ON Semiconductor®

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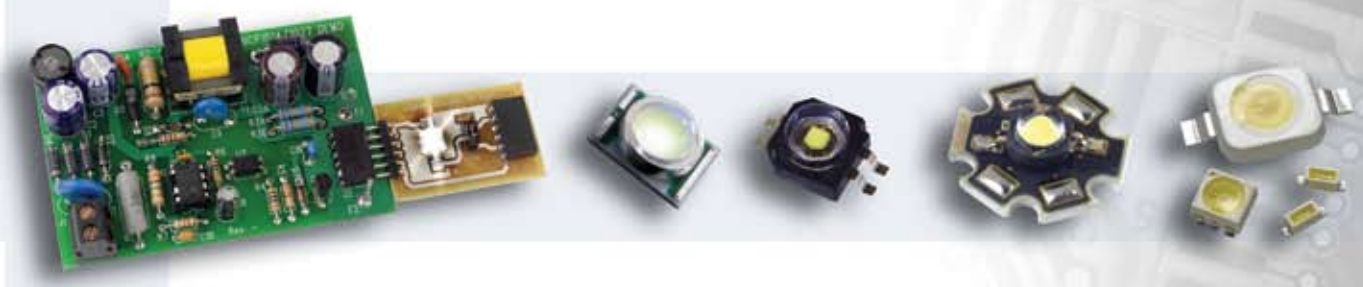
Selection. Service. Support.
Power Solutions from ON Semiconductor

LED Driver Design & Selector Guide

Covering low voltage, high voltage, AC and DC solutions for driving LED lighting applications from ON Semiconductor.

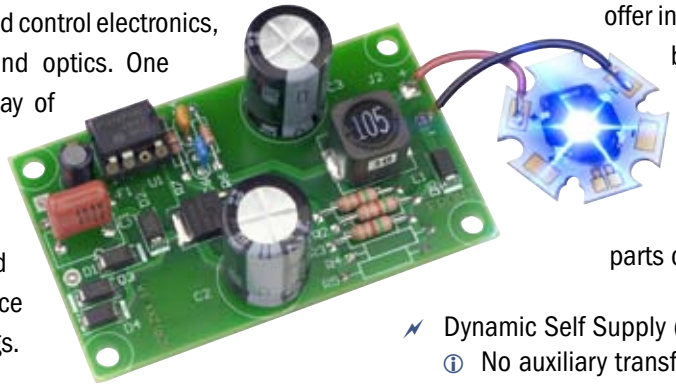


Introduction

Over the last several years there has been significant progress in the evolution of LEDs. They have been transformed from devices that had been used for indication to products driving the next generation of illumination. The benefits of LEDs are numerous:

- Broad color spectrum
- Compact in size
- Energy efficient
- Mercury free
- Long operating life
- Fully dimmable
- No IR or UV in beam
- Low voltage

High-brightness LEDs are critical to creating a solid-state lighting evolution that offers dramatic implications to lighting design, global energy conservation, and innovative products. A holistic approach is required for this evolution where LEDs are integrated with power conversion and control electronics, thermal management solutions and optics. One example that can be seen ever day of the beginnings of this successful transition is LED-based traffic signals which have become ubiquitous due to enhanced reliability, reductions in maintenance costs and significant energy savings.



Reference design using the NCP1216 in a non-isolated constant current buck configuration

Driving LEDs

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.

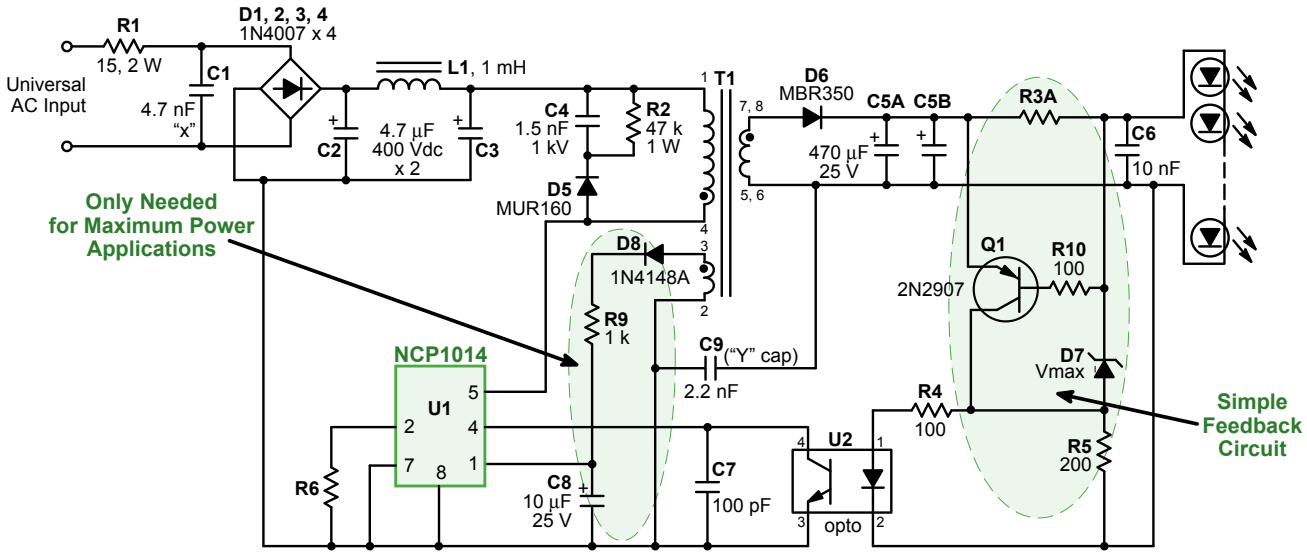
ON Semiconductor has been focused on applying our low voltage and high voltage technologies and applying our expertise in power management solutions to the challenges of solid state lighting; be it in a portable display product, interior automotive lighting, or a ballast for LED signage. In the following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

Offline Switch Mode Power Supply Solutions

...Minimize complexity, reduce board space and improve efficiency

ON Semiconductor has a long history in transforming power from the AC main into usable energy in a wide variety of different applications and power ranges from a few watts to hundreds of watts. We have developed Very High Voltage Integrated Circuit technologies (VHVIC) that combine high voltage switching transistors with medium voltage analog circuits that allow us to offer integrated cost-effective solutions for a broad range of power needs. We offer a wide variety of fixed frequency controllers as well as converters which integrate the high voltage FET into a simplified economical lower parts count solution.

- Dynamic Self Supply (DSS) capability
  - No auxiliary transformer winding
- Current-mode control with adjustable skip-cycle capability
  - Provides excellent efficiency at light loads
  - No acoustic noise generation
- Fixed frequencies up to 200 kHz
  - Offers suitable solution for all applications
- High-voltage start-up-current source
  - Clean loss less start-up sequence
- Frequency jittering
  - Reduces EMI signature
- Internal short–circuit protection independent of auxiliary voltage
  - Reliable short-circuit protection, immediately reducing the output power



NCP1014 Configured as a Constant Current Isolated Offline LED Driver

Power Switching Regulators

Device	Max Output Power[1] (W)	Mode	Peak Current Limit (mA)	Typ[2] $R_{DS(ON)}$ (Ω)	Min HV Startup	Frequency Options (kHz)	Soft-Start	Package(s)
NCP1050	10	Gated Osc	100	22	20	44, 100, 136		PDIP-7, SOT-223
NCP1051	10	Gated Osc	200	22	20	44, 100, 136		PDIP-7, SOT-223
NCP1052	10	Gated Osc	300	22	20	44, 100, 136		PDIP-7, SOT-223
NCP1053	20	Gated Osc	400	10	20	44, 100, 136		PDIP-7, SOT-223
NCP1054	20	Gated Osc	530	10	20	44, 100, 136		PDIP-7, SOT-223
NCP1055	20	Gated Osc	680	10	20	44, 100, 136		PDIP-7, SOT-223
NCP1010	4	Current	100	22	30	65, 100, 130	✔	PDIP-7, SOT-223[3]
NCP1011	11	Current	250	22	30	65, 100, 130	✔	PDIP-7, SOT-223, Gullwing[4]
NCP1012	11	Current	250	11	30	65, 100, 130	✔	PDIP-7, SOT-223[3]
NCP1013	15	Current	350	11	30	65, 100, 130	✔	PDIP-7, SOT-223[3]
NCP1014	19/17[1]	Current	450	11	30	65, 100	✔	PDIP-7, SOT-223, Gullwing[4]
NCP1028	25	Current	800	8	30	65, 100	✔	PDIP-7

BOLD denotes new or pending device. 1. Maximum power output with DSS. 2. Typical at 25°C. 3. Gullwing package available on demand. 4. Gullwing SMD DIP-7.

Fixed Frequency Controllers

Device	Max Output Power (W)	Output Gate Drive (mA) @ V_{CC} = 11 V	Frequency Options (kHz)	500V Off-Line Startup FET	Dynamic Self Supply	Freq Jittering	Over Voltage Protection	Soft-Start	Ramp Compensation	Brown-Out	Package(s)
NCP1200	150/40[1]	250	40, 60, 100	✔	✔				EXT		SO-8, PDIP-8
NCP1201	150	250	60, 100	✔		✔			EXT	✔	SO-8, PDIP-8
NCP1203	150	250	40, 60, 100	✔		✔			EXT		SO-8, PDIP-8
NCP1216/A[2]	150/100[1]	500	65, 100, 133	✔	✔	✔		✔[3]	INT		SO-8, PDIP-7
NCP1217/A[2]	150	500	65, 100, 133	✔		✔	✔	✔[3]	INT		SO-7, PDIP-7
NCP1212	150	500	Adj Up to 150			✔		✔	EXT		SO-8, PDIP-8
NCP1230	150	500	65, 100, 133	✔		✔	✔		INT		SO-7, PDIP-7

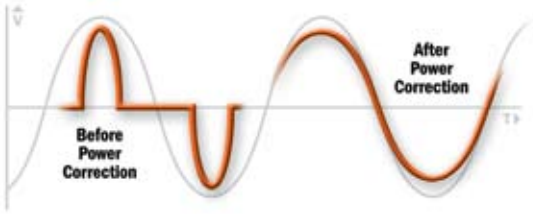
1. Maximum power output with DSS. 2. "A" Versions have a 50% Max Duty Cycle for forward topologies. 3. Soft-Start on "A" versions only.

For lower power applications 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 which offers 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.

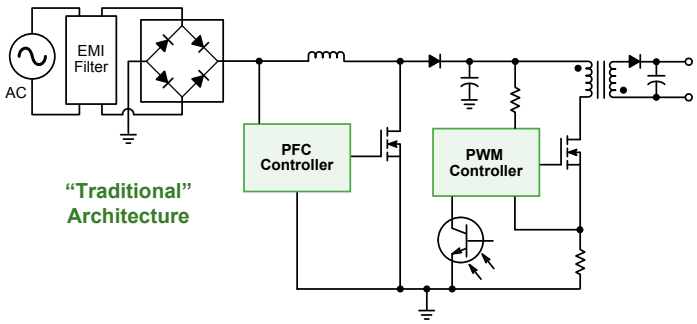
Power Factor Correction

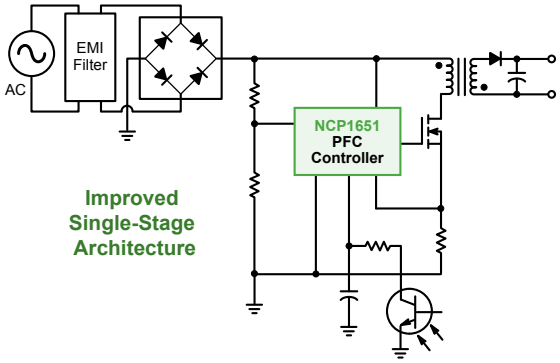
...Minimize THD and Maximize PF and Efficiency

IEC 1000-3-2 standards set regulations to limit the harmonics injected into the AC line. Specifically for lighting applications, these apply if the input power is greater than 25 W (Class C). In addition in some jurisdictions even if formal IEC compliance is not required, a minimum power factor may be required. A front-end Power Factor Controller is then required in these applications. Adding such a stage can lead to difficulties in meeting other system requirements like efficiency and space unless judicious design choices are made.



Fortunately, these challenges are understood by ON Semiconductor, which has a portfolio of innovative PFC controllers matching the designers' wishes of simple, compact and robust solutions. ON Semiconductor offers support for traditional 2 stage applications and has introduced several unique solutions to further simply the solution such as the NCP1651 single stage flyback controller.





Applications

- Ballasts
- Traffic Signals
- Streetlights
- Luminaries

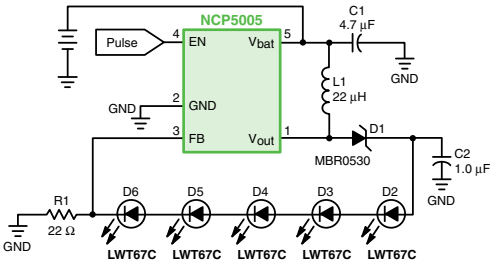
Power Factor Controllers

Device	Max Output Power (W)	Topology	Mode	Operation Mode	HV Start-Up	Over Voltage Protection	Under Voltage Protection	Current Limit	In-Rush Detect	Shutdown	Package(s)
NCP1651	250	Single-Stage Flyback	Continuous Conduction Mode/ Discontinuous Conduction Mode	Average Current	✔			✔		✔	SO-16
NCP1601	400	Boost	Discontinuous Conduction Mode	Fixed Frequency Voltage		✔	✔	✔	✔	✔	SO-8
NCP1603	250	Combo Flyback[1]	Discontinuous Conduction Mode	Current	✔	✔	✔	✔	✔	✔	SO-16
NCP1606	200	Boost	Critical Conduction Mode	Voltage		✔	✔	✔		✔	PDIP-8, SO-8

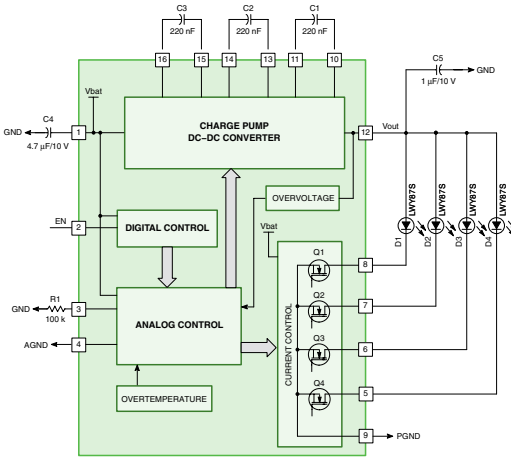
BOLD denotes new device. 1. NCP1603 is a combination of NCP1601 and NCP1230.

Portable Applications

High-brightness LEDs have made inroads into two major portable applications: backlighting of small color LCD panels and keyboards and replacement of incandescent bulbs for torch (flashlight) applications. 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 both inductive and charge pump topologies. The inductive solution offers the best overall efficiency while the charge pump solution takes up a minimize amount of space and height due to the use of low profile ceramic capacitors as the energy transfer mechanism.



Inductive Solution – NCP5005



Charge Pump Solution – NCP5604A

Low Voltage LED Drivers

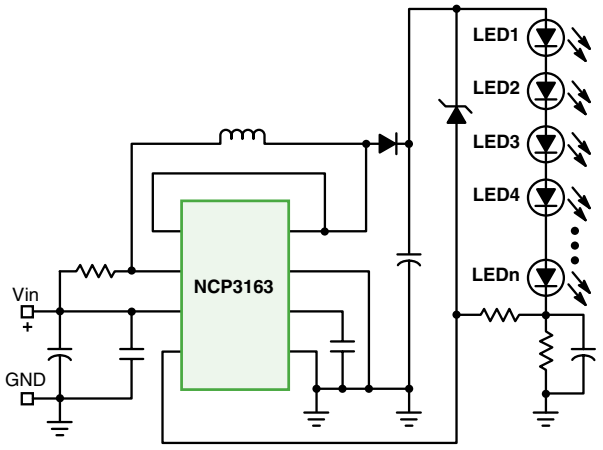
Application	LED Type	Number of LEDs/ Connection	Topology	Product	Key Feature
Display Backlighting	Standard, 10-25 mA	2 LEDs/Parallel	Linear	**NUD4301**: Adjustable (1-30 mA) constant current driver; DFN-8 (2 x 2 mm)	Linear or PWM dimming
		2 - 5 LEDs/Series	Inductive	NCP5006/5007: Up to 92% efficiency PFM boost, 21 V/ 1 W output; thin SOT-23-5 (3 x 3 mm)	Simple, open LED output clamp
		3 - 5 LEDs/Series	Inductive	**NCP5005**: Enhanced version of NCP5006 - high EMI immunity	Enhanced EMI immunity, best for RF sensitive application
		2 - 5 LEDs/Series	Inductive	**NCP5010**: 1 MHz PWM boost, 22 V/0.5 W output, integrated rectifier & true-cutoff; uBump-8 (1.7 x 1.7 mm)	Highly integrated driver
		2 LEDs/Parallel	Charge Pump	**NCP5602**: 90% peak efficiency, 2 outputs (25 mA each), 2% current matching, I2C; LLGA-12 (2 x 2 mm)	ICON mode; I2C dimming control
		2 LEDs/Parallel	Charge Pump	**NCP5612***: 2 outputs (25 mA each), I2C; LLGA-12 (2 x 2 mm)	ICON mode; S-Wire link dimming control
		2 - 6 LEDs/Series	Inductive	NCP1406: Up to 90% efficiency, PFM (up to 1 MHz), 25 V/0.5 W output; thin SOT-23-5 (3 x 3 mm)	Can operate from 1 or 2 alkaline or Ni-based cells
		3 or 4 LEDs/Parallel	Charge Pump	**NCP5604A/B**: Consistent 90% efficiency, 3 or 4 outputs (25 mA each), 0.5% current matching; TQFN-16 (3 x 3 x 0.8 mm)	NCP5604A: Drives 4 LEDs NCP5064B: Drives 3 LEDs
Flash (Torch)	Low current - up to 50 mA for 1 cell/100 mA for 2 cell	Single LED	Inductive	NCP1400ASN50: Fixed frequency PWM micropower boost converter; thin SOT-23-5 (3 x 3 mm)	Can operate from 1 or 2 alkaline or Ni-based cells
	Medium current/Multi-die WLED, 100-350 mA	Single (or multiple in parallel)	Charge Pump	**NCP5603**: 200 mA cont/350 mA pulsed, voltage regulated output, 4.5 V or 5 V, 75% eff; DFN-10 (3 x 3 mm)	High-current single output charge pump
	Medium current up to 50 mA for 2 cell and 100 mA for 3 cell	2 - 6 LEDs/Series	Inductive	NCP1406: Up to 90% efficiency, PFM (up to 1 MHz), 25 V/0.5 W output; thin SOT-23-5 (3 x 3 mm)	Simple, low cost
	High current WLED, up to 600 mA	Single (or multiple in parallel)	Inductive	NCP1421: PFM boost (up to 1.2 MHz), sync rec, output up to 5 V, 600 mA cont, 94% eff, true-cutoff, 50 nA shutdown current; Micro8 (3 x 5 mm)	Synchronous rectification
	High current WLED, up to 800 mA	Single (or multiple in parallel)	Inductive	NCP1422: PFM boost (up to 1.2 MHz), sync rec, output up to 5 V, 800 mA cont, 94% eff, true-cutoff, 50 nA shutdown current; DFN-10 (3 x 3 mm)	Synchronous rectification
	High current WLED, up to 1 A	2 - 5 LEDs/Series	Inductive	**NCP5050***: 23 V/4.5 W output, PWM, 1.7 MHz; DFN-10	Integrated switch for 2 adjustable output current levels
Single Driver for Backlight & Flash	LED (10 - 25 mA), Flash LED (100 - 400 mA)	4 LEDs + Flash LED	Charge Pump	**NCP5608**: Consistent 90% efficiency, 8 outputs (4 @ 25 mA each + 4 @ 100 mA each), 0.5% current matching; TQFN-24 (4 x 4 mm)	One chip lighting solution
OLED Driver Supply	–	–	Inductive	NCP1406: Up to 90% efficiency, PFM (up to 1 MHz), 25 V/ 0.5 W output; thin SOT-23-5 (3 x 3 mm)	Can operate from 1 or 2 alkaline or Ni-based cells

BOLD denotes new or pending device. * For additional information, please contact product marketing.

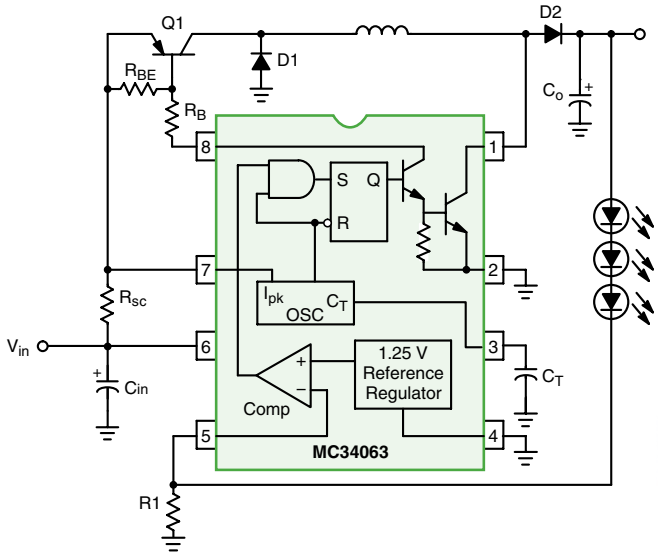
Mid-Voltage Applications

Beyond portable powered applications, there is a diverse set of high-brightness LED applications that operate from power supplies in the range of 8-40 VDC and include the following power sources – Lead-Acid batteries, 12-36 VDC adapters, solar cells, as well as low voltage 12 and 24 VAC alternating current systems. There are numerous lighting applications that fall in this category:

- Track lighting
- Landscape and path lighting
- Automotive and transportation
- Solar powered lights
- Display case lighting



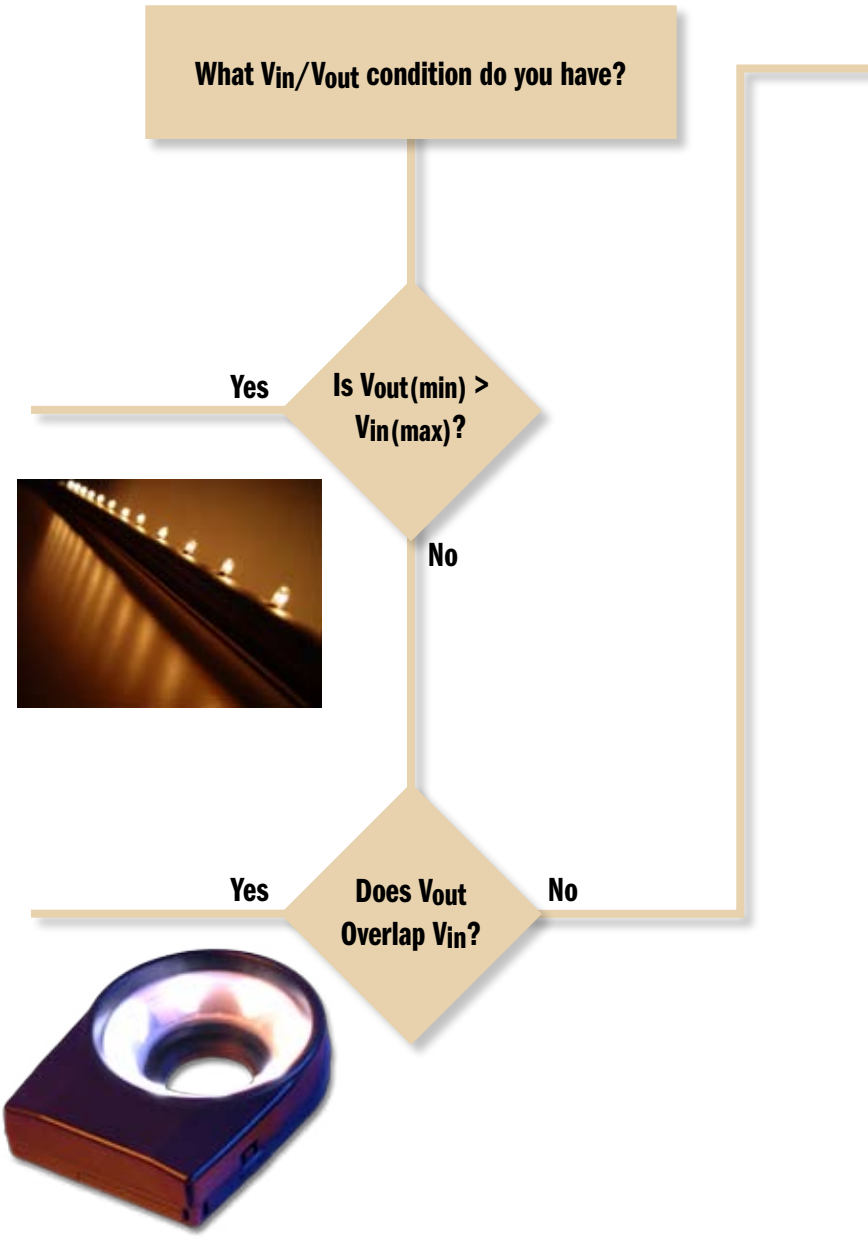
Boost (Step-Up) Topology



Buck/Boost (shown) **or SEPIC Topology**

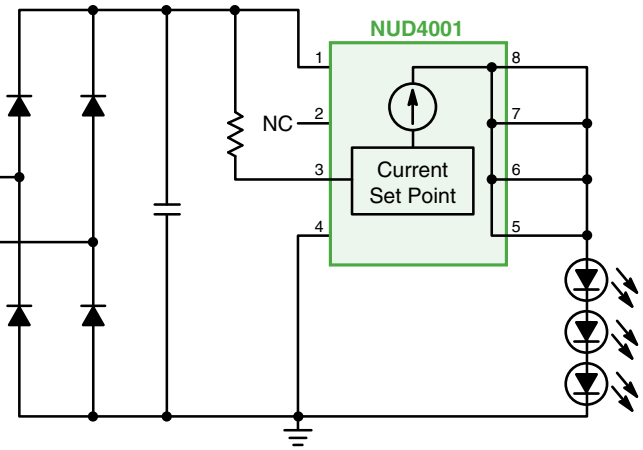
Even though the objective is to drive the LEDs with constant current, the first thing that has to be understood is the input and output voltage variation of the application. The forward voltage of the LEDs is determined by the material properties, junction temperature range, drive current, and manufacturing tolerance. With this information, the right linear or switching power supply topology can be selected.

CHOOSING YOUR TOPOLOGY



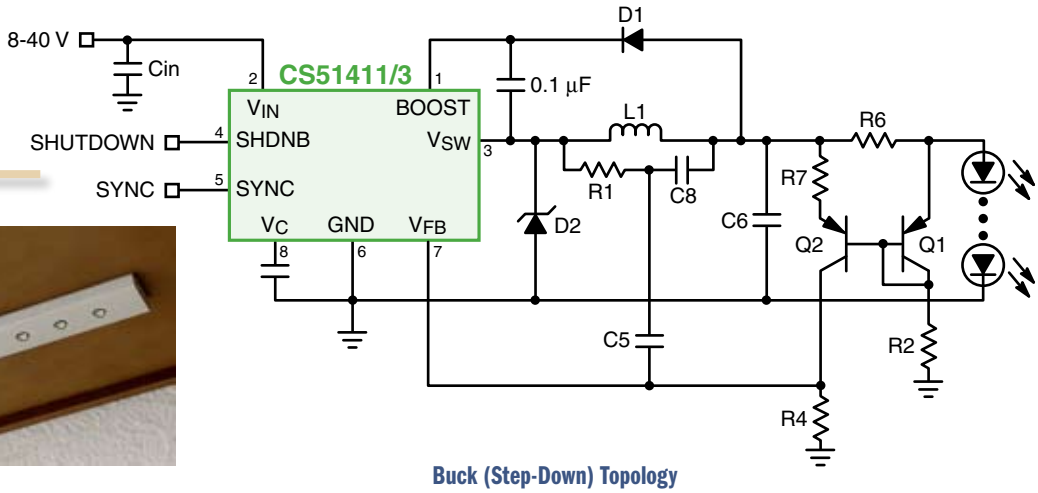
For Low Power

Is Vin(min) > Vout(max)?



Linear Current Source

For High Power



Buck (Step-Down) Topology

DC-DC Converters

Device	Description	Topologies	V_{in} Range (V)	Switch Current[1] (A)	Package(s)	Comments
NUD4011	High Voltage, Low Current LED Driver	Linear	12 - 200	0.07	SO-8	
NUD4001	Up-to-500 mA Constant Current LED Driver (Automotive Grade)	Linear	5.0 - 30	0.5	SO-8	Peak Voltage (<1 msec) of 60 V
MC34063	Up-to-100 kHz Burst-Mode Voltage-Mode Converter	Buck, Boost, Buck/Boost	3.0 - 40	1.5	SO-8	Available in automotive grade versions
CS51411/3	260/520 kHz Buck Regulator with Synchronization Capability	Buck (Step-down)	4.5 - 40	1.5	SO-8, DFN	For automotive grade, see NCV51411
CS51412/4	260/520 kHz Buck Regulator with External Bias Capability	Buck (Step-down)	4.5 - 40	1.5	SO-8, DFN	
CS5171/3	280/560kHz Boost Regulator	Step-up or SEPIC	2.7 - 30	1.5	SO-8	
NCP3063	Up-to-200 kHz Burst-Mode Voltage-Mode Converter	Buck, Boost, Buck/Boost	3.0 - 40	1.5	SO-8, DFN	
LM2576	52 kHz PWM Step-Down Switching Regulator	Buck (Step-down)	7.0 - 40	3.0	TO-220, D2PAK	
NCP3163	Up-to-200 kHz Burst-Mode Voltage-Mode Converter	Buck, Boost, Buck/Boost	2.5 - 40	3.4	SO-16WB, DFN	Thermally enhanced package
MC33163	Up-to-50 kHz Burst-Mode Voltage-Mode Converter	Buck, Boost, Buck/Boost	2.5 - 40	3.4	SO-16WB	Available in automotive grade versions

BOLD denotes new device. 1. For switching regulators, this current is used to calculate LED current based on Vin and Vout conditions.

Sales and Design Assistance from ON Semiconductor

For additional design information, please see the following ON Semiconductor Application Notes

AND8091/D	TriColor LED Driver Minimizes Control Lines
AND8109/D	LED Constant Curent Source Driver Scheme
AND8135/D	Efficient High Power Flash Light
AND8137/D	High Current LED - Isolated Low Voltage AC Drive
AND8138/D	DC-DC SEPIC Converter for Driving High Brightness LEDs
AND8146/D	High Current LED - Capacitive Drop Drive Application Note
AND8156/D	NUD4001 & NUD4011 Low Cost Integrated Current Sources
AND8171/D	NCP1421/2 Reference Designs for High-Power White LEDs
AND8172/D	Understanding the Noise out of Inductor Based White LED Drivers
AND8192/D	Charge Pump Based Multiple LED Driver
AND8197/D	NUD4001 LED Driver Demo Board
AND8198/D	Using the NUD4001 to Drive High Current LEDs
AND8224/D	NCP101x Universal Offline LED Flasher Circuit
AND8234/D	NUD4001 Dimming Ability Demo Board
HBD853/D	Power Factor Correction Handbook
NCP5010DEMO/D	NCP5010 White LED Driver Demo Board
SMPSRM/D	SMPS Reference Manual

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