EVALUATION KIT AVAILABLE

MAXIM

Ultra-Efficient Negative Charge-Pump LED Driver with Dual LDOs in 3mm x 3mm Thin QFN

MAX8822

General Description

The MAX8822 drives up to four white light-emitting diodes (LEDs) with regulated constant current for display backlighting in cell phones, digital cameras, PDAs, and other handheld devices. By utilizing a proprietary negative 0.5x inverting charge pump and innovative independent low-dropout (LDO) adaptive current regulators, very high efficiency is achieved over the full 1-cell Li+ battery voltage range, even with large LED V_F mismatch. The 1MHz fixed-frequency switching allows for tiny external components. The regulation scheme is optimized to ensure low EMI and low input ripple. Two 200mA, low-noise, high power-supply-rejection-ratio (PSRR) LDOs with programmable output voltages are included on-chip to provide power to camera modules or other devices.

The MAX8822 features a single-wire, serial-pulse control-logic interface that programs LED current and the output voltages of the LDOs. The LED dimming range is pseudo-logarithmic from 24mA to 0.1mA in 31 steps. LDO output voltages are programmable in 16 different combinations to meet various camera module requirements.

The MAX8822 includes soft-start, thermal shutdown, open- and short-circuit protection.

Applications

White LED Backlighting

Cell Phones and Smartphones

Typical Operating Circuit
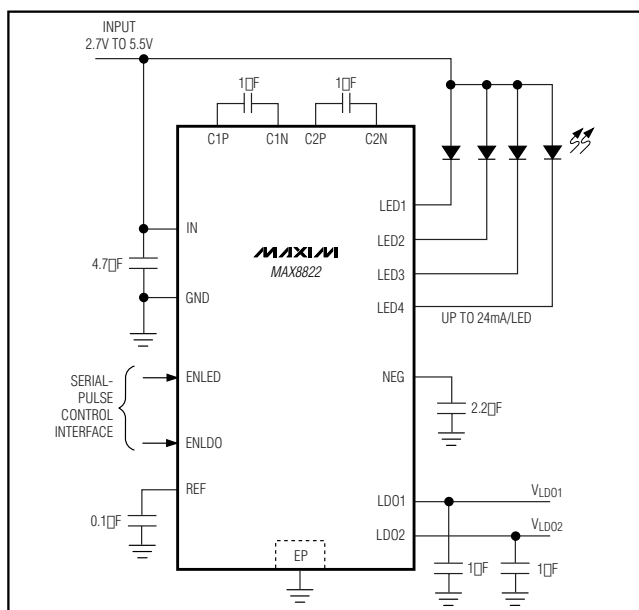
Features

♦ **High-Efficiency Charge Pump for Up to Four White LEDs**
   Independent Adaptive Voltage Supply for Each LED
   24mA to 0.1mA Dimming Range
   1% (typ) Current Accuracy and 0.3% Current Matching
   Low 65µA (typ) Quiescent Current

♦ **Dual 200mA Low-Noise, High PSRR LDOs**
   16 Different Output Voltage Combinations Up to 3.3V
   High 60dB PSRR at 10kHz

♦ **Flexible Single-Wire Control for Dimming and LDO Output Voltage**

♦ **Low 0.5µA (typ) Shutdown Mode**

♦ **Soft-Start Limits Inrush Current**

♦ **Thermal Shutdown and Open- and Short-Circuit Protection**

♦ **Tiny 16-Pin, 3mm x 3mm Thin QFN Package (0.8mm max Height) with Exposed Paddle**
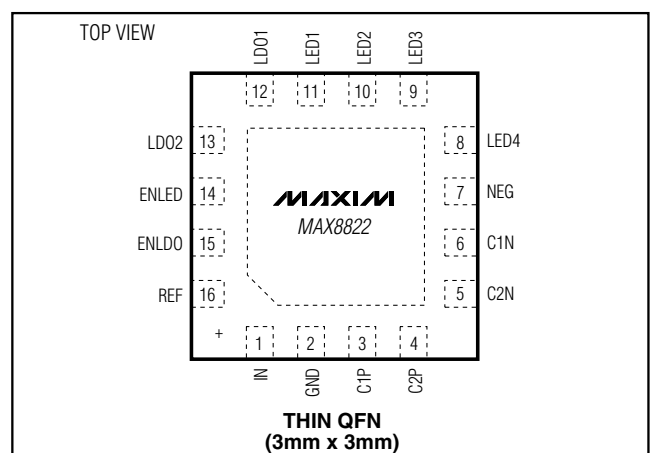
Ordering Information

PART	PIN-PACKAGE	TOP MARK	PKG CODE
MAX8822ETE+	16 Thin QFN-EP* (3mm x 3mm)	AFW	T1633-5

Note: *The device is specified over the -40°C to +85°C extended temperature range.*
+Denotes a lead-free package.
*EP = Exposed paddle.

Pin Configuration

THIN QFN (3mm x 3mm)

MAXIM_____ **Maxim Integrated Products** 1

Ultra-Efficient Negative Charge-Pump LED Driver with Dual LDOs in 3mm x 3mm Thin QFN

MAX8822

ABSOLUTE MAXIMUM RATINGS

IN, C1N, C2N, REF, ENLED, ENLDO, LDO1, LDO2
   to GND ....-0.3V to +6.0V
IN, REF, ENLED, ENLDO, LDO1, LDO2
   to NEG ....-0.3V to +6.0V
LED_, C1N, C2N to NEG ....-0.3V to (V_{IN} + 0.3V)
C1P, C2P to GND ....-0.3V to (V_{IN} + 0.3V)
NEG to GND ....-6.0V to +0.3V
NEG, LDO1, LDO2 Short-Circuit Current to GND .....Continuous

Continuous Power Dissipation (T_A = +70°C)
   16-Pin Thin QFN 3mm x 3mm
   (derate 14.7mW/°C above +70°C) 1177mW
Operating Temperature Range ....-40°C to +85°C
Junction Temperature...+150°C
Storage Temperature Range ....-65°C to +150°C
Lead Temperature (soldering, 10s) ....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.6V, V_{GND} = 0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
IN Operating Voltage			2.7		5.5	V
Undervoltage Lockout (UVLO) Threshold	V_{IN} rising		2.25	2.45	2.65	V
UVLO Hysteresis				100		mV
Shutdown Supply Current	ENLED = ENLDO = GND	T_A = +25°C		0.5	5	μA
		T_A = +85°C		0.5		
IN Operating Supply Current	Charge pump inactive, I_{LED1} = I_{LED2} = I_{LED3} = I_{LED4} = 0.1mA			65	100	μA
	Charge pump active, V_{IN} = 2.7V, 1MHz switching, I_{LED1} = I_{LED2} = I_{LED3} = I_{LED4} = 0.1mA			1.4		mA
Thermal-Shutdown Threshold				160		°C
Thermal-Shutdown Hysteresis				20		°C
SERIAL-PULSE CONTROL						
Logic Input-High Voltage (V_{IH})	V_{IN} = 2.7V to 5.5V		1.4			V
Logic Input-Low Voltage (V_{IL})	V_{IN} = 2.7V to 5.5V				0.4	V
Logic Input Current	V_{IL} = 0V or V_{IH} = 5.5V	T_A = +25°C		0.01	1	μA
		T_A = +85°C		0.1		
t_{SHDN}	See Figures 1 and 2 (Note 2)		2.5			ms
t_{LO}	See Figures 1 and 2		0.5		500	μs
t_{HI}	See Figures 1 and 2		0.5		500	μs
t_{INIT}	First high pulse from shutdown (Figures 1 and 2)		100			μs
t_{HOLD}	Pulse width to latch EN_ count (Figures 1 and 2) (Note 3)		2.5			ms
CHARGE PUMP						
Switching Frequency				1		MHz
Soft-Start Time				0.5		ms
Charge-Pump Regulation Voltage	(V_{IN} - V_{NEG})			5		V
Open-Loop NEG Output Resistance	(V_{NEG} - 0.5 x V_{IN}) / I_{NEG}			2.8	5.0	Ω
NEG Shutdown Discharge Resistance	All LEDs off, EN_ = GND			10		kΩ

MAXIM

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3.6V, V_{GND} = 0V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
CURRENT REGULATOR (LED1–LED4)						
Programmable Current Range			0.1		24.0	mA
Current Accuracy	$I_{LED\_}$ = 24mA, T_A = +25°C		-2	±1	+2	%
	$I_{LED\_}$ = 24mA, T_A = -40°C to +85°C		-3		+3	
	$I_{LED\_}$ = 0.1mA, T_A = +25°C			±5		
LED_ Dropout Voltage	$I_{LED\_}$ = 24mA (Note 4)	Charge pump inactive		60	120	mV
		Charge pump active		80	250	
LED_ Current Regulator Switchover Threshold (Inactive to Active)	$V_{LED\_}$ falling		125	150	175	mV
LED_ Current Regulator Switchover Hysteresis				100		mV
LED_ Shutdown Leakage Current	All LEDs off, ENLED = GND	T_A = +25°C		0.01	5	µA
		T_A = +85°C		0.1		
LDO_						
Output Current	(Note 5)		200			mA
Current Limit	V_{LDO} = 0V		220		750	mA
LDO1 Dropout Voltage	I_{LDO1} = 200mA, V_{LDO1} = 2.8V (Notes 5 and 6)			150	250	mV
LDO2 Dropout Voltage	I_{LDO2} = 200mA, V_{LDO2} = 2.8V (Notes 5 and 6)			300	550	mV
Line Regulation	3.4V ≤ V_{IN} < 5.5V, I_{LDO} = 100mA			1		mV/V
Load Regulation	50µA < I_{LDO} < 200mA			0.1		mV/mA
Power-Supply Rejection $\Delta V_{OUT}/\Delta V_{IN}$	10Hz to 10kHz, C_{LDO} = 1µF, I_{LDO} = 30mA			60		dB
Output Noise Voltage (RMS)	100Hz to 100kHz, C_{LDO} = 1µF, I_{LDO} = 30mA			45		µV$_{RMS}$
LDO1 Output Voltage	I_{LDO1} = 100mA (Note 7)	ENLDO count = 5		1.2		V
		ENLDO count = 6, 13		1.8		
		ENLDO count = 1, 3, 7, 9, 14	2.716	2.800	2.884	
		ENLDO count = 2, 4, 8, 15		3.3		
LDO2 Output Voltage	I_{LDO2} = 100mA (Note 7)	ENLDO count = 1, 2		1.2		V
		ENLDO count = 3, 4, 10		1.5		
		ENLDO count = 5, 6, 7, 8, 11	1.746	1.800	1.854	
		ENLDO count = 9, 12		2.8		
Ground Current	I_{LDO} = 500µA			50		µA
Shutdown Output Impedance	ENLDO = GND			1		kΩ

Note 1: Limits are 100% production tested at T_A = +25°C. Specifications over the operating temperature range are guaranteed by design.
Note 2: Hold EN_ low for at least 2.5ms to guarantee shutdown.
Note 3: Hold EN_ high for at least 2.5ms to latch EN count.
Note 4: LED dropout voltage is defined as the LED_ to GND voltage when current into LED_ drops 10% from the value at V_{LED} = 0.5V.
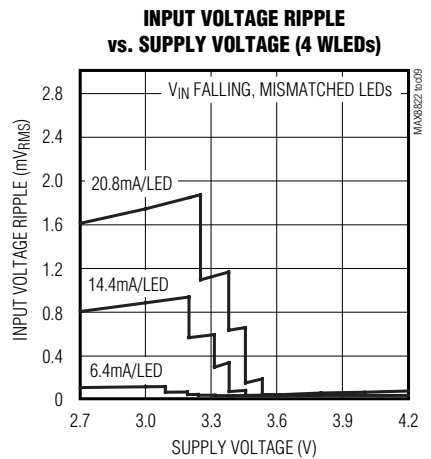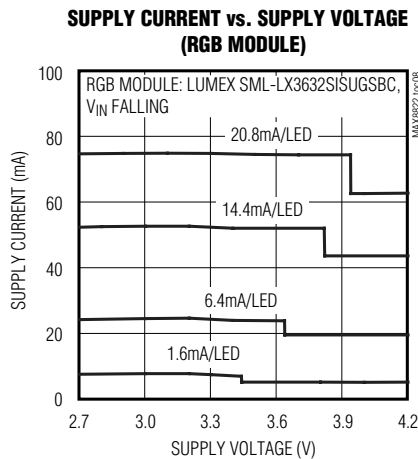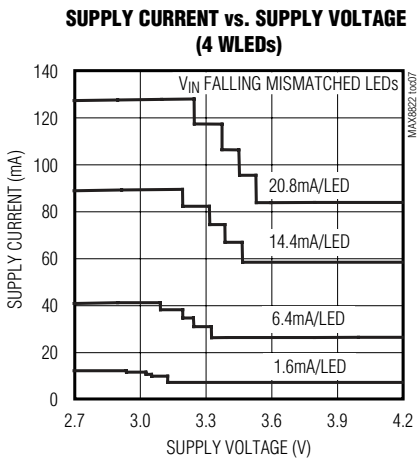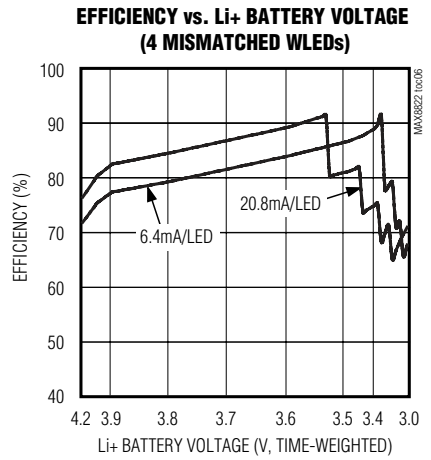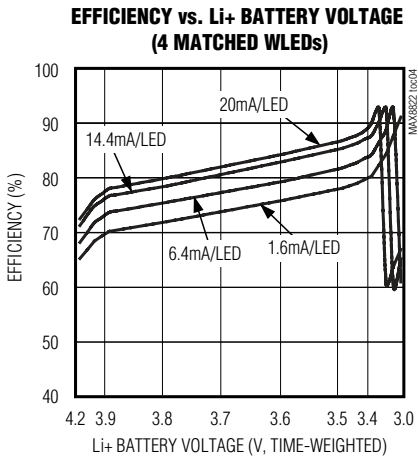**Note 5:** Guaranteed by design, not production tested.
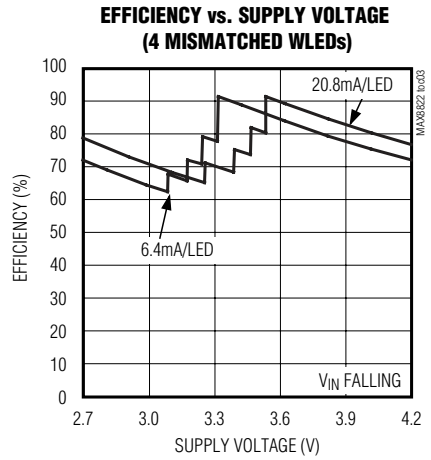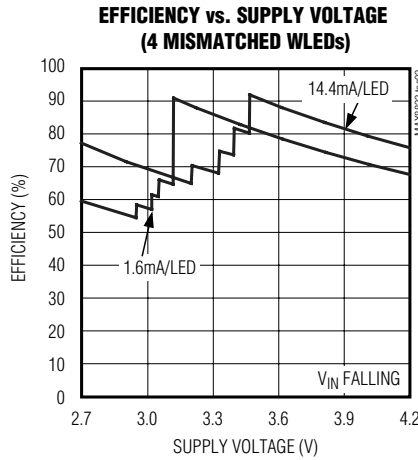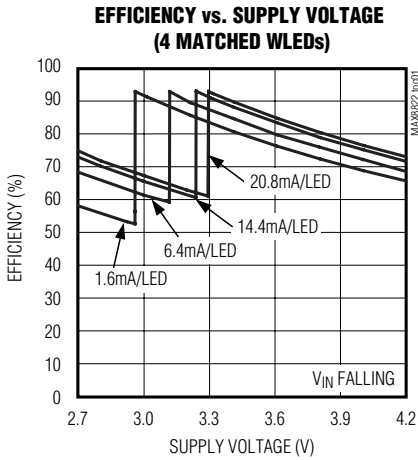**Note 6:** LDO dropout voltage is defined as V_{IN} - V_{OUT} when V_{OUT} has dropped 100mV below the initial value of V_{OUT} when V_{IN} = V_{OUT} + 0.8V.
Note 7: LDO output voltage corresponds to the LDO output voltage programmed by pulsing ENLDO low by the given count and then holding ENLDO high for greater than t_{HOLD} to set the voltage value. See Figure 2.

Ultra-Efficient Negative Charge-Pump LED Driver with Dual LDOs in 3mm x 3mm Thin QFN
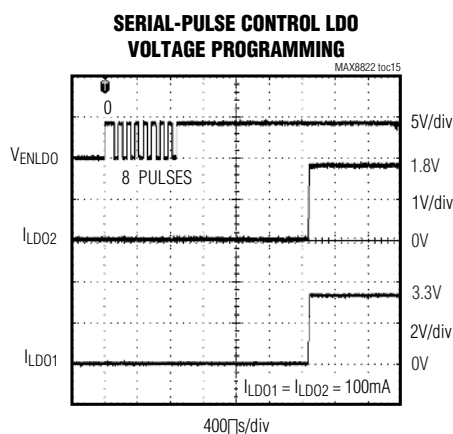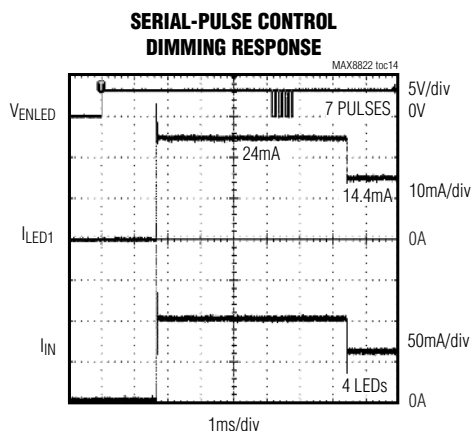
Typical Operating Characteristics

(V$_{IN}$ = 3.6V, V$_{EN\_}$ = V$_{IN}$, Circuit of _Typical Operating Circuit_, T$_A$ = +25°C, unless otherwise noted.)
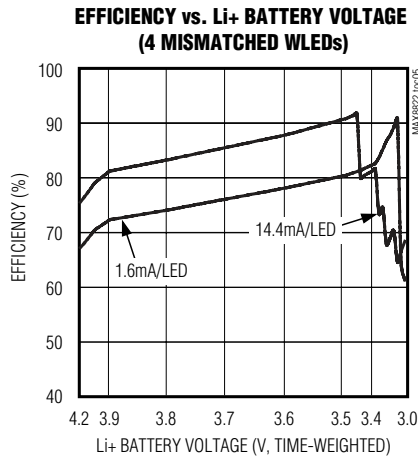
EFFICIENCY vs. SUPPLY VOLTAGE (4 MATCHED WLEDs)

EFFICIENCY vs. SUPPLY VOLTAGE (4 MISMATCHED WLEDs)

EFFICIENCY vs. SUPPLY VOLTAGE (4 MISMATCHED WLEDs)

EFFICIENCY vs. Li+ BATTERY VOLTAGE (4 MATCHED WLEDs)

EFFICIENCY vs. Li+ BATTERY VOLTAGE (4 MISMATCHED WLEDs)

EFFICIENCY vs. Li+ BATTERY VOLTAGE (4 MISMATCHED WLEDs)

SUPPLY CURRENT vs. SUPPLY VOLTAGE (4 WLEDs)

SUPPLY CURRENT vs. SUPPLY VOLTAGE (RGB MODULE)

INPUT VOLTAGE RIPPLE vs. SUPPLY VOLTAGE (4 WLEDs)

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Ultra-Efficient Negative Charge-Pump LED Driver with Dual LDOs in 3mm x 3mm Thin QFN
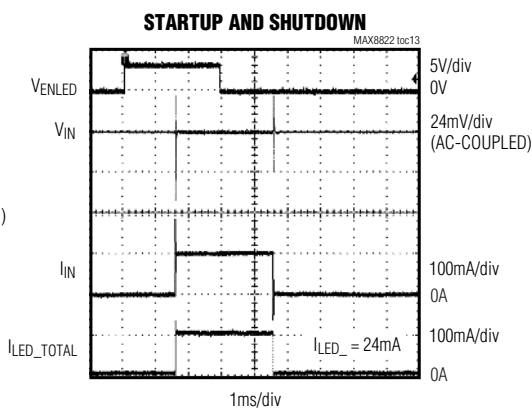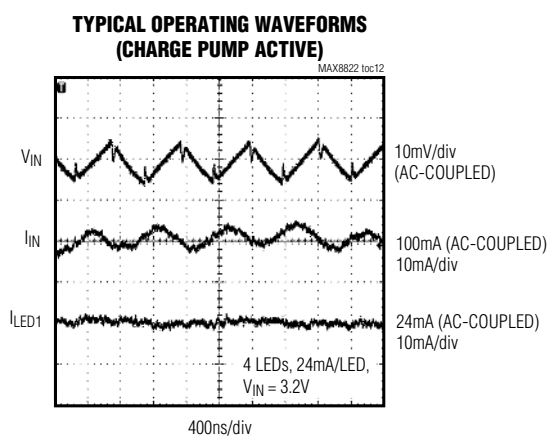
Typical Operating Characteristics (continued)
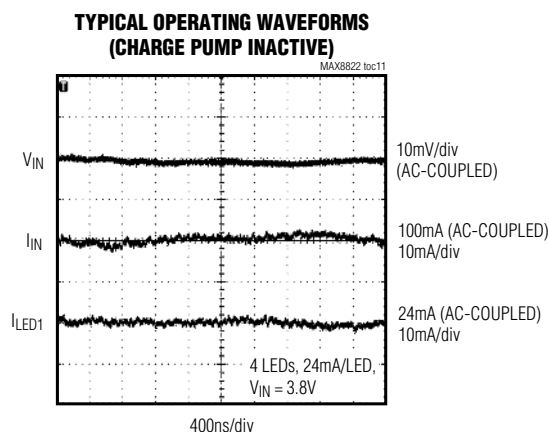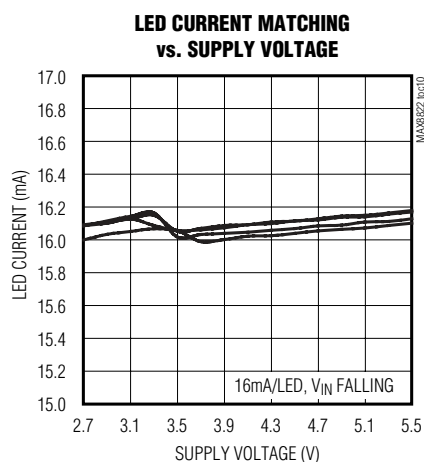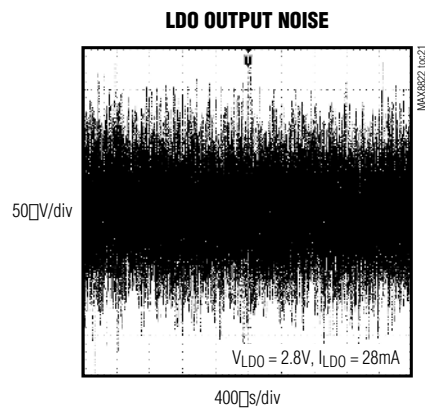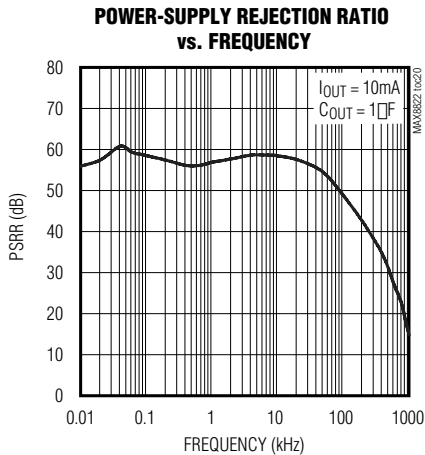
(V_{IN} = 3.6V, $V_{EN\_}$ = V_{IN}, Circuit of *Typical Operating Circuit*, T_A = +25°C, unless otherwise noted.)

LED CURRENT MATCHING vs. SUPPLY VOLTAGE

MAX8822 toc10

16mA/LED, V_{IN} FALLING

TYPICAL OPERATING WAVEFORMS (CHARGE PUMP INACTIVE)

MAX8822 toc11

V_{IN} — 10mV/div (AC-COUPLED)
I_{IN} — 100mA (AC-COUPLED) 10mA/div
I_{LED1} — 24mA (AC-COUPLED) 10mA/div
4 LEDs, 24mA/LED, V_{IN} = 3.8V
400ns/div

TYPICAL OPERATING WAVEFORMS (CHARGE PUMP ACTIVE)

MAX8822 toc12

V_{IN} — 10mV/div (AC-COUPLED)
I_{IN} — 100mA (AC-COUPLED) 10mA/div
I_{LED1} — 24mA (AC-COUPLED) 10mA/div
4 LEDs, 24mA/LED, V_{IN} = 3.2V
400ns/div

STARTUP AND SHUTDOWN

MAX8822 toc13

V_{ENLED} — 5V/div 0V
V_{IN} — 24mV/div (AC-COUPLED)
I_{IN} — 100mA/div 0A
I_{LED_TOTAL} — 100mA/div $I_{LED\_}$ = 24mA 0A
1ms/div

SERIAL-PULSE CONTROL DIMMING RESPONSE

MAX8822 toc14

V_{ENLED} — 5V/div 0V 7 PULSES
I_{LED1} — 24mA 14.4mA 10mA/div 0A
I_{IN} — 50mA/div 4 LEDs 0A
1ms/div

SERIAL-PULSE CONTROL LDO VOLTAGE PROGRAMMING

MAX8822 toc15

V_{ENLDO} — 5V/div 8 PULSES 1.8V 1V/div
I_{LDO2} — 0V
3.3V
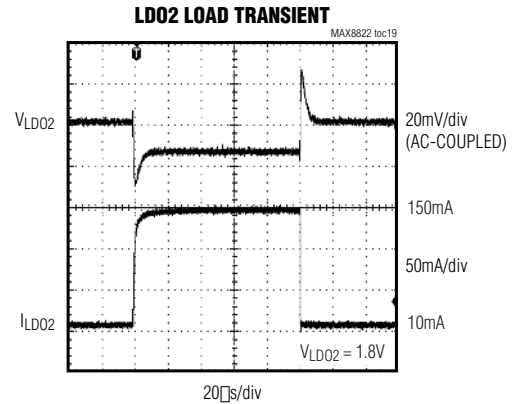I_{LDO1} — 2V/div 0V I_{LDO1} = I_{LDO2} = 100mA
400µs/div

MAX8822

(V_{IN} = 3.6V, $V_{EN\_}$ = V_{IN}, Circuit of _Typical Operating Circuit_, T_A = +25°C, unless otherwise noted.)

**LINE-TRANSIENT RESPONSE
(NO MODE CHANGE)**

MAX8822 toc16

V_{IN} 4.2V
    500mV/div
3.7V   (AC-COUPLED)

I_{IN} 100mA/div

    0mA

I_{LED_TOTAL} 100mA/div

    0mA

    $I_{LED\_}$ = 24mA

1ms/div

**LINE-TRANSIENT RESPONSE
(MODE CHANGE)**

MAX8822 toc17

V_{IN} 3.8V
    500mV/div
3.4V   (AC-COUPLED)

I_{IN} 100mA/div

    0mA

I_{LED_TOTAL} 100mA/div

    0mA

    $I_{LED\_}$ = 24mA

1ms/div

LDO1 LOAD TRANSIENT

MAX8822 toc18

V_{LDO1} 20mV/div
    (AC-COUPLED)

    150mA

    50mA/div

I_{LDO1} 10mA

    V_{LDO1} = 2.8V

20μs/div

LDO2 LOAD TRANSIENT

MAX8822 toc19

V_{LDO2} 20mV/div
    (AC-COUPLED)

    150mA

    50mA/div

I_{LDO2} 10mA

    V_{LDO2} = 1.8V

20μs/div

**POWER-SUPPLY REJECTION RATIO
vs. FREQUENCY**

MAX8822 toc20

I_{OUT} = 10mA
C_{OUT} = 1μF

PSRR (dB)

80
70
60
50
40
30
20
10
0
0.01   0.1   1   10   100   1000
FREQUENCY (kHz)

LDO OUTPUT NOISE

MAX8822 toc21

50μV/div

    V_{LDO} = 2.8V, I_{LDO} = 28mA

400μs/div

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Pin Description

PIN	NAME	FUNCTION
1	IN	Supply Voltage Input. Bypass IN to GND with a 4.7µF ceramic capacitor placed as close as possible to the IC. The input voltage range is 2.7V to 5.5V.
2	GND	Ground. Connect to system ground. GND is used for charge-pump switching currents.
3	C1P	Transfer Capacitor 1 Positive Connection. Connect a 1µF ceramic capacitor from C1P to C1N.
4	C2P	Transfer Capacitor 2 Positive Connection. Connect a 1µF ceramic capacitor from C2P to C2N.
5	C2N	Transfer Capacitor 2 Negative Connection. Connect a 1µF ceramic capacitor from C2P to C2N.
6	C1N	Transfer Capacitor 1 Negative Connection. Connect a 1µF ceramic capacitor from C1P to C1N.
7	NEG	Charge-Pump Output. Bypass NEG to GND with a 2.2µF ceramic capacitor placed as close as possible to the IC.
8–11	LED4–LED1	LED Current Regulators. Connect LED_ to the cathodes of the external LEDs. LED_ is high impedance in shutdown. Connect any unused LED_ to IN to disable the corresponding current regulator. LED_ current is programmed by pulsing ENLED as described in the *LED Dimming Control* section.
12	LDO1	LDO1 Output. Bypass LDO1 to GND with a 1µF ceramic capacitor placed as close as possible to the IC. The LDO1 and LDO2 output voltage combination is selected by pulsing ENLDO low. See the *LDO1/LDO2 Output Voltage Control* section.
13	LDO2	LDO2 Output. Bypass LDO2 to GND with a 1µF ceramic capacitor placed as close as possible to the IC. The LDO1 and LDO2 output voltage combination is selected by pulsing ENLDO low. See the *LDO1/LDO2 Output Voltage Control* section.
14	ENLED	WLED Enable and Dimming Control Input. Pulse ENLED low to program LED_ current. Hold ENLED low for at least 2.5ms to place the LED drivers in shutdown. See the *LED Dimming Control* section.
15	ENLDO	LDO Enable and Voltage Control Input. Pulse ENLDO low to program the output voltage of both LDO1 and LDO2 to one of sixteen different combinations. Hold ENLDO low for at least 2.5ms to place the LDOs in shutdown. See the *LDO1/LDO2 Output Voltage Control* section.
16	REF	Reference. Bypass REF to GND with a 0.1µF ceramic capacitor placed as close as possible to the IC. V_{REF} regulates to 1.2V (typ).
—	EP	Exposed Paddle. Connect EP to GND. For good thermal dissipation, solder the exposed paddle to the power ground plane.

MAX8822

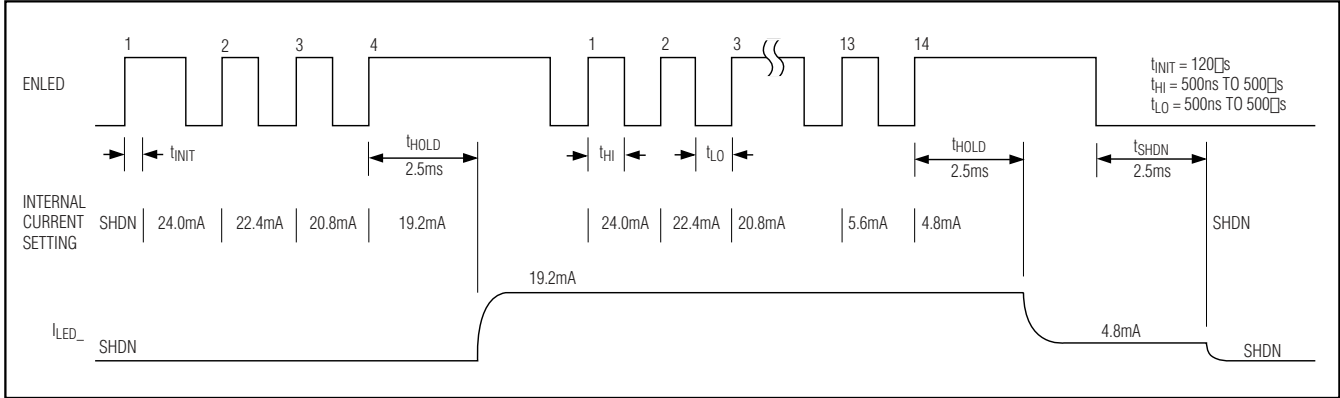# Ultra-Efficient Negative Charge-Pump LED Driver with Dual LDOs in 3mm x 3mm Thin QFN

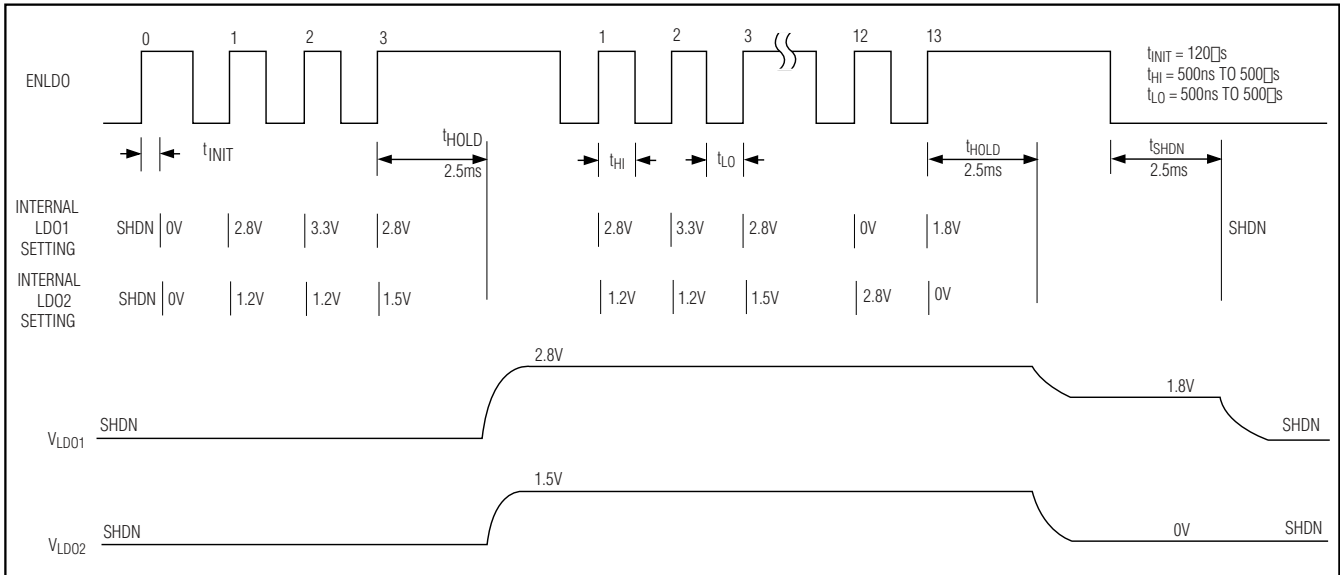Figure 1. Timing Characteristics for LED Serial-Pulse Control Interface

Figure 2. Timing Characteristics for LDO Serial-Pulse Control Interface

Detailed Description

The MAX8822 drives up to four white LEDs (WLEDs) with regulated constant current for display backlighting in cell phones, cameras, PDAs, and other handheld devices. The IC also includes two low-noise, high-PSRR, 200mA LDOs for powering camera modules or other devices. Figure 3 depicts the MAX8822 block diagram.

The MAX8822 IC utilizes a 0.5x inverting charge pump and extremely low-dropout current regulators to achieve high efficiency over the full 1-cell Li+ battery voltage range. The charge pump remains inactive unless the LED current regulators require additional voltage to prevent them from entering dropout. To maximize efficiency, the current regulators operate with as little as 150mV voltage drop. Additionally, each LED current regulator is independently monitored and switched, ensuring the least possible power consumption to extend battery life (see the *Adaptive Current Regulator Switchover* section for details).

MAXIM
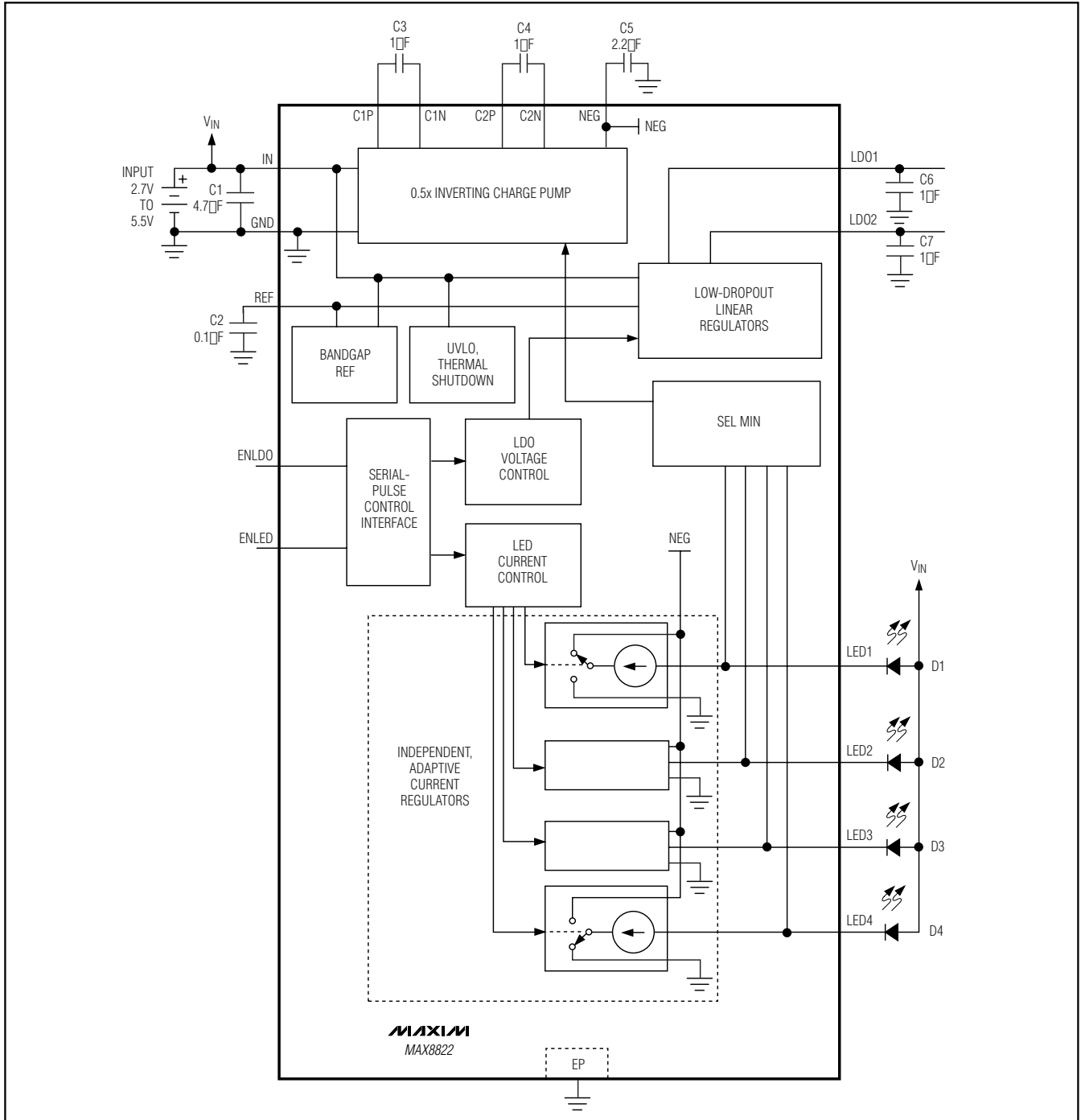
MAX8822

Figure 3. MAX8822 Functional Block Diagram and Application Circuit

Figure 4. Current Regulator Returning to GND

Figure 5. Current Regulator Returning to NEG

The LED current and LDO output voltages are programmed using a serial-pulse control interface. Pulse ENLED low (as discussed in the *LED Dimming Control* 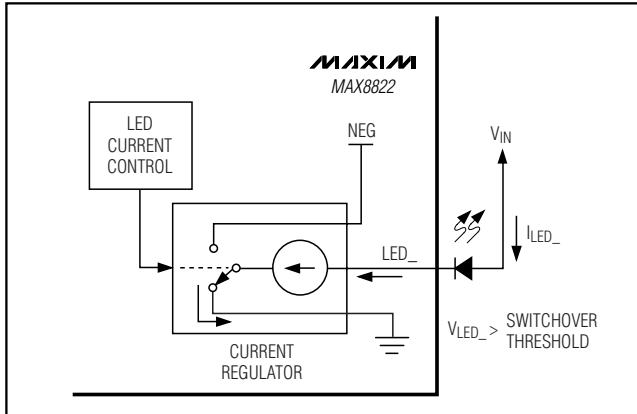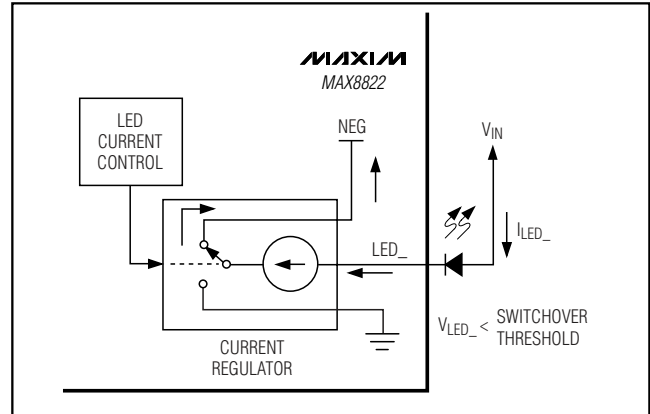section) to decrease the LED current from 24mA to 0.1mA, or hold ENLED low for at least 2.5ms to place the LED current regulators in shutdown mode. LED dimming is controlled in 31 pseudo-logarithmic steps. Pulse ENLDO low (as discussed in the *LDO1/LDO2 Output Voltage Control* section) to choose LDO1 and LDO2 output voltages from one of 16 combinations including off. Drive both ENLED and ENLDO low for at least 2.5ms to place the IC in low-power (0.5µA typ) shutdown mode. The MAX8822 includes soft-start, thermal shutdown, and open- and short-circuit protection.

Adaptive Current Regulator Switchover

When V_{IN} is higher than the forward voltage of an LED plus the 150mV (typ) dropout voltage of the current regulator, the LED current returns through GND (Figure 4). If this condition is satisfied for all four WLEDs, the charge pump remains inactive. When V_{IN} drops such that the current regulator voltage ($V_{LED\_}$) cannot be maintained above the dropout voltage for any of the individual LEDs, the charge pump activates and generates a voltage on NEG that is no greater than 5V (typ) below V_{IN}. For any current regulator that is detected at the switchover threshold voltage of 150mV (typ, V_{IN} falling), internal circuitry switches that current regulator's return path from GND to NEG to provide enough voltage across that regulator to overcome dropout (Figure 5). When $V_{LED\_}$ rises to 250mV (typ), the return of that current regulator is switched back from NEG to GND. Each current regulator is independently monitored to detect when switchover is required. Since the LED current is switched for only the individual LED current regulators requiring higher voltage, power consumption is minimized.

LED Dimming Control

The MAX8822 uses a serial-pulse control interface to program the intensity of the LEDs. The dimming range is pseudo-logarithmic from 24mA to 0.1mA in 31 steps. All active LED current regulators are programmed to the same value, with a 1% (typ) current accuracy and 0.3% current matching between regulators. To program the LED current, pulse ENLED (500ns to 500µs pulse width), as shown in Figure 1. An internal register accumulates the pulse count on the rising edge of the ENLED pulse. See Table 1 for the LED current values and the corresponding ENLED pulse count. Once the desired pulse count is met, hold ENLED high for at least 2.5ms (t_{HOLD}) to internally latch the pulse-count value and enable the LED_ current at the programmed level. If ENLED is pulsed more than 31 times before latching, the pulse count restarts at 1 on the 32nd rising edge. To program a new LED current level, follow the previous sequence from the beginning. Drive ENLED low for greater than 2.5ms (typ) to place the LED current regulators in shutdown. When the MAX8822 starts up with ENLED high, the LEDs turn on at full brightness.

If dimming control is not required, ENLED works as a simple on/off logic control. Drive ENLED high for at least 2.5ms to enable the LED current regulators, or drive ENLED low for at least 2.5ms for shutdown. The LED drivers operate at 100% brightness and off under these conditions.

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Table 1. ENLED Pulse Count and Programmed LED_ Current

ENLED PULSE COUNT*	PROGRAMMED LED_ CURRENT (mA)	ENLED PULSE COUNT*	PROGRAMMED LED_ CURRENT (mA)
1	24.0	17	2.8
2	22.4	18	2.4
3	20.8	19	2.0
4	19.2	20	1.6
5	17.6	21	1.4
6	16.0	22	1.2
7	14.4	23	1.0
8	12.8	24	0.8
9	11.2	25	0.7
10	9.6	26	0.6
11	8.0	27	0.5
12	6.4	28	0.4
13	5.6	29	0.3
14	4.8	30	0.2
15	4.0	31**	0.1
16	3.2	—	—

*Rising edge.

**If ENLED is pulsed more than 31 times, the pulse count restarts at 1 on the 32nd rising edge.

Low LED Current Levels

The MAX8822 internally generates a PWM signal to obtain higher resolution at lower currents. As LED current is set below 6.4mA, the IC adjusts not only LED DC current, but the duty cycle is controlled by the PWM signal. The frequency of the PWM dimming signal is set at 1kHz with a minimum duty cycle of 1/16 to avoid the LED flickering effect to human eyes. Table 2 shows the current level and the corresponding duty cycle.

LDO1/LDO2 Output Voltage Control

Similar to the LED dimming control structure, the MAX8822 uses serial-pulse control to program the output voltages of LDO1 and LDO2 to one of sixteen different combinations. To program the LDO voltages, pulse ENLDO low (500ns to 500µs pulse width), as shown in Figure 2. An internal register accumulates the pulse count on the rising edge of the ENLDO pulse. An initial pulse (t_{INIT}) is required to enable the LDOs from shutdown. See Table 3 for LDO voltage combinations and the corresponding ENLDO pulse count. When the desired pulse count is met, hold ENLDO high for at least 2.5ms (t_{HOLD}) to internally latch the pulse-count value and program the LDO output voltages at the desired level. If ENLDO is pulsed for more than 15 counts, LDO1 and LDO2 are off when the count is

Table 2. Internal PWM Duty Cycle vs. LED Set Current

DUTY CYCLE (n/16th)	I_{LED} (mA)	DUTY CYCLE (n/16th)	I_{LED} (mA)
16	6.4	12	1.2
14	5.6	10	1.0
12	4.8	8	0.8
10	4.0	7	0.7
16	3.2	6	0.6
14	2.8	5	0.5
12	2.4	4	0.4
10	2.0	3	0.3
16	1.6	2	0.2
14	1.4	1	0.1

latched (the count does not roll over). To program new LDO_ output voltages, follow the previous sequence from the beginning. Do not include the initial t_{INIT} pulse when programming LDO voltages unless enabling the LDOs from shutdown (the OFF setting is not shutdown). Pulling ENLDO low for greater than 2.5ms places the LDOs in shutdown.

Ultra-Efficient Negative Charge-Pump LED Driver with Dual LDOs in 3mm x 3mm Thin QFN

Table 3. ENLDO Pulse Count and LDO1 and LDO2 Output Voltage Selection

ENLDO PULSE COUNT*	PROGRAMMED LDO1 VOLTAGE (V)	PROGRAMMED LDO2 VOLTAGE (V)
0**	0	0
1	2.8	1.2
2	3.3	1.2
3	2.8	1.5
4	3.3	1.5
5	1.2	1.8
6	1.8	1.8
7	2.8	1.8
8	3.3	1.8
9	2.8	2.8
10	0	1.5
11	0	1.8
12	0	2.8
13	1.8	0
14	2.8	0
15***	3.3	0

*Rising edge.

**Initial pulse is only required to enable LDOs from shutdown.

***If ENLDO is pulsed for more than 15 counts, V_{LDO1} and V_{LDO2} are 0V (not shutdown) when the count is latched (the count does not roll over).

Shutdown Mode

The MAX8822 features a shutdown mode to reduce power consumption. Hold ENLED low for at least 2.5ms to place the LEDs in shutdown. LED shutdown pulls NEG to GND through a 10kΩ internal resistor. Hold ENLDO low for at least 2.5ms to place the LDOs in shutdown. LDO shutdown pulls LDO_ to GND through a 1kΩ internal resistor. The MAX8822 consumes only 0.5µA of supply current when both the LED current regulators and LDOs are in shutdown mode.

LDO and LED Thermal Shutdown

The MAX8822 includes two thermal-limit circuits that protect the IC from temperatures exceeding +160°C (typ). The first circuit monitors the internal LED_ regulator temperature and shuts down the entire IC when the temperature limit is violated. The second circuit monitors the internal LDO temperature and shuts down only the LDOs when the temperature limit is violated. The thermal-shutdown condition clears after temperature

has cooled by 20°C (typ) and resets the LEDs and LDOs in the default condition of $I_{LED\_}$ = 24mA and V_{LDO1} = V_{LDO2} = 0V.

Power-Up LED Short Detection and Open-Fault Protection

The MAX8822 contains special circuitry to detect an LED_ short-circuit condition at startup only, and disables that current regulator to avoid wasting battery power. If an LED fails short-circuit detection after startup, that current regulator continues current-regulated operation until IC power is cycled and the short circuit is detected during the subsequent startup.

An open-circuit LED failure drives the voltage on the corresponding LED current-regulator output below the switchover threshold, enabling the charge pump.

Applications Information

Input Ripple

For LED drivers, input ripple is more important than output ripple. The amount of input ripple depends on the source supply's output impedance. Add a lowpass filter to the input of the MAX8822 to further reduce input ripple. Alternatively, increasing C_{IN} reduces input ripple.

Using Fewer Than Four LEDs

The MAX8822 can operate with fewer than four LEDs. Disable the unused current regulator by connecting LED_ to IN. If an unused LED_ is not connected to IN, the MAX8822 operates as if an open LED has been detected. In this condition, the open-circuit LED_ drives the voltage on the corresponding output below the switchover threshold, enabling the charge pump.

Component Selection

Ceramic capacitors are recommended due to their small size, low cost, and low ESR. Select ceramic capacitors that maintain their capacitance over temperature and DC bias. Capacitors with X5R or X7R temperature characteristics generally perform well. Recommended values are shown in the *Typical Operating Circuit*. Using a larger value input capacitor helps to reduce input ripple (see the *Input Ripple* section).

The LDO output capacitor size affects LDO stability. A 1µF ceramic capacitor is recommended to maintain stability for load currents up to 200mA.

PCB Layout and Routing

The MAX8822 is a high-frequency switched-capacitor voltage regulator. For best circuit performance, use a solid ground plane and place all capacitors as close as possible to the IC. Use large traces for the power-supply inputs to minimize losses due to parasitic trace

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resistance and to route heat away from the device. The exposed paddle lowers the thermal resistance of the package by providing a direct-heat conduction path from the die to the printed circuit board (PCB). Connect the exposed paddle to the GND plane directly under the IC, but do not rely on EP for ground functions. For good thermal dissipation, solder the exposed paddle to the power ground plane. Refer to the MAX8822 evaluation kit data sheet for an example PCB layout.
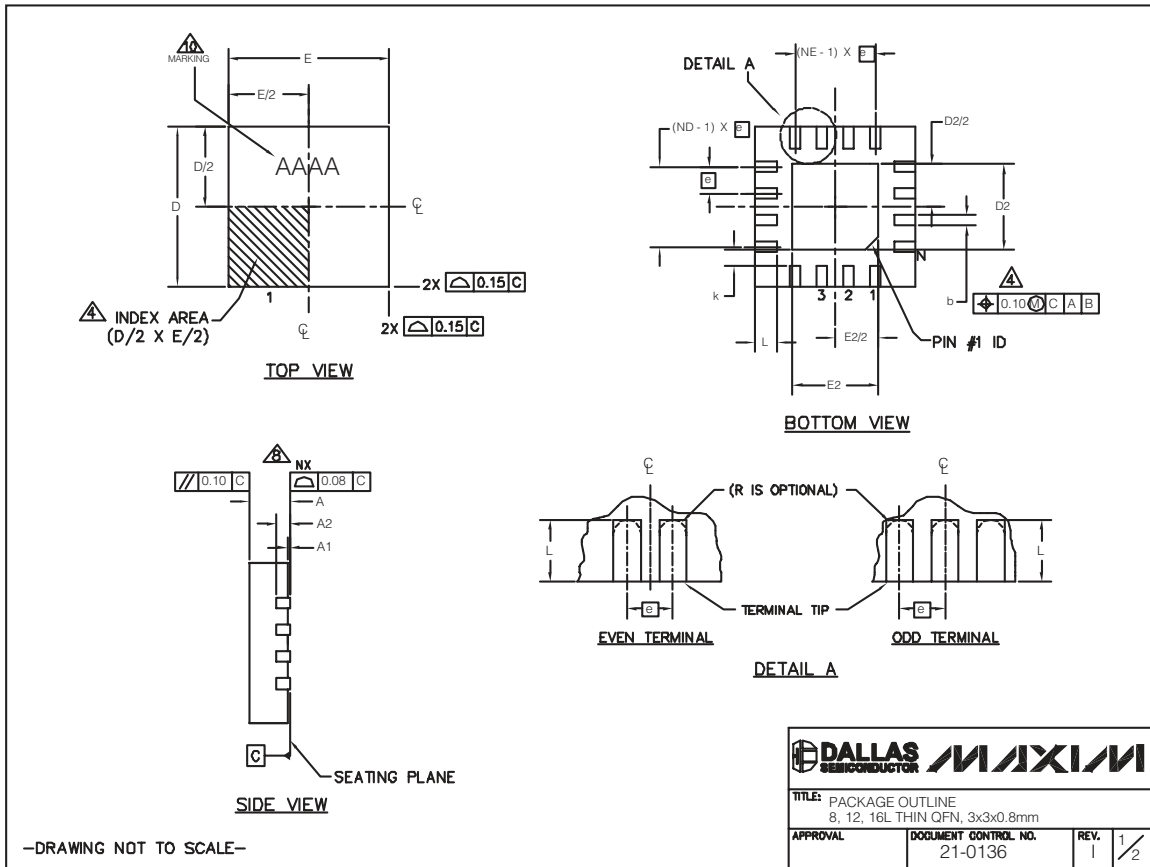
_____Chip Information

PROCESS: BiCMOS

MAX8822

Ultra-Efficient Negative Charge-Pump LED Driver with Dual LDOs in 3mm x 3mm Thin QFN

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)

TITLE: PACKAGE OUTLINE
8, 12, 16L THIN QFN, 3x3x0.8mm

APPROVAL | DOCUMENT CONTROL NO. 21-0136 | REV. I | 1/2

12x16L QFN THIN.EPS

MAX8822

Ultra-Efficient Negative Charge-Pump LED Driver with Dual LDOs in 3mm x 3mm Thin QFN

Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)

PKG	8L 3x3			12L 3x3			16L 3x3		
REF.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.70	0.75	0.80	0.70	0.75	0.80	0.70	0.75	0.80
b	0.25	0.30	0.35	0.20	0.25	0.30	0.20	0.25	0.30
D	2.90	3.00	3.10	2.90	3.00	3.10	2.90	3.00	3.10
E	2.90	3.00	3.10	2.90	3.00	3.10	2.90	3.00	3.10
e	0.65 BSC.			0.50 BSC.			0.50 BSC.		
L	0.35	0.55	0.75	0.45	0.55	0.65	0.30	0.40	0.50
N	8			12			16		
ND	2			3			4		
NE	2			3			4		
A1	0	0.02	0.05	0	0.02	0.05	0	0.02	0.05
A2	0.20 REF			0.20 REF			0.20 REF		
k	0.25	-	-	0.25	-	-	0.25	-	-

EXPOSED PAD VARIATIONS								
PKG. CODES	D2			E2			PIN ID	JEDEC
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.		
TQ833-1	0.25	0.70	1.25	0.25	0.70	1.25	0.35 x 45°	WEEC
T1233-1	0.95	1.10	1.25	0.95	1.10	1.25	0.35 x 45°	WEED-1
T1233-3	0.95	1.10	1.25	0.95	1.10	1.25	0.35 x 45°	WEED-1
T1233-4	0.95	1.10	1.25	0.95	1.10	1.25	0.35 x 45°	WEED-1
T1633-2	0.95	1.10	1.25	0.95	1.10	1.25	0.35 x 45°	WEED-2
T1633F-3	0.65	0.80	0.95	0.65	0.80	0.95	0.225 x 45°	WEED-2
T1633FH-3	0.65	0.80	0.95	0.65	0.80	0.95	0.225 x 45°	WEED-2
T1633-4	0.95	1.10	1.25	0.95	1.10	1.25	0.35 x 45°	WEED-2
T1633-5	0.95	1.10	1.25	0.95	1.10	1.25	0.35 x 45°	WEED-2

NOTES:
1. DIMENSIONING & TOLERANCING CONFORM TO ASME Y14.5M-1994.
2. ALL DIMENSIONS ARE IN MILLIMETERS. ANGLES ARE IN DEGREES.
3. N IS THE TOTAL NUMBER OF TERMINALS.
4. THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JESD 95-1 SPP-012. DETAILS OF TERMINAL #1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE INDICATED. THE TERMINAL #1 IDENTIFIER MAY BE EITHER A MOLD OR MARKED FEATURE.
5. DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.20 mm AND 0.25 mm FROM TERMINAL TIP.
6. ND AND NE REFER TO THE NUMBER OF TERMINALS ON EACH D AND E SIDE RESPECTIVELY.
7. DEPOPULATION IS POSSIBLE IN A SYMMETRICAL FASHION.
8. COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
9. DRAWING CONFORMS TO JEDEC MO220 REVISION C.
10. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
11. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.
12. WARPAGE NOT TO EXCEED 0.10mm.

—DRAWING NOT TO SCALE—

DALLAS SEMICONDUCTOR /VI/IXI/VI

TITLE: PACKAGE OUTLINE
8, 12, 16L THIN QFN, 3x3x0.8mm

APPROVAL	DOCUMENT CONTROL NO.	REV.	
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