120mA 6-Channel Charge Pump White LED Driver with Low Dropout Current Source

■ General Description

The LN9376 is a high performance white LED driver. It integrates current sources and automatic mode selection charge pump. The part maintains the high efficiency by utilizing an x1/x1.5 fractional charge pump and low dropout current sources. The small equivalent x1 mode open loop resistance and ultra-low dropout voltage of current source extend the operating time of x1 mode and optimize the efficiency of Li-ion battery in white LED applications.

The LN9376 supports up to 6 white LEDs and regulates a constant current for uniform intensity. The part implements a 4-bit DAC for brightness control. Users can easily configure the LED current from 1.25mA to 20mA by a serial pulse. The dimming of white LEDs current can be achieved by applying a pulse signal to the EN pin. There are totally 16 steps of current could be set by users. The operating voltage range is 2.7V to 5.5V. Internal soft start circuitry effectively reduces the in-rush current while both start-up and mode transition. The load is disconnected from VIN while shutdown and the shutdown current is less than 1μA.

■ Applications

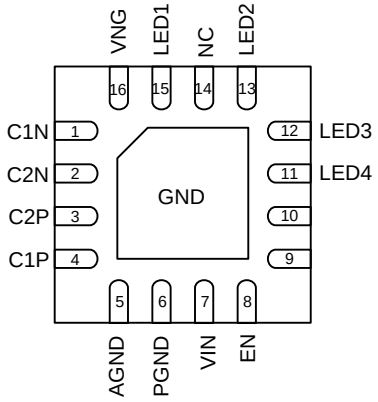
- Mobile Phone, DSC, MP3
- White LED Backlighting
- LCD Display Supply

■ Features

- 85% average efficiency over battery life
- Support up to 6 white LEDs
- 80mv typical current source dropout
- Support up to120mA output current
- 2% Typical led current accuracy
- 2% Typical led current matching
- Soft start function
- Auto charge pump mode selection
- Output over voltage protection
- 16-step brightness control
- Low input noise and emi
- Low 1μA shutdown current

■ Package

- QFN3×3-16



QFN3*3-16
(Top View)

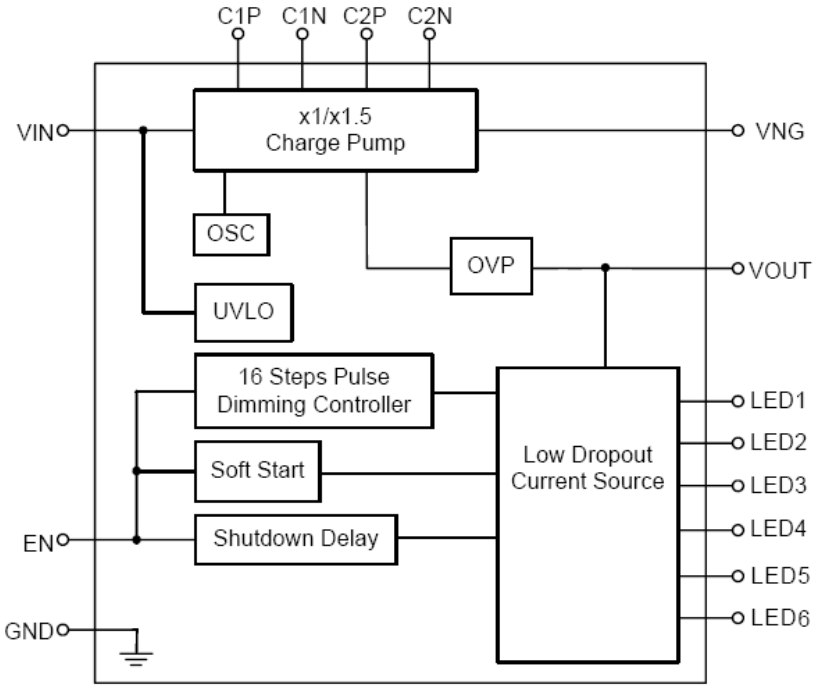
■ Ordering Information

Package	Marking	Symbol	Description
WBFBP3X3-16L （QFN33-16）	9376 XXXX	LN9376-20	6 white LEDs，Each LED maximum current is 20mA，Chip Enable (Active High)
WBFBP3X3-16L （QFN33-16）	9376 XXXX	LN9376-25	6 white LEDs，Each LED maximum current is 25mA，Chip Enable (Active High)

■ Pin Function Description

Pin Number	Pin Name	Pin Function
1	C1N	Negative terminal of bucket capacitor 1
2	C2N	Negative terminal of bucket capacitor 2
3	C2P	Positive terminal of bucket capacitor 2
4	C1P	Positive terminal of bucket capacitor 1
5	AGND	Analog ground
6	PGND	Power ground.
7	VIN	Power input voltage
8	EN	Chip enable (active high),and connects to gpio pin of mcu
9	LED6	Current sink for LED6.(if not in use ,pin should be connected to Vin)
10	LED5	Current sink for LED5.(if not in use ,pin should be connected to Vin)
11	LED4	Current sink for LED4.(if not in use ,pin should be connected to Vin)
12	LED3	Current sink for LED3.(if not in use ,pin should be connected to Vin)
13	LED2	Current sink for LED2.(if not in use ,pin should be connected to Vin)
14	NC	Internal no connect
15	LED1	Current sink for LED1.(if not in use ,pin should be connected to Vin)
16	VNG	Charge pump output
Exposed Pad 17	GND	Exposed pad should be soldered to PCB board and connected to gnd.

■ Function Block Diagram



■ Absolute Maximum Ratings

(Ta=25°C)

Item	Symbol		Absolute maximum ratings	Unit
Input Voltage	V_{IN}		-0.3～6.0	V
Output Voltage	V_{OUT}		-0.3～6.0	V
EN Voltage	V_{EN}		-0.3～6.0	V
Power Dissipation	P_D	QFN3×3-16	1.47	W
Package Thermal Resistance	θ_{JA}	QFN3×3-16	68	°C/W
Junction Temperature	Tjun		150	℃
Operating Temperature range	Topr		-40～＋85	
Storage Temperature range	Tstg		-65～＋150	
Lead Temperature (Soldering, 10 sec.)	Tlead		260	
ESD Susceptibility	HBM(Human Body Mode)		3000	V
	MM(Machine Mode)		200	

Caution: The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

■ Electrical Characteristics

(Ta=25℃, unless otherwise noted)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Units
Input supply voltage	V_{IN}		2.7		5.5	V
Undervoltage lockout threshold	V_{UVLO}	VIN rising or falling	1.8	2.0	2.4	V
Undervoltage lockout hysterresis				100		mV
Shutdown current	I_{SHDN}	VIN=5.5V, EN=0V	-	1	10	μA
Quiescent of x1 mode	I_Q×1	x1 Mode, VIN = 5.5V, LED OFF		1.8		mA
Iled accuracy	$I_{LED-ERR}$	2mA<ILED<20mA		2	8	%
Current matching	$I_{LED-LED-ERR}$	2mA<ILED<30mA		1	5	
×1 mode to ×1.5 mode Transition voltage(vin falling)	V_{TRANS}	VLED=3.4V, ILED1=ILED2=ILED3=ILED4=15mA		3.6		V
Oscillator frequency	F_{OSC}			500K		HZ
Output over voltage protection	V_{OVP}	VIN-VOUT		5.5	6	V
Thermal shutdown threshold				150		℃
Thermal shutdown hysteresis				10		℃
EN low time for shut down	T_{SHDN}		2			mS
EN low time for dimming	T_{LO}		0.5		500	μS
EN high time for dimming	T_{HI}		0.5			μS
EN logic-high threshold voltage	V_{IH}		1.5			V
EN logic-low threshold voltage	V_{IL}				0.4	V

■ Typical Application Circuit

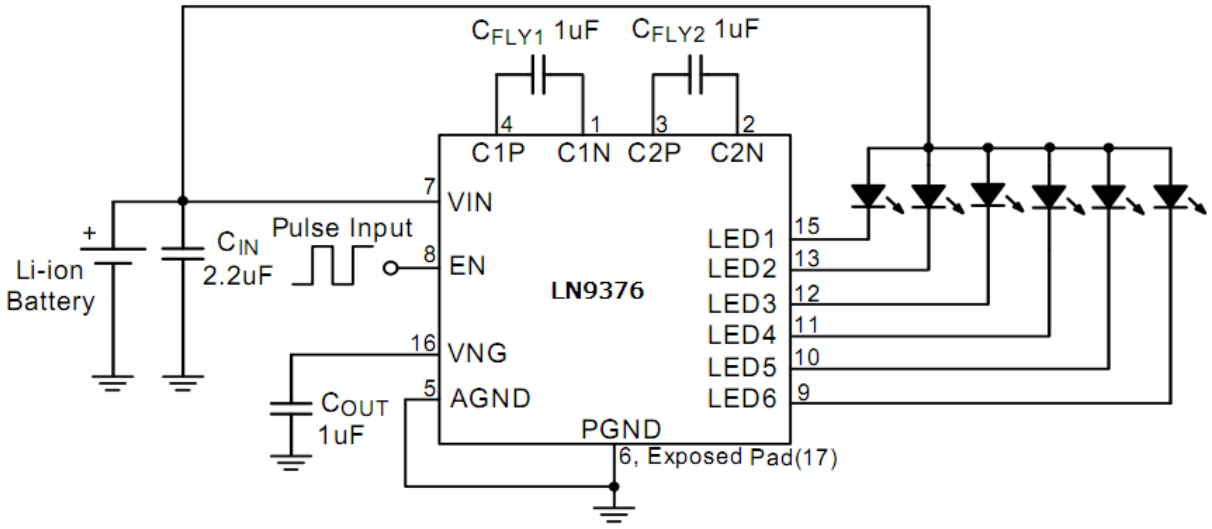


Figure 1. For 6-WLEDs Application Circuit

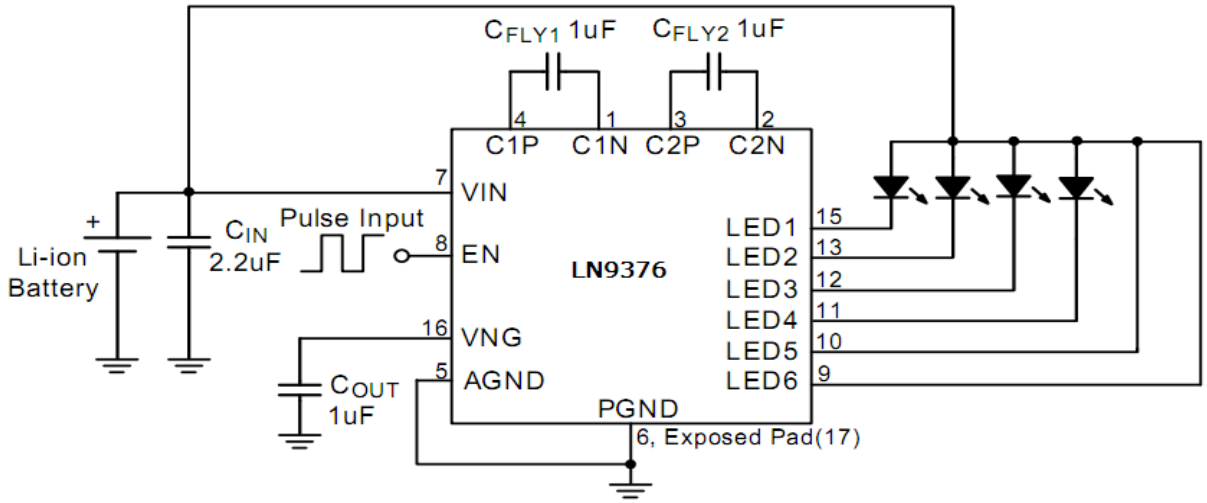


Figure 2. For 6-WLEDs Application Circuit

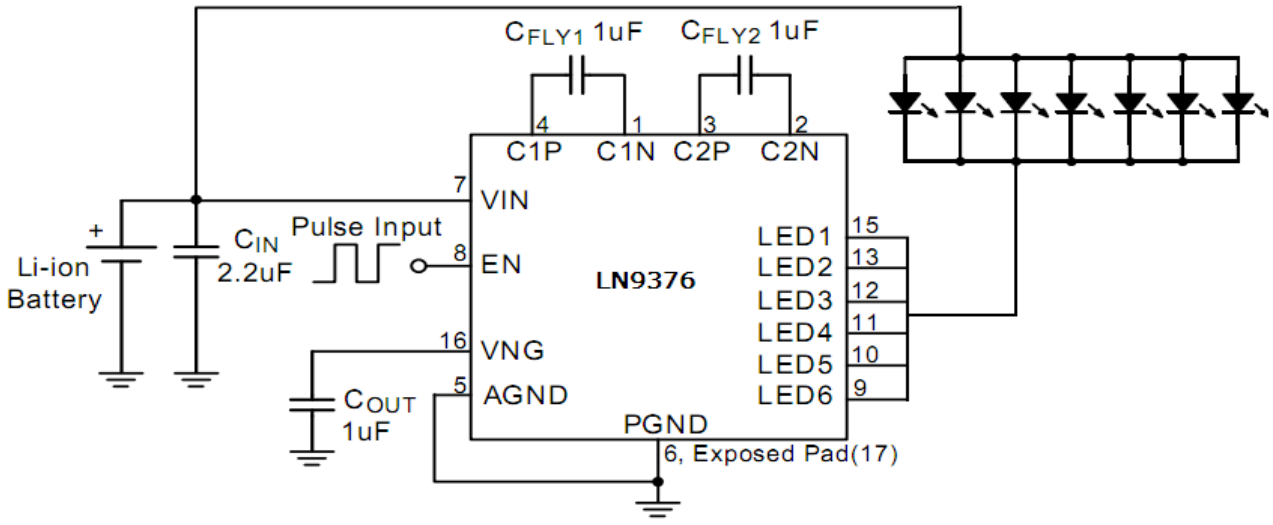


Figure 3. For more than 6-WLEDs Application Circuit

■ Operation

The LN9376 uses a fractional switched capacitor charge pump to power up to six white LEDs with a programmable current for uniform intensity. The part integrates current sources and automatic mode selection charge pump. It maintains the high efficiency by utilizing an x1/x1.5 fractional charge pump and current sources. The small equivalent x1 mode open loop resistance and ultra-low dropout voltage of current source extend the operating time of x1 mode and optimize the efficiency in white LED applications.

Brightness Control

The LN9376 implements a pulse dimming method to control the brightness of white LEDs. Users can easily configure the LED current from 1.25mA to 20mA by a serial pulse. The dimming of white LEDs' current can be achieved by applying a pulse signal to the EN pin. There are totally 16 steps of current could be set by users.

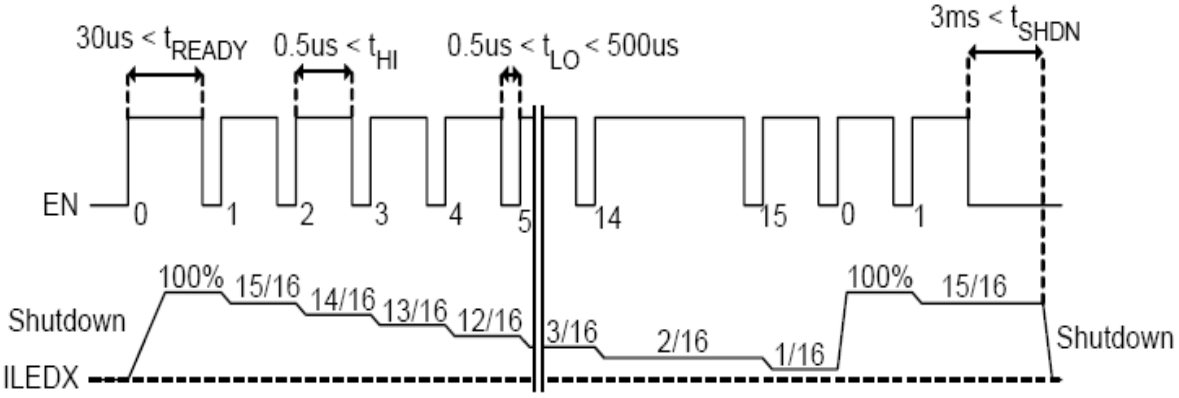


Figure 4. Brightness control by pulse dimming

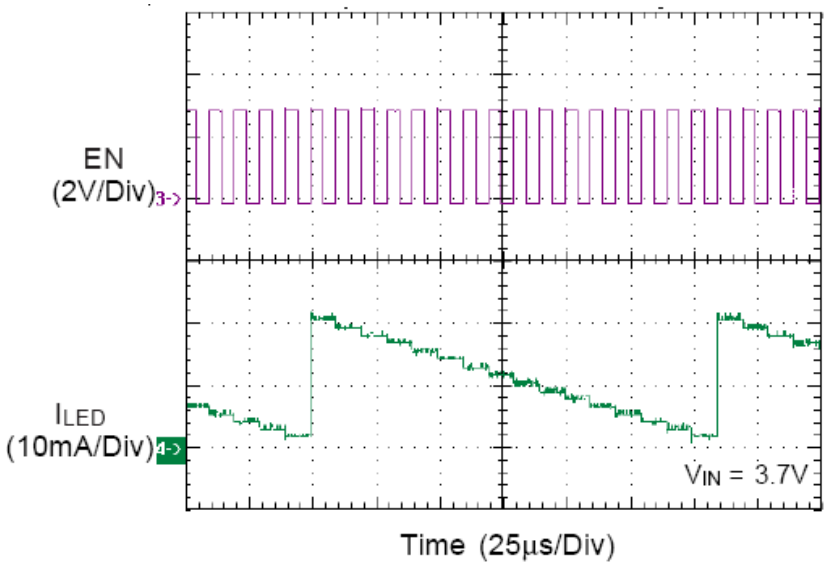


Figure 5. Examples of pulse adjust brightness

Mode Decision

The LN9376 uses a smart mode selection method to decide the working mode for optimizing the efficiency. Mode decision circuit senses the output and LED voltage for up/down selection. The LN9376 automatically switches to x1.5 mode whenever the dropout condition is detected from the current source and returns to x1 mode whenever the dropout condition releases.

LED connection

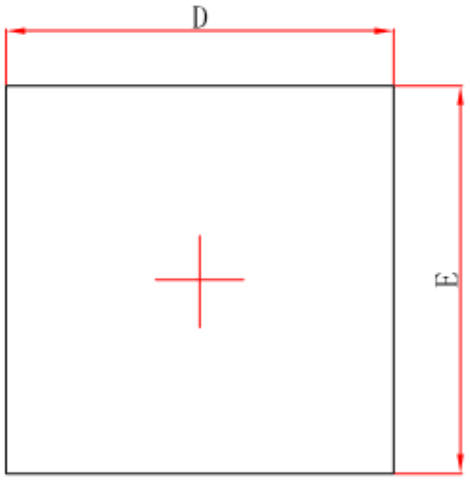
The LN9376 supports up to 6 white LEDs. The six LEDs are connected from VIN to pin 9, 10, 11, 12,13 and 14 respectively. If the LED is not used, the LED pin should be connected to VIN directly.

Selecting Capacitors

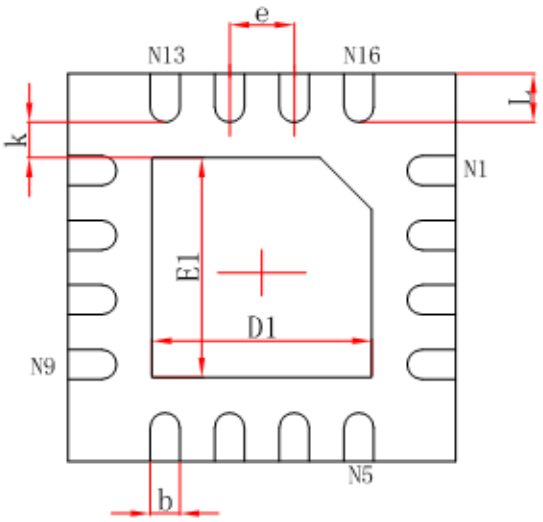
To get the better performance of LN9376, the selection of peripherally appropriate capacitor and value is very important. These capacitors determine some parameters such as input/output ripple voltage, power efficiency, maximum supply current by charge pump, To reduce the input and output ripple effectively, the low ESR ceramic capacitors are recommended. For LED driver applications, the input voltage ripple is more important than output ripple. Input ripple is controlled by input capacitor CIN, increasing the value of input capacitance can further reduce the ripple. Practically, the input voltage ripple depends on the power supply impedance. The flying capacitor C1 and C2 determine the supply current capability of the charge pump and to influence the overall efficiency of system. The lower value will improve efficiency, but it will limit the LED's current at low input voltage.

■ Package Information

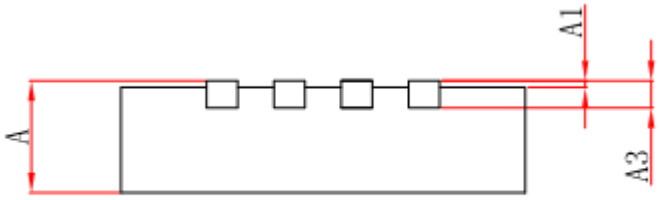
- **QFN3×3-16**



Top View



Bottom View



Side View

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700/0.800	0.800/0.900	0.028/0.031	0.031/0.035
A1	0.000	0.050	0.000	0.002
A3	0.203REF.		0.008REF.	
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
D1	1.600	1.800	0.063	0.071
E1	1.600	1.800	0.063	0.071
k	0.200MIN.		0.008MIN.	
b	0.180	0.300	0.007	0.012
e	0.500TYP.		0.020TYP.	
L	0.300	0.500	0.012	0.020