ON Semiconductor®

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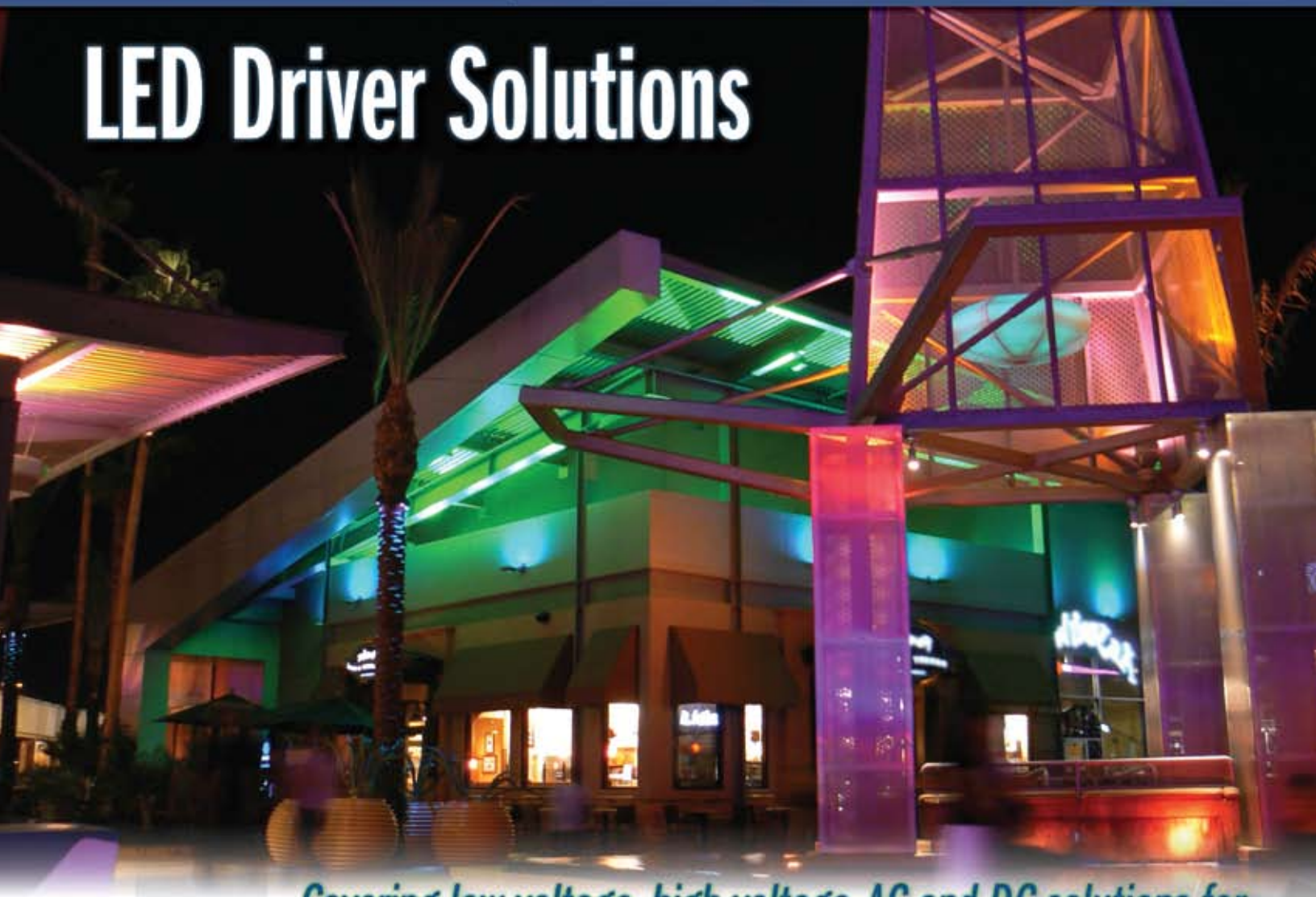
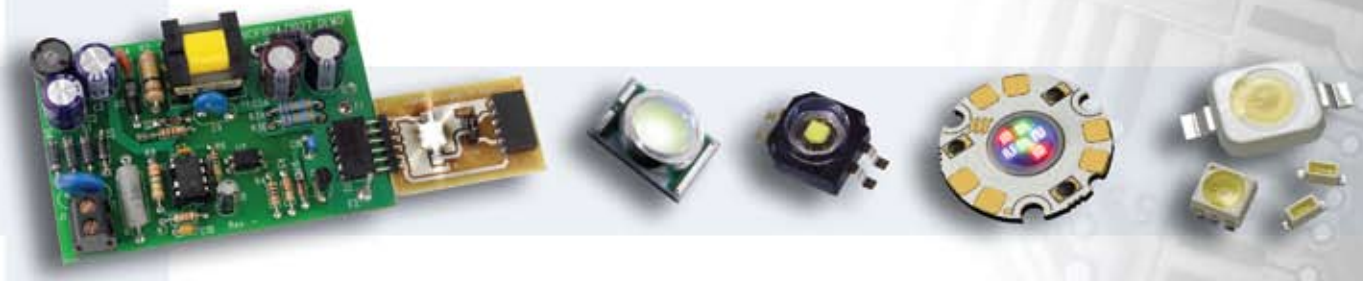
Power Solutions from ON Semiconductor

LED Driver Solutions



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



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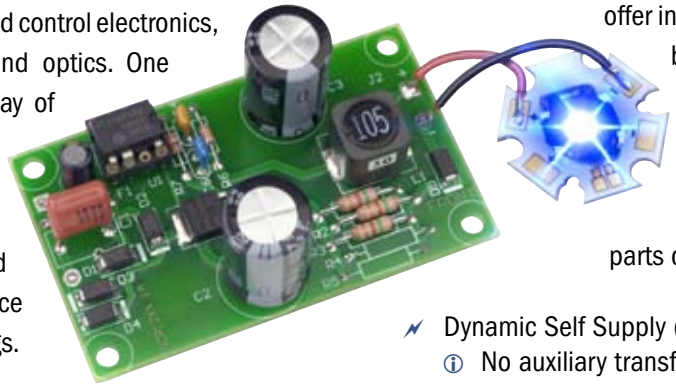
Introduction

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.

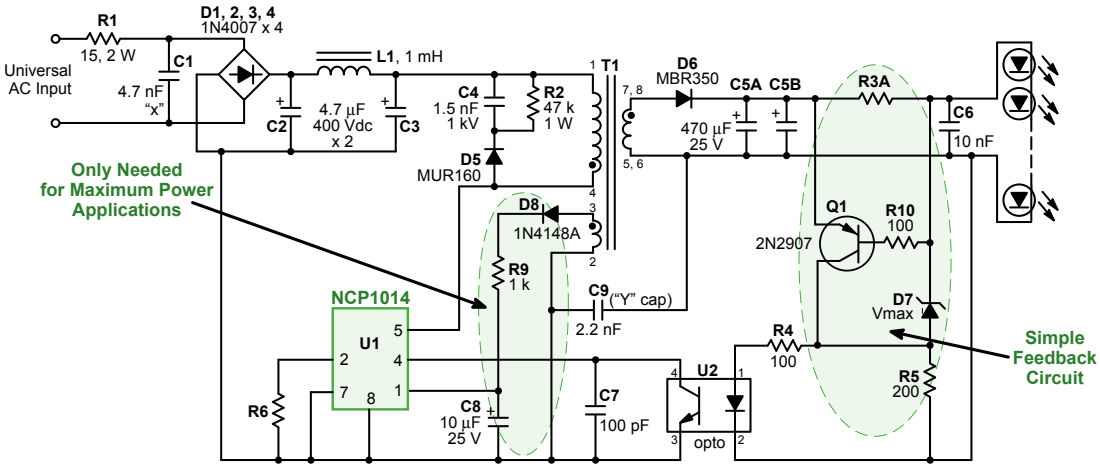
ON Semiconductor has been focused on applying our low voltage and high voltage technologies and applying our expertise in power management solutions to the challenges of solid state lighting; be it in a portable display product, interior automotive lighting, or a ballast for LED signage. In the following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

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]
NCP1015	19/14[1]	Current	450	11	30	65, 100		PDIP-7
NCP1028	25	Current	800	8	30	65, 100	✔	PDIP-7

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

Switching 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		SOIC-8, PDIP-8
NCP1201	150	250	60, 100	✔		✔			EXT	✔	SOIC-8, PDIP-8
NCP1203	150	250	40, 60, 100	✔		✔			EXT		SOIC-8, PDIP-8
NCP1216/A[2]	150/100[1]	500	65, 100, 133	✔	✔	✔		✔[3]	INT		SOIC-8, PDIP-7
NCP1217/A[2]	150	500	65, 100, 133	✔		✔	✔	✔[3]	INT		SOIC-7, PDIP-7
NCP1212	150	500	Adj Up to 150			✔		✔	EXT		SOIC-8, PDIP-8
NCP1230	150	500	65, 100, 133	✔		✔	✔		INT		SOIC-7, PDIP-7
NCP1351	50	150	Variable	✔		✔	✔		INT		SOIC-8

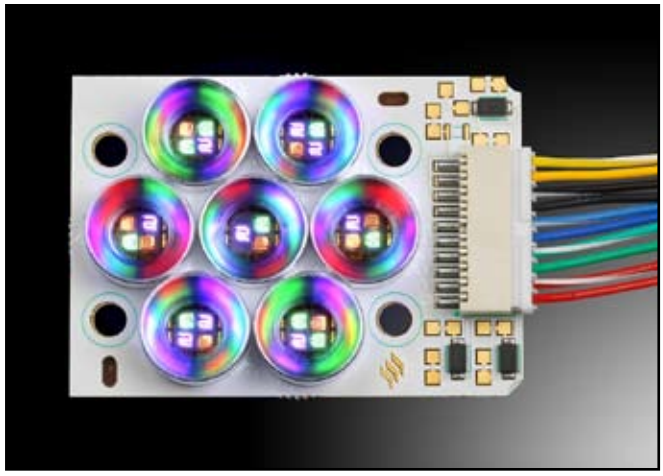
1. Maximum power output with DSS. 2. "A" Versions have a 50% Max Duty Cycle for forward topologies. 3. Soft-Start on "A" versions only.

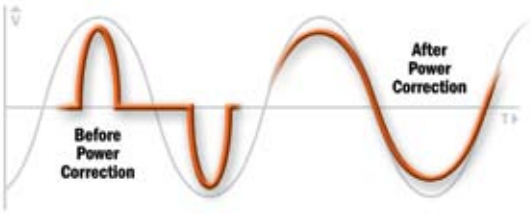
For lower power applications less than 25 W (230 Vac), an integrated power switching regulator is most often used as it minimizes total parts count in a design. Above that power range, controllers can be used which offers the designer flexibility in selecting the high voltage FET that is most suitable 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

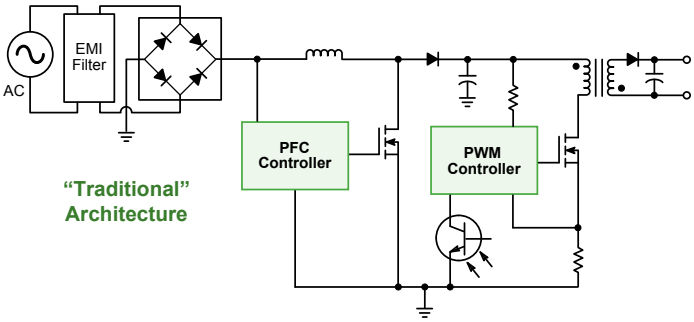
...Minimize THD and Maximize PF and Efficiency

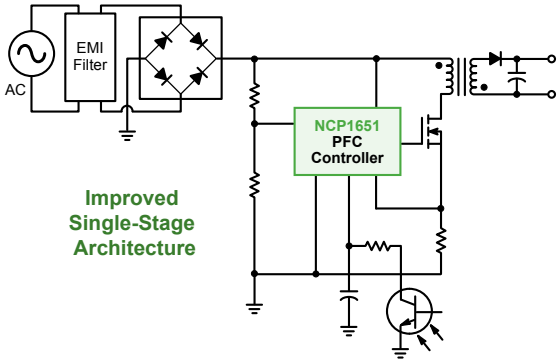
IEC 1000-3-2 standards set regulations to limit the harmonics injected into the AC line. Specifically for lighting applications, these apply if the input power is greater than 25 W (Class C). In addition in some jurisdictions even if formal IEC compliance is not required, a minimum power factor may be 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

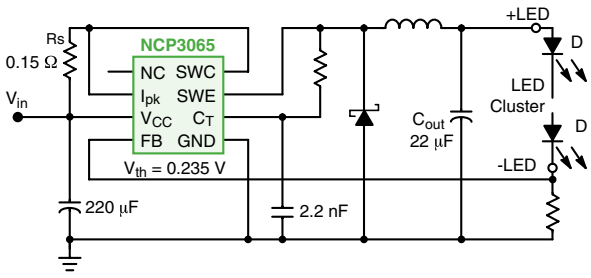
Device	Max Output Power (W)	Topology	Mode	Operation Mode	HV Start-Up	Over Voltage Protection	Under Voltage Protection	Current Limit	In-Rush Detect	Shutdown	Package(s)
NCP1651	250	Single-Stage Flyback	Continuous Conduction Mode/ Discontinuous Conduction Mode	Average Current	✔			✔		✔	SOIC-16
NCP1601	400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

1. NCP1603 is a combination of NCP1601 and NCP1230.

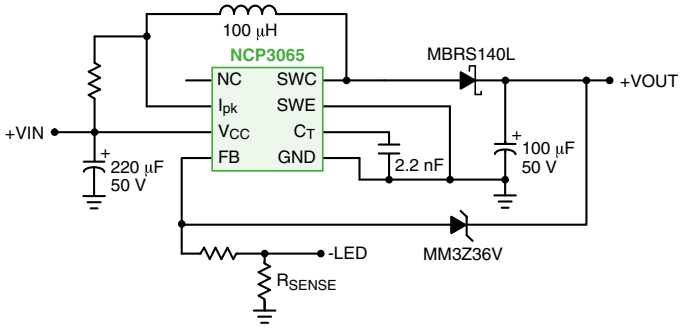
Mid-Voltage Applications

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 lighting; solar powered lighting; and display case lighting.

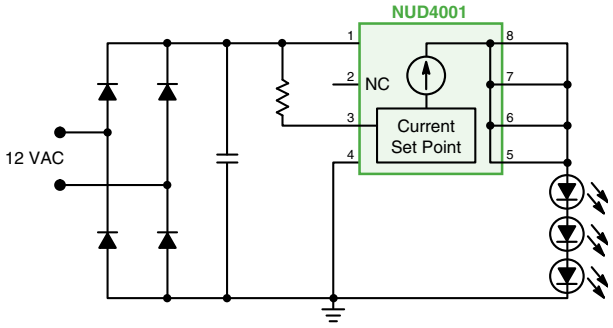
Even though the objective is to drive the LEDs with constant current, the first thing that has to be understood is the input and output voltage variation of the application. The forward voltage of the LEDs is determined by the material properties, junction temperature range, drive current, and manufacturing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



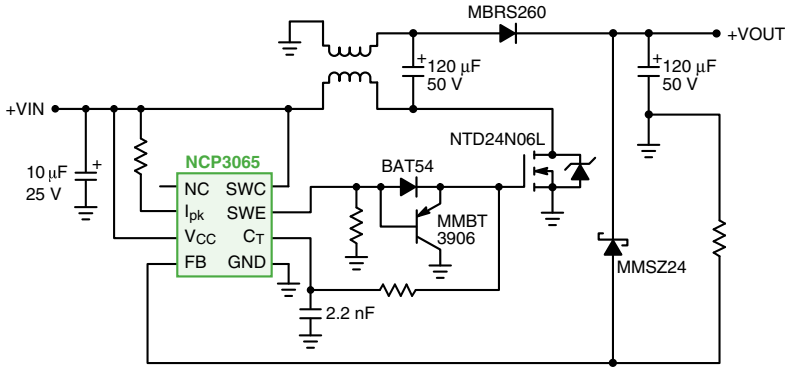
Buck Application Circuit



Boost Application Circuit



Linear Current Source



SEPIC Application Circuit

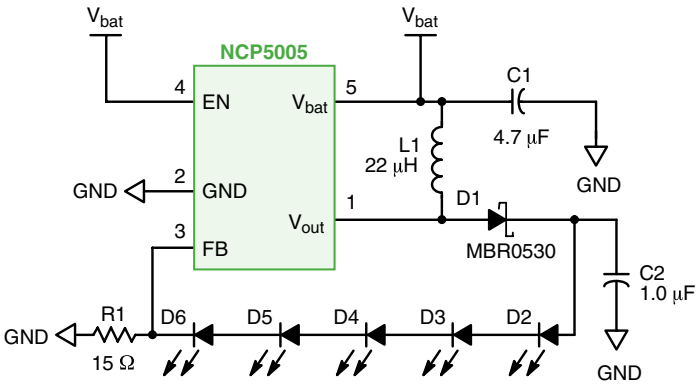
DC-DC Converters

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	SOIC-8	
NUD4001	Up-to-500 mA Constant Current LED Driver (Automotive Grade)	Linear	5.0 - 30	0.5	SOIC-8	Peak Voltage (<1 msec) of 60 V
NCP3065	Up-to-200 kHz Burst-Mode Voltage-Mode Converter	Buck, Boost, Buck/Boost	3.0 - 40	1.5	SOIC-8, DFN-8, PDIP-8	Can also be used as a controller
NCP3163	Up-to-200 kHz Burst-Mode Voltage-Mode Converter	Buck, Boost, Buck/Boost	2.5 - 40	3.4	SOIC-16WB, DFN-16	Thermally enhanced package
MC34063	Up-to-100 kHz Burst-Mode Voltage-Mode Converter	Buck, Boost, Buck/Boost	3.0 - 40	1.5	SOIC-8	Available in automotive grade versions
MC33163	Up-to-50 kHz Burst-Mode Voltage-Mode Converter	Buck, Boost, Buck/Boost	2.5 - 40	3.4	SOIC-16WB	Available in automotive grade versions
CS51411/3	260/520 kHz Buck Regulator with Synchronization Capability	Buck (Step-down)	4.5 - 40	1.5	SOIC-8, DFN-18	For automotive grade, see NCV51411
CS51412/4	260/520 kHz Buck Regulator with External Bias Capability	Buck (Step-down)	4.5 - 40	1.5	SOIC-8, DFN-18	
CS5171/3	280/560kHz Boost Regulator	Step-up or SEPIC	2.7 - 30	1.5	SOIC-8	
LM2576	52 kHz PWM Step-Down Switching Regulator	Buck (Step-down)	7.0 - 40	3.0	TO-220, D2PAK	

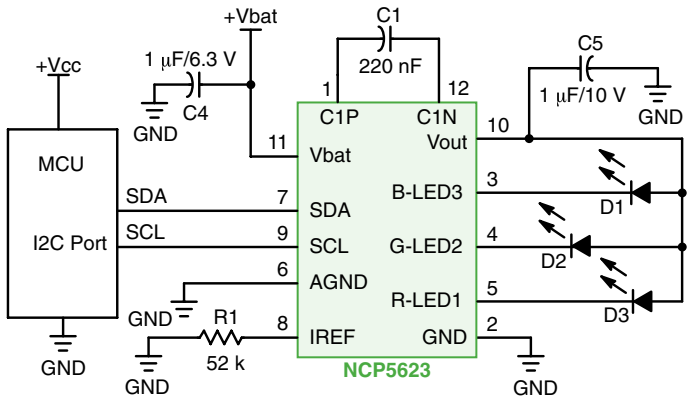
1. For switching regulators, this current is used to calculate LED current based on Vin and Vout conditions.

Portable Applications

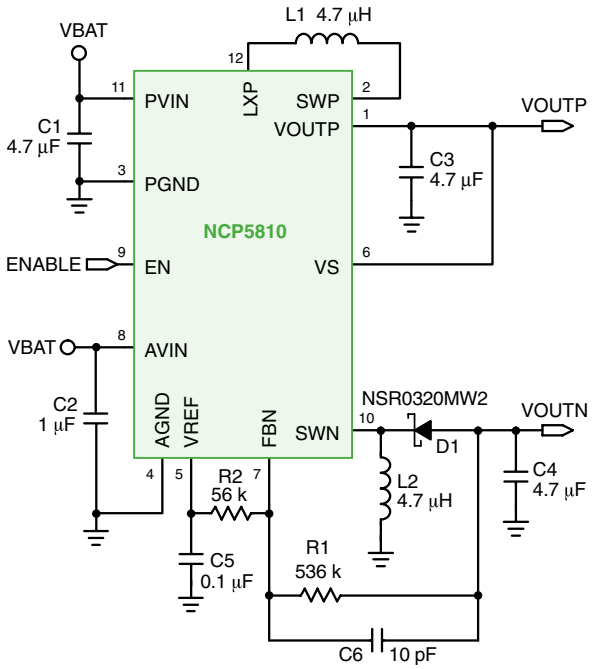
White LED and RGB tricolor LEDs are widely used for backlighting small color LCD panels and keyboards, as well as indicators. High brightness LEDs are used as flash light sources in cell phones and digital cameras. These applications require optimized solutions which can maximize battery lifetime as well as minimize the PCB area and height. ON Semiconductor has a variety of solutions using 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 to Drive 5 LEDs



Charge Pump WLED or RGB Tricolor LED Driver



Active Matrix Organic LED Power IC

Oraganic Light Emitting Diode (OLED)

Organic Light Emitting Diode (OLED) is an emerging display technology. The first OLED panels available were passive matrix OLED (PMOLED). Due to its driving topology, its display size is limited to within 1.8", and are commonly used in MP3 player and cellphone sub-display. The new active matrix OLED (AMOLED) technology however is free from display size limit, and present key advantages comparing to TFT LCD: wide viewing angle, high contrast ratio, very fast response time and thin, thanks to the elimination of backlight. AMOLED panels are used as main display on cellphone and MP3 players. ON Semiconductor offers the market-leading AMOLED power ICs - NCP5810 and its derivatives that meet the very stringent requirements of the AMOLED driver circuit.

Inductive-Boost White LED Drivers for LCD Backlighting and Photo Flash (LED/Xenon)

Product	Input Voltage Range (V)	Maximum Output Voltage (Typ, V)	Output Current	Condition	Number of LEDs/ Configuration	Swiching Mode/ Frequency	Dimming Method	Efficiency (%)	Operating Quiescent Current (Typ.)	Shutdown Current (Typ.)	Package	Note
NCP5005	2.7 - 5.5	24	40 mA	Over 5 LED, Vin 3.6 V	2 to 5/Series	PFM, Up to 2.25 MHz	PWM	90	–	0.3 μA	TSOP-5 (3 x 3 mm)	EMI Immunity
NCP5010	2.7 - 5.5	22	30 mA	Over 5 LED, Vin 3.3 V	2 to 5/Series	PWM, 1 MHz	PWM	85	400 μA	2 μA	Flip-chip-8 (1.7 x 1.7 mm)	Integrated Protections
NCP1422	1.0 - 5.0	5	800 mA	Vout 3.3 V, Vin 2.5 V	1 for Flash	PFM, Up to 1.2 MHz	PWM	94	1.3 μA	0.05 μA	DFN-10 (3 x 3 mm)	Internal Synchronous Rectification
NCP5050	2.7 - 5.5	22	600 mA	Vout 10 V, Vin 4.2 V	**Flash**: 2 to 5/ Series **Backlight**: Up to 120 LEDs in multiple branches	PWM, 1.7 MHz	PWM	88	2 mA	2 μA	Thin DFN-10 (3 x 3 x 0.8 mm)	Internal Switch Between Torch & Flash Current; 1.2 s Time-out
NCP5080	2.7 - 5.5	40	1.5 A	Peak Current	Xenon Flash Tube	Flyback	n/a	Depend on transformer	0.5 mA	1 μA	LLGA-12 (3 x 3 x 0.5 mm)	Unique Photo Sense Input; IGBT Drive

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

Product	Input Voltage Range (V)	Number of Outputs	Total Output Current (mA)	Regulation Mode	Charge Pump Operating Mode	LED-LED Current Matching (Typ)	Dimming Method	Number of Current Level/ Profile	Operating Quiescent Current (Typ)	Shutdown Current (Typ)	Package	Note
NCP5603	2.85 - 5.5	1	350 mA Pulse	Voltage	1X, 1.5X, 2X	–	PWM	Depends on System	1 mA	2.5 μA	DFN-10 (3 x 3 mm)	4.5V/5V Output, Short Circuit Protection
NCP5612	2.7 - 5.5	2	60	Current	1X, 1.5X	±0.2%	S-Wire Link (Single Wire Serial Link)	16/Linear	0.6 mA	1 μA	LLGA-12 (2 x 2 x 0.5 mm)	Built-in "Icon" Mode, OVP, Short Circuit Protection
NCP5623	2.7 - 5.5	3 (Ind.)	90	Current	1X, 2X	±0.5%	I^2C	32/Quasi-Log	0.35 mA	0.8 μA	LLGA-12 (2 x 2 x 0.55 mm)	Built-in "Gradual Dimming", OVP
NCP5604 A/B	2.7 - 5.5	3 or 4	100	Current	1X, 1.33X, 1.5X, 2X	±0.2%	PWM	Depends on System	1 mA	0.3 μA	WQFN-16 (3 x 3 x 0.8 mm)	Short Circuit Protection, OVP
NCP5608	2.7 - 5.5	8 (3/4 for Backlight; 4 Flash)	500 mA (Total) 400 mA (Flash)	Current	1X, 1.33X, 1.5X, 2X	±0.5%	I^2C	128/Linear	0.5 mA	5 μA	QFN-24 (4 x 4 x 0.8 mm)	Backlight + Flash Cambo Solution; Thermal Shutdown, Low Battery Return Noise

AMOLED and PMOLED Power IC

Product	Input Voltage Range (V)	PMOLED or AMOLED	Positive Output Voltage (V)	Pos Output Current Capability (Typ)	Negative Output Voltage (V)	Transient Voltage (Typ, mV)	Switching Mode/ Frequency (MHz)	Efficiency (%)	Operating Quiescent Current (Typ)	Shutdown Current (Typ)	Package	Note
NCP5810	2.7 - 4.6	AMOLED Panel Up to 3"	+ 4.6	270 mA	-2 to -15	4	PWM/1.75	83	1 mA	2 μA	Thin LLGA/ uDFN-12 (3 x 3 x 0.55 mm)	Soft Start, True-Cutoff
NCP5810A*	2.7 - 5.5	AMOLED Panel Up to 5"	Vcc to 9 V	200 mA (with Vout 5 V)	-2 to -15	4	PWM/1.75	85	1 mA	2 μA	uDFN-12 (3 x 3 x 0.55 mm)	Soft Start, True-Cutoff
NCP1406	1.4 - 5.5	Small PMOLED Panel	25	25	n/a	Refer to Data Sheet	PFM/1	85	0.7 mA	0.3 μA	TSOP-5 (3 x 3 mm)	Soft Start, Thermal Shutdown, Undervoltage Lockout

* Pending 1Q08.

Sales and Design Assistance from ON Semiconductor

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

AND8109/D	LED Constant Current Source Drive Scheme
AND8135/D	Efficient High Power Flash Light
AND8138/D	DC-DC SEPIC Converter for Driving High Brightness LEDs
AND8156/D	NUD4001 & NUD4011 Low Cost Integrated Current Sources
AND8171/D	NCP1421/2 Reference Designs for High-Power White LEDs
AND8192/D	Charge Pump Based Multiple LED Driver
AND8224/D	NCP101x Universal Offline LED Flasher Circuit
AND8294/D	Medium Size Backlight NCP5050: Drive Up to 120 LEDs (6-10 in Series Config)
AND8298/D	High Intensity LED Drivers Using NCP3065/NCV3065
AND8302/D	Linear LED Drivers to Replace Boost Converters for Backlighting Applications
DN06001/D	NCP3063: 9 V to 36 Vin dc, Constant Current LED Driver
DN06004/D	CS5171: SEPIC LED Driver
DN06018/D	CS51411/NCV51411: 12V or 24Vin DC, Constant Current LED Driver
DN06027/D	NCP1013: Universal Input, 5 W, LED Ballast
DN06031/D	NCP3065: High Brightness LED SEPIC Driver
DN06033/D	NCP3065: SEPIC LED Driver for MR16

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