6-Channel Ultra-efficient fractional LED Driver

- REVISION 1 -

INTRODUCTION

DESCRIPTION

The MN3006 is a high efficiency beyond 95% quad-mode fractional charge pump that can drive up to six LEDs programmable by a one wire digital interface that features a low drop-out voltage below 50mV**. It was designed to potentially increase the talk time by upto 21% in mobile devices** (depending upon LED forward voltages, current requirements and total battery drain). It also features a low noise input ripple voltage achieved by operating at a constant switching frequency which allows the use of small external ceramic capacitors. The multi-fractional charge pump supports a wide range of input voltages from 2.5V to 5.5V.The EN/SET logic input functions as a chip enable and a "1-wire" addressable interface for control.

APPLICATIONS

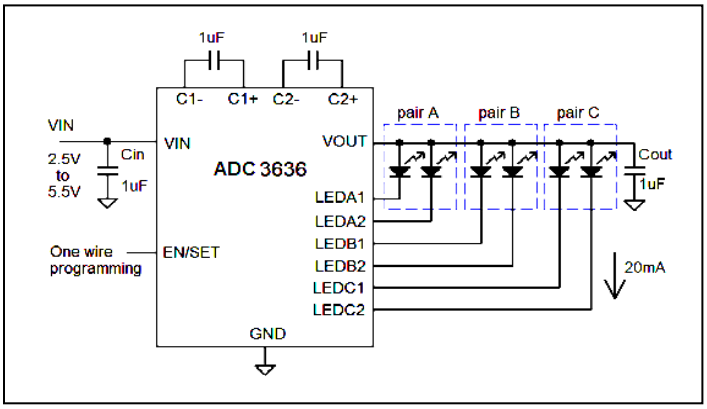
- LCD Display Backlight
- Color RGB LEDs
- Cellular Phones
- Digital Still Cameras
- Handheld Devices

New feature-rich mobile devices are moving towards power consuming video/display centric technologies (eg. Video, TV, MP4, GPS). The MN3006 is the First LED controller geared to efficiently control larger and higher resolution, higher size displays that are kept on for longer periods of time.
Since 50% of the power is now consumed by LED/LCD displays, the MN3006 is the most innovative and efficient solution to bring a sustainable advantage in the marketplace.

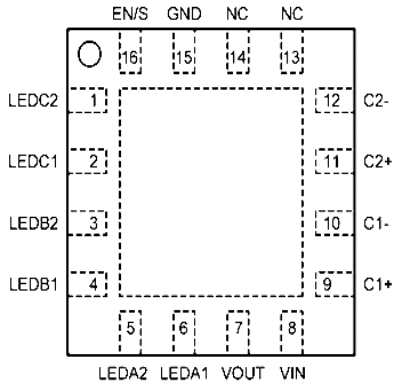
FEATURES

- Tri-mode charge pump: 1x, 1.5x, 2x
- Drives up to 6 LEDs at 32mA each
- Power efficiency up to 95%
- Drop-out voltage of only 50mV
- Low noise input ripple in all modes
- "Zero" current shutdown mode
- Soft start and current limiting
- Short circuit protection
- Thermal shutdown protection
- Tiny 3mm x 3mm, 16-lead TQFN package

TYPICAL APPLICATION CIRCUIT



PIN CONFIGURATION



ELECTRICAL CHARACTERISTICS

ABSOLUTE MAXIMUM RATING		
Parameter	**Rating**	**Unit**
VIN, LEDx, C1±, C2± voltage	6	V
VOUT voltage	7	V
EN/SET voltage	VIN + 0.7V	V
Storage Temperature Range	-65 to +160	°C
Junction Temperature Range	-40 to +125	°C
Lead Temperature	300	°C

RECOMMENDED OPERATING CONDITIONS		
Parameter	**Rating**	**Unit**
VIN	2.5 to 5.5	V
Ambient Temperature Range	-40 to +85	°C
I_{LED} per LED pin	0 to 32	mA
Total Output Current	0 to 192	mA

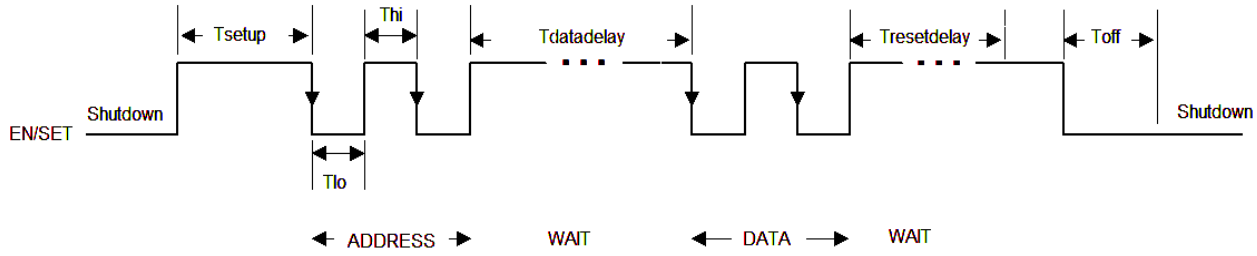
Typical application circuit with external components is shown on page 1.

OPERATING CHARACTERISTICS

PARAMETER	TEST CONDITIONS	PARAMETERS			UNITS
	VIN = 3.6V, EN = High, T_{AMB} = 25°C, otherwise specified	MIN.	TYP.	MAX.	
Quiescent Current I_Q	1x mode, no load 1.5x mode, no load 2x mode, no load V_{EN} = 0V	- - - -	0.5 3 2.5 tbd	- - - -	mA mA mA µA
Shutdown Current I_{QSHDN}	1mA ≤ I_{LED}≤ 31mA	-	tbd	-	µA
LED Current Accuracy $I_{LED-ACC}$	1x mode, I_{OUT} = 100mA	-	±3	1	%
LED Channel Matching $I_{LED-DEV}$	5x mode, I_{OUT} = 100mA 2x mode, I_{OUT} = 100mA	-	±3	1	%
Output Resistance R_{OUTT}	open loop	- - -	0.5 3.5 6	- - -	Ω
Charge Pump Frequency F_{osc}	2x mode 1.5x mode	0.8 0.8	1.0 1.0	1.4 1.4	MHz MHz
Output short circuit Current Limit I_{SC_MAX}	V_{OUT} < 0.5V	-	80	-	mA

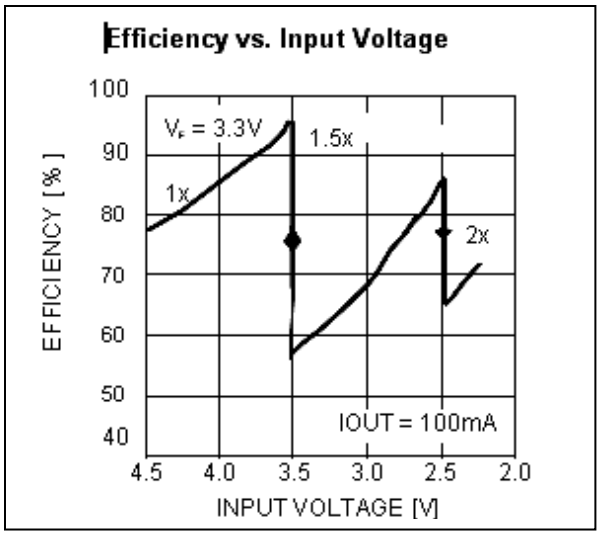
Transition Thresholds LED_{TH} 1 x to 1.5x or 1.5x to 2x		**-**	**50**	**-**	**mV**
Hysteresis Voltage V_{HYS}		**-**	**400**	**-**	**mV**
Transition Filter Delay T_{DF}	**0 to 700mV**	**-**	**500**	**-**	**µs**
Input Current Limit I_{IN_MAX}		**450**	**-**	**-**	**mA**
Input Leakage $I_{EN/DIM}$		**-**	**-**	**1**	**µA**
Logic High Level V_{HI}		**-1**	**-**	**-**	**V**
Logic Low Level V_{LO}		**1.3**	**-**	**0.4**	**V**
Thermal Shutdown T_{SD}		**-**	**150**	**-**	**°C**
Thermal Hysteresis T_{HYS}		**-**	**20**	**-**	**°C**
Undervoltage lockout VUVLO		**-**	**2**	**-**	**V**
EN/SET setup from shutdown T_{SETUP}		**10**	**-**	**-**	**µs**
Program low time T_{LO}EN/SET		**0.2**	**-**	**100**	**µs**
Program high time T_{HI}EN/SET		**0.2**	**-**	**100**	**µs**
Low time to shutdown T_{OFF}EN/SET		**1.5**	**-**	**-**	**ms**
EN/SET Delay to DATA $T_{DATADELAY}$		**500**	**-**	**1000**	**µs**
EN/SET Delay High to ADDRESS $T_{RESETDELAY}$		**2**	**-**	**-**	**ms**

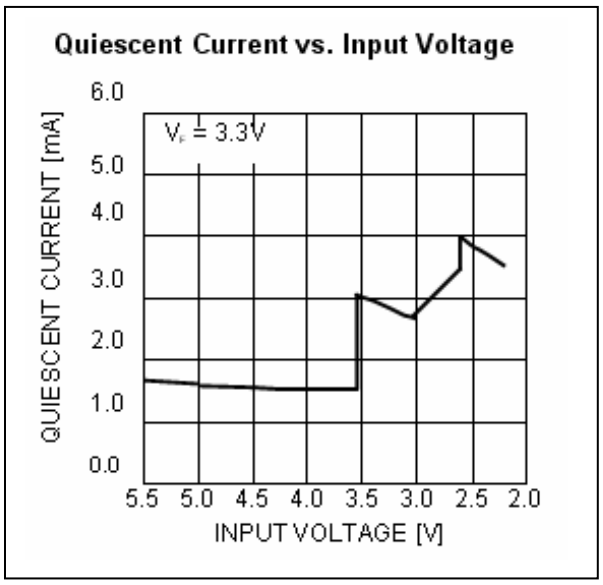
Figure 1. EN/SET One Wire Addressable Timing Diagram

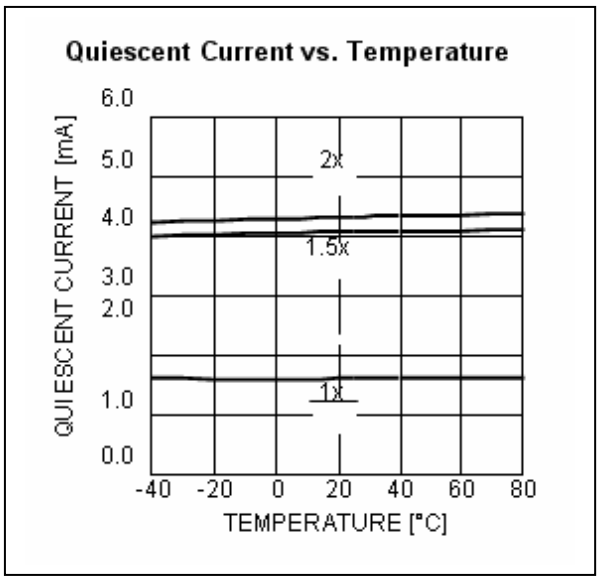


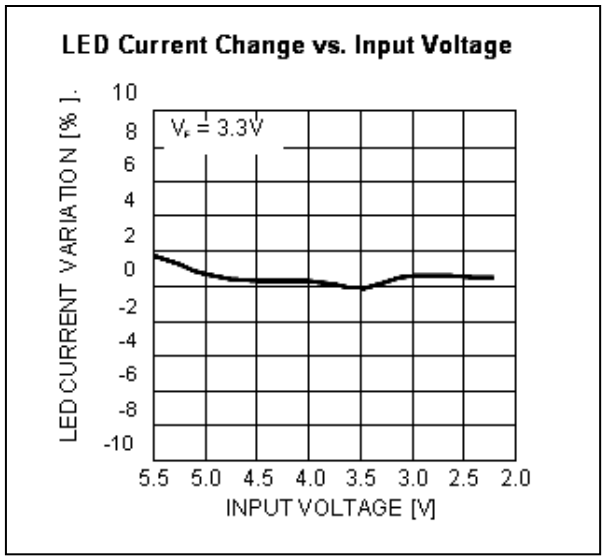
TYPICAL PERFORMANCE CHARACTERISTICS

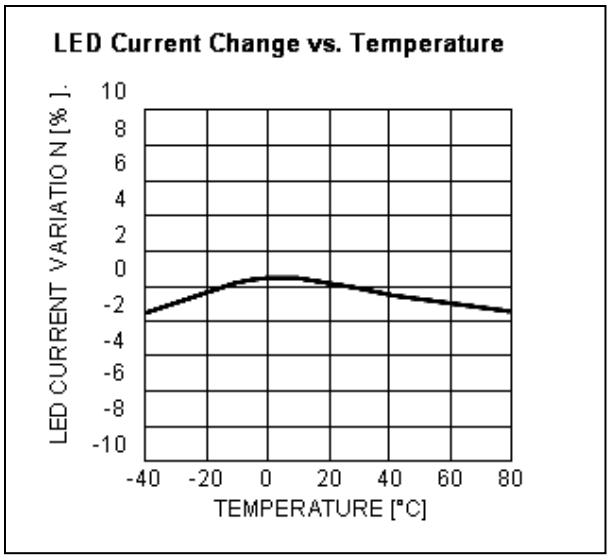
VIN = 3.6V, I_{OUT} = 120mA (6 LEDs at 20mA), C_{IN} = C_{OUT} = C1 = C2 = 1µF, T_{AMB} = 25°C unless otherwise specified.

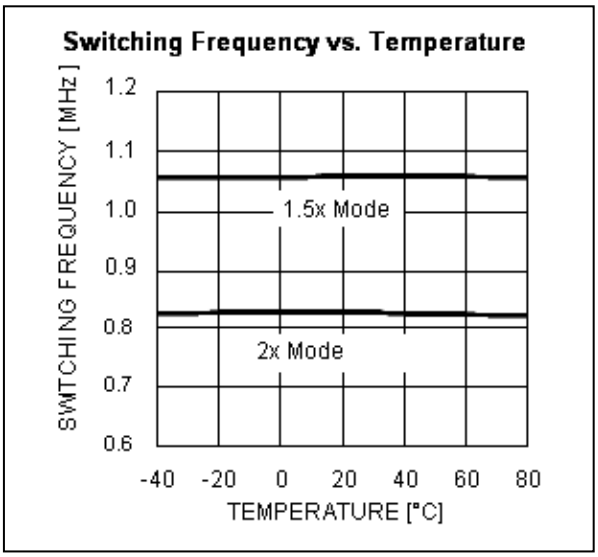


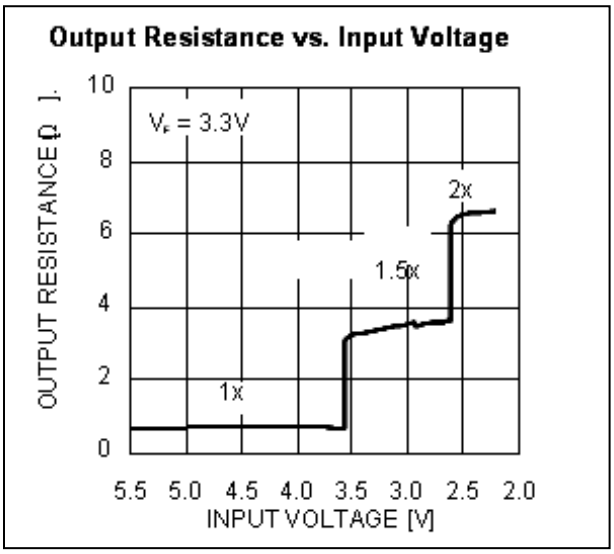


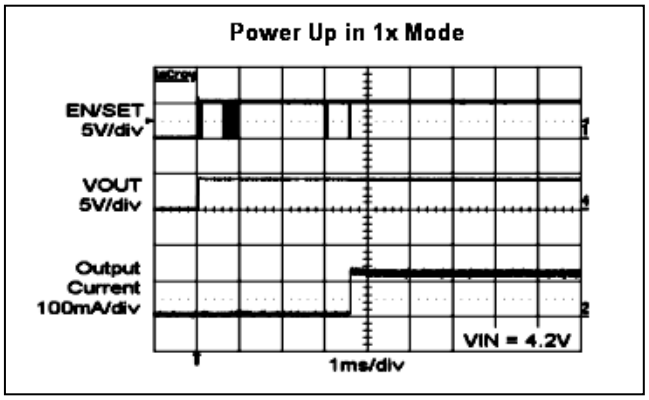


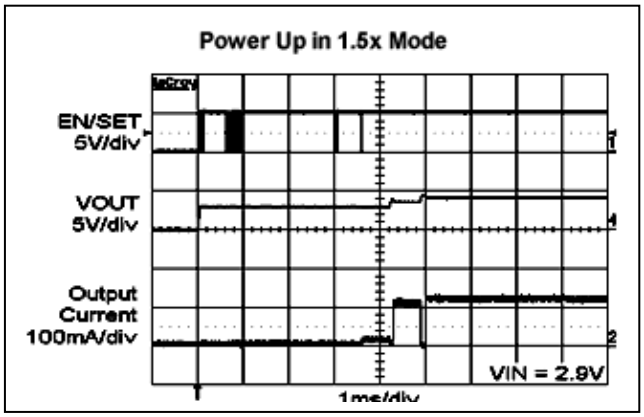


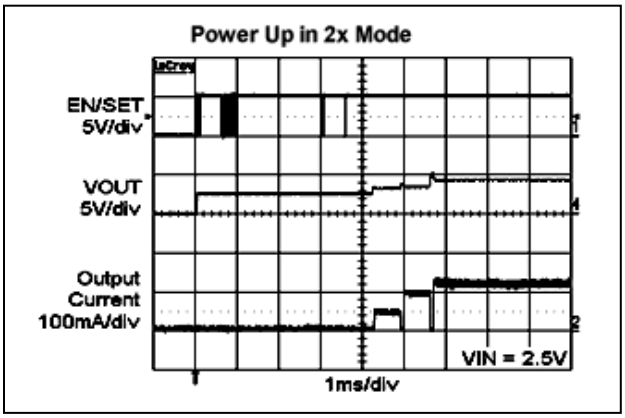












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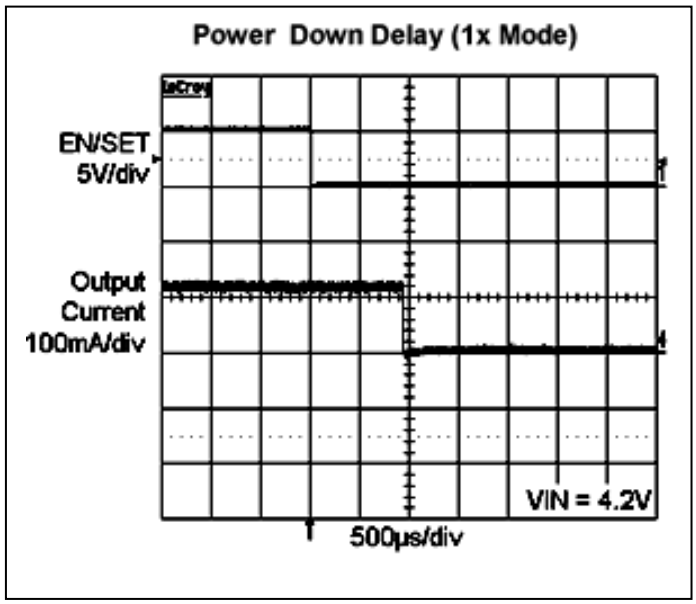

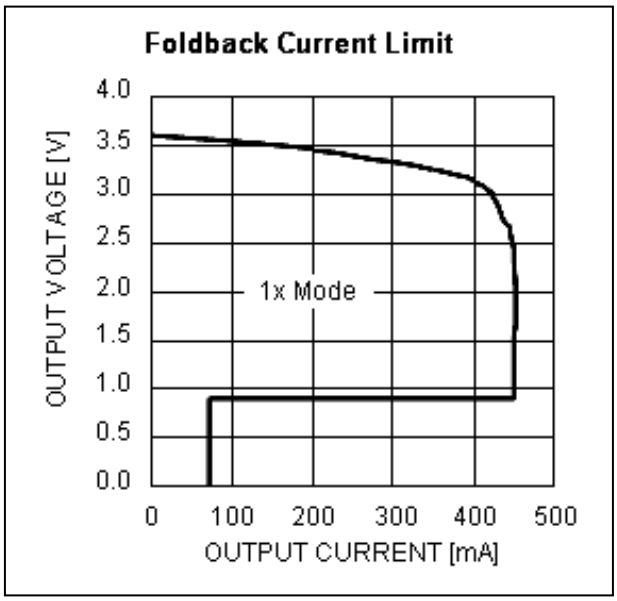

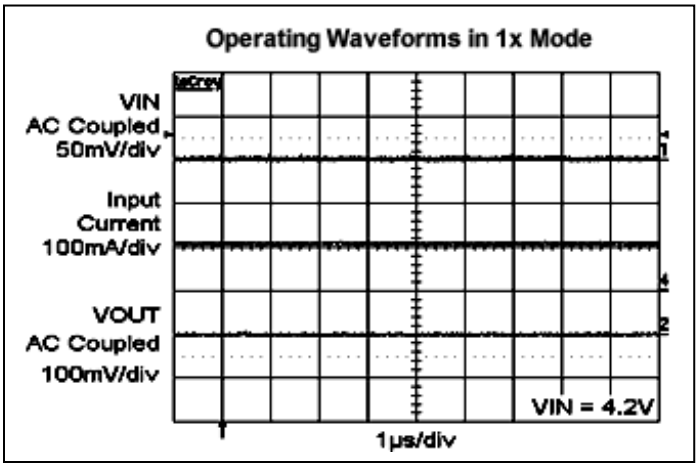

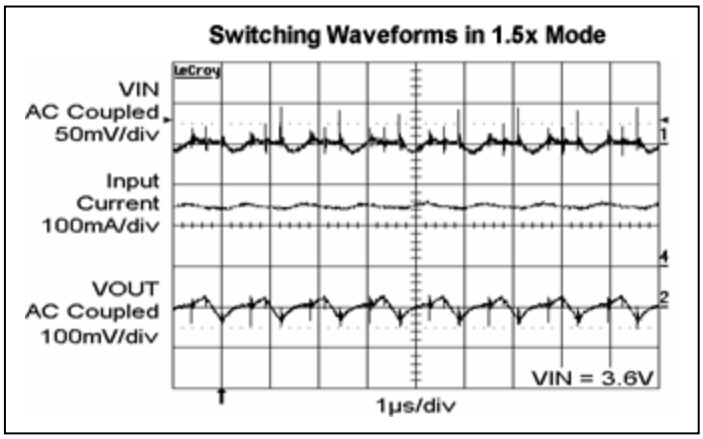

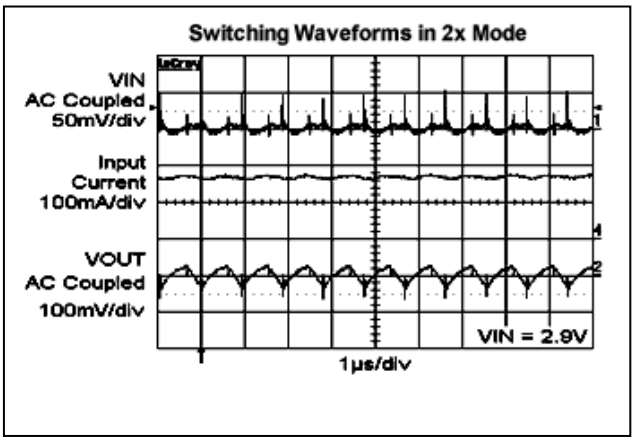

PIN DESCRIPTION

Number	Name	Description
1	LEDC2	LEDC2 cathode terminal
2	LEDC1	LEDC1 cathode terminal
3	LEDB2	LEDB2 cathode terminal
4	LEDB1	LEDB1 cathode terminal
5	LEDA2	LEDA2 cathode terminal
6	LEDA1	LEDA1 cathode terminal
7	VOUT	Charge pump output, connect to LED anodes
8	VIN	Charge pump input, connect to battery or supply
9	C1+	Bucket capacitor 1, positive terminal
10	C1-	Bucket capacitor 1, negative terminal
11	C2+	Bucket capacitor 2, positive terminal
12	C2-	Bucket capacitor 2, negative terminal
13/14	NC	No connect
15	GND	Ground reference
16	EN/SET	Device enable (active high) and 1 wire control input
TAB	TAB	Connect to GND on the PCB

PIN FUNCTION

VIN is the supply pin for the charge pump. A small 1µF ceramic bypass capacitor is required between the VIN pin and ground near the device.The operating input voltage range is from 2.5V to 5.5V. Whenever the input supply falls below the under-voltage threshold (2V) all the LED channels will be automatically disabled and the device register are reset to default values.

EN/SET i the enable and one wire addressable control logic input for all LED channels. Guaranteed levels of logic high and logic low are set at 1.3V and 0.4V respectively. When EN/SET is initially taken high, the device becomes enabled and all LED currents remain at 0mA. To place the device into zero current mode, the EN/SET pin must be held low for more than 1.5ms.

VOUT is the charge pump output that is connected to the LED anodes. A small 1µF ceramic bypass capacitor is required between the VOUT pin and ground near the device.

GND is the ground reference for the charge pump. The pin must be connected to the ground plane on the PCB.

C1+, C1- are connected to each side of the ceramic bucket capacitor C1.

C2+, C2- are connected to each side of the ceramic bucket capacitor C2.

LEDxx provide the internal regulated current for each of the LED cathodes. These pins enter high-impedance zero current state whenever the device is placed in shutdown mode.

TAB is the exposed pad underneath the package. For best thermal performance, the tab should be soldered to the PCB and connected to the ground plane.

BLOCK DIAGRAM

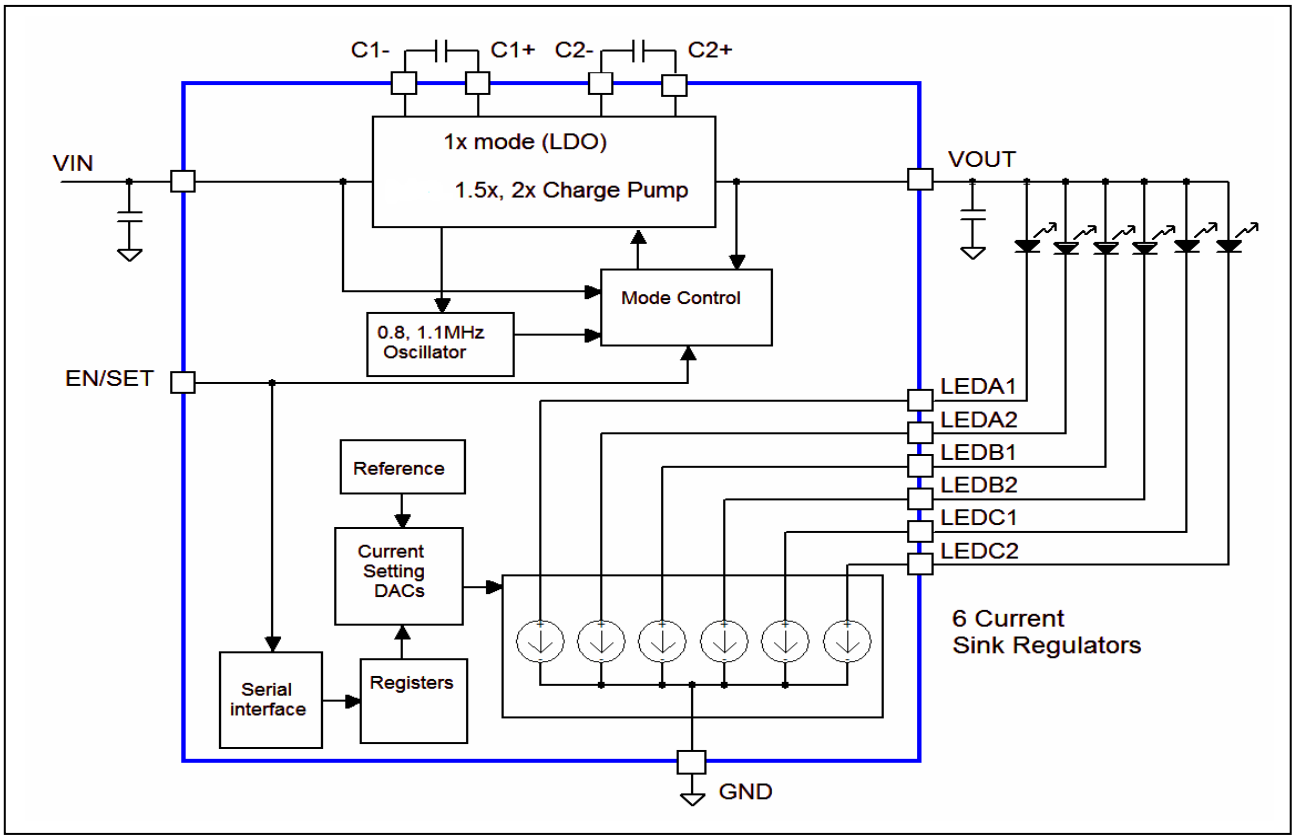

Figure 2. MN3006 Functional Block Diagram

BASIC OPERATION

At power-up, the MN3006 starts operating in 1x mode where the output will be approximately equal to the input supply voltage (less any internal voltage losses). If the output voltage is sufficient to regulate all LED currents, the device remains in 1x operating mode.

If the input voltage is insufficient again or falls to a level where the regulated currents cannot be maintained, the device will automatically switch to the 1.5x boost mode (after a fixed delay time of about 400us).

Note: The drop-out is only 50mV and Power efficiency can be as high as 95%

In 1.5x mode, the output is approximately equal to 1.5 times the input supply voltage (less any internal voltage losses).

If the input voltage fails more or is still insufficient to drive the LEDs, it will automatically switch again into 2x mode where the output is approximately equal to 2 times the input supply voltage (less any internal voltage losses).

If the device detects a sufficient input voltage is present to drive all LED currents in 1x mode, it will change automatically back to 1x mode. This only applies for changing back to the 1x mode.

Unused LED Channels

For applications with only four or two LEDs, unused LED banks can be disabled via the enable register internally and left to float.

For applications with 5 LEDs or less, unused LEDs can also be disabled by connecting the LED pin directly to VOUT. If LED pin voltage is within 1V of VOUT, then the channel is switched off and a 200µA test current is placed in the channel to sense when the channel moves below VOUT –1V

Protection Mode

If an LED is disconnected, the output voltage VOUT automatically limits at about 5.5V. This is to prevent the output pin from exceeding its absolute maximum rating.

If the die temperature exceeds +150°C the driver will enter a thermal protection shutdown mode. When the device temperature drops by about 20°C the device will resume normal operation.

LED Selection

LEDs with forward voltages (V_F) ranging from 1.3V to 5.0V may be used with the MN3006. Selecting LEDs with lower V_F is recommended in order to improve the efficiency by keeping the driver in 1x mode longer as the battery voltage decreases.

For example, if a white LED with a V_F of 3.3V is selected over one with V_F of 3.5V, the MN3006 will stay in 1x mode for lower supply voltage of 0.2V. This helps improve the efficiency and extends battery life.

External Components

The driver requires two external 1µF ceramic capacitors for decoupling input, output, and for the charge pump. Both capacitors type X5R and X7R are recommended for the LED driver application. In all charge pump modes, the input current ripple is kept very low by design and an input bypass capacitor of 1µF is sufficient.

In 1x mode, the device operates in linear mode and does not introduce switching noise back onto the supply.

Recommended Layout

In charge pump mode, the driver switches internally at a high frequency. It is recommended to minimize trace length to all four capacitors. A ground plane should cover the area under the driver IC as well as the bypass capacitors. Short connection to ground on capacitors CIN and COUT can be implemented with the use of multiple via. A copper area matching the TQFN exposed pad (TAB) must be connected to the ground plane underneath. The use of multiple via
improves the package heat dissipation.

Programming guide

The programming guide can be made available under NDA

