

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

## 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.

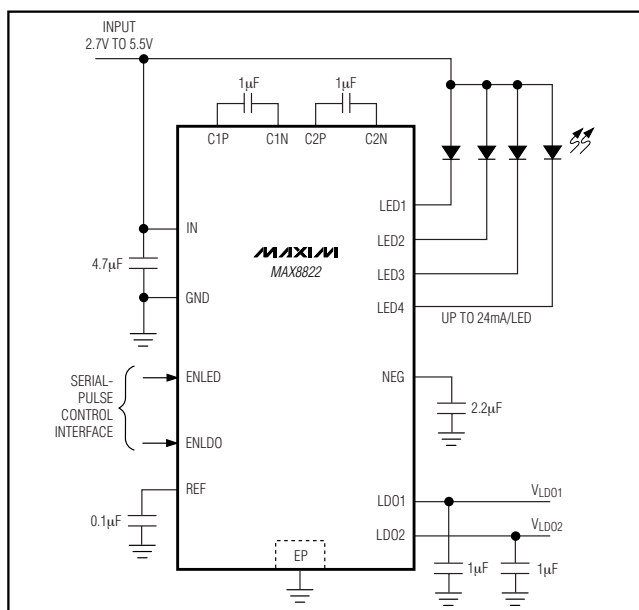
The MAX8822 features a single-wire, serial-pulse control logic interface that programs LED current and the output voltages of the LDOs. The LED dimming range is pseudo-logarithmic from 24mA to 0.1mA in 31 steps. LDO output voltages are programmable in 16 different combinations to meet various camera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

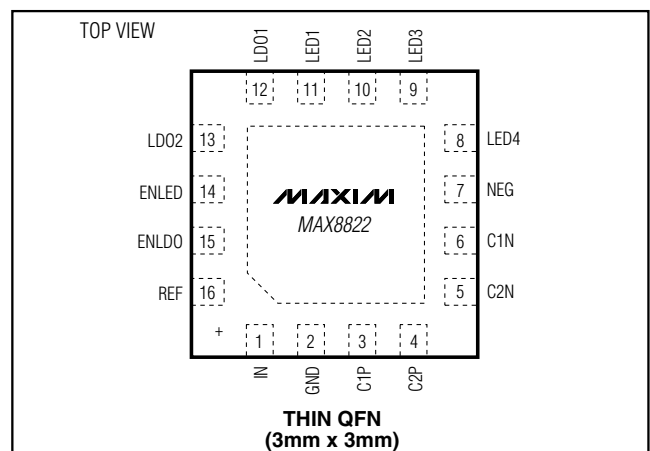
| PART        | PIN-PACKAGE                    | TOP MARK | PKG CODE |
|-------------|--------------------------------|----------|----------|
| MAX8822ETE+ | 16 Thin QFN-EP*<br>(3mm x 3mm) | AFW      | T1633-5  |

**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



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

## 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<sub>-</sub>, C1N, C2N to NEG .....-0.3V to (V<sub>IN</sub> + 0.3V)  
C1P, C2P to GND .....-0.3V to (V<sub>IN</sub> + 0.3V)  
NEG to GND .....-6.0V to +0.3V  
NEG, LDO1, LDO2 Short-Circuit Current to GND .....Continuous

Continuous Power Dissipation (T<sub>A</sub> = +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<sub>IN</sub> = 3.6V, V<sub>GND</sub> = 0V, T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

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

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

## ELECTRICAL CHARACTERISTICS (continued)

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

| PARAMETER  | CONDITIONS  | MIN                          | TYP     | MAX   | UNITS      |       |
|--|---|------------------------------|---------|-------|------------|-------|
| <b>CURRENT REGULATOR (LED1–LED4)</b>                             |   |                              |         |       |            |       |
| Programmable Current Range                                       |   | 0.1                          |         | 24.0  | mA         |       |
| Current Accuracy   | $I_{LED\_} = 24mA$ , $T_A = +25^{\circ}C$                   | -2                           | $\pm 1$ | +2    | %          |       |
|  | $I_{LED\_} = 24mA$ , $T_A = -40^{\circ}C$ to $+85^{\circ}C$ | -3                           |         | +3    |            |       |
|  | $I_{LED\_} = 0.1mA$ , $T_A = +25^{\circ}C$                  |                              | $\pm 5$ |       |            |       |
| 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,<br>ENLED = GND                                | $T_A = +25^{\circ}C$         | 0.01    | 5     | $\mu A$    |       |
|  |   | $T_A = +85^{\circ}C$         | 0.1     |       |            |       |
| <b>LDO_</b>  |   |                              |         |       |            |       |
| 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  | $3.4V \leq V_{IN} < 5.5V$ , $I_{LDO} = 100mA$               |                              | 1       |       | mV/V       |       |
| Load Regulation  | $50\mu A < I_{LDO} < 200mA$                                 |                              | 0.1     |       | mV/mA      |       |
| Power-Supply Rejection $\Delta V_{OUT}/\Delta V_{IN}$            | 10Hz to 10kHz, $C_{LDO} = 1\mu F$ , $I_{LDO} = 30mA$        |                              | 60      |       | dB         |       |
| Output Noise Voltage (RMS)                                       | 100Hz to 100kHz, $C_{LDO} = 1\mu F$ , $I_{LDO} = 30mA$      |                              | 45      |       | $\mu VRMS$ |       |
| 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   | $I_{LDO} = 500\mu A$  |                              | 50      |       | $\mu A$    |       |
| Shutdown Output Impedance  | ENLDO = GND   |                              | 1       |       | k $\Omega$ |       |

**Note 1:** Limits are 100% production tested at  $T_A = +25^{\circ}C$ . 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.

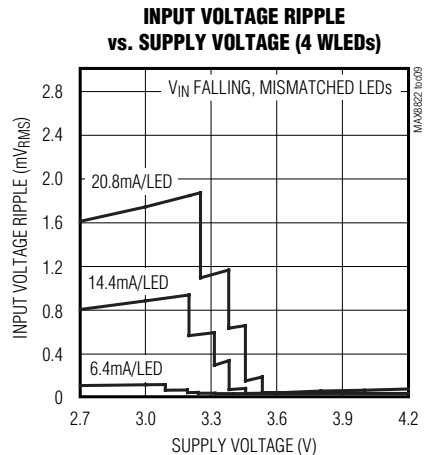
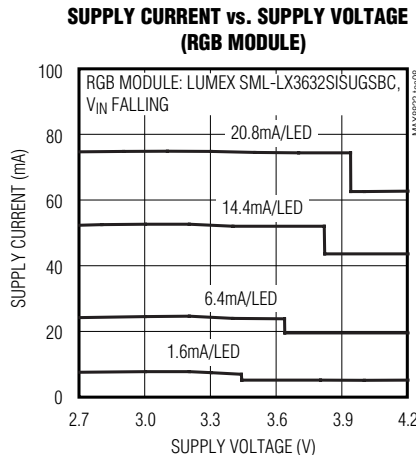
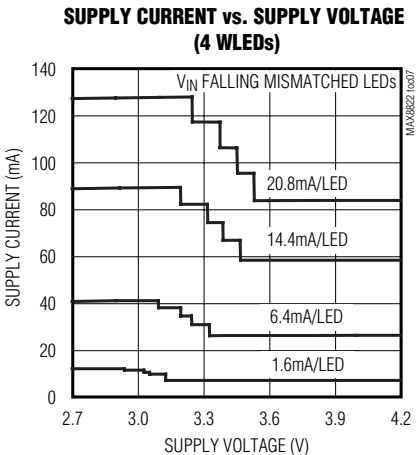
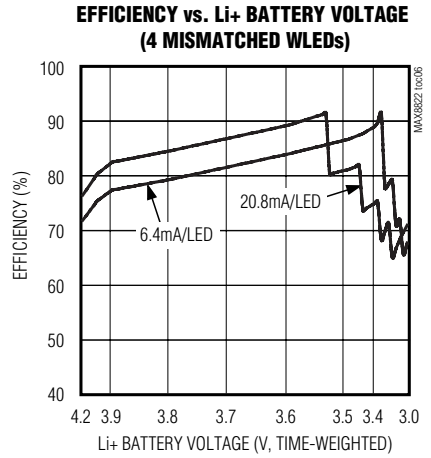
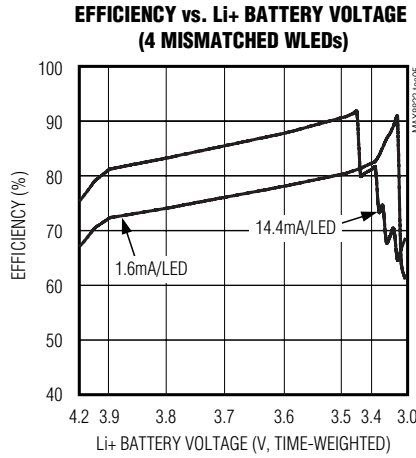
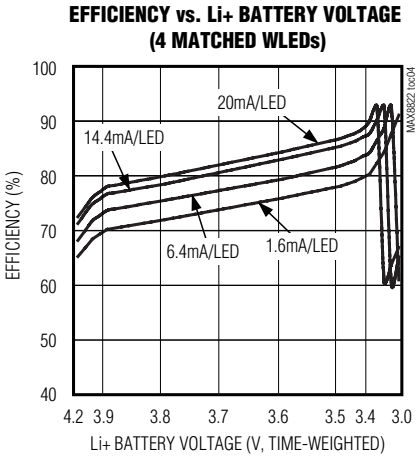
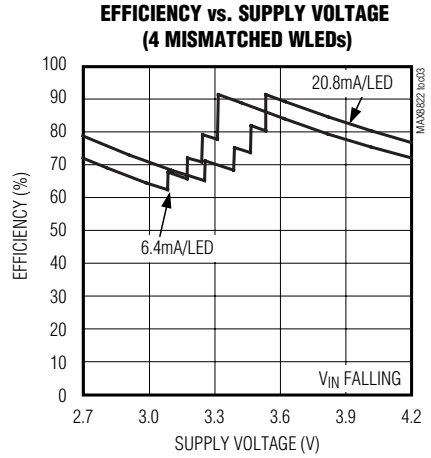
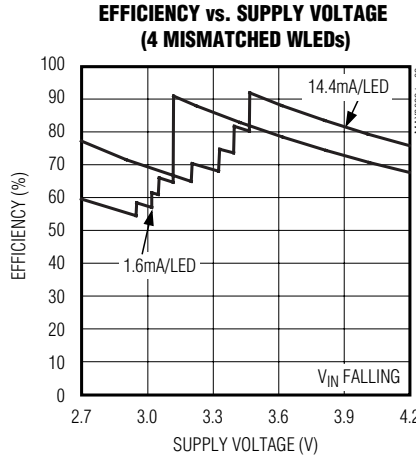
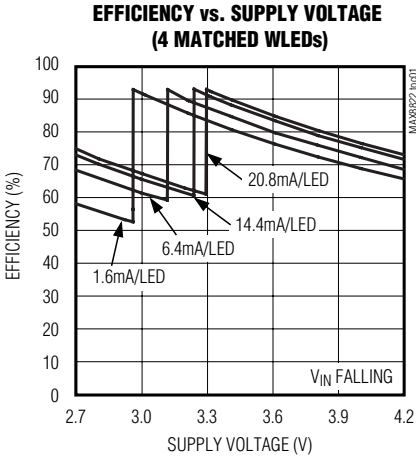
**Note 6:** LDO dropout voltage is defined as  $V_{IN} - V_{OUT}$  when  $V_{OUT}$  has dropped 100mV below the initial value of  $V_{OUT}$  when  $V_{IN} = V_{OUT} + 0.8V$ .

**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

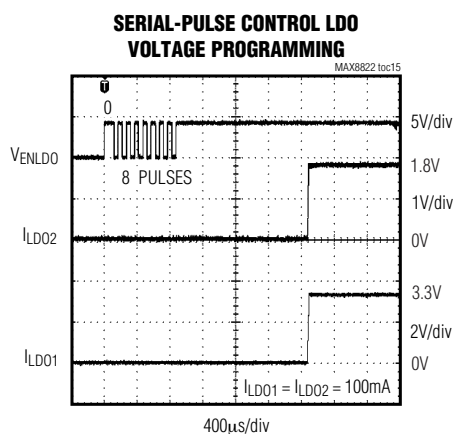
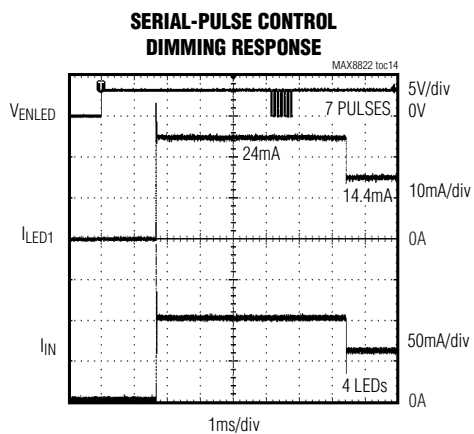
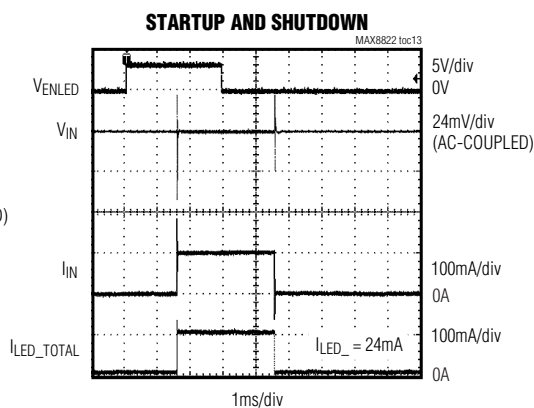
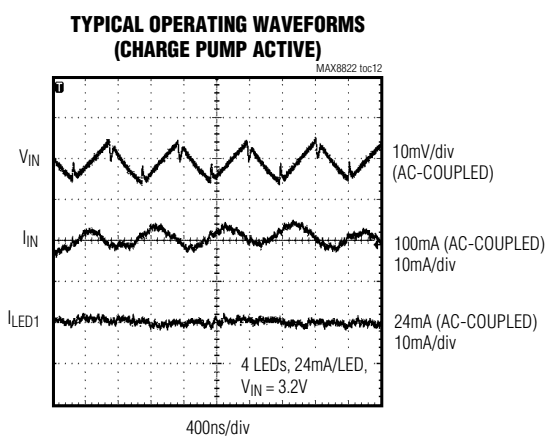
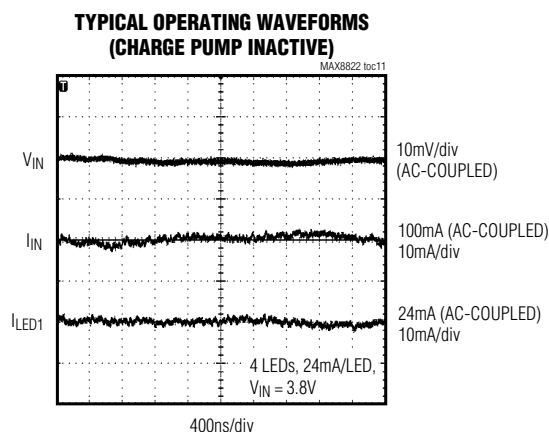
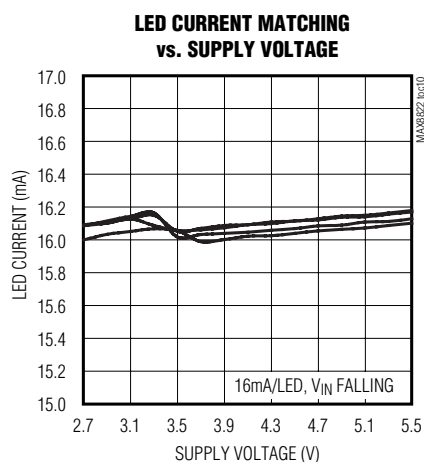
( $V_{IN} = 3.6V$ ,  $V_{EN\_} = V_{IN}$ , Circuit of *Typical Operating Circuit*,  $T_A = +25^{\circ}C$ , unless otherwise noted.)



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

## Typical Operating Characteristics (continued)

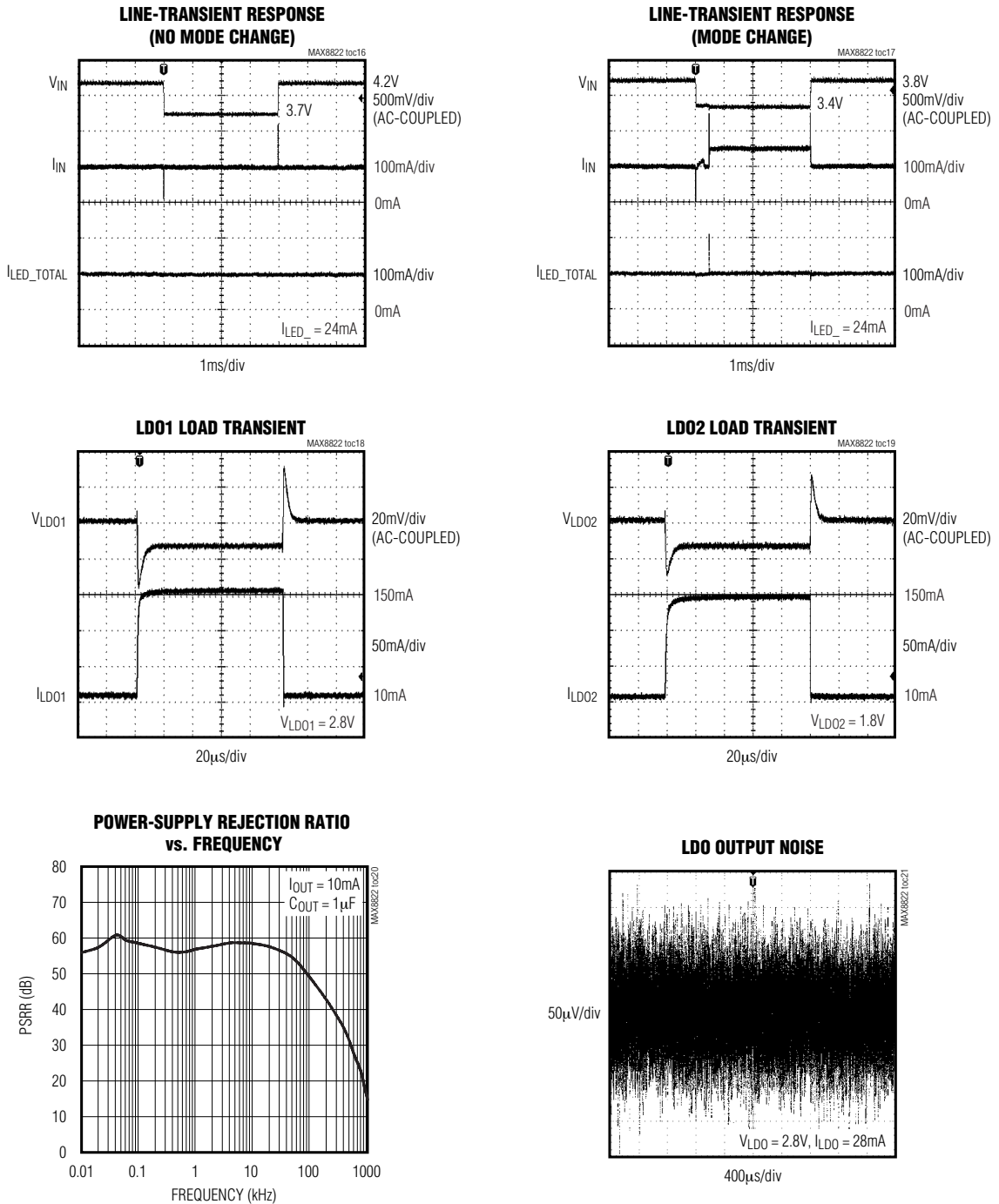
( $V_{IN} = 3.6V$ ,  $V_{EN\_} = V_{IN}$ , Circuit of *Typical Operating Circuit*,  $T_A = +25^\circ C$ , unless otherwise noted.)



# 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*,  $T_A = +25^\circ C$ , unless otherwise noted.)



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

## Pin Description

MAX8822

| PIN  | NAME      | FUNCTION   |
|------|-----------|--|
| 1    | IN        | Supply Voltage Input. Bypass IN to GND with a 4.7 $\mu$ F 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 1 $\mu$ F ceramic capacitor from C1P to C1N.   |
| 4    | C2P       | Transfer Capacitor 2 Positive Connection. Connect a 1 $\mu$ F ceramic capacitor from C2P to C2N.   |
| 5    | C2N       | Transfer Capacitor 2 Negative Connection. Connect a 1 $\mu$ F ceramic capacitor from C2P to C2N.   |
| 6    | C1N       | Transfer Capacitor 1 Negative Connection. Connect a 1 $\mu$ F ceramic capacitor from C1P to C1N.   |
| 7    | NEG       | Charge-Pump Output. Bypass NEG to GND with a 2.2 $\mu$ F ceramic capacitor placed as close as possible to the IC.  |
| 8–11 | LED4–LED1 | LED Current Regulators. Connect LED_ <sub>n</sub> to the cathodes of the external LEDs. LED_ <sub>n</sub> is high impedance in shutdown. Connect any unused LED_ <sub>n</sub> to IN to disable the corresponding current regulator. LED_ <sub>n</sub> current is programmed by pulsing ENLED as described in the <i>LED Dimming Control</i> section. |
| 12   | LDO1      | LDO1 Output. Bypass LDO1 to GND with a 1 $\mu$ F 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 <i>LDO1/LDO2 Output Voltage Control</i> section.  |
| 13   | LDO2      | LDO2 Output. Bypass LDO2 to GND with a 1 $\mu$ F 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 <i>LDO1/LDO2 Output Voltage Control</i> section.  |
| 14   | ENLED     | WLED Enable and Dimming Control Input. Pulse ENLED low to program LED_ <sub>n</sub> current. Hold ENLED low for at least 2.5ms to place the LED drivers in shutdown. See the <i>LED Dimming Control</i> 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 <i>LDO1/LDO2 Output Voltage Control</i> section.  |
| 16   | REF       | Reference. Bypass REF to GND with a 0.1 $\mu$ F ceramic capacitor placed as close as possible to the IC. V <sub>REF</sub> 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.  |

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

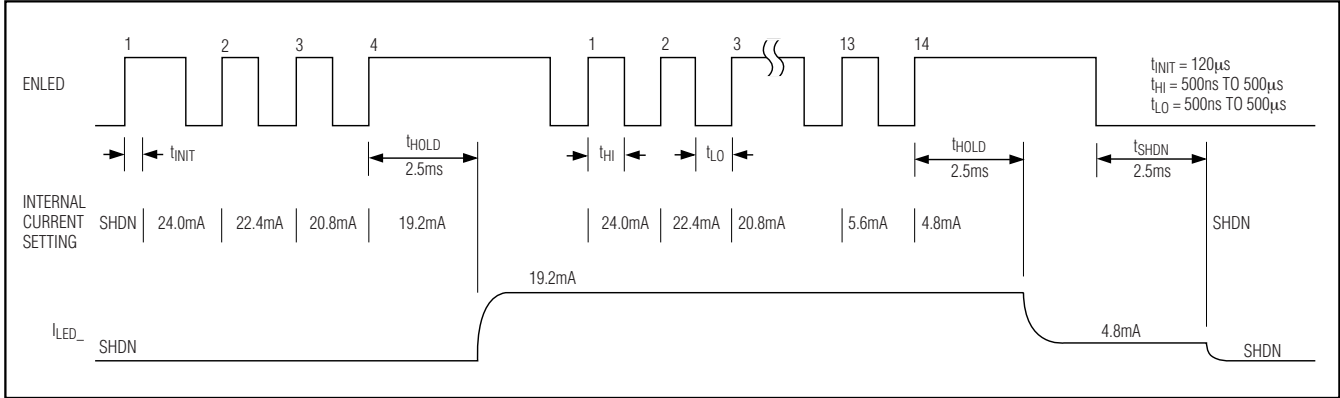


Figure 1. Timing Characteristics for LED Serial-Pulse Control Interface

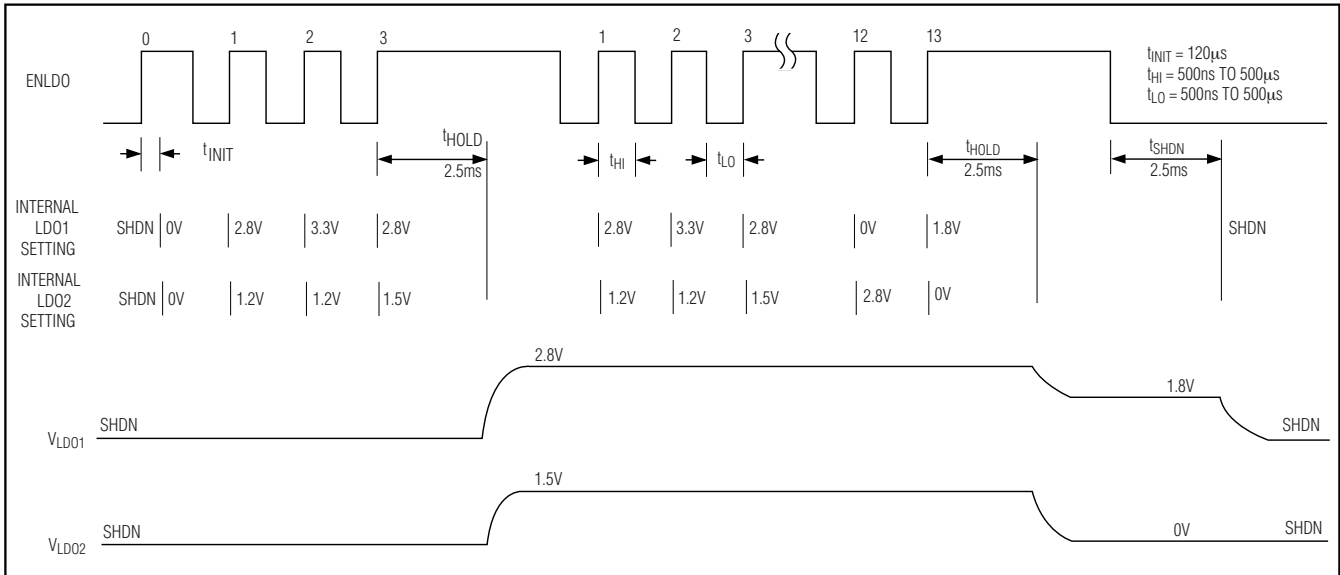


Figure 2. Timing Characteristics for LDO Serial-Pulse Control Interface

## 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).



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

**MAX8822**

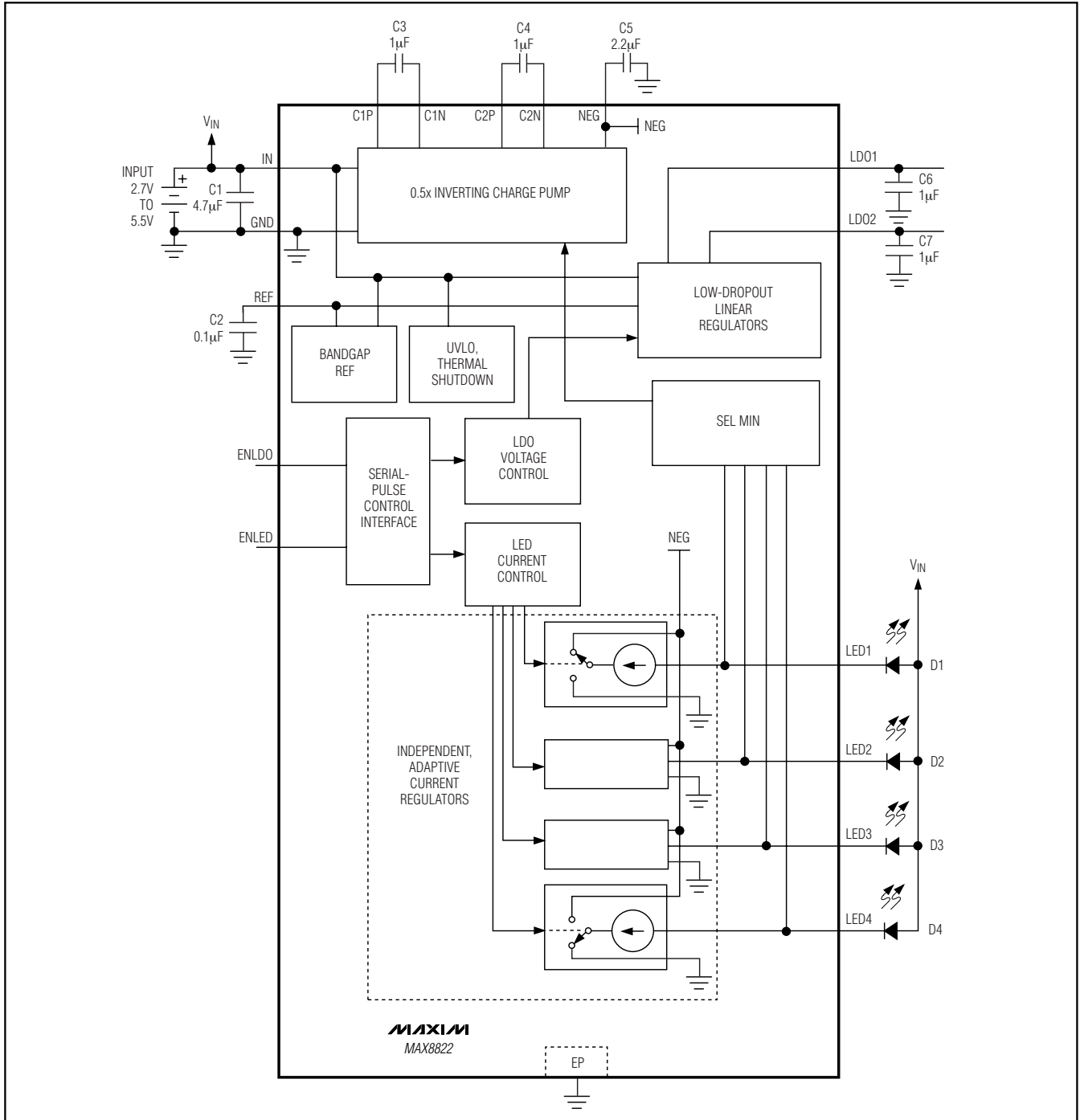


Figure 3. MAX8822 Functional Block Diagram and Application Circuit

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

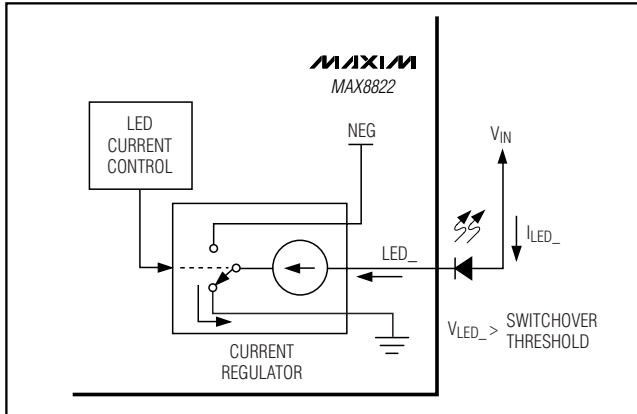


Figure 4. Current Regulator Returning to GND

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.

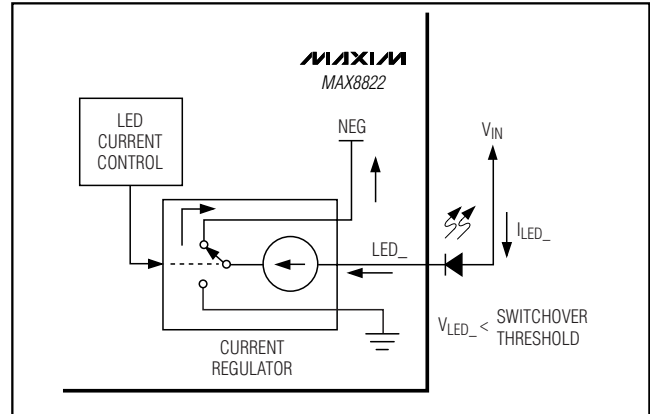


Figure 5. Current Regulator Returning to NEG

### 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 32<sup>nd</sup> 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.

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

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 32<sup>nd</sup> 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 <sub>LED</sub> (mA) | DUTY CYCLE (n/16th) | I <sub>LED</sub> (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 10k $\Omega$  internal resistor. Hold ENLDO low for at least 2.5ms to place the LDOs in shutdown. LDO shutdown pulls LDO\_ to GND through a 1k $\Omega$  internal resistor. The MAX8822 consumes only 0.5 $\mu$ A 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  $I_{LED\_} = 24\text{mA}$  and  $V_{LDO1} = V_{LDO2} = 0\text{V}$ .

## 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 1 $\mu$ F 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

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

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**

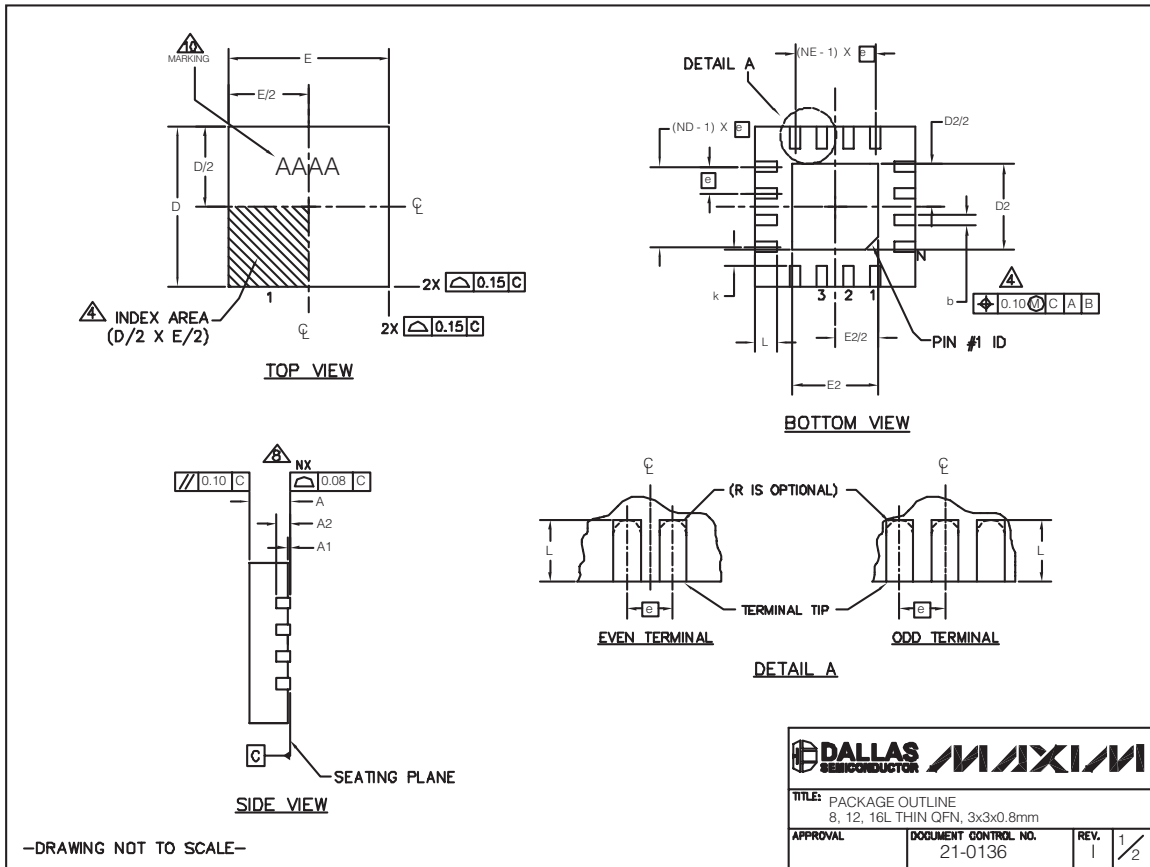
PROCESS: BiCMOS

**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](http://www.maxim-ic.com/packages).)



12x16L QFN THINPES

|   |  |
|---|--|
|   |  |
| <b>TITLE:</b> PACKAGE OUTLINE<br>8, 12, 16L THIN QFN, 3x3x0.8mm |  |
| <b>APPROVAL:</b>  | <b>DOCUMENT CONTROL NO.</b><br>21-0136 |
| <b>REV.</b><br>I  | 1/2                                    |

# 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](http://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      | -    | -    |

| PKG CODES | EXPOSED PAD VARIATIONS |      |      |      |      |      | PIN ID      | JEDEC  |
|-----------|------------------------|------|------|------|------|------|-------------|--------|
|           | D2                     |      |      | E2   |      |      |             |        |
|           | 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-

|  |                                 |              |     |
|--|---------------------------------|--------------|-----|
| <b>DALLAS SEMICONDUCTOR</b>                              |                                 | <b>MAXIM</b> |     |
| TITLE: PACKAGE OUTLINE<br>8, 12, 16L THIN QFN, 3x3x0.8mm |                                 |              |     |
| APPROVAL   | DOCUMENT CONTROL NO.<br>21-0136 | REV.<br>1    | 2/2 |

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Телефон: 8 (812) 309-75-97 (многоканальный)

Факс: 8 (812) 320-03-32

Электронная почта: [ocean@oceanchips.ru](mailto:ocean@oceanchips.ru)

Web: <http://oceanchips.ru/>

Адрес: 198099, г. Санкт-Петербург, ул. Калинина, д. 2, корп. 4, лит. А