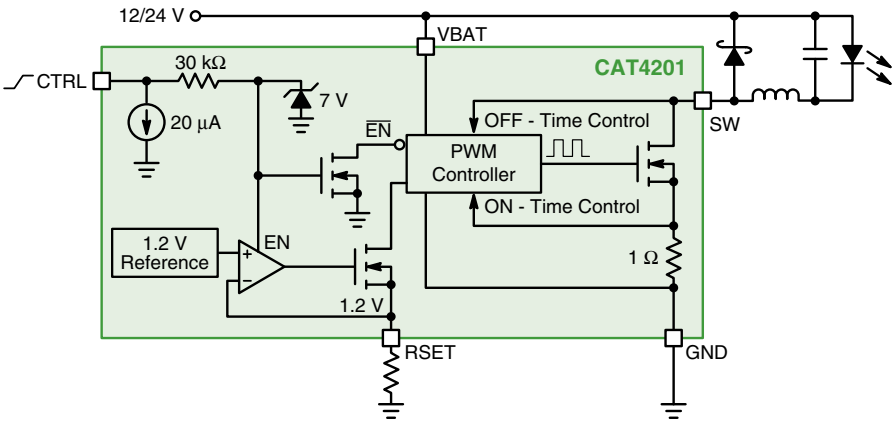
Applications

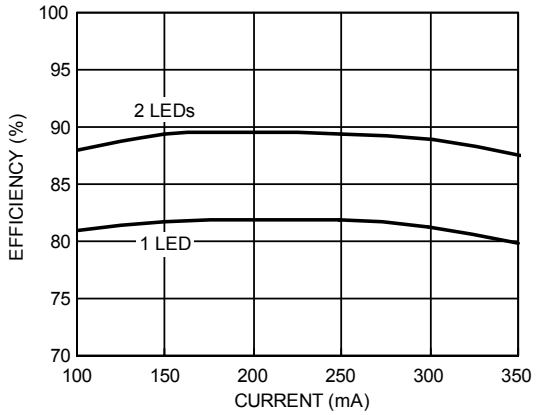
- MR16 bulbs
- Light bars
- Architectural lighting
- Transportation lighting
- Signage
- Solar powered lighting

Resources

- Evaluation Board







Efficiency vs LED Current

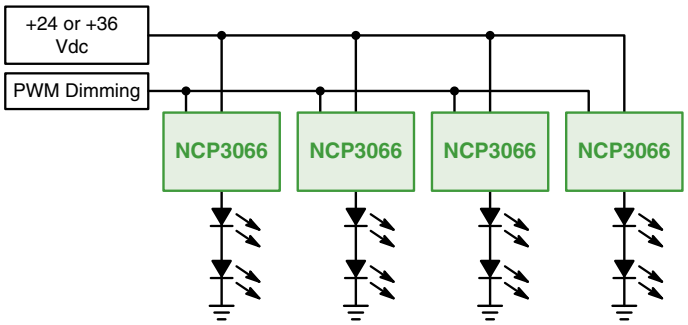
Design for General Illumination – NCP3066

Features

- LED drive current up to 3 A
- External switch to increase current
- Dedicated dimming pin
- Cap-less output option
- 300:1 dimming range

Resources

- Evaluation Board NCP3066S3BCKGEVB



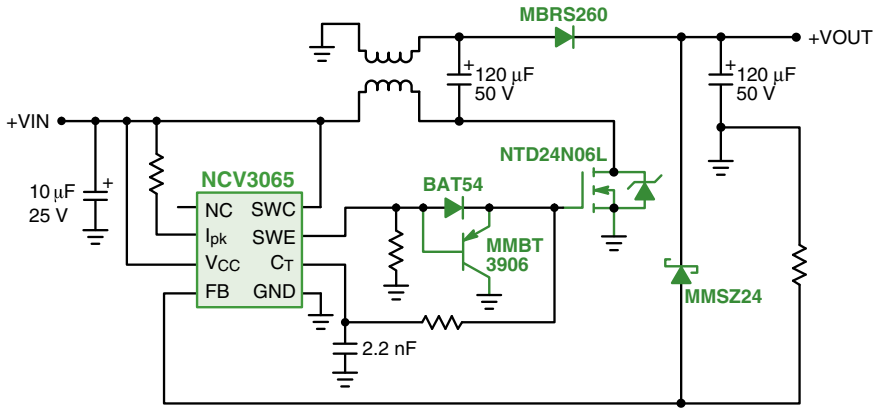
Design for Automotive LED Driver – NCV3065

Features

- LED drive current up to 700 mA
- External switch to improve efficiency
- PWM and analog dimming
- Handles transients up to 40 V
- AEC-Q100 Qualified

Resources

- Evaluation Board NCP3065D3SLDGEVB



SEPIC Application Circuit

Design Resources for NCP3066 and NCP/NCV3065 Series

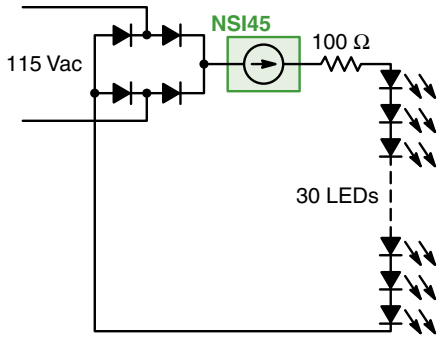
NCP3066DFSEPGEVB
SEPIC Evaluation Board

Application	Device	Evaluation Board	Design Note
Buck <3 A	NCP3065	NCP30653ABCKGEV	-
SEPIC MR16 <1 A	NCP3065	NCP3065D1SLDGEVB	DN06033/D
SEPIC MR16 <1 A	NCP3066	NCP3066DFSEPGEVB	-
Boost <1 A	NCP3066	NCP3066SCBSTGEVB	-
SEPIC <700 mA (Auto)	NCV3065	NCP3065D3SLDGEVB	DN06031/D
Buck/Boost MR16 <650 mA	NCP3065	-	DN06048/D
General	NCP3065, NCP3066	Application Note AND8298/D	
General	NCP3065	Design Worksheet 'NCP3065 DWS.XLS'	
General	NCP3066	Design Worksheet 'NCP3066 DWS.XLS'	

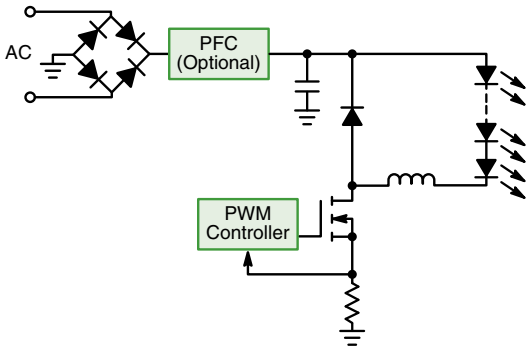
AC-DC

AC Line Powered LED Drivers

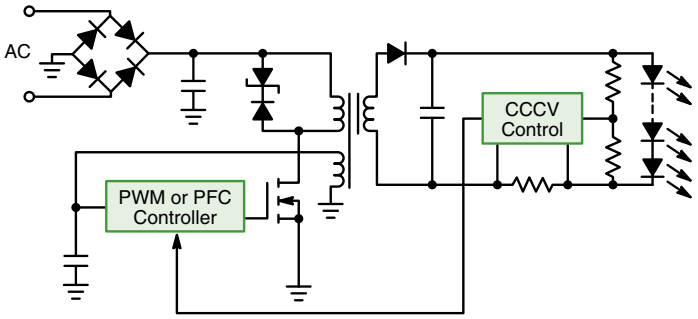
There are numerous topologies for driving LEDs off the AC mains, depending on the requirements of the application (size, efficiency, power factor, power delivered, drive current). Fortunately, ON Semiconductor provides a wide range of power solutions, whether the application is a 5 W LED under-cabinet light or a 150 W LED streetlight.



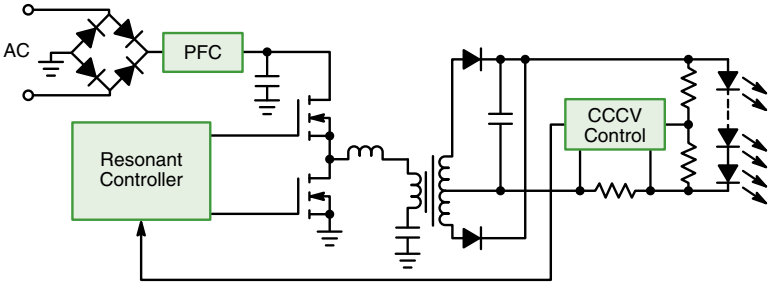
Non-Isolated Linear Driver



Non-Isolated Buck Driver

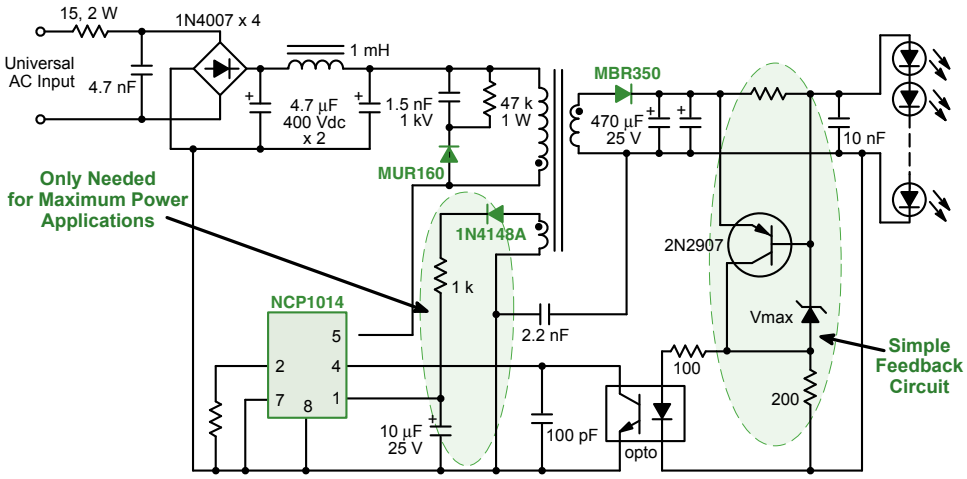


Single-Stage Flyback LED Driver



Dual-Stage Power Factor Corrected Isolated LED Driver

Switching Regulators & Controllers for AC-DC



NCP1014 Configured as a Constant Current Isolated Offline LED Driver

For applications of less than 25 W (230 Vac), an integrated power switching regulator is most often used as it minimizes total parts count in a design. Above that power range, controllers can be used that offer the designer flexibility in selecting the high voltage FET that is most suitable for the application. The controllers can be used in isolated or non-isolated applications and ON Semiconductor offers a variety of different value added features to allow the designer to optimize their design to their specific system requirements.

PWM Method	Device	Control Mode	Switching Frequency (kHz)	Frequency Jittering (%)	HV Startup	Dynamic Self Supply	Short Circuit Protection	Brown-Out Protection	Over Voltage Protection	Soft Start (ms)	Drive Capability Source/Sink (mA)	Temperature (°C)	Package(s)	Comments
Fixed Frequency	NCP1200	Current	40, 60, 100	±0.7	✔	✔	✔[1]				250 / 250	-25 to +125	SOIC-8, PDIP-8	–
	NCP1203	Current	40, 60, 100		✔						250	-40 to +125	SOIC-8, PDIP-8	–
	NCP1216/A	Current	65, 100, 133	±4	✔	✔	✔[1]			1.0[2]	500	0 to +125	SOIC-8, PDIP-7	Limited duty cycle to 50%[2]
	NCP1217/A	Current	65, 100, 133		✔				✔	1.0[2]	500	0 to +125	SOIC-8, PDIP-7	Limited duty cycle to 50%[2]
	NCP1219	Current	65, 100	±7.5	✔	✔	✔[1]			4.8	500 / 800	-40 to +125	SOIC-7	Adjustable Max duty cycle, ±5% current sense accuracy
	NCP1230	Current	100	±6.4	✔		✔		✔	2.5	500 / 800	-40 to +125	SOIC-8, PDIP-7	–
	NCP1271	Current	65, 100	±7.5	✔		✔		✔	4	500 / 800	-40 to +125	SOIC-7	–

PWM Method	Device	Control Mode	Frequency Clamp Max ON Time (µs)	Frequency Clamp Min OFF Time (µs)	HV Startup	Dynamic Self Supply	Short Circuit Protection	Brown-Out Protection	Over Voltage Protection	Soft Start (ms)	Drive Capability Source/Sink (mA)	Temperature (°C)	Package(s)	Comments
Quasi Resonant	NCP1207A	Current	NO	8	✔	✔	✔		✔	1	500 / 500	-40 to +125	SOIC-8, PDIP-8	–
	NCP1308	Current	NO	10	✔	✔	✔		✔	1	500 / 500	0 to +125	SOIC-8	–
	NCP1337	Current	67	35	✔	✔	✔	✔	✔	4	500 / 500	0 to +125	SOIC-8, PDIP-7	Brown out protection
	NCP1351	Current	Fixed Ton	Variable			✔				300 / 150	0 to +125	SOIC-8, PDIP-8	Dedicated LED driver reference design
	NCP1377	Current	NO	3, 8	✔				✔	1	500 / 500	0 to +125	SOIC-7, PDIP-7	–

PWM Method	Device	Control Mode	Switching Frequency (kHz)	HV Startup	Dynamic Self Supply	Short Circuit Protection	Brown-Out Protection	Over Voltage Protection	Soft Start	Thermal Shutdown	Temperature (°C)	Package(s)	Comments
Resonant Half Bridge	NCP1392/3	Voltage	Adjustable to 250	✔	✔	✔	✔	✔	✔	✔	-40 to +125	SOIC-8	Fixed dead time options, PFC okay, 100 ms startup timer
	NCP1395	Voltage	Adjustable to 250	✔		✔	✔	✔	✔	✔	-40 to +125	SOIC-16, PDIP-16	Adjustable dead time
	NCP1396	Voltage	Adjustable to 250	✔	✔	✔	✔	✔	✔	✔	-40 to +125	SOIC-16, PDIP-16	–
	NCP1397	Voltage	Adjustable to 250	✔	✔	✔	✔	✔	✔	✔	-40 to +125	SOIC-16	Enhanced soft start, dual level current protection

1. When DSS is used. 2. 'A' Version.

Power Factor Correction for AC-DC

Device	Topology	Conduction Mode	Control	HV Start-up	Overvolage Protection	Undervoltage Protection	Current Limit	Power Limit	Brown Out	PFC Okay	In-Rush Detect	Package(s)	Notes
NCP1601	Boost	Critical/Discontinuous	Fixed Frequency Voltage		✔	✔	✔				✔	SOIC-8, PDIP-8	
NCP1605	Boost	Critical/Discontinuous	Current	✔	✔	✔	✔		✔	✔	✔	SOIC-16	
NCP1606	Boost	Critical	Voltage		✔	✔	✔					SOIC-8	
NCP1607	Boost	Critical	Voltage		✔	✔	✔					SOIC-8	Enhanced fault protection
NCP1608	Boost	Critical	Voltage		✔	✔	✔					SOIC-8, PDIP-8	Wide dynamic power range
NCP1631	Boost	Interleaf FC-CrM[1]	Voltage		✔	✔	✔		✔	✔		SOIC-8, PDIP-8	Interleaf operation
NCP1653	Boost	Continuous Current	Average Current		✔	✔	✔	✔			✔	SOIC-8, PDIP-8	67/100 kHz versions
NCP1654	Boost	Continuous Current	Average Current		✔	✔	✔	✔	✔		✔	SOIC-8, PDIP-8	65/133/200 kHz versions
NCP1652A	1-Stage Flyback	Continuous Current	Average Current	✔		✔	✔	✔	✔			SOIC-16	Active clamp option
NCL30000	1-Stage Flyback/ Buck	Critical	Average Current		✔	✔	✔					SOIC-8	
NCL30001*	1-Stage Flyback	Continuous Current	Average Current	✔		✔	✔	✔	✔			SOIC-16	

1. Frequency clamped Critical Conduction mode. Note: All devices have a temperature range of –40 to +125 °C. * Pending 1H10

Constant Current, Constant Voltage References

Device	$V_{(BR)}$ Typ (V)	Tolerance (%)	I_Q Typ (mA)	I_R Min (μA)	V_{CC} Max (V)	Package
NCP4300A	2.6	1	–	80	36	SOIC-8
NCS1002	2.5	0.4	0.4	75	36	SOIC-8

Resources

- Application Note AND8395/D

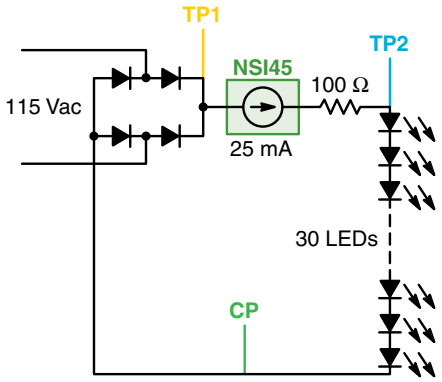
Low Current LED String Driver – NSI45025

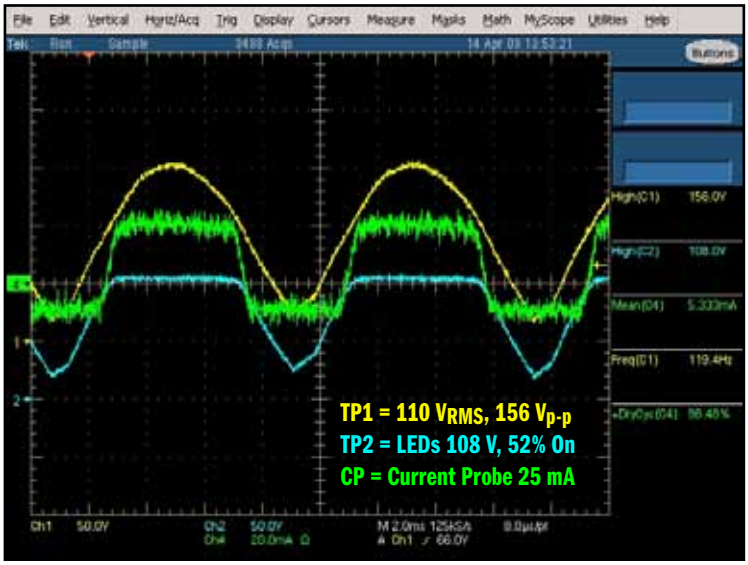
Features

- Constant current as AC voltage increases
- No delay in turn on after LED threshold voltage is reached
- Bright LEDs at low voltages
- LEDs protected from voltage surge

Applications

- LED light bulbs
- Rope lights
- Cove lighting
- Accent lighting
- Under-cabinet lighting





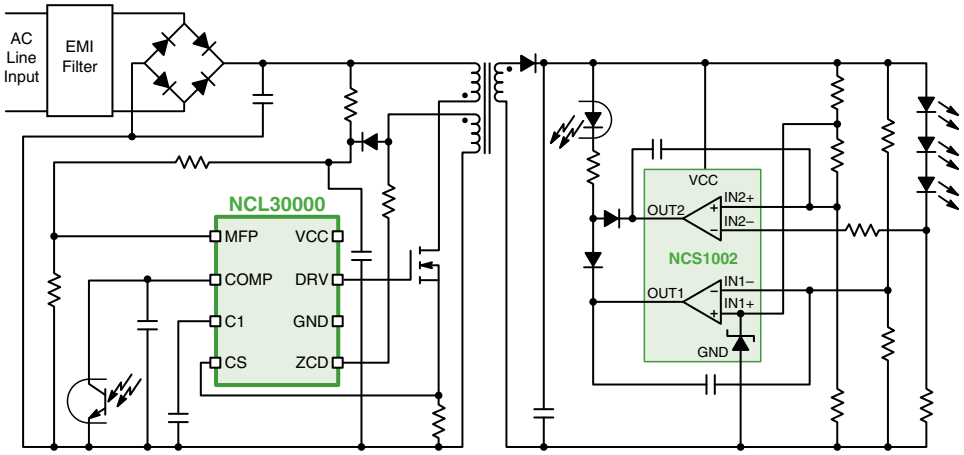
Power Factor Corrected Triac-Dimmable Driver – NCL30000

Features

- CRM flyback topology
- Scalable controller based architecture
- Efficiency > 83%
- PFC > 0.9
- Triac and trailing edge dimmable

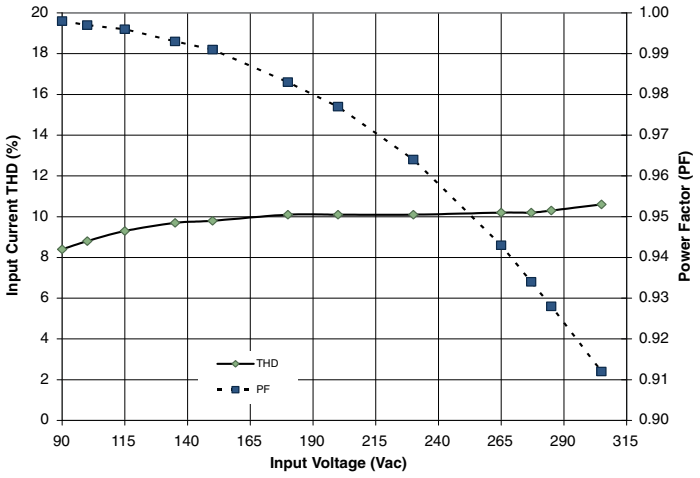
Applications

- Down lights
- LED par bulbs
- Low bay lighting
- LED power supplies

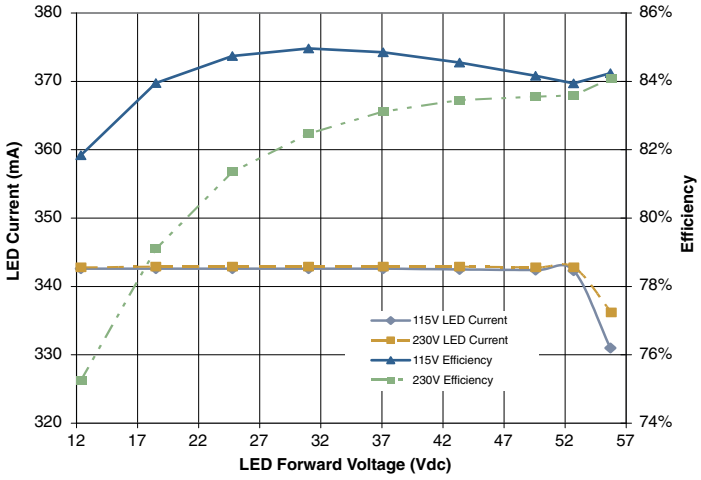


Resources

- Application Notes AND8448/D and AND8451/D
- Evaluation Boards NCL30000LED1GEVB, NCL30000LED2GEVB, and NCL30000LED3GEVB



THD and Power Factor with 36.9 V Load



LED Current and Efficiency at 115 and 230 Vac

NCL30000 Evaluation Board

Up to 8 W LED Driver Reference Design for ENERGY STAR® Residential Lighting

Features

- Isolated flyback, power limited to 8 W
- Power factor > 0.8 @ 115 Vac
- Wide input and output operation voltage: 350 – 1000 mA
- Regulated output current
- Open LED protection
- Output short circuit protection
- Linear dimming control

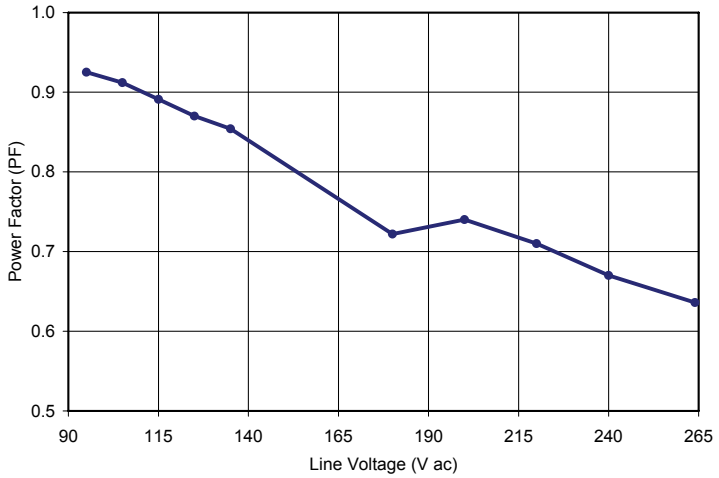
Applications

- Desk lamps
- Under-cabinet lighting
- Step lighting
- Pendant lights

Resources

- Design Note DN06051/D
- Evaluation Board

This circuit has been specifically optimized to meet the DOE ENERGY STAR SSL Luminaire requirements for residential lighting applications, which require a minimum power factor of 0.7.



Non-Isolated Offline Buck Controller – NCP1216

Features

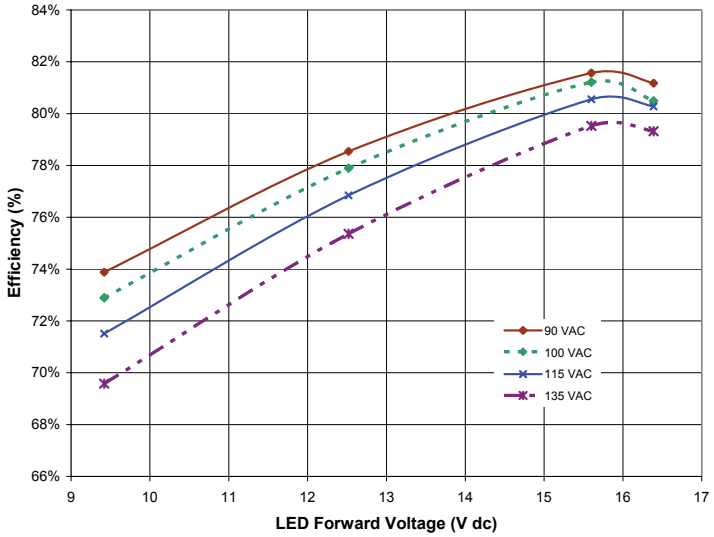
- Peak current control buck
- Scalable controller based architecture
- Dynamic self supply from AC mains
- Fixed frequency with EMI jittering
- Efficiency > 80%
- Exceeds EMI norms

Applications

- Wall sconces
- Task lighting
- Step lighting
- LED bulb replacements

Resources

- Design Note DN06050/D



LED Power Supply for Street and Area Lighting

Generating the light needed to replace an HID or HPS lamp requires a large array of LEDs. LEDs can be configured in various arrangements depending on the end product. One approach converts the AC input into a regulated DC output voltage that powers multiple parallel LED strips. This is illustrated in application note AND8394, where the NCP1652A is used to convert 90-265 Vac into 48 Vdc in a single power factor corrected flyback power supply. The other approach, illustrated with the NCL30001, provides a regulated constant current to drive the LEDs directly, thus eliminating the linear or DC-DC conversion stage built in to the light strips.

Features

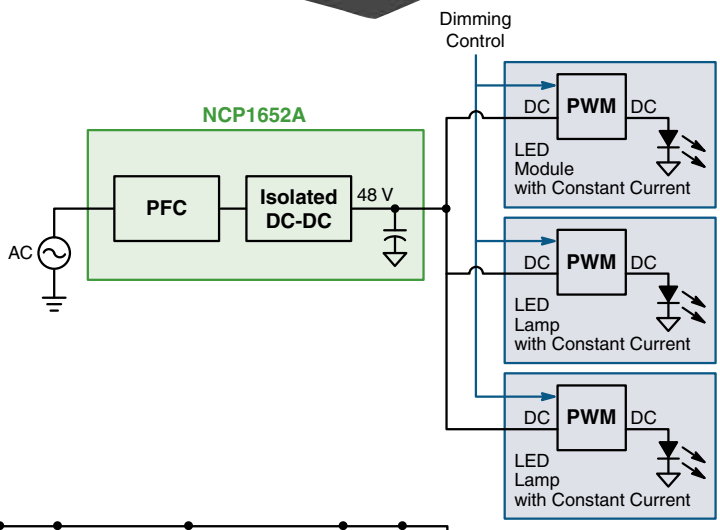
- Single stage power factor correction
- Adjustable fixed frequency with EMI jittering
- Brownout detector
- Optional latched input for OTP and OVP
- Efficiency >87%

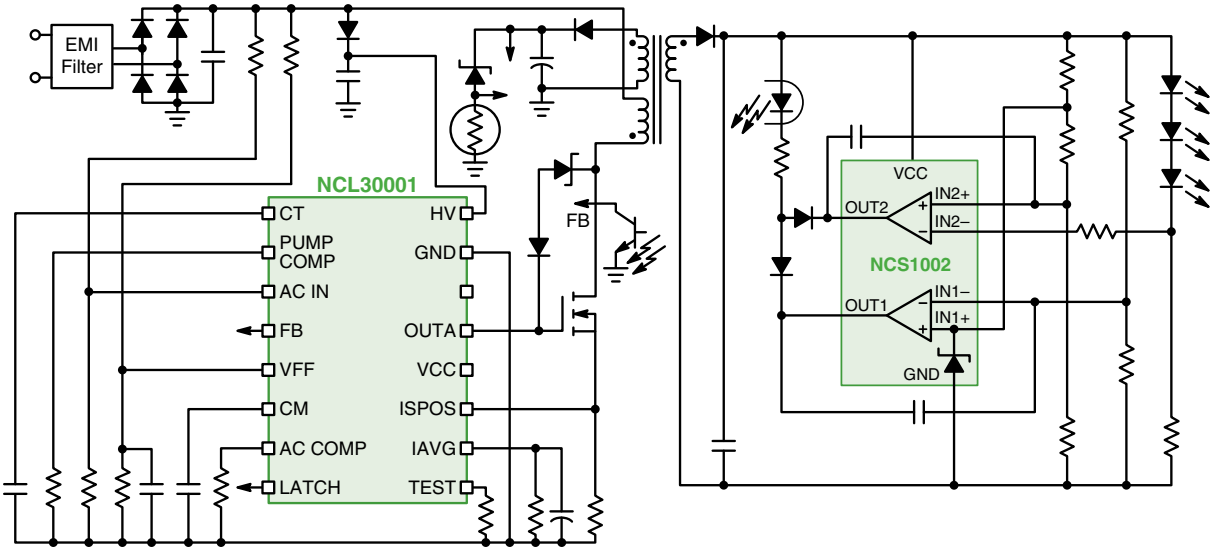
Applications

- Parking lights
- Wall packs
- Street lighting
- Architectural lighting

Resources

- Application Note AND8394/D





NCL30001 Application Diagram

LED String Protection – NUD4700

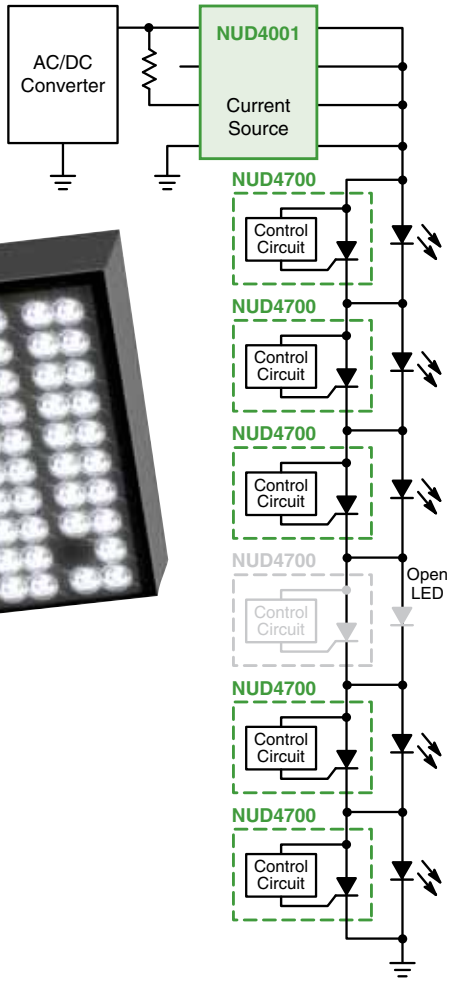
The preferred method of driving LEDs is to have them in strings so that the currents are all matched for equal brightness. While LEDs are highly reliable, if any single LED were to fail open, the whole string would be turned off. This is not an acceptable option in important lighting applications such as street lighting. To address this need, ON Semiconductor provides the NUD4700 LED current bypass protector. The NUD4700 is an electronic shunt that provides a current bypass, in the case where a single LED within an LED string goes into open circuit. This ensures that an entire string of LEDs will not be extinguished should one LED fail.

Features

- SCR crowbar operation
- Automatically resets if the LED heals or is replaced
- Low leakage when LED operating: ~100 μA
- Shunt path activates when LED open: ~1.0 V drop

Applications

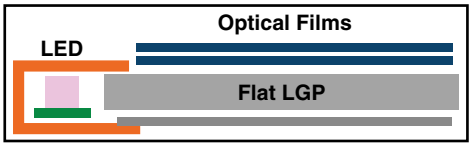
- Street lights
- Tunnel lighting
- Architectural lighting
- High bay lighting

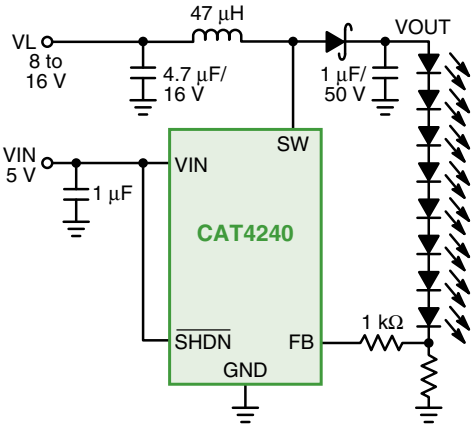


BACKLIGHTING

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.





Device	Topology	V_{IN} (V)	LEDs	Total I_{OUT} Max (mA)	I_{SW-LIM} (mA)	V_{OUT} Max (V)	Dimming Interface	Package(s)
CAT4237	Inductive Boost	2.0 - 5.5	8	40	450	32	PWM	TSOT-23-5
NCP5021	Inductive Boost	2.7 - 5.5	8	50	800	28	I^2C	µQFN-16
CAT4238	Inductive Boost	2.0 - 5.5	10	30	450	38	PWM	TSOT-23-5
CAT4240	Inductive Boost	2.0 - 5.5	10	300	850	38	PWM	TSOT-23-5
CAT4106	Inductive Boost / Linear	3.0 - 5.5 / 25	10 x 4	700	1000	36	PWM	TSSOP-16, TQFN-16
CAT4026	6-Channel Linear	-0.3 to 7	Varies	External Transistors			PWM, Analog	SO-28

6-Channel LED Controller for Large Panel LED Backlighting – CAT4026

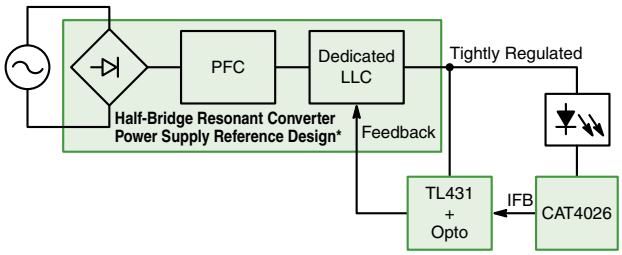
The CAT4026 is a large panel LED controller designed to control 6 constant current high voltage LED strings. Control circuitry monitors the lowest cathode voltage and generates a feedback control signal. Two approaches can be implemented: either a voltage feedback signal is fed into an external DC-DC converter; or a current feedback control is fed directly the main power supply,* which is usually a half-bridge resonant power supply converter. Each LED channel current is accurately controlled by sensing an external resistor and controlling a low cost bipolar transistor. LED current in all 6 channels can be controlled by PWM dimming or analog dimming. Fault detection and robust protection is provided for every possible fault scenario on the LED strings.

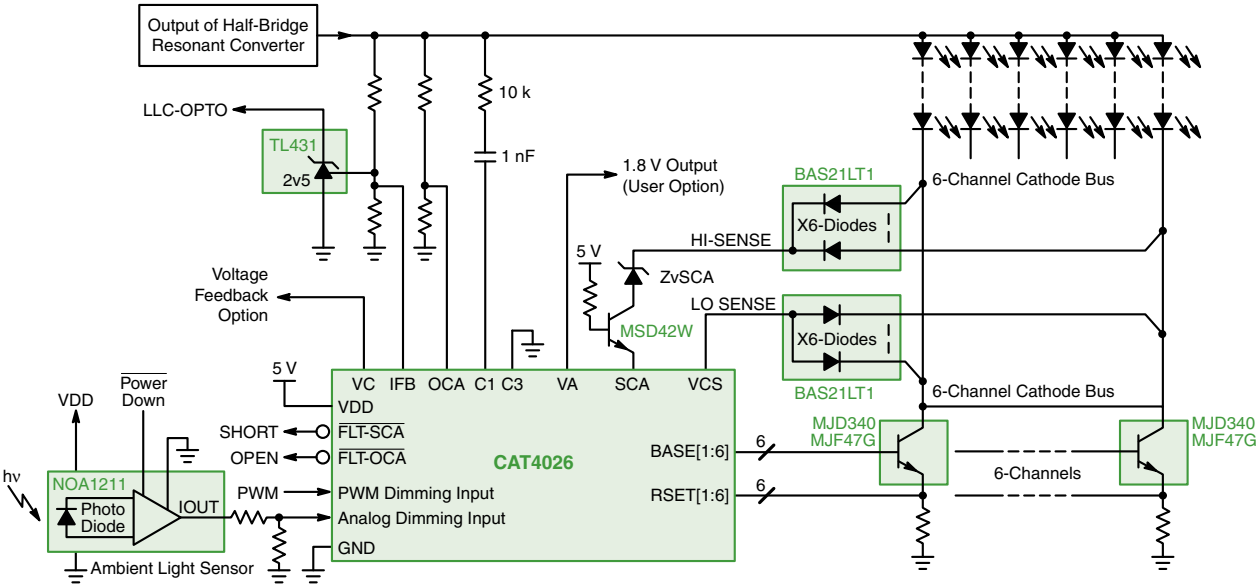
Features

- Voltage Feedback Control to External DC-DC converter
- Current Feedback Control to main power supply Half-Bridge Resonant Converter*
- PWM and Analog Dimming
- Zero Current Shutdown Mode
- Auto-Recovery Fault Detection (All Modes)
- Shorted Cathode-Ground (SCG) Fault Protection
- Shorted Cathode-Anode (SCA) Fault Protection
- Open Cathode-Anode (OCA) Fault Protection
- Over-Voltage Protection (OVP)
- Thermal Shutdown Protection

Applications

- Large LCD Panels Backlighting (e.g. LED-TV)
- LED General Lighting
- High bay lighting





* Complete power supply reference design for half-bridge resonant converter also available from www. onsemi.com

BACKLIGHTING

Highly Integrated LED Backlight Controller, Boost Converter and 4 Channel Driver – CAT4106

Features

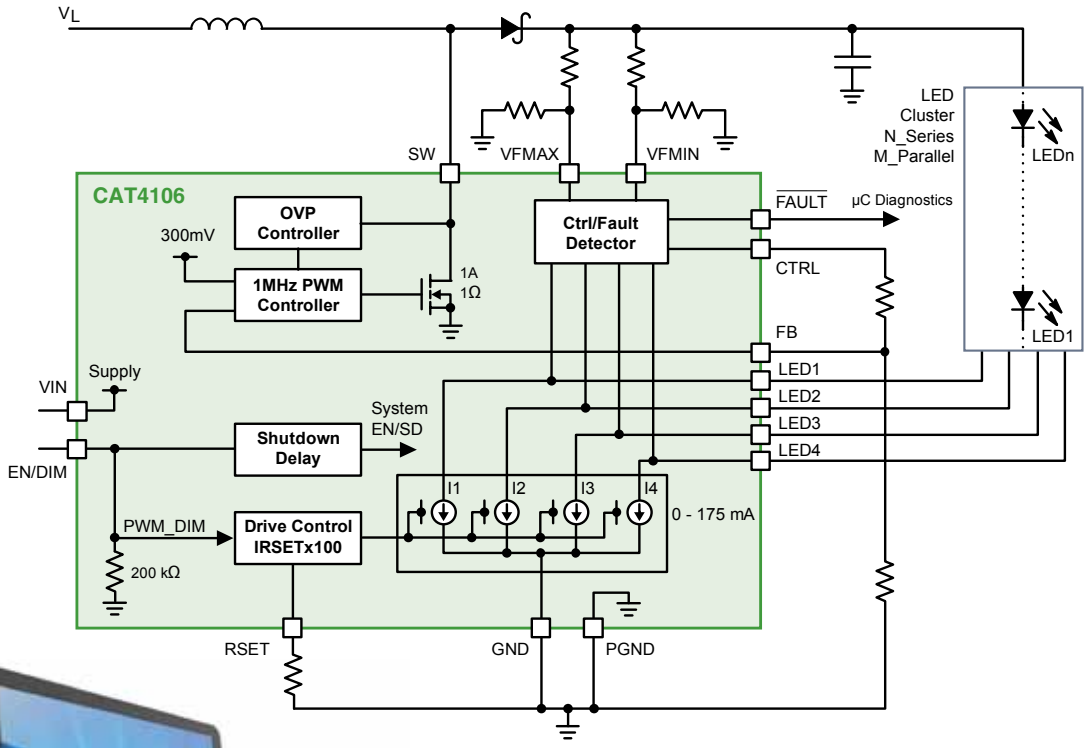
- Drives up to 40 (4 x 10) – 36 V per string
- 1 MHz DC-DC boost converter with OVP
- Low dropout LED channels, 500 mV at 175 mA
- Tight channel-to-channel current matching
- Up to 2 kHz PWM dimming interface
- Programmable short and open LED detection
- Thermal shutdown
- Exposed pad packaging, TQFN-16 and TSSOP-16

Applications

- Notebooks
- Monitors
- Tablets
- Small LCD-TVs
- Test equipment
- Medical instruments
- Touch panels

Resources

- Evaluation Board



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

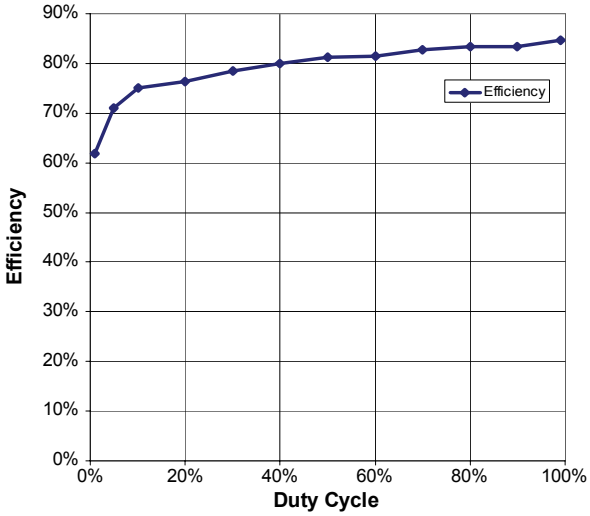
- 1 MHz frequency capability
- 1 A sink/source gate drive
- Programmable pulse-by-pulse overcurrent protection
- Programmable soft start

Resources

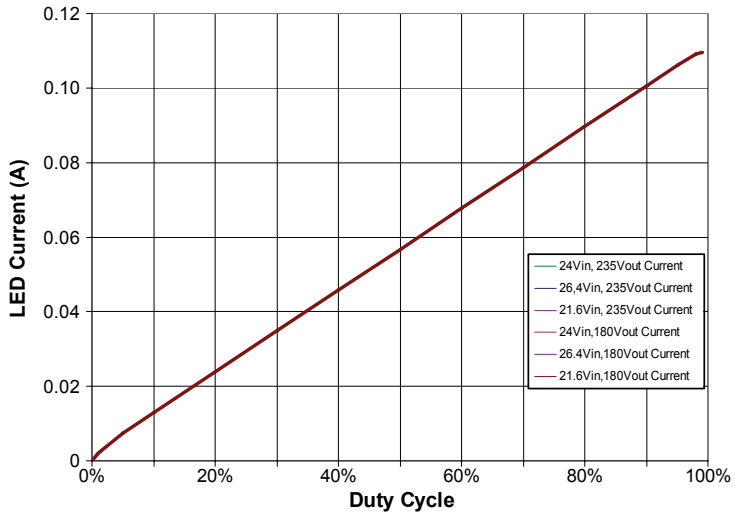
- Design Note DN06062/D

Applications

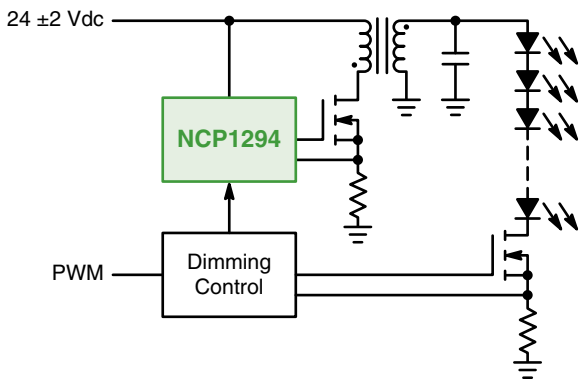
- Monitors
- LCD-TVs
- Test equipment
- Medical instruments
- Touch panels



Efficiency vs Dim Duty Cycle



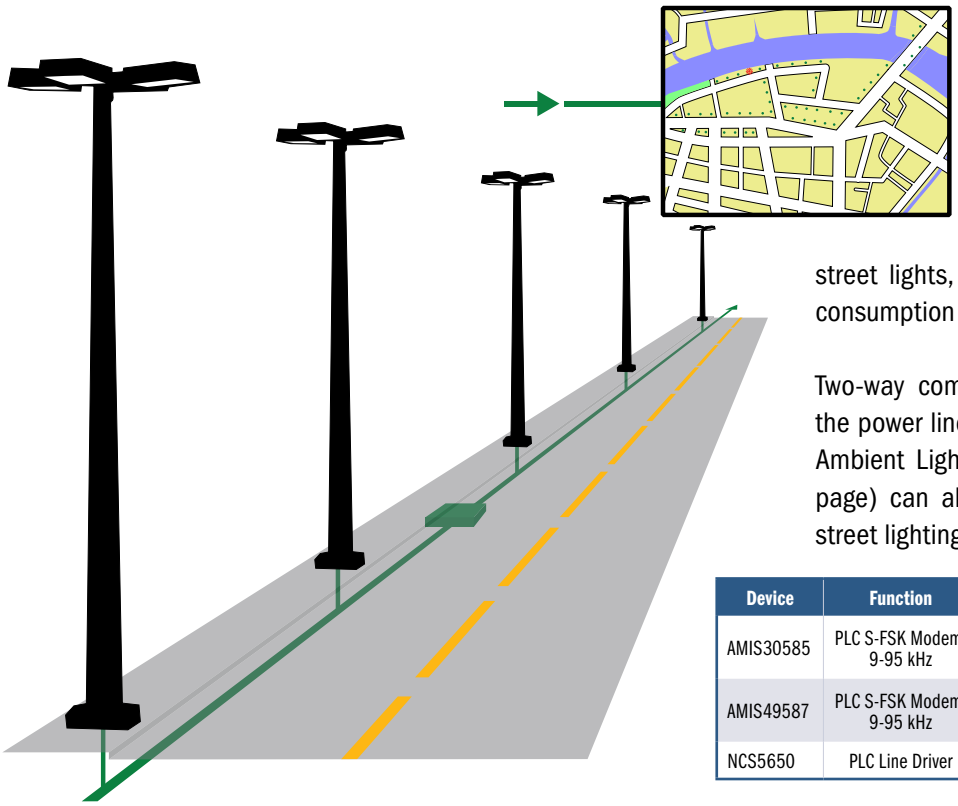
LED PWM Dimming Curve



Reference Design Block Diagram

INTERFACE

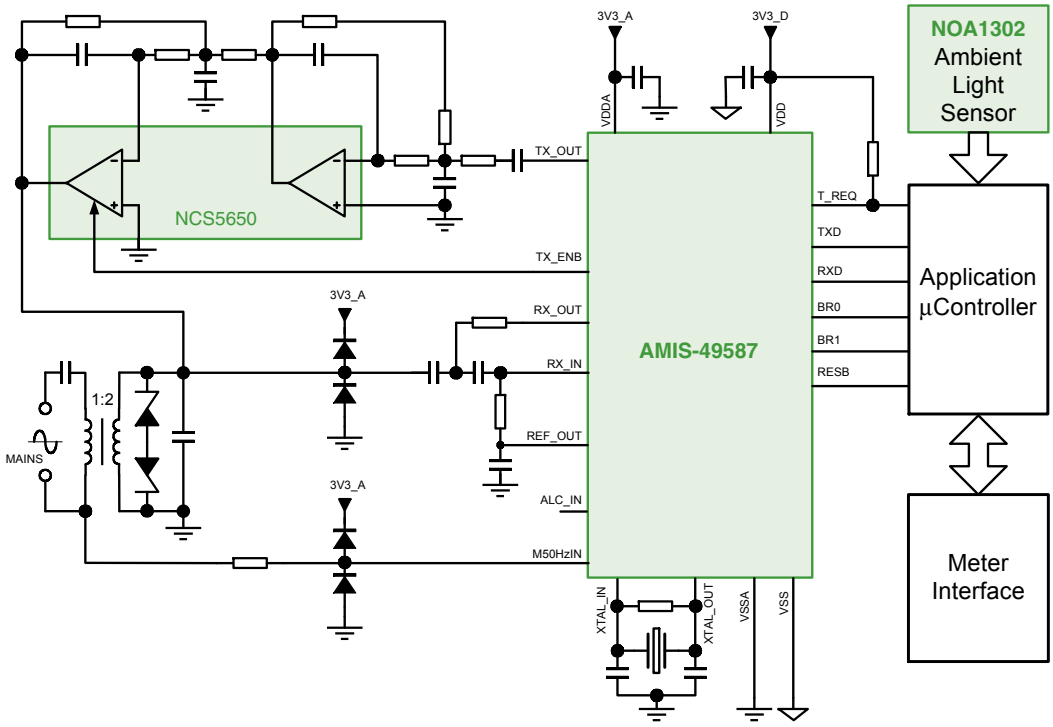
Intelligent Control for Street Lights



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 (Power Line Carrier) modems. Ambient Light Sensors such as the NOA1302 (see next page) can also be used to control the output levels of street lighting.

Device	Function	Speed	Bit Synchronization	Core	Package
AMIS30585	PLC S-FSK Modem, 9-95 kHz	1200 Baud	Automatic/Manual (SYNCHRO Bit Mode Value)	ARM7TDMi, 24 MHz	PLCC-28
AMIS49587	PLC S-FSK Modem, 9-95 kHz	2400 Baud	Manual	ARM7TDMi, 24 MHz	PLCC-28, QFN-52
NCS5650	PLC Line Driver	–	–	–	QFN-20



Ambient Light Sensors

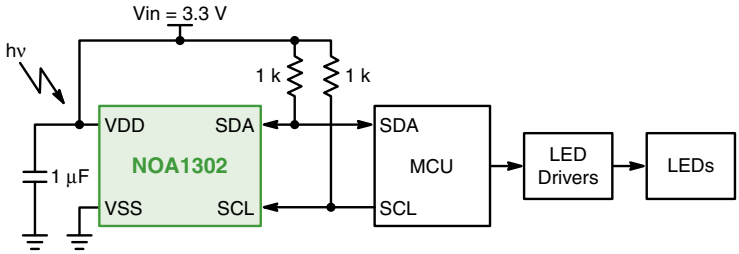
Ambient light sensors (ALS) are a natural companion to any LED lighting application where it is desirable to enhance the user experience and conserve energy. For example, ALS devices automatically dim the backlight level of mobile phone screens to produce a light output sufficient for the user to see clearly, but without consuming more power than necessary, maximizing battery life. ALS devices exhibit photopic light response characteristics, meaning they closely match human eye response. This is important to provide the appropriate response to different light sources such as fluorescent, LED and sunlight. ALS devices from ON Semiconductor also exhibit excellent low light response due to their built-in dark-current compensation, and have analog and digital outputs. Analog ALS devices output a current directly proportional to the ambient light level. Digital devices integrate an ADC and output a digital count proportional to the ambient light level over the I2C bus. Customized versions with user defined filter response and other features are available.

Features

- Photopic light response
- Dark current compensation
- Very low power consumption
- ~0 lux to over 100 k lux range
- Power down mode
- Selectable gain ranges
- Programmable integration time
- Linear response over full range
- Variable slope integrating 16-bit ADC
- Requires no external components

Applications

- Cell phones, PDAs, MP3 players, GPS
- Internet Mobile Devices (IMD)
- Cameras, video recorders
- Mobile devices with displays or backlit keypads
- Laptops, notebooks, digital signage
- LCD/LED TV/monitors, digital picture frame
- Headlamps, dashboard & car interior lighting
- LED indoor/outdoor residential, street lights



LED Backlighting Control

Device	Type	Output	Voltage Range (V)	Operating Current @ 100 Lux (µA, Typ)	Power Down Current (µA, Typ)	Package
NOA1211*	Analog	Current	2.0 - 5.5	58	0.2	CDFN-6
NOA1302	Digital	I2C	3.0 - 3.6	550	–	CTSSOP-8
NOA1305*	Digital	I2C	1.62 - 3.63	115	3	CDFN-6

* Pending 1H10

Proximity Sensors

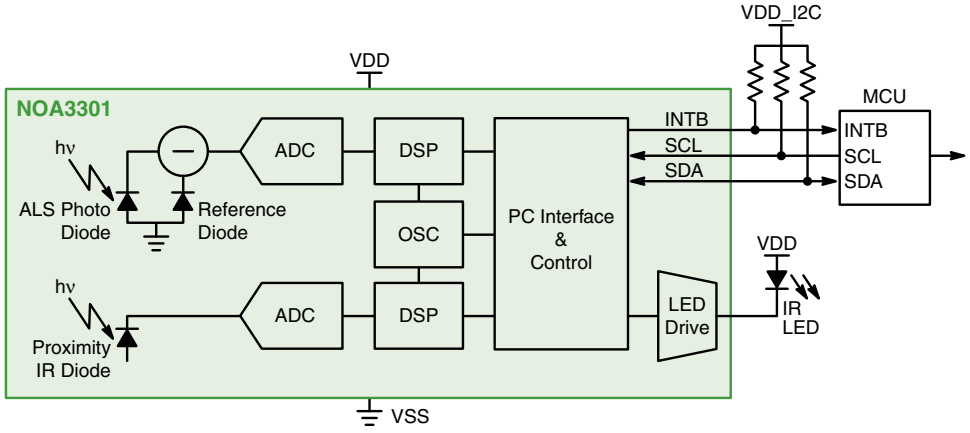
Proximity sensors provide an optical method to measure proximity (near/far), distance, and gestures using a combination of light sensors and LEDs. Proximity sensors find application in removing mechanical proximity switches, turning off mobile device displays when held close to the ear, or even detecting gestures near a smart-phone screen. Proximity sensors work by reflecting and detecting infrared light emitted by standard IR LEDs driven by the proximity sensor. They exhibit excellent IR bandpass filter characteristics and include an ambient light sensor to facilitate setting backlight display levels, include power down features to maximize battery life, and communicate over the I2C serial bus. Customized versions with user defined filter response and various configurations of LED drivers and sensors are available.

Features

- Up to 100 mm and beyond distance range
- 50 dB proximity threshold range
- 40:1 LED driver range
- IR and ambient light rejection
- Dark current compensation
- Photopic light response
- Output count proportional to ambient light intensity
- 20-bit effective proximity threshold range
- Senses ambient light from 0 to 64 k lux with 16-bit resolution
- Programmable interrupt function including threshold detect and or relative change to the last read out
- Tri-mode I2C interface, including 3.4 MHz high speed mode
- Only one external component: IR LED

Applications

- Smart phones, mobile internet devices, MP3 players, GPS
- Mobile device displays and backlit keypads



Device	Type	Output	Voltage Range (V)	Proximity Sensing Current with LED Drive (μA, Typ)	Ambient Light Sensing Current (μA, Typ)	Standby Current (μA, Typ)	Package
NOA3301*	PS+ALS	I2C	2.3 - 3.6	300	200	1	CDFN-6

* Pending 1H10

Technical Support

Design Notes	Document ID
NCP1294: High Voltage LED Driver (24 V input to 110 V output @ 100 mA)	DN06062/D
NCP1014: Improving the Power Factor of Isolated Flyback Converters for Residential ENERGY STAR® LED Luminaire Power Supplies	DN06051/D
NCP1216: 7 W, 90-135 Vac, 500 mA LED Driver	DN06050/D
NCP3065: 12 Vac or 12 Vdc MR-16 Sharp ZENIGATA LED Module	DN06048/D
NCP1034: High Voltage Driver for HB-LED	DN06047/D
NCP1351: Universal Input, 20 W, LED Ballast	DN06040/D
NCP1014: Low Power, Off-Line Buck, CVCC Power Supply	DN06037/D
NCP3065: SEPIC LED Driver for MR16	DN06033/D
NCP3065: High Brightness LED SEPIC Driver	DN06031/D
NCP1013: Universal Input, 5 W, LED Ballast	DN06027/D
CS51411, NCV51411: 12 V or 24 Vin DC, Constant Current LED Driver	DN06018/D
NCP1027: 1 A, 12 W Constant Current Off-Line LED Driver	DN06006/D
CS5171: SEPIC LED Driver	DN06004/D
Tutorials/White Papers	**Document ID**
LED - Driving High Brightness LEDs in the General Lighting Marketplace	TND345/D
LED Lighting Definitions & Characteristics	TND328/D
LED Lighting Solutions	TND370/D
SOL - Solar Powered LED Street Lighting	TND346/D
Halogen Desk Lamp Conversion to LEDs	TND358/D
Application Notes	**Document ID**
CAT32 White LED Driver Efficiency and Inductor Value Tradeoffs	AND8423/D
Simple Secondary Side Vcc Source for Low Power CVCC Power Supplies	AND8395/D
A 48 V/ 2 A High Efficiency, Single Stage, Isolated Power Factor Corrected Power Supply for LED Drivers and Telecom Power	AND8394/D
Thermal Considerations for the ON Semiconductor Family of Discrete Constant Regulators (CCR) for Driving LEDs in Automotive Applications	AND8391/D
Automotive Applications: The Use of Discrete Constant Current Regulators (CCR) For CHMSL Lighting	AND8349/D
700 mA LED Power Supply Using Monolithic Controller and Off-Line Current Boosted (Tapped Inductor) Buck Converter	AND8328/D
Buck Boost LED Driver using NCP3063 Controller, FETs & Current Sensing	AND8306/D
350 mA Buck Boost LED Driver using Bipolar Junction Transistors	AND8305/D
High Intensity LED Drivers Using NCP3065/NCV3065	AND8298/D
Medium Size Backlight NCP5050: Drive Up to 120 LEDS (6 to 10 in Series Configuration)	AND8294/D
LED Driving with NCP/V3063	AND8289/D
Implement Extra Functions with the NCP5608 LED Driver	AND8268/D
Controlling the NCP5602 with the I^2C Software	AND8267/D
Implement the Single Wire Protocol	AND8264/D
Utilizing a White LED Driver to Drive Xenon Flashes in Cameras and Phones	AND8236/D
Configuring the NCL30000 for TRIAC Dimming	AND8448/D
Using the NUD4001 to Drive High Current LEDs	AND8198/D
NUD4001 Dimming Ability Demonstration Board	AND8234/D

Application Notes (cont.)	Document ID
NCP101x LED Flasher with Luxeon V Star LED	AND8224/D
Power Stage Design Guidelines for the NCL30000 Single Stage CrM Flyback LED Driver	AND8451/D
NUD4001 LED Driver Demonstration Boards	AND8197/D
Charge Pump Based Multiple LED Driver	AND8192/D
NCP1421/2 Ref Designs for High-Power White LED Flash Applications	AND8171/D
NUD4001 and NUD4011 Current Sources for LEDs Lighting Applications	AND8156/D
High Current LED - Capacitive Drop Drive Application Note	AND8146/D
High Current LED - Isolated Low Voltage AC Drive Application Note	AND8137/D
Efficient High Power Flash Light	AND8135/D
LED Constant Current Source Scheme	AND8109/D
Demo Boards	**Board ID**
5W Universal Input LED Driver	NCP1013LEDGEVB
90-305 Vac, 0.8 Power Factor, 8 W LED Driver	NCP1014LEDGTGEVB
360 mA 24 V LED Driver	NCP1014LEDR2GEVB
720 mA 18 V LED Driver	NCP1028LEDGEVB
90-135 Vac Non-Isolated Buck LED Driver Demo Board	NCP1216LEDGEVB
20 W Universal Input LED Driver	NCP1351LEDGEVB
High Current LED Driver Evaluation Board	NCP1422LEDGEVB
NCP3065 Buck 3 A Evaluation Board	NCP30653ABCKGEVB
SEPIC LED Driver MR16BULB	NCP3065D1SLDGEVB
SEPIC LED Driver 350 mA	NCP3065D2SLDGEVB
SEPIC LED Driver 700 mA	NCP3065D3SLDGEVB
NCP3065 Buck Demo Board	NCP3065SOBCKGEVB
NCP3065 Boost Demo Board	NCP3065SOBSTGEVB
NCP3066 DFN SEPIC Demo Board	NCP3066DFSEPGEVB
NCP3066 3 A SOIC Buck Demo Board	NCP3066S3BCKGEVB
NCP3066 SOIC8 Buck Demo Board	NCP3066SCBCKGEVB
NCP3066 SOIC8 Boost Demo Board	NCP3066SCBSTGEVB
High Power Lighting Evaluation Board	NCP5030MTTXGEVB
4.5 W Inductive Boost LED driver	NCP5050GEVB
NCP5602 Evalutation Board	NCP5602EVB
High Efficiency Charge Pump Converter / White LED Driver Eval Board	NCP5603GEVB
NCP5604A 4-output LED Driver Evaluation Board	NCP5604AAGEVB
NCP5604B 3-output LED Driver Evaluation Board	NCP5604BAGEVB
NCP5608 Evalutation Board	NCP5608EVB
NCP5612 Evalutation Board	NCP5612GEVB
15 W 350 mA 100/115 Vac Triac Dimmer	NCL30000LED1GEVB
15 W 350 mA 220/240 Vac Triac Dimmer	NCL30000LED2GEVB
17 W 350 mA 90-305 Vac Flyback PFC	NCL30000LED3GEVB
NUD4001 LED Driver Revision A Evaluation Board	NUD4001DEVB

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