19-4921; Rev 0; 3/10

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI



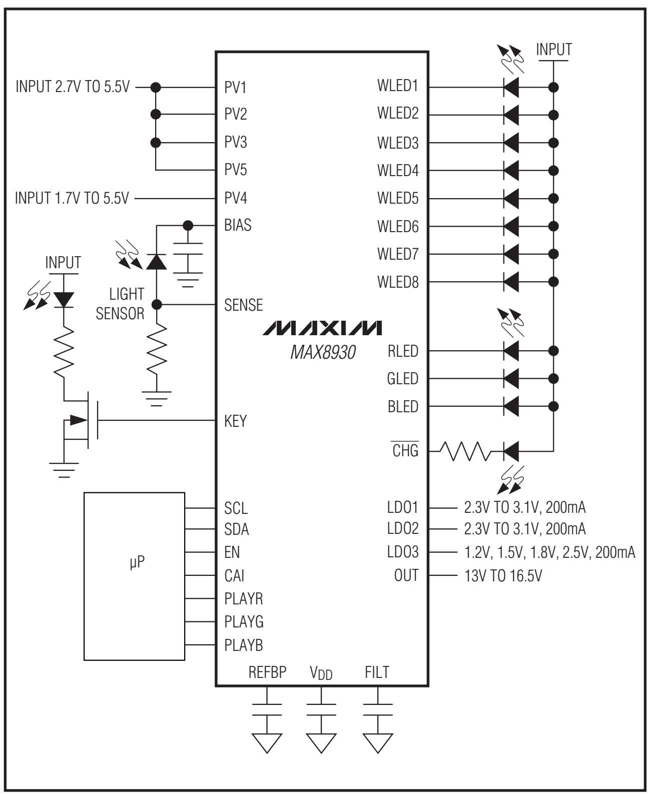
## General Description

The MAX8930 integrates a charge pump for white LED display backlighting with ambient light control (ALC) feature. The high-efficiency, adaptive-mode 1x/-0.5x charge pump drives up to 11 LEDs (8 WLEDs + RGB LED) with constant current for uniform brightness. The LED current is adjustable from 0.1mA to 25.6mA in 256 linear steps through I$^2$C. High accuracy and LED-to-LED current matching are maintained throughout the adjustment range. The MAX8930 includes soft-start, thermal shutdown, open-circuit, and short-circuit protection.

Three 200mA LDOs are provided with programmable output voltages to provide power to external circuitry. These three LDOs can also be configured for a GPO function through the I$^2$C. A step-up converter is also available on the MAX8930 for biasing a PMOLED subpanel.

The MAX8930 is available in the 49-bump, 3.17mm x 3.17mm WLP package.

## Simplified Application Circuit




## Features

- ♦ **White LED Charge Pump**
- ♦ **Adaptive 1x or -0.5x Negative Modes**
- ♦ **11 Low-Dropout LED Current Sinks with 25.6mA to 0.1mA in 256 Dimming Steps**
- ♦ **Ramp-Up/Down Control for Main White LED**
- ♦ **Ramp-Up/Down Control for RGB LED**
- ♦ **Individual Brightness Control for Each White, RGB LED**
- ♦ **Low 240µA (typ) Quiescent Current**
- ♦ **Ambient Light Control (ALC) for Any Type of Light Sensor**
- ♦ **Content Adaptive Interface**
- ♦ **I$^2$C-Compatible Control Interface**
- ♦ **Three Programmable LDOs Up to 200mA**
- ♦ **Step-Up DC-DC Converter with Programmable Output for PMOLED Application**
- ♦ **Low 0.1µA Shutdown Current**
- ♦ **2.7V to 5.5V Supply Voltage Range**
- ♦ **Thermal Shutdown**
- ♦ **Open and Short-Circuit Protection**

## Applications

Cell Phones and Smartphones

PDAs, Digital Cameras, Camcorders, and Other Portable Equipment

## Ordering Information

| PART | TEMP RANGE | PIN-PACKAGE |
|---|---|---|
| MAX8930EWJ+ | -40°C to +85°C | 49 WLP 0.4mm pitch |

*+Denotes a lead(Pb)-free/RoHS-compliant package.*

***Typical Operating Circuit appears at end of data sheet.***

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## ABSOLUTE MAXIMUM RATINGS

PV_, $V_{DD}$, EN, CAI, PLAY_, BIAS,
SENSE, REFBP, ECAGND to AGND.................-0.3V to +6.0V
PV_, $V_{DD}$, PGND_, AGND to NEG .......................-0.3V to +6.0V
ECAGND, PGND_ to AGND................................-0.3V to +0.3V
WLED_, RGB_, C1N, C2N,
C1P, C2P to NEG.........-0.3V to ($V_{PV1}$ + $V_{PV2}$ + $V_{PV3}$ + 0.3V)
FILT to AGND .......................................... -0.3V to ($V_{PV3}$ + 0.3V)
SCL, SDA to AGND................................. -0.3V to ($V_{DD}$ + 0.3V)
LDO_ to AGND........................... -0.3V to ($V_{PV3}$ + $V_{PV4}$ + 0.3V)
SW to PGND3.......................................... -0.3V to ($V_{PV5}$ + 0.3V)
LX, OUT to PGND3 .............................................-0.3V to +22V
KEY to AGND ..........................................-0.3V to ($V_{PV3}$ + 0.3V)
Continuous Power Dissipation ($T_A$ = +70°C)
49-Pin WLP 3.17mm x 3.17mm
(derate 20mW/°C above +70°C)...............................1600mW
Operating Temperature Range.......................... -40°C to +85°C
Junction Temperature ....................................................+150°C
Storage Temperature Range........................... -65°C to +150°C
Soldering Temperature (reflow) .....................................+260°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

($V_{PV\_}$ = $V_{EN}$ = $V_{DD}$ = 3.7V, $V_{PGND\_}$ and $V_{AGND}$ = 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 |
|---|---|---|---|---|---|---|
| PV1, PV2, PV3, PV5 Operating Voltage | | | 2.7 | | 5.5 | V |
| Undervoltage Lockout Threshold | $V_{PV1}$, $V_{PV2}$, $V_{PV3}$, $V_{PV5}$ rising | | 2.25 | 2.45 | 2.65 | V |
| UVLO Hysteresis | | | | 100 | | mV |
| PV4 Operating Voltage | | | 1.7 | | 5.5 | V |
| $V_{DD}$ Operating Range | $V_{DD}$ is supply voltage for I²C input block only; all other logic is supplied from PV_ | | 1.7 | | 5.5 | V |
| PV_ Shutdown Supply Current 1 (All Outputs Off, I²C Disabled) | EN = AGND, $V_{DD}$ = 0V | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |
| PV_ Shutdown Supply Current 2 (All Outputs Off, I²C Enabled) | $V_{DD}$ = $V_{PV3}$, EN = AGND | $T_A$ = +25°C | | 2 | 10 | µA |
| | | $T_A$ = +85°C | | 2 | | |
| $V_{DD}$ Shutdown Threshold | $V_{DD}$ falling, hysteresis = 50mV | | 1.15 | 1.4 | 1.65 | V |
| Supply Current | 1x mode, no load, ALC off, step-up off, $I_{LDO\_}$ = 0mA | | | 240 | 400 | µA |
| | -0.5x mode, 4MHz switching, each $I_{LED\_}$ = 0.1mA, ALC off, $I_{LDO}$ = 0mA, step-up $I_o$ = 0mA at $V_{PV3}$ = 2.7V (Note 2) | | | 6.8 | | mA |
| Reference Bypass (REFBP) Output Voltage | 0µA ≤ $I_{REFBP}$ ≤ 1µA | | 1.164 | 1.200 | 1.236 | V |
| REFBP Supply Rejection | 2.5V ≤ $V_{PV3}$ ≤ 5.5V | | | 0.2 | 5 | mV |
| Thermal Shutdown | | | | +160 | | °C |
| Thermal Shutdown Hysteresis | | | | 20 | | °C |

## $I^2C$ INTERFACE CHARACTERISTICS

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| SDA, SCL Input High Voltage | $V_{DD}$ = 1.7V to 5.5V | | 0.7 x $V_{DD}$ | | | V |
| SDA, SCL Input Low Voltage | $V_{DD}$ = 1.7V to 5.5V | | | | 0.3 x $V_{DD}$ | V |
| SDA, SCL Input Current | $V_{IL}$ = 0V or $V_{IH}$ = 5.5V, $V_{DD}$ = 5.5V | $T_A$ = +25°C | | 0.01 | 1 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |
| SDA Output Low Voltage | $I_{SDA}$ = 3mA, for acknowledge (Note 3) | | | 0.03 | 0.4 | V |
| Clock Frequency | (Note 3) | | 100 | | 400 | kHz |
| Bus-Free Time Between START and STOP | $t_{BUF}$ (Note 3) | | 1.3 | | | µs |
| Hold Time Repeated START Condition | $t_{HD,STA}$ (Note 3) | | 0.6 | 0.1 | | µs |
| SCL Low Period | $t_{LOW}$ (Note 3) | | 1.3 | 0.2 | | µs |
| SCL High Period | $t_{HIGH}$ (Note 3) | | 0.6 | 0.2 | | µs |
| Setup Time Repeated START Condition | $t_{SU,STA}$ (Note 3) | | 0.6 | 0.1 | | µs |
| SDA Hold Time | $t_{HD,DAT}$ (Note 3) | | 0 | 0.01 | | µs |
| SDA Setup Time | $t_{SU,DAT}$ (Note 3) | | 100 | 50 | | ns |
| Setup Time for STOP Condition | $t_{SU,STO}$ (Note 3) | | 0.6 | 0.1 | | µs |

## CHARGE PUMP CHARACTERISTICS

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| Switching Frequency | | | 4 | | MHz |
| Pump Soft-Start Time | | | 0.5 | | ms |
| Charge-Pump Regulation Voltage (and OVP) | $V_{PV1}$, $V_{PV2}$ - $V_{NEG}$ | 4.3 | 5 | | V |
| Open-Loop NEG Output Resistance | (0.5 x ($V_{PV1}$ or $V_{PV2}$) - $V_{NEG}$)/$I_{NEG}$ | | 1.3 | 2.49 | Ω |
| Guaranteed Output Current | LED $V_{FMAX}$ = 3.9V, $V_{PV1}$ = $V_{PV2}$ = 3.2V | 281 | | | mA |
| NEG Discharge Resistance in Shutdown | All LEDs off | | 10 | | kΩ |

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## CURRENT SINK DRIVER CHARACTERISTICS

| PARAMETER | CONDITIONS | | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Current Setting Range | WLED1–WLED8, RGB programmable by $I^2C$ | | | 0.1 | | 25.6 | mA |
| WLED_, RGB Ramp-Up/Ramp-Down Time | Main WLED_ and RGB ramp-up/ramp-down in 0.1mA increments; 8 steps are programmable through $I^2C$; ramp-up and ramp-down times are set separately | | | | 0 (default) | | ms/ 0.1mA |
| | | | | | 0.016 | | |
| | | | | | 0.064 | | |
| | | | | | 0.128 | | |
| | | | | | 0.256 | | |
| | | | | | 0.512 | | |
| | | | | | 1.024 | | |
| | | | | | 2.048 | | |
| WLED_, RGB Current Accuracy | 25.6mA setting, $T_A$ = +25°C | | | -2.5 | | +2.5 | % |
| | 0.1mA setting, $T_A$ = +25°C | | | -50 | ±10 | +50 | |
| WLED_, RGB Current Matching | WLED1–WLED8, RGB (Note 4) | | | | 5 | 10 | % |
| WLED_, RGB $R_{DSON}$ | 1x mode | | | | 2.68 | | Ω |
| | -0.5x mode | | | | 4.12 | | |
| WLED_, RGB Current Regulator Dropout Voltage | 25.6mA setting (Note 5) | 1x mode | $T_A$ = 0°C to +85°C | | 62 | 120 | mV |
| | | | $T_A$ = -40°C | | 62 | 150 | |
| | | -0.5x mode | | | 95 | 200 | |
| WLED_, RGB Current Regulator Switchover Threshold (1x to -0.5x) | $V_{LED}$ falling | | | 125 | 150 | 175 | mV |
| WLED_, RGB Current Regulator Switchover Hysteresis | | | | | 100 | | mV |
| WLED_, RGB Leakage in Shutdown | All LEDs off | $T_A$ = +25°C | | | 0.01 | 5 | µA |
| | | $T_A$ = +85°C | | | 0.1 | | |

## LDO1 CHARACTERISTICS

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| Output Voltage $V_{LDO1}$ (Default) | 200mA at $V_{PV3}$ = 3.6V | 2.522 | 2.6 | 2.678 | V |
| Programmable Output Voltage | $I_{LDO1}$ = 50mA | 2.231 | 2.3 | 2.369 | V |
| | | 2.425 | 2.5 | 2.575 | |
| | | 2.522 | 2.6 | 2.678 | |
| | | 2.619 | 2.7 | 2.781 | |
| | | 2.716 | 2.8 | 2.884 | |
| | | 2.813 | 2.9 | 2.987 | |
| | | 2.910 | 3.0 | 3.090 | |
| | | 3.007 | 3.1 | 3.193 | |
| Output Current | | 200 | | | mA |
| Current Limit | $V_{LDO1}$ = 90% of nominal regulation voltage (Note 3) | 250 | 475 | 750 | mA |
| Dropout Voltage | $I_{LDO1}$ = 200mA, $T_A$ = +25°C | | 120 | 300 | mV |
| Line Regulation | 3.4V ≤ $V_{PV3\_}$ ≤ 5.5V, $I_{LDO1}$ = 150mA | | 2.4 | | mV |
| Load Regulation | 1mA < $I_{LDO1}$ < 200mA | | 25 | | mV |

## LDO1 CHARACTERISTICS (continued)

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| Power-Supply Rejection $\Delta V_{LDO1}/\Delta V_{PV3}$ | f = 10Hz to 10kHz, $I_{LDO1}$ = 10mA, $C_{LDO1}$ = 1µF | | 60 | | dB |
| Output Noise Voltage (RMS) | f = 100Hz to 100kHz, $I_{LDO1}$ = 10mA, $C_{LDO1}$ = 1µF | | 45 | | $\mu V_{RMS}$ |
| Minimum Output Capacitor | $I_{LDO1}$ < 200mA | | 1 | | µF |
| Startup Time from Shutdown | $I_{LDO1}$ = 150mA (Note 3) | | 40 | 100 | µs |
| Startup Transient Overshoot | $I_{LDO1}$ = 150mA (Note 3) | | 3 | 50 | mV |
| Shutdown Output Impedance | LDO1 disabled through $I^2C$ (default on) | | 1 | | kΩ |

## LDO2 CHARACTERISTICS

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| Output Voltage $V_{LDO2}$ (Default) | 200mA at $V_{PV3}$ = 3.6V | 2.813 | 2.9 | 2.987 | V |
| Programmable Output Voltage | $I_{LDO2}$ = 50mA | 2.231 | 2.3 | 2.369 | V |
| | | 2.425 | 2.5 | 2.575 | |
| | | 2.522 | 2.6 | 2.678 | |
| | | 2.619 | 2.7 | 2.781 | |
| | | 2.716 | 2.8 | 2.884 | |
| | | 2.813 | 2.9 | 2.987 | |
| | | 2.910 | 3.0 | 3.090 | |
| | | 3.007 | 3.1 | 3.193 | |
| Output Current | | 200 | | | mA |
| Current Limit | $V_{LDO2}$ = 90% of nominal regulation voltage (Note 4) | 250 | 475 | 750 | mA |
| Dropout Voltage | $I_{LDO2}$ = 200mA, $T_A$ = +25°C | | 120 | 300 | mV |
| Line Regulation | 3.4V ≤ $V_{PV3\_}$ ≤ 5.5V, $I_{LDO2}$ = 150mA | | 2.4 | | mV |
| Load Regulation | 1mA < $I_{LDO2}$ < 200mA | | 25 | | mV |
| Power-Supply Rejection $\Delta V_{LDO2}/\Delta V_{PV3}$ | f = 10Hz to 10kHz, $I_{LDO2}$ = 10mA, $C_{LDO2}$ = 1µF | | 60 | | dB |
| Output Noise Voltage (RMS) | f = 100Hz to 100kHz, $I_{LDO2}$ = 10mA, $C_{LDO2}$ = 1µF | | 45 | | $\mu V_{RMS}$ |
| Minimum Output Capacitor | $I_{LDO2}$ < 200mA | | 1 | | µF |
| Startup Time from Shutdown | $I_{LDO2}$ = 150mA (Note 3) | | 40 | 100 | µs |
| Startup Transient Overshoot | $I_{LDO2}$ = 150mA (Note 3) | | 3 | 50 | mV |
| Shutdown Output Impedance | LDO2 disabled through $I^2C$ (default on) | | 1 | | kΩ |

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## LDO3 CHARACTERISTICS

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| Input Operating Range | $V_{PV4}$ | 1.7 | | 5.5 | V |
| Output Voltage $V_{LDO3}$ | 200mA at $V_{PV4}$ = 2.4V | 1.764 | 1.80 | 1.854 | V |
| Programmable Output Voltage | $V_{PV4}$ = 1.8V, $I_{LDO3}$ = 50mA | 1.164 | 1.2 | 1.236 | V |
| | | 1.455 | 1.5 | 1.545 | |
| | $V_{PV4}$ = 3.7V, $I_{LDO3}$ = 50mA | 1.764 | 1.80 | 1.854 | |
| | | 2.425 | 2.5 | 2.575 | |
| Output Current | | | | 200 | mA |
| Current Limit | $V_{LDO3}$ = 90% of nominal regulation voltage (Note 4) | 250 | 475 | 750 | mA |
| Dropout Voltage | $I_{LDO3}$ = 200mA, $T_A$ = +25°C | | 120 | 300 | mV |
| Line Regulation | 2.4V ≤ $V_{PV4}$ ≤ 5.5V, $I_{LDO3}$ = 150mA | | 2.4 | | mV |
| Load Regulation | 1mA < $I_{LDO3}$ < 200mA | | 25 | | mV |
| Power-Supply Rejection $\Delta V_{LDO3}/\Delta V_{PV4}$ | f = 10Hz to 10kHz, $I_{LDO3}$ = 10mA, $C_{LDO3}$ = 2.2µF | | 60 | | dB |
| Output Noise Voltage (RMS) | f = 100Hz to 100kHz, $I_{LDO3}$ = 10mA, $C_{LDO3}$ = 2.2µF | | 75 | | µ$V_{RMS}$ |
| Minimum Output Capacitor | 0µA < $I_{LDO3}$ < 200mA (Note 3) | 2.2 | | | µF |
| Startup Time from Shutdown | $I_{LDO3}$ = 150mA (Note 3) | | 100 | 250 | µs |
| Startup Transient Overshoot | $I_{LDO3}$ = 150mA (Note 3) | | 3 | 50 | mV |
| Shutdown Output Impedance | LDO3 disabled through $I^2C$ (default on) | | 1 | | kΩ |

## STEP-UP CONVERTER CHARACTERISTICS

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Input Operating Range | $V_{PV5}$ | | 2.7 | | 5.5 | V |
| Line Regulation | $V_{OUT}$ = 14V, $I_{OUT}$ = 5mA, $V_{PV5}$ = 2.7V to 5.5V | | | 0.1 | | %/V |
| Load Regulation | $V_{OUT}$ = 14V, $I_{OUT}$ = 0mA to 5mA, $V_{PV5}$ = 3.7V | | | 0.1 | | %/mA |
| LX Voltage Range | | | | | 20 | V |
| LX Switch Current Limit | | | 192 | 241 | 289 | mA |
| LX Leakage Current | $V_{LX}$ = 20V, step-up converter disabled | $T_A$ = +25°C | | 0.01 | 2 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |
| Isolation pMOS $R_{DS(ON)}$ | $V_{PV5}$ = 2.7V, $I_{SW}$ = 100mA | | | 1.5 | 2.4 | Ω |
| pMOS Rectifier $R_{DS(ON)}$ | LX to OUT, $V_{PV5}$ = 3.7V, $I_{LX}$ = 100mA | | | 4.0 | | Ω |
| Isolation pMOS Current Limit | $V_{PV5}$ = 3.7V, $V_{SW}$ = 0V | | 0.15 | 0.3 | 0.6 | A |
| Isolation pMOS Leakage Current | SW = PGND3, $V_{PV5}$ = 5.5V | $T_A$ = +25°C | | 0.01 | 1 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |
| SW Soft-Start Time | $V_{PV5}$ = 2.7V | | | 0.2 | | ms |
| nMOS $R_{DS(ON)}$ | $V_{PV5}$ = 3.7V, $I_{LX}$ = 100mA | | | 0.9 | 1.5 | Ω |
| Maximum LX On-Time | | | 8 | 11 | 14 | µs |
| Minimum LX Off-Time | $V_{OUT}$ > 12V | | 1.6 | 2 | 2.4 | µs |
| OVP Threshold | No feedback, $V_{OUT}$ rising | | 17.6 | 18.5 | 19.4 | V |
| OVP Threshold Hysteresis | | | | 1 | | V |

## STEP-UP CONVERTER CHARACTERISTICS (continued)

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Current Limit Propagation Delay (LX) | | | | 55 | | ns |
| Output Voltage Accuracy | $V_{PV5}$ = 3.7V, $I_{OUT}$ = 0mA | $T_A$ = 0°C to +85°C | -2 | | +2 | % |
| | | $T_A$ = -40°C | -2.5 | | +2.5 | |
| Programmable Output Voltage | $V_{PV5}$ = 3.7V, $I_{OUT}$ = 0mA | | | 13.0 | | V |
| | | | | 13.5 | | |
| | | | | 14.0 | | |
| | | | | 14.5 | | |
| | | | | 15.0 | | |
| | | | | 15.5 | | |
| | | | | 16.0 | | |
| | | | | 16.5 | | |

## AMBIENT LIGHT SENSOR INTERFACE

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| BIAS Output Voltage | $I_{BAIS}$ = 200µA, $V_{PV3}$ = 3.2V to 5.5V | | 2.85 | 3.0 | 3.15 | V |
| BIAS Output Current | $V_{BIAS}$ = 3.0V ±5% | | | | 30 | mA |
| BIAS Dropout Voltage | $I_{BIAS}$ = 10mA (Note 3) | | | 125 | 250 | mV |
| SENSE Input Voltage Range | | | 0 | | $V_{BIAS}$ x 255/256 | V |
| BIAS Discharge Resistance in Shutdown | | | | 1.0 | 1.5 | kΩ |
| ADC Resolution | | | | 8 | | Bit |
| ADC Integral Nonlinearity Error | | | -3 | | +3 | LSB |
| ADC Differential Nonlinearity Error | | | -1 | | +1 | LSB |
| SENSE Input Impedance | $T_A$ = +25°C (Note 3) | | 1 | | | MΩ |
| Waiting Time for ADC Movement After ALCEN = 1 | $V_{BIAS}$ = 3V | Bit 0 = 0 in 02h register | | 32 | | ms |
| | | Bit = 1 in 02h register | | 64 (default) | | ms |

## KEY CHARACTERISTICS

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Low-Level Output Voltage | $I_{SINK}$ = 1mA | | | | 0.4 | V |
| High-Level Output Voltage | $I_{SOURCE}$ = 1mA | | 1.8 | | | V |
| nMOS Output Leakage Current | At complementary output, $V_{PV3}$ = 3.7V (Note 6) | $T_A$ = +25°C | | 0.01 | 1 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |
| pMOS Output Leakage Current | At complementary output, $V_{PV3}$ = 3.7V (Note 6) | $T_A$ = +25°C | | 0.01 | 1 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## CAI CHARACTERISTICS

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| PWM Low-Level Input Voltage | | | | | 0.4 | V |
| PWM High-Level Input Voltage | | | 1.4 | | | V |
| PWM Dimming Frequency | $C_{FILT}$ = 0.1µF (Note 3) | | 0.1 | 0.2 | 15 | kHz |
| Current Dimming Range | Duty cycle = 0% to 100% (Note 3) | | 0 | | 25.6 | mA |
| PWM Dimming Resolution | 1% ≤ duty cycle ≤ 100% (Note 3) | | | 0.256 | | mA/% |
| CAI Enable Blanking Time ($t_B$) | Time from CAI enable until dimming control switches to CAI input (Note 4) | | | 10 | | ms |
| Input Leakage Current | CAI = GND or $V_{CAI}$ = 3.7V | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | $T_A$ = +85°C | | 1 | | |

## GPO (OPEN-DRAIN OUTPUT) CHARACTERISTICS

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Low-Level Output Voltage | $I_{SINK}$ = 1mA | | | | 0.2 | V |
| Output Leakage Current | $V_{LDO\_}$ = 2.6V | $T_A$ = +25°C | | 0.1 | | µA |
| | | $T_A$ = +85°C | | 1 | | |

## EN CHARACTERISTICS

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Low-Level Input Voltage | | | | | 0.4 | V |
| High-Level Input Voltage | | | 1.4 | | | V |
| Input Leakage Current | $V_{EN}$ = 0V or 3.7V | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | $T_A$ = +85°C | | 1 | | |

## PLAYR/PLAYG/PLAYB CHARACTERISTICS

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| Low-Level Input Voltage | | | | 0.4 | V |
| High-Level Input Voltage | | 1.4 | | | V |
| ON/OFF PWM Frequency | (Note 3) | 2 | | 200 | Hz |
| PLAY_ Minimum High Time | PLAY_ active high<br>(Bit 1 = low in Register 20h) (Note 3) | 80 | | | µs |
| PLAY_ Minimum Low Time | PLAY_ active low<br>(Bit 1= high in Register 20h) (Note 3) | 80 | | | µs |
| Pulldown Resistor to AGND | | | 800 | | kΩ |

## $\overline{CHG}$ PIN CHARACTERISTICS

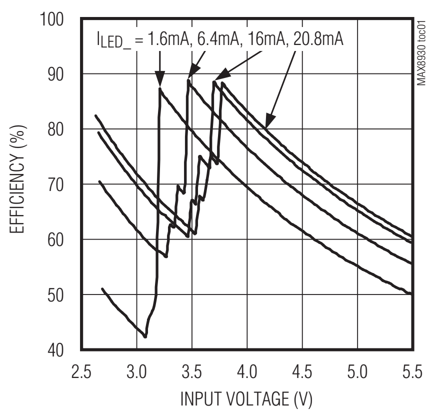
| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Low-Level Voltage | $I_{\overline{CHG}}$ = 5mA | | | 0.05 | 0.2 | V |
| Leakage Current | $V_{\overline{CHG}}$ = 3.7V | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | $T_A$ = +85°C | | 1 | | |

**Note 1:** Limits are 100% production tested at $T_A$ = +25°C. Limits over the operating temperature range are guaranteed by design.
**Note 2:** 0.1mA LED load current is not included.
**Note 3:** Guaranteed by design. Not production tested.
**Note 4:** LED current matching is defined as: ($I_{MAX}$ - $I_{MAX}$)/25.6mA. Matching is for LEDs within the RGB group (RLED, GLED, BLED) or the white LED group (WLED1–WLED8).
**Note 5:** Dropout voltage is defined as the LED_ to AGND voltage at which current into LED_ drops 10% from the value at $V_{LED\_}$ = 0.5V at 1x mode.
**Note 6:** $V_{KEY}$ = 0V when pulling low, leakage current from PV3. $V_{KEY}$ = 3.7V when pulling high, leakage current is to GND.

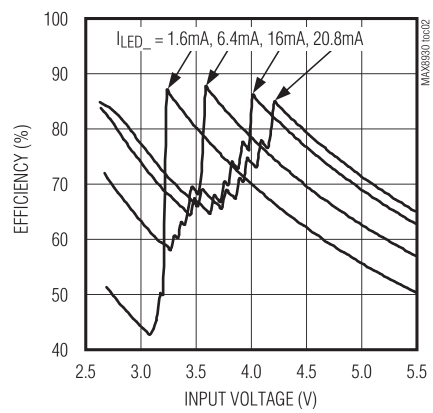
## *Typical Operating Characteristics*

($V_{PV\_}$ = $V_{EN}$ = 3.7V, circuit of Figure 1, $T_A$ = +25°C, unless otherwise noted.)

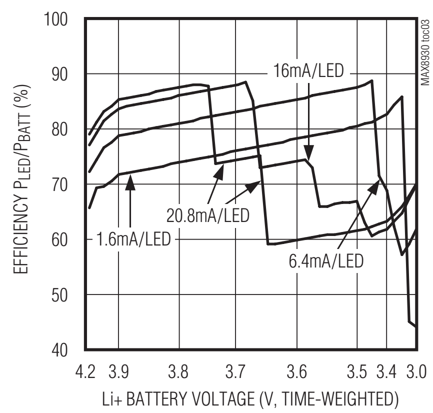
**WLED EFFICIENCY vs. INPUT VOLTAGE, 6 MATCHED WLEDS**



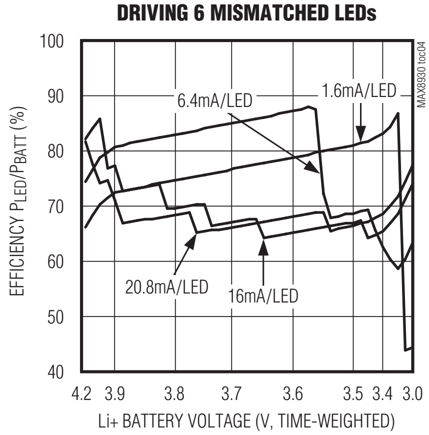

**WLED EFFICIENCY vs. INPUT VOLTAGE, 6 MISMATCHED WLEDS**



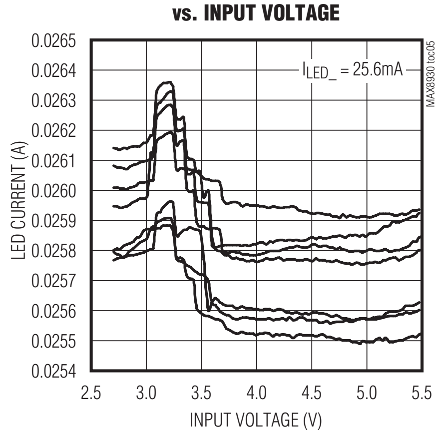

**EFFICIENCY vs. Li+ BATTERY VOLTAGE DRIVING 6 MATCHED LEDs**



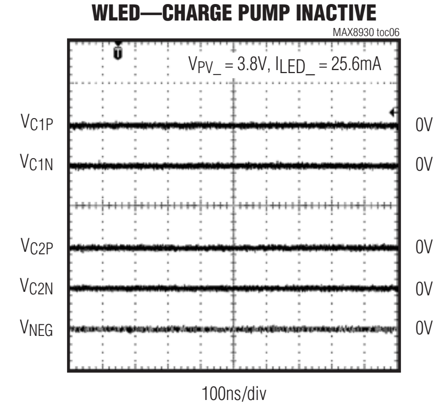

**EFFICIENCY vs. Li+ BATTERY VOLTAGE DRIVING 6 MISMATCHED LEDs**




**WLED CURRENT MATCHING vs. INPUT VOLTAGE**



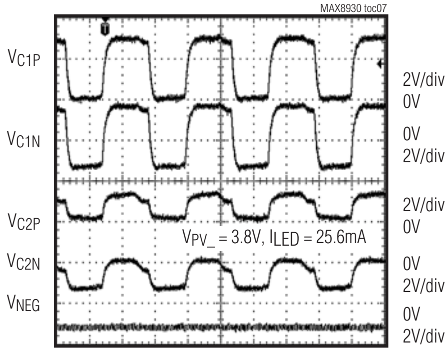

**WLED—CHARGE PUMP INACTIVE**

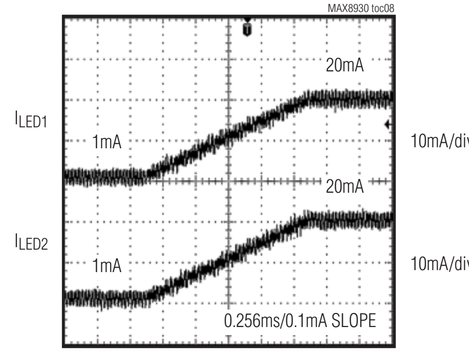


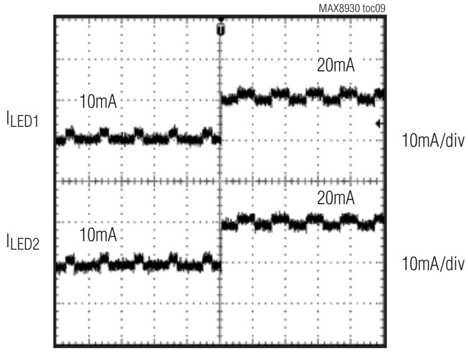
# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

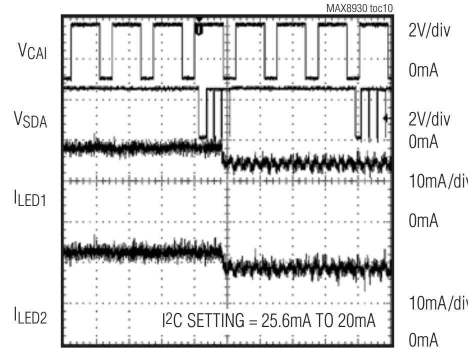
## Typical Operating Characteristics (continued)

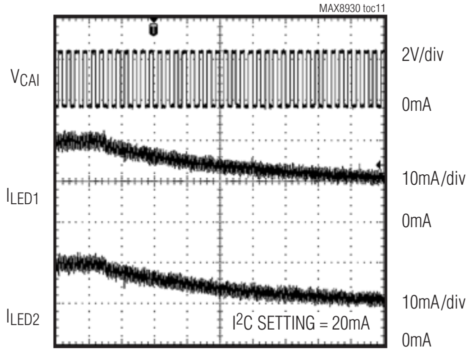
($V_{PV\_} = V_{EN} = 3.7V$, circuit of Figure 1, $T_A = +25°C$, unless otherwise noted.)

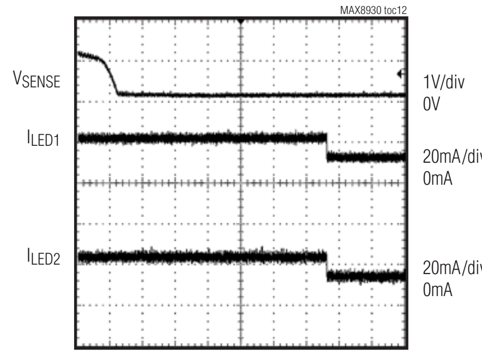


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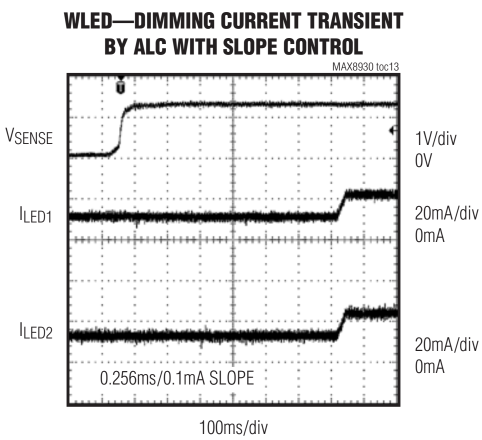
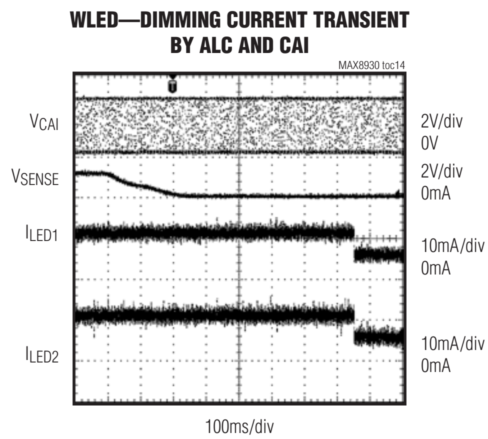
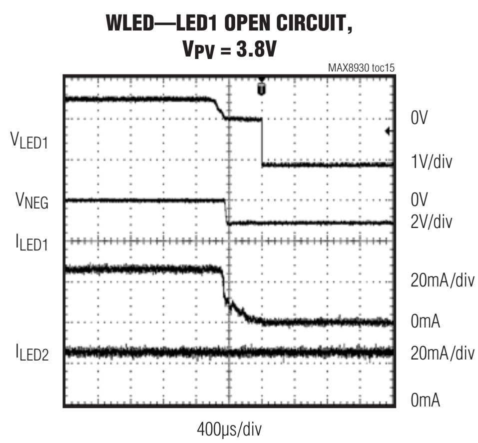
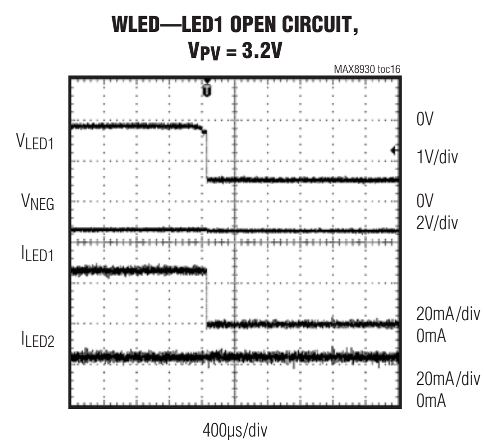
## Typical Operating Characteristics (continued)

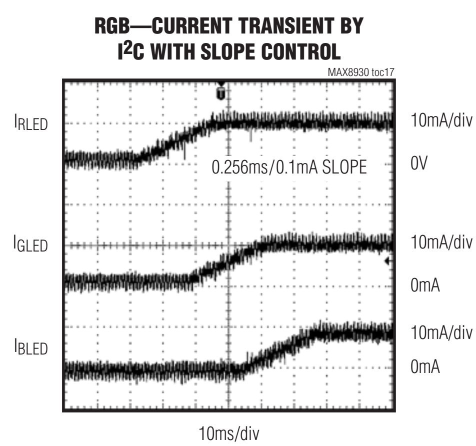
($V_{PV\_} = V_{EN} = 3.7V$, circuit of Figure 1, $T_A = +25°C$, unless otherwise noted.)

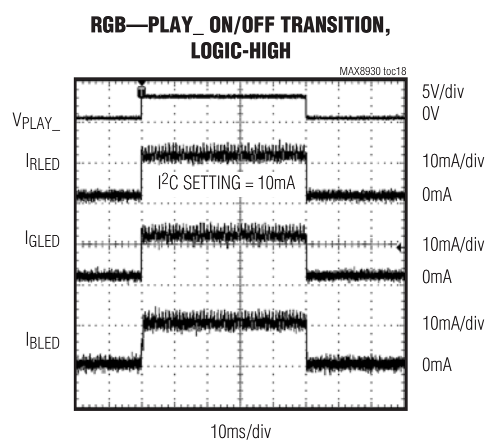


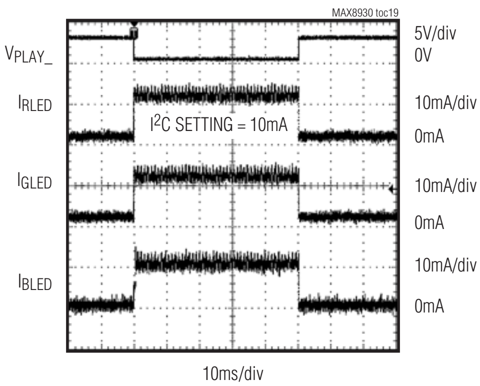



# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

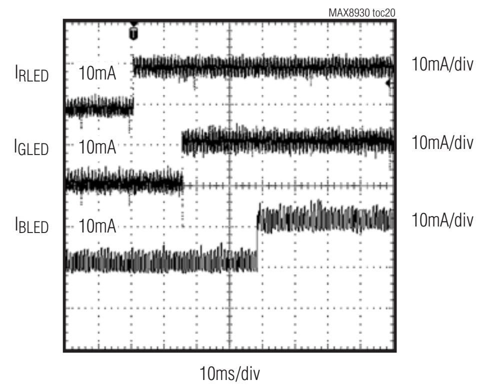
## Typical Operating Characteristics (continued)

($V_{PV\_} = V_{EN} = 3.7V$, circuit of Figure 1, $T_A = +25°C$, unless otherwise noted.)

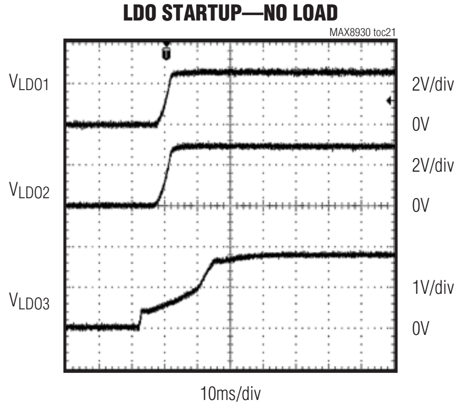
**RGB—PLAY_ ON/OFF TRANSITION, LOGIC-LOW**



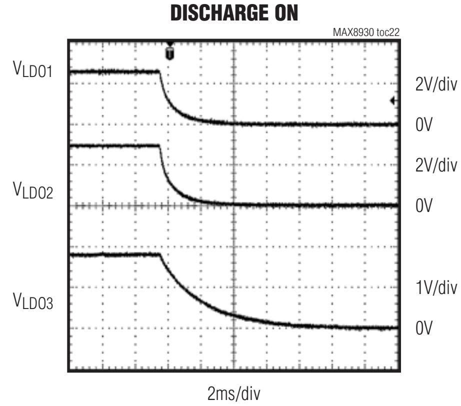

**RGB—PLAY_ ON/OFF TRANSITION AND I2C COMING**



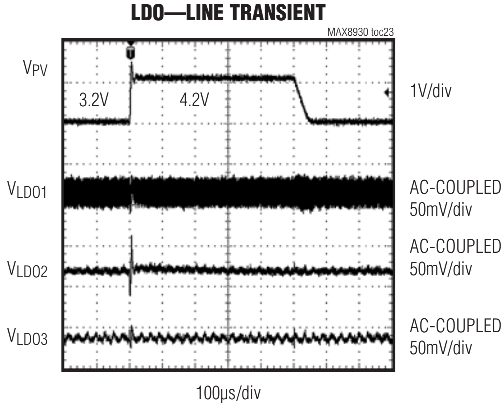

**LDO STARTUP—NO LOAD**



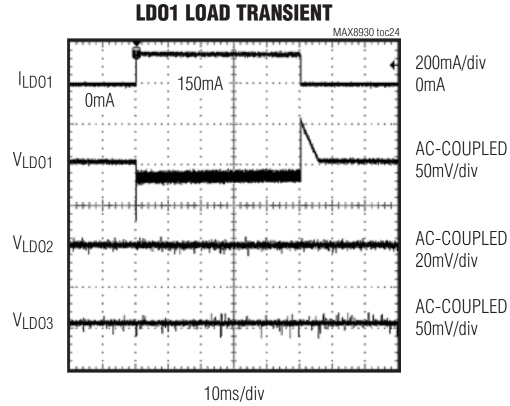

**LDO SHUTDOWN—DEFAULT ACTIVE DISCHARGE ON**




**LDO—LINE TRANSIENT**



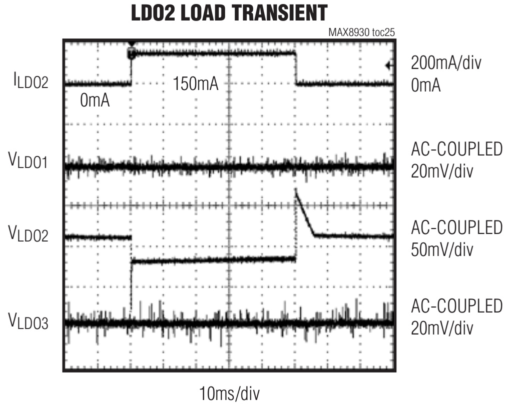

**LDO1 LOAD TRANSIENT**



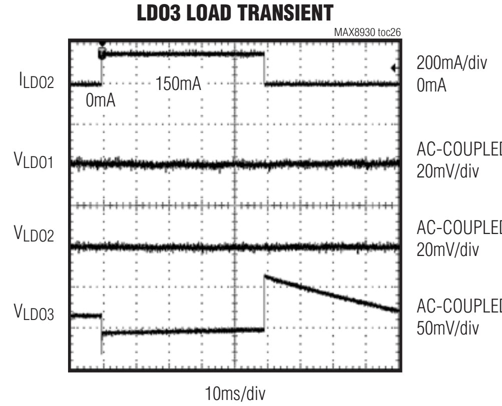
## Typical Operating Characteristics (continued)

($V_{PV\_} = V_{EN} = 3.7V$, circuit of Figure 1, $T_A = +25°C$, unless otherwise noted.)

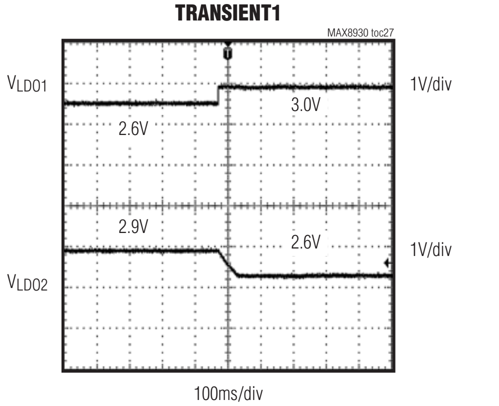
**LDO2 LOAD TRANSIENT**



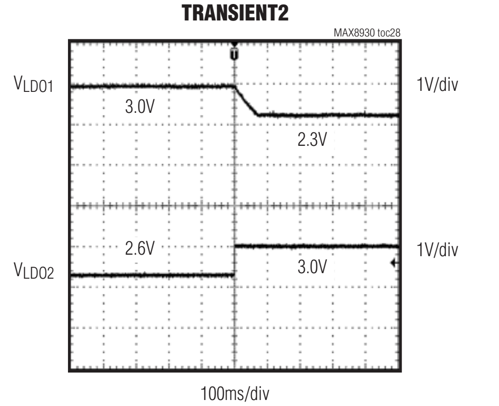

**LDO3 LOAD TRANSIENT**



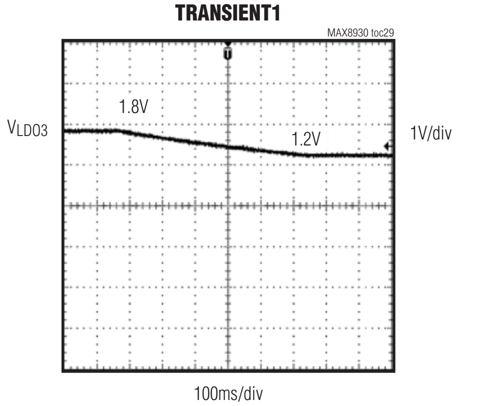

**LDO1 AND LDO2—OUTPUT VOLTAGE TRANSIENT1**



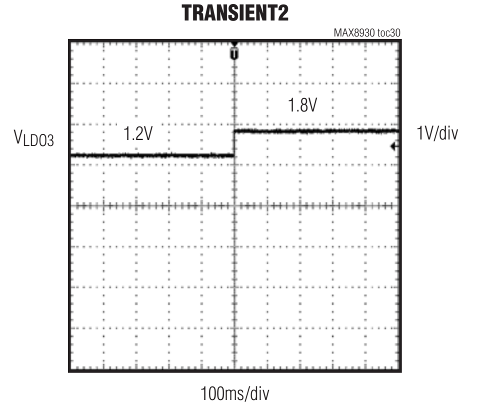

**LDO1 AND LDO2—OUTPUT VOLTAGE TRANSIENT2**




**LDO3—OUTPUT VOLTAGE TRANSIENT1**




**LDO3—OUTPUT VOLTAGE TRANSIENT2**

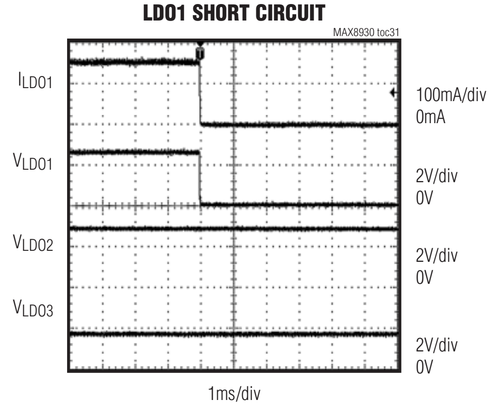


# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

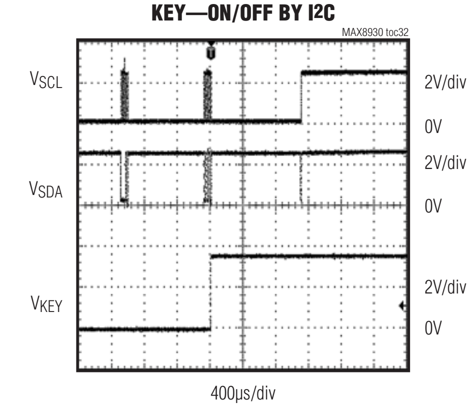
## Typical Operating Characteristics (continued)

($V_{PV\_}$ = $V_{EN}$ = 3.7V, circuit of Figure 1, $T_A$ = +25°C, unless otherwise noted.)

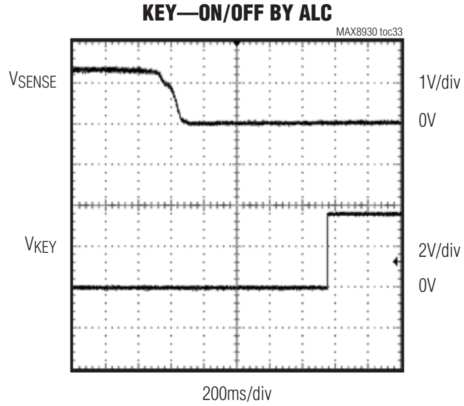
**LDO1 SHORT CIRCUIT**



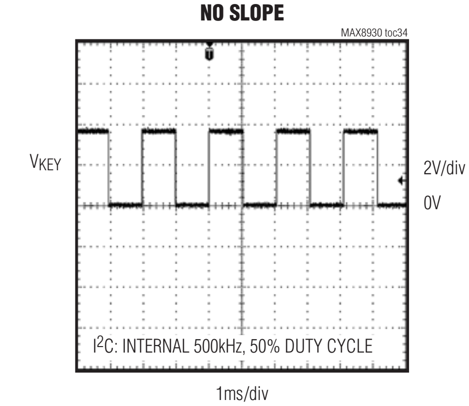

**KEY—ON/OFF BY I2C**



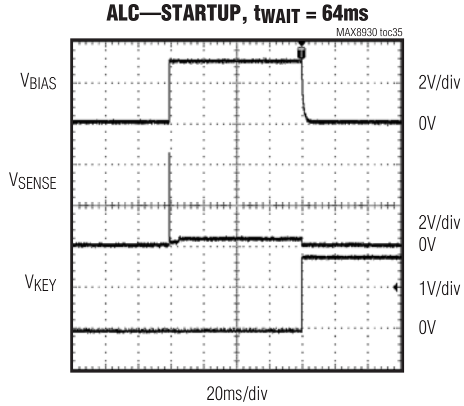

**KEY—ON/OFF BY ALC**



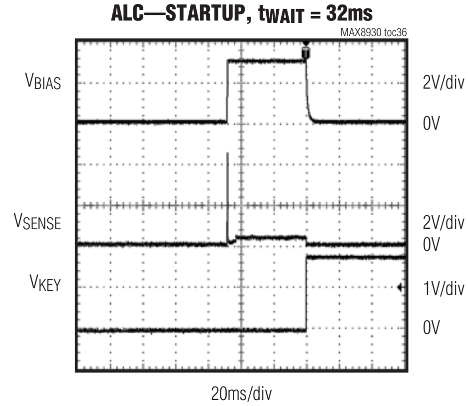

**KEY—ON/OFF BY INTERNAL PWM, NO SLOPE**




**ALC—STARTUP, $t_{WAIT}$ = 64ms**



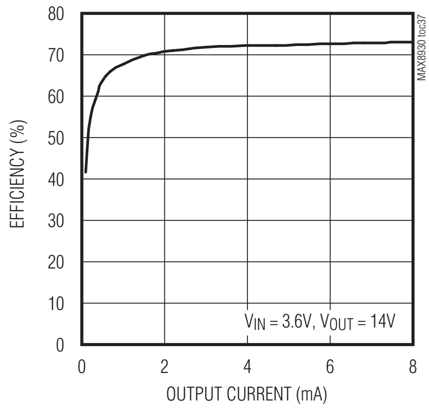

**ALC—STARTUP, $t_{WAIT}$ = 32ms**



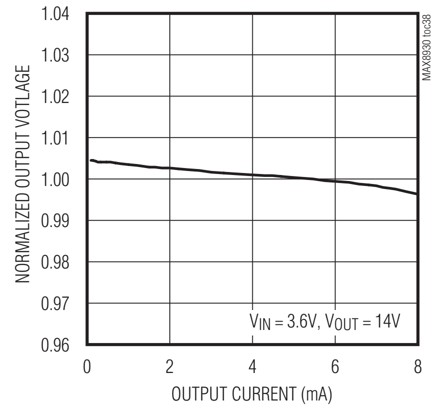
## Typical Operating Characteristics (continued)

($V_{PV\_} = V_{EN} = 3.7V$, circuit of Figure 1, $T_A = +25°C$, unless otherwise noted.)

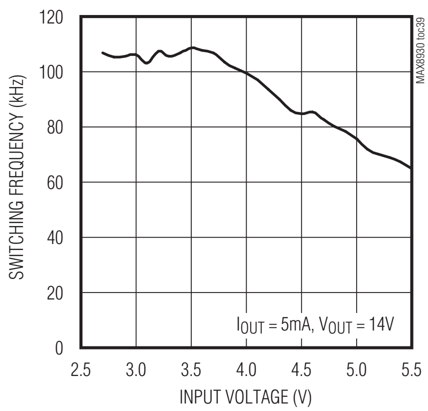
**STEP-UP EFFICIENCY vs. LOAD CURRENT**



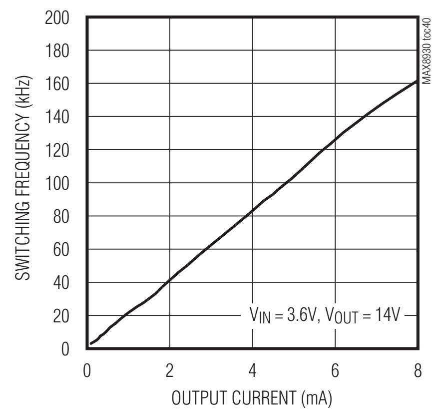

**STEP-UP LOAD REGULATION vs. OUTPUT CURRENT**



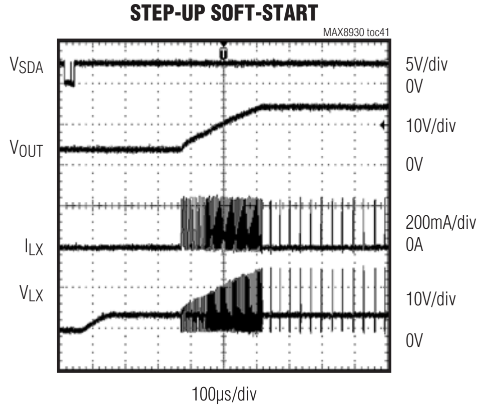

**STEP-UP SWITCHING FREQUENCY vs. INPUT VOLTAGE**



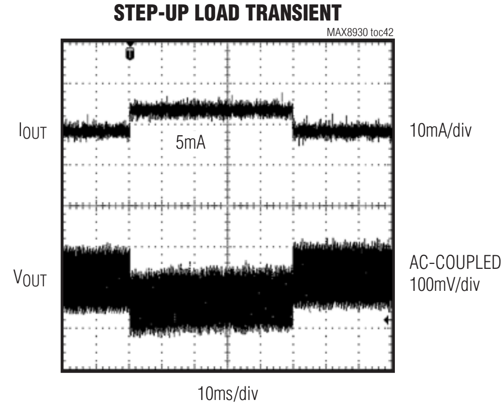

**STEP-UP SWITCHING FREQUENCY vs OUTPUT CURRENT**




**STEP-UP SOFT-START**



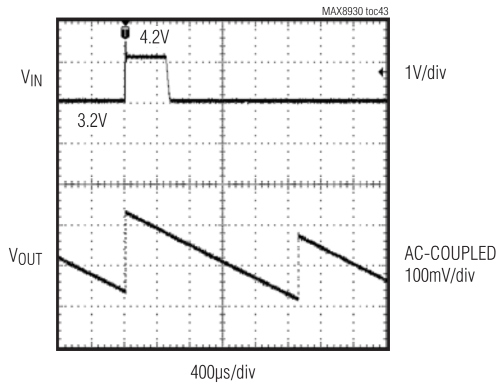

**STEP-UP LOAD TRANSIENT**



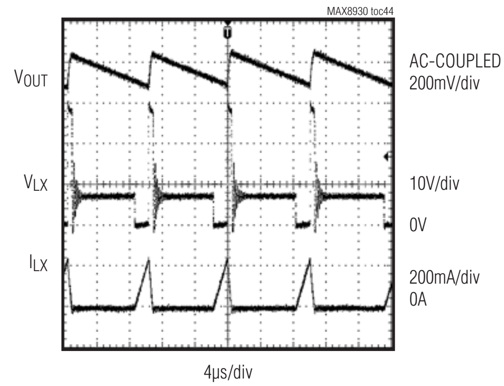
## Typical Operating Characteristics (continued)

($V_{PV\_}$ = $V_{EN}$ = 3.7V, circuit of Figure 1, $T_A$ = +25°C, unless otherwise noted.)

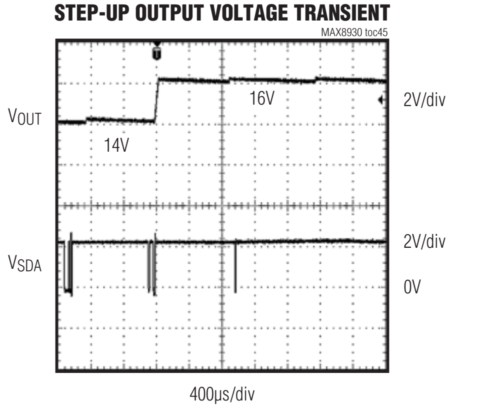
**STEP-UP LINE TRANSIENT**



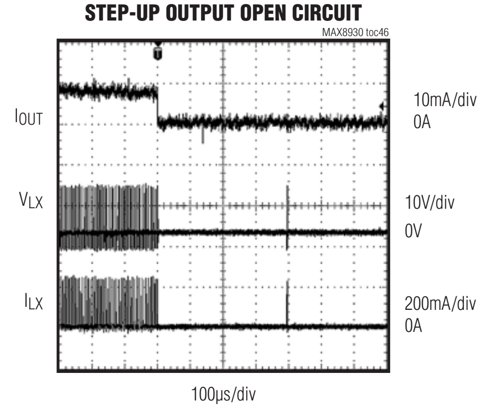

**STEP-UP SWITCHING WAVEFORMS**



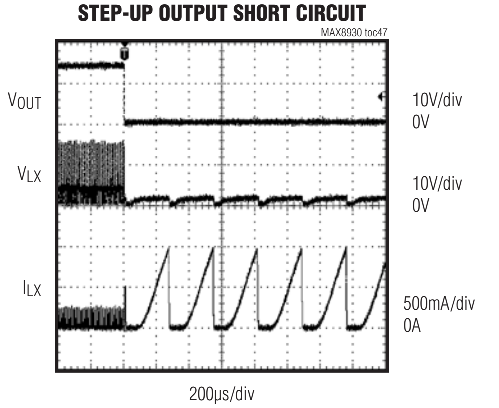

**STEP-UP OUTPUT VOLTAGE TRANSIENT**



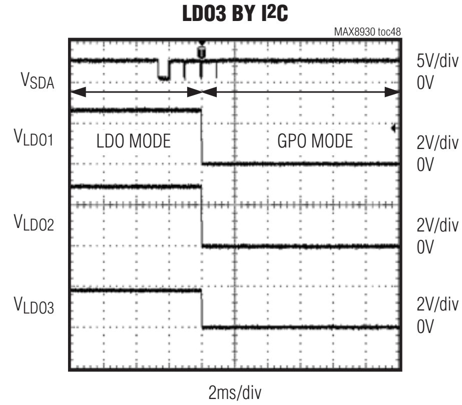

**STEP-UP OUTPUT OPEN CIRCUIT**




**STEP-UP OUTPUT SHORT CIRCUIT**




**GPO—ON/OFF MODE LDO1, LDO2, LDO3 BY I2C**



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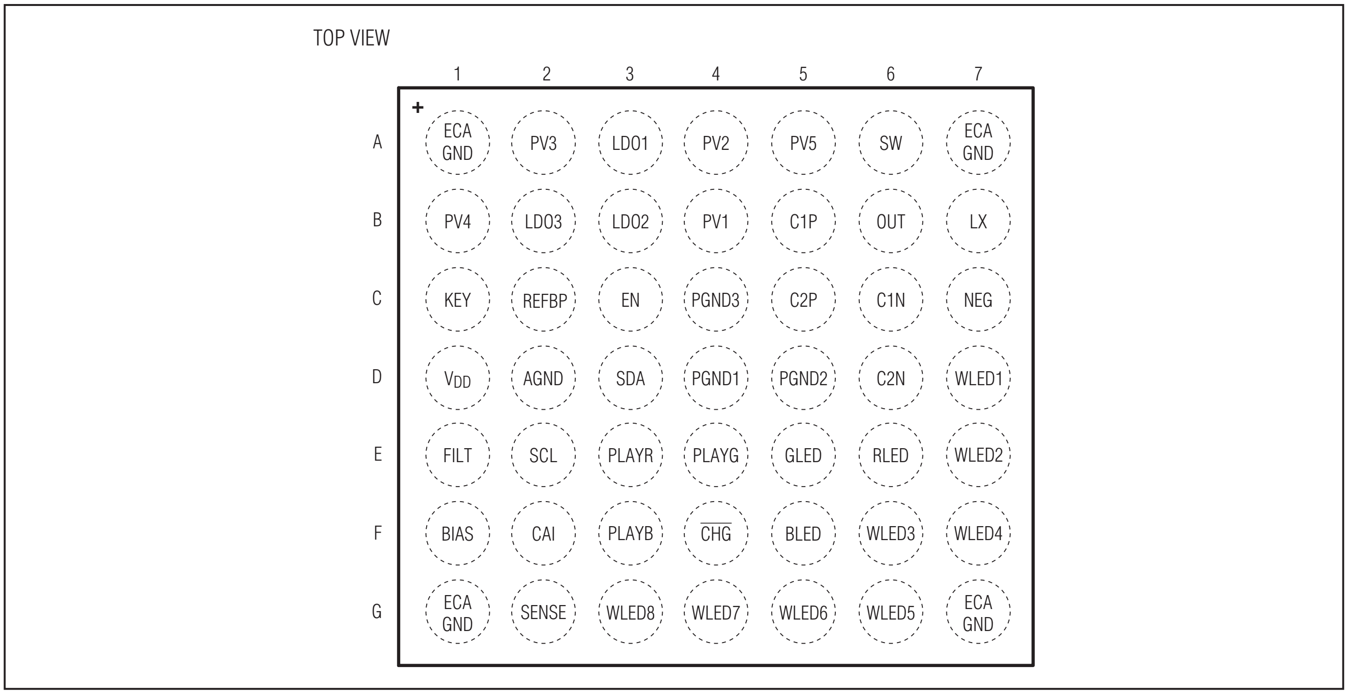
## Pin Configuration




## Pin Description

| PIN | NAME | FUNCTION |
|---|---|---|
| **EXTERNALLY CONNECTED TO PGND** | | |
| A1, A7, G1, G7 | ECAGND | Connect to AGND |
| **POWER INPUT SUPPLY AND POWER GROUND** | | |
| A2 | PV3 | Supply Voltage Input for Ref, Bias, LDO1, and LDO2. The input voltage range is 2.7V to 5.5V. Bypass PV3 to AGND with a 2.2µF ceramic capacitor as close as possible to the IC. PV3 is high impedance during shutdown. Connect PV3 to PV1, PV2, and PV5. |
| A4 | PV2 | Supply Voltage Input. Connect PV2 to PV1. |
| A5 | PV5 | Supply Voltage Input for the Step-Up Converter. The input voltage range is 2.7V to 5.5V. Bypass PV5 to PGND3 with a 1µF ceramic capacitor as close as possible to the IC. PV5 is high impedance during shutdown. Connect PV5 to PV1, PV2, and PV3. |
| B1 | PV4 | Supply Voltage Input for LDO3. The input voltage range is 1.7V to 5.5V. Bypass PV4 to AGND with a 2.2µF ceramic capacitor as close as possible to the IC. PV4 is high impedance during shutdown. If PV4 is not used separately, connect PV4 to PV1. |
| B4 | PV1 | Supply Voltage Input for Charge-Pump Circuitry. The input voltage range is 2.7V to 5.5V. Bypass PV1 to PGND1 and PGND2 with a 4.7µF to 10µF ceramic capacitor as close as possible to the IC. PV1 is high impedance during shutdown. Connect PV1 to PV2, PV3, and PV5. |
| C4 | PGND3 | Power Ground for the Step-Up Converter |
| D4 | PGND1 | Power Ground for the Charge-Pump Block |
| D5 | PGND2 | Power Ground for the Charge-Pump Block |

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## Pin Description (continued)

| PIN | NAME | FUNCTION |
|---|---|---|
| **LDO FUNCTION** | | |
| A3 | LDO1 | Output of LDO1. The default value is 2.6V. Bypass LDO1 to AGND with a 1µF ceramic capacitor as close as possible to the IC. |
| B3 | LDO2 | Output of LDO2. The default value is 2.9V. Bypass LDO2 to AGND with a 1µF ceramic capacitor as close as possible to the IC. |
| B2 | LDO3 | Output of LDO3. The default value is 1.80V. Bypass LDO3 to AGND with a minimum 2.2µF ceramic capacitor as close as possible to the IC. |
| **LOGIC AND ENABLE FUNCTION** | | |
| D1 | $V_{DD}$ | Logic-Supply Voltage Input. Bypass $V_{DD}$ to AGND with a 0.1µF ceramic capacitor as close as possible to the IC. The input range is 1.7V to 5.5V. |
| D3 | SDA | $I^2C$ Data Input. Data is read on the rising edge of SCL. Connect a 1.5kΩ resistor from SDA to $V_{DD}$. |
| E2 | SCL | $I^2C$ Clock Input. Data is read on the rising edge of SCL. Connect a 1.5kΩ resistor from SCL to $V_{DD}$. |
| D2 | AGND | Analog Ground. Connect AGND to the system ground plane. |
| C3 | EN | Hardware Enable Input for the IC. Drive EN high to activate the IC. Drive EN low to disable the IC. |
| **WLED AND RGB DIMMING RELATED FUNCTION** | | |
| F2 | CAI | Brightness Control Input by Contents Adaptive Interface (DPWM signal). CAI varies the brightness of main WLEDs from 0% to 100%. The dimming frequency is typically 200Hz. When CAI is used as the main control method for main white LEDs, the ramp-up/ramp-down is automatically disabled. |
| E3 | PLAYR | On/Off Input for the Red LED Current Regulator. The PLAYR signal can be either active high or active low. Program either active high or active low through the 20h register. |
| E4 | PLAYG | On/Off Input for the Green LED Current Regulator. The PLAYG signal can be either active high or active low. Program either active high or active low through the 20h register. |
| F3 | PLAYB | On/Off Input for the Blue LED Current Regulator. The PLAYB signal can be either active high or active low. Program either active high or active low through the 20h register. |
| E1 | FILT | PWM Filter Capacitor. Connect a 0.1µF ceramic capacitor between FILT and AGND as close as possible to FILT. |
| C1 | KEY | Key Backlight Control Output. Two threshold values for ON/OFF are available and programmable through the $I^2C$ serial interface. KEY on/off function is controlled by the $I^2C$, ALC, or the internal 500Hz PWM signal. Program the settings for KEY through the $I^2C$ interface. |
| C2 | REFBP | 1.20V Reference output. Bypass REFBP to AGND with 0.1µF ceramic capacitor as close as possible to the IC. Do not load REFBP. |
| **AUTOMATIC LUMINANCE CONTROL** | | |
| F1 | BIAS | Bias Output for an External Light Sensor. Bypass BIAS to AGND with a 1µF ceramic capacitor as close as possible to the IC. The BIAS output is 3.0V. |
| G2 | SENSE | Input from Ambient Light Sensor. Connect a 5.1kΩ resistor from SENSE to AGND. |
| **CHARGE-PUMP BLOCK** | | |
| B5 | C1P | Transfer Capacitor 1 Positive Connection. Connect a 1µF ceramic capacitor from C1P to C1N. |
| C6 | C1N | Transfer Capacitor 1 Negative Connection. Connect a 1µF ceramic capacitor from C1P to C1N. |
| C5 | C2P | Transfer Capacitor 2 Positive Connection. Connect a 1µF ceramic capacitor from C2P to C2N. |
| C7 | NEG | Charge-Pump Negative Output. Connect a 1µF to 2.2µF ceramic capacitor from NEG to PGND1. In shutdown, an internal 10kΩ resistor pulls NEG to PGND. |
| D6 | C2N | Transfer Capacitor 2 Negative Connection. Connect a 1µF ceramic capacitor from C2P to C2N. |

## Pin Description (continued)

| PIN | NAME | FUNCTION |
|---|---|---|
| **WLED AND RGB** | | |
| D7 | WLED1 | WLED Current Sink Regulator. Current into WLED1 is based upon the programmed internal $I^2C$ registers. Connect WLED1 to the cathodes of external LEDs. WLED1 is high impedance during shutdown. If unused, short WLED1 to PV3. |
| E7 | WLED2 | WLED Current Sink Regulator. Current into WLED2 is based upon the programmed internal $I^2C$ registers. Connect WLED2 to the cathodes of external LEDs. WLED2 is high impedance during shutdown. If unused, short WLED2 to PV3. |
| F6 | WLED3 | WLED Current Sink Regulator. Current into WLED3 is based upon the programmed internal $I^2C$ registers. Connect WLED3 to the cathode of an external WLED. WLED3 is high impedance during shutdown. If unused, short WLED3 to PV3. |
| F7 | WLED4 | WLED Current Sink Regulator. Current into WLED4 is based upon the programmed internal $I^2C$ registers. Connect WLED4 to the cathode of an external LED. WLED4 is high impedance during shutdown. If unused, short WLED4 to P3. |
| G6 | WLED5 | WLED Current Sink Regulator. Current into WLED5 is based upon the programmed internal $I^2C$ registers. Connect WLED5 to the cathode of an external WLED. WLED5 is high impedance during shutdown. If unused, short WLED5 to either PV3 or disable the regulator. |
| G5 | WLED6 | WLED Current Sink Regulator. Current into WLED6 is based upon the programmed internal $I^2C$ registers. Connect WLED6 to the cathode of an external WLED. WLED6 is high impedance during shutdown. If unused, short WLED6 to either PV3 or disable the regulator. |
| G4 | WLED7 | WLED Current Sink Regulator. Current into WLED7 is based upon the programmed internal $I^2C$ registers. Connect WLED7 to the cathode of an external WLED. WLED7 is high impedance during shutdown. If unused, short WLED7 to either PV3 or disable the regulator. |
| G3 | WLED8 | WLED Current Sink Regulator. Current into WLED8 is based upon the programmed internal $I^2C$ registers. Connect WLED8 to the cathode of an external WLED. WLED8 is high impedance during shutdown. If unused, short WLED8 to either PV3 or disable the regulator. |
| E6 | RLED | Red LED Connection. The brightness is set up by $I^2C$. ON/OFF is synchronized with the PWM signal applied to PLAYR pin. RLED maximum brightness is enabled/disabled through the serial interface. |
| E5 | GLED | Green LED Connection. The brightness is set up by $I^2C$. ON/OFF is synchronized with the PWM signal applied to PLAYG pin. GLED maximum brightness is enabled/disabled through the serial interface. |
| F5 | BLED | Blue LED Connection. The brightness is set up by $I^2C$. ON/OFF is synchronized with the PWM signal applied to PLAYB pin. BLED maximum brightness is enabled/disabled through the serial interface. |
| **BOOST CONVERTER** | | |
| B6 | OUT | Step-Up Converter Output. Bypass OUT to GND with a 1µF ceramic capacitor. During shutdown, OUT is pulled to PGND3 by an internal 1MΩ resistor. |
| A6 | SW | Isolation Switch Output for the Step-Up Converter. SW is internally connected to the drain of a p-channel MOSFET and used to isolate the output of the step-up from the input during shutdown. If true shutdown is not required, SW can be left open with the input supply connected directly to the inductor. |
| B7 | LX | Inductor Switching Connection. Connect the inductor between LX and SW. For most applications, use a 22µH inductor. |
| **STATUS INDICATOR** | | |
| F4 | $\overline{CHG}$ | Charging Status Output. $\overline{CHG}$ is an open-drain output that goes low when the battery is charging. On/off is operated by $I^2C$. $\overline{CHG}$ is high impedance when the IC is in shutdown mode. Enable $\overline{CHG}$ through the $I^2C$ interface. |

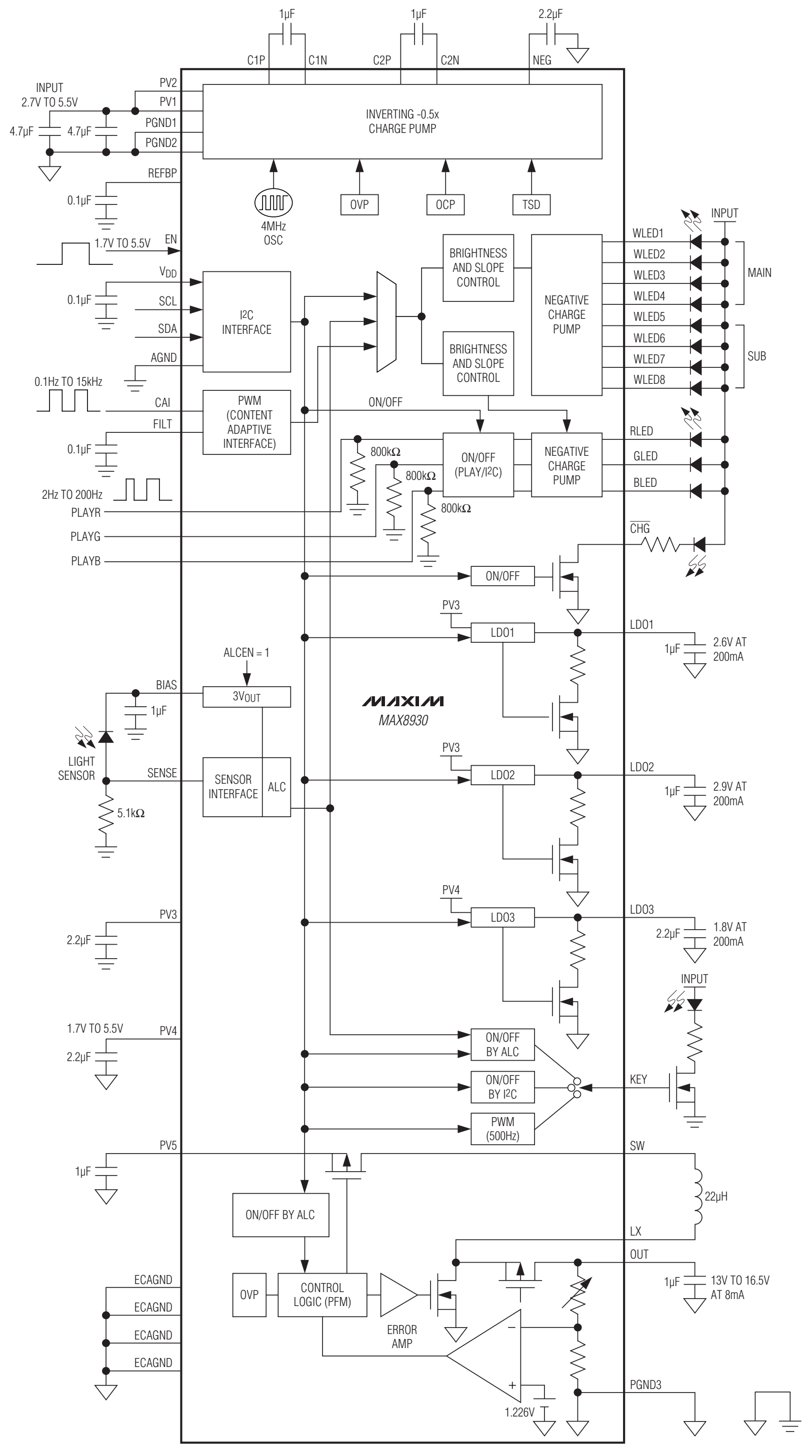



*Figure 1. Typical Application and Block Diagram*

## External Components

| PIN | EXTERNAL COMPONENTS | NOTES |
|---|---|---|
| PV1, PV2, PV3, PV5 | 10µF<br>Total capacitance ≥ total LDO, boost, and charge-pump capacitance | System stability |
| PV4 | 2.2µF | LDO stability |
| $V_{DD}$ | 0.1µF | Decoupling |
| BIAS | 1µF | LDO compensation |
| LDO1 | 1µF | LDO compensation |
| LDO2 | 1µF | LDO compensation |
| LDO3 | 2.2µF | LDO compensation |
| FILT | 0.1µF | Noise filter |
| REFBP | 0.1µF | Noise filter |
| C1P, C1N | 1µF | Charge pump |
| C2P, C2N | 1µF | Charge pump |
| NEG | 2.2µF | Charge pump |
| WLED1–WLED8 | White LED | — |
| RLED, GLED, BLED | Red, green, blue LED | — |
| $\overline{CHG}$ | A resister, for example 10kΩ | Current limit |
| SW, LX | 22µH | Boost converter |
| OUT | 1µF | Boost stability |
| SENSE | 5.1kΩ | Converter ambient light to a voltage |
| ALC | Toshiba TPS852 | Any type (linear/log) of photo IC |

***Note:*** *All output capacitors are ceramic and X7R/X5R type.*

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## Detailed Description

The MAX8930 integrates a negative charge pump for both white LED display backlighting with ambient light control (ALC) function, content adaptive interface (CAI) function, and R/G/B LED. There is one step-up converter for passive matrix OLED (PMOLED) oriented application and three LDOs with programmable output voltage. The three LDO outputs are able to convert to GPO (general-purpose output) status through an $I^2C$ command. The MAX8930 includes soft-start, thermal shutdown, open-circuit, and short-circuit protection in the charge-pump circuitry.

### Reset Control

The MAX8930 uses two different methods of reset: software and hardware.

**Software Reset:** All the registers are initiated by RESET = 1 at Register 00h. After that, the values in all registers come back to POR (power-on-reset) state. The bit of RESET in 00h is automatically returned to 0. Auto return to 0.

**Hardware Reset:** Hardware reset is done by toggling EN from logic-high to logic-low. All the registers under hardware reset conditions are returned to their initial values (POR) and stop receiving any commands.

### Open-Circuit and Short-Circuit Protection

If any WLED/RGB fails as an open circuit, that LED pin pulls to ground, and the IC is forced into -0.5X mode. Therefore, connect any unused WLED_/RGB pins to PV1, PV2, or PV3 to disable the corresponding current regulator. The MAX8930 contains special circuitry to detect this condition and disables the corresponding current regulator to avoid wasting battery current.

### Thermal Shutdown

The MAX8930 includes a thermal-limit circuit that shuts down the IC at about +160°C. The part turns on after the IC cools by approximately 20°C.

Thermal shutdown is applied to the following blocks:

- White and RGB LED driver
- Step-up converter
- LDO1, LDO2, LDO3
- SBIAS

### LED Charge Pump

The charge pump drives up to 8 white LEDs (4 WLEDs for main and 4 WLEDs for sub) and 3 RGB LEDs with regulated constant current for both display backlight and fun light applications. By utilizing individually adaptive 1x/-0.5x negative charge-pump modes and extremely low-dropout current regulators, it is able to achieve high efficiency over the full 1-cell lithium battery input voltage range. High-frequency switching of 4MHz allows for tiny external components. The regulation scheme is optimized to ensure low EMI and low input ripple. Each channel for WLED and RGB LED has the capability of delivering 25.6mA with 256 dimming steps (0.1mA per step). The current-level adjustment is programmed by an $I^2C$ command. Figure 2 is the flow chart of the startup and mode-change algorithm.

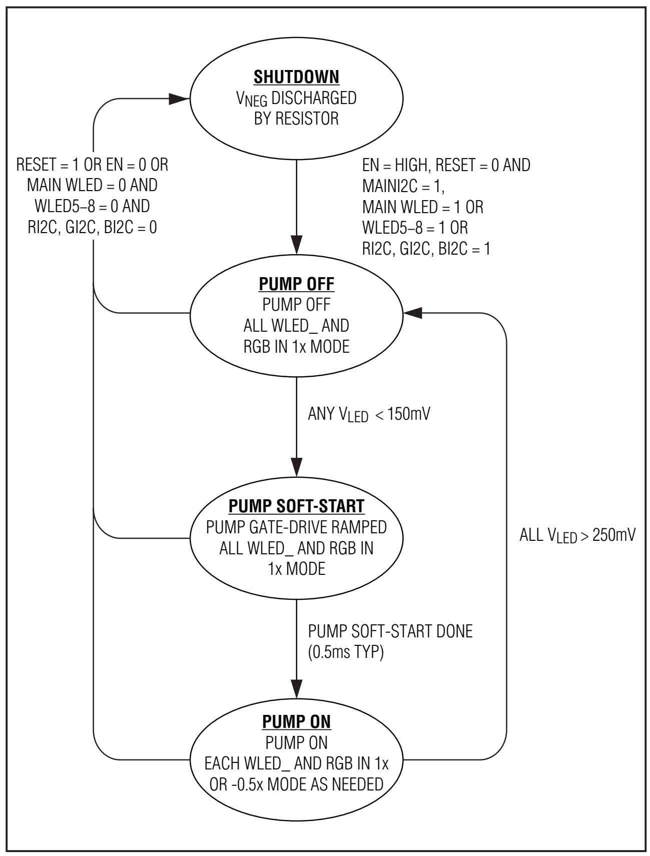



*Figure 2. Startup and Mode Change Algorithm*

### WLED1–WLED8 Driver Operation

The white LED current regulators are composed of 4 main-group drivers (WLED1–WLED4) and 4 subgroup drivers (WLED5–WLED8). The current of the main-group LEDs can be selected by an $I^2C$ register. Both ambient light control (ALC) mode and ramp-up/ramp-down control are applied to only the main-group white LEDs.

The subgroup LEDs can choose either individual control or can belong to the main group based on the status of a bit in the register (01h and 02h). In this function, combinations can be adjusted as required. For example, main 4ch + sub 4ch or main 5ch + sub 3ch.

The CAI (PWM) signal from either the LCD driver module or baseband chipset controls only the main-group WLEDS. The up/down slope control can be programmed by the setting of the 0Ah register when the main LEDs are controlled by either $I^2C$ or ALC.

For main LEDs, there are three different dimming control methods, $I^2C$, ALC, and CAI. The dimming range for main LEDs and sub LEDs is from 0.1mA to 25.6mA in 0.1mA increments.

### RGB Driver Operation

The brightness for each color LED has 256 different steps (0.1mA to 25.6mA). The RGB LED can be activated by either the high/low status of the PLAY_ PWM signal or by $I^2C$ ON/OFF command. The default dimming control is $I^2C$ command. An $I^2C$ command for dimming can adjust the current of each RGB individually. The operation of ON/OFF by $I^2C$ command also allows individual control. However, the operation of ON/OFF by PWM to PLAY_ RGB is group control. To operate with either an active-high or active-low signal coming from the microprocessor such as audio processor, the register related to active high or active low should be selected first (the bit 1 in 20h). When a call comes in or music plays, all RGB LEDs are allowed to be activated by either a PWM signal applied to PLAY_ or a designated register by $I^2C$.

The main purpose for the PLAY_ is for ON/OFF control function and not for dimming control. If the dimming current is set to 10mA on each RGB LED, the PWM signal to PLAY_ RGB turns all of the current regulators on or off at the same time. However, the dimming current for RGB can be set by $I^2C$ command during ON/OFF operation. When the PLAY_ is in active-high period, the RGB current regulator is on with 10mA current. When the PLAY_ is in the opposite state (active-low period), the RGB regulator is off with 0mA current. The default method to turn the RGB LED on is to pull the PLAY_ input high with a minimum on-time of 80µs in active-high mode. If bit 1 in 20h is set to 1, then all current regulators for RGB are activated by active-low signal with a minimum off-time of 80µs. The up/down slope control can be programmed by the setting of the 0Bh register when the RGB LEDs are controlled by $I^2C$ only.

If bit 7 in 20h is set to logic-low, then slope up/down is automatically deactivated.

### CAI (Contents Adaptive Interface) Operation

A 200Hz PWM signal is applied to the CAI pin. The CAI signal can be from either the LCD driver module with gamma correction information or from the baseband chipset. The main WLED can be activated by either the high/low status of the CAI PWM signal or with either an active-high or active-low signal coming from either a LCD driver module or baseband chipset. The corresponding register bit (bit 0 in 02h) should be set to either, 1 or 0 by $I^2C$ command.

Depending on the duty cycle, the brightness varies from 0mA to 25.6mA with the resolution of 0.256mA per 1% duty variation. In control of CAI (PWM) independently, the existing brightness setting from either $I^2C$ or ALC is overwritten because CAI has the priority over $I^2C$ and ALC.

See the *Dimming by Digital PWM on CAI Only* and *Dimming by Both Digital PWM on CAI and Either $I^2C$ or ALC at the Same Time* sections for details on the CAI dimming control.

### Dimming by Digital PWM on CAI Only

When the digital PWM (DPWM) signal (100Hz ~15kHz) is provided by either the baseband or CPU for dimming the brightness, the MAX8930 DPWM function takes over the responsibility of dimming the main WLEDs. The dimming by CAI is initiated by setting CAI (bit 7 of Register 02h) to 1. After the set-up, both $I^2C$ register dimming settings and ALC no longer control the dimming current for the main WLEDs. The frequency range on the CAI pin is from 100Hz to 15kHz, where 0% duty cycle corresponds to 0mA and 100% duty cycle corresponds to full current, 25.6mA.

When CAI is set to 1, the ramp-up/down slope for main WLED_ is automatically disabled by the MAX8930 control logic. Figure 3 is the timing diagram on initiating CAI. The MAX8930 maintains its previous dimming setting for $t_B$ (10ms typ) to allow the PWM filter time to settle to its average value before activating CAI dimming. This is done automatically inside the IC. The bit of MAINI2C

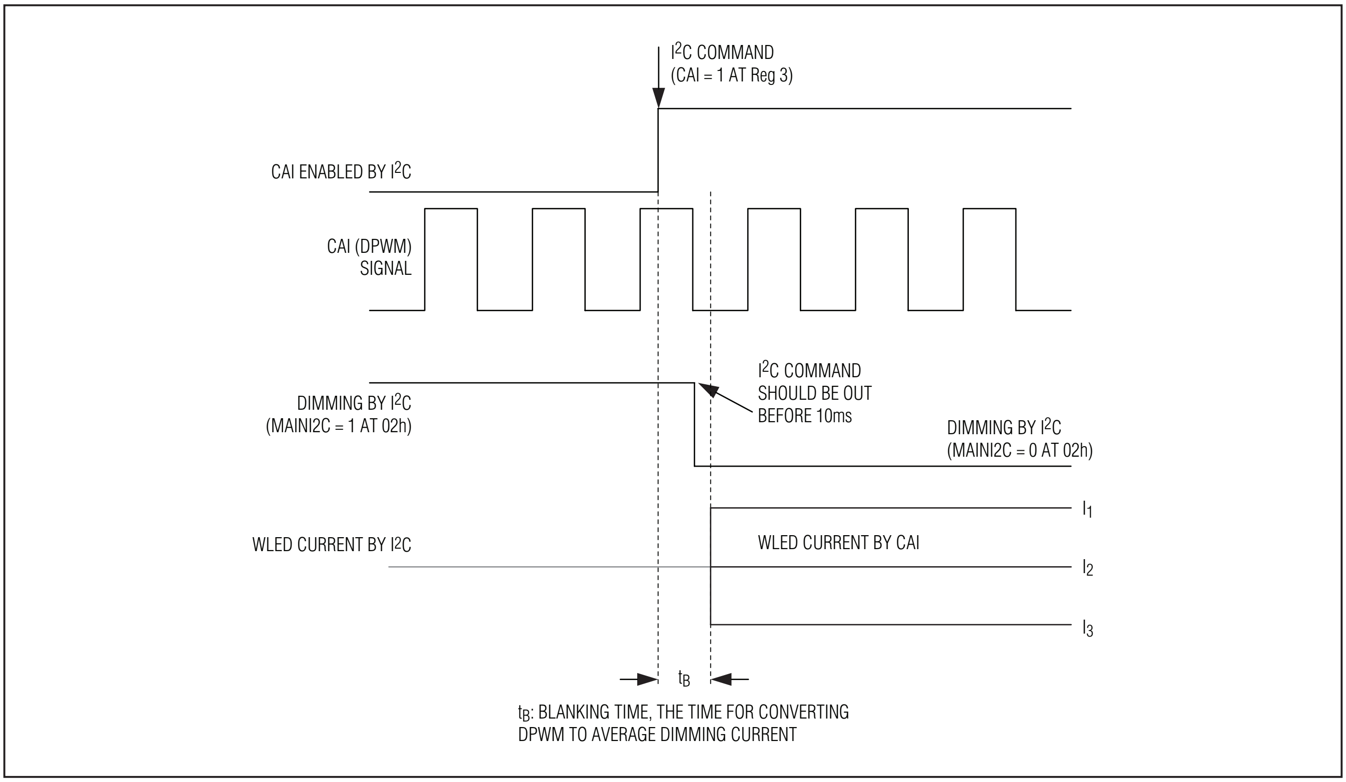



*Figure 3. Timing Diagram of Stand-Alone CAI Dimming Operation*

should be set to 0 in less than $t_B$, 10ms (typ) for CAI dimming to be exclusively through DPWM.

If this setup fails, the previous dimming current is still effective even though bit 7 in 02h (CAI) has been set to 1.

The current of I1, I2, and I3 of Figure 3 is different depending on the duty cycle of DPWM.

$t_B$ is the settling time for the CAI input filter to calculate an average value for the dimming current.

### *Dimming by Both Digital PWM on CAI and Either $I^2C$ or ALC at the Same Time*

If an end-user wants to see either TV or a movie, the LCD driver module may take care of dimming control independently. In this situation, the output signal from the LCD module has some color information. For example, (16mA/LED) + gamma correction can make the user feel the same brightness of the LCD screen compared to (20mA/LED) + no gamma correction.

In this combined dimming control, any dimming current set earlier by either the $I^2C$ register or the ALC register is the value corresponding with 100% duty cycle of the CAI signal.

### *Ambient Light Control Operation*

Dimming of the LCD backlight and ON/OFF control of the keypad backlight are possible on the basis of the data detected by an external ambient light sensor. The ALC consists of the following segments:

- Bias function (3V output)
- 8-bit ADC with an average filter
- A slope process function
- A LOG scale conversion function

A wide range of ambient light sensors can be used with the MAX8930, including photo diode, photo transistor, photo IC (a linear output/LOG output), etc. The detected amount of ambient light is changed into digital data by

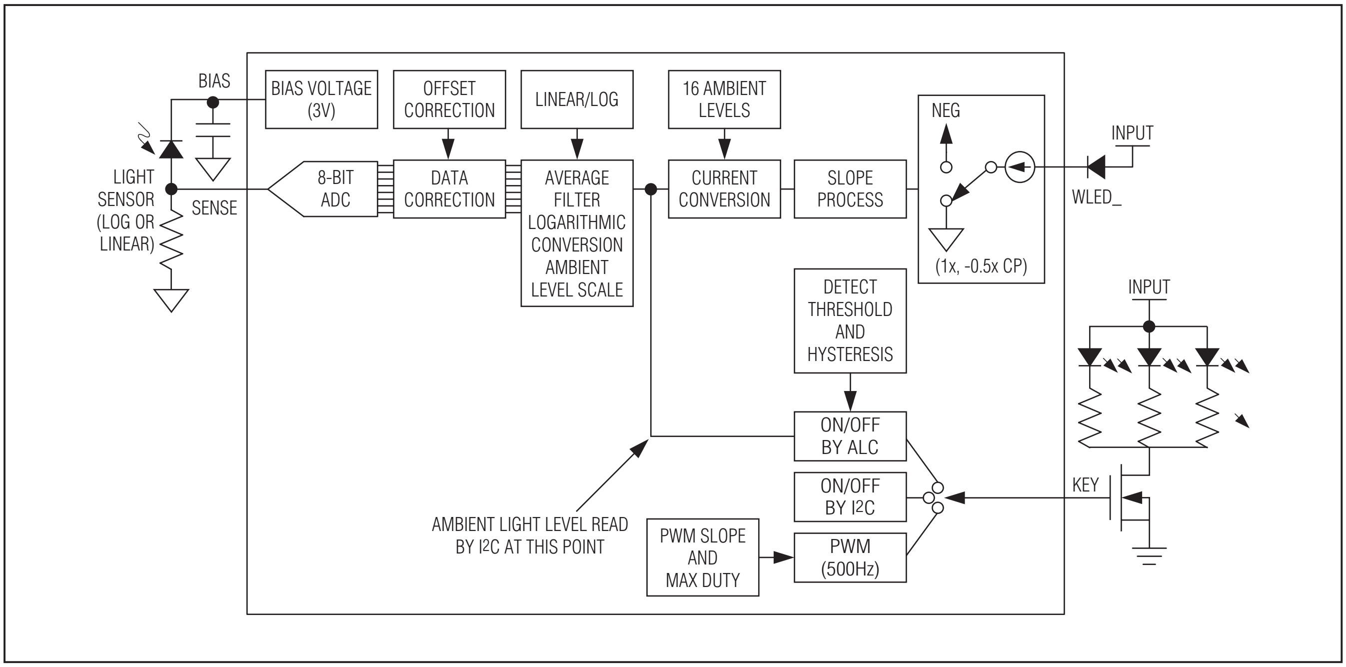



*Figure 4. ALC Block Diagram*

the embedded digital processing. This data can be read through the I2C (0Dh).

The conversion to LED current can be accomplished either through a built-in initial lookup table or a built-in user settable lookup table.

When ALC is activated, the brightness settings of the main LEDs are controlled through the ALC control circuitry and not by the baseband processor. The default setting on power-on reset is for control by the baseband processor.

### *ON/OFF of ALC Block for Main WLEDs*

ALC operation can be activated independently for the main LED and the keypad backlight. The ALCEN bit in register 00h activates ambient light control. The KBALC bit in register 00h activates ON/OFF for the keypad backlight in ALC mode. For keypad backlight, the output is simple logic-high/logic-low.

### *Bias Voltage for a Sensor*

An embedded LDO with a nominal 3V output provides the bias voltage for the ambient light sensor. This bias output is enabled as soon as the ALCEN bit is set to 1.

The operation of the bias output voltage has two options based on the value of the SBIAS bit (bit 7 in Register 0Ch). When this bit is set to 1, the bias output is synchronized with the measurement cycle. This means that the bias voltage generator is active only when a measurement cycle is being performed. The measurement cycle has four different times, 0.52s, 1.05s, 1.57s, and 2.10s. When this bit is set to 0, the bias output is always on as long as the ALCEN bit is set to 1.

### *Brightness Data Conversion*

16 different dimming steps are available depending on the ambient light condition. The selection of the log or linear conversion is possible by the setting of the LSTY bit (bit 6 of register 0Ch).

**Linear type sensor:** LOG conversion

**Log type sensor:** Data bypass

The brightness data can be read through I2C (Register at 0Dh).

### *LED Current Conversion*

The following is the initial current value to each level of ambient light. This value can be overwritten by I2C command.

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## Table 1. Brightness Data Conversion Settings

| AMBIENT LEVEL | WITH LOG CONVERSION (LINEAR TYPE OF SENSOR) | WITHOUT LOG CONVERSION (LOG TYPE OF SENSOR) |
|---|---|---|
| 0h | $V_{SBIAS}$ x 0/256 | $V_{SBIAS}$ x 0/256 ~ $V_{SBIAS}$ x 17/256 |
| 1h | $V_{SBIAS}$ x 1/256 | $V_{SBIAS}$ x18/256 ~ $V_{SBIAS}$ x 26/256 |
| 2h | $V_{SBIAS}$ x 2/256 | $V_{SBIAS}$ x 27/256 ~ $V_{SBIAS}$ x 36/256 |
| 3h | $V_{SBIAS}$ x 3/256 ~ $V_{SBIAS}$ x 4/256 | $V_{SBIAS}$ x 37/256 ~ $V_{SBIAS}$ x 47/256 |
| 4h | $V_{SBIAS}$ x 5/256 ~ $V_{SBIAS}$ x 6/256 | $V_{SBIAS}$ x 48/256 ~ $V_{SBIAS}$ x 59/256 |
| 5h | $V_{SBIAS}$ x 7/256 ~ $V_{SBIAS}$ x 9/256 | $V_{SBIAS}$ x 60/256 ~ $V_{SBIAS}$ x 71/256 |
| 6h | $V_{SBIAS}$ x 10/256 ~ $V_{SBIAS}$ x 13/256 | $V_{SBIAS}$ x 72/256 ~ $V_{SBIAS}$ x 83/256 |
| 7h | $V_{SBIAS}$ x 14/256 ~ $V_{SBIAS}$ x 19/256 | $V_{SBIAS}$ x 84/256 ~ $V_{SBIAS}$ x 95/256 |
| 8h | $V_{SBIAS}$ x 20/256 ~ $V_{SBIAS}$ x 27/256 | $V_{SBIAS}$ x 96/256 ~ $V_{SBIAS}$ x 107/256 |
| 9h | $V_{SBIAS}$ x 28/256 ~ $V_{SBIAS}$ x 38/256 | $V_{SBIAS}$ x 108/256 ~ $V_{SBIAS}$ x 119/256 |
| Ah | $V_{SBIAS}$ x 39/256 ~ $V_{SBIAS}$ x 53/256 | $V_{SBIAS}$ x 120/256 ~ $V_{SBIAS}$ x 131/256 |
| Bh | $V_{SBIAS}$ x 54/256 ~ $V_{SBIAS}$ x 74/256 | $V_{SBIAS}$ x 132/256 ~ $V_{SBIAS}$ x 143/256 |
| Ch | $V_{SBIAS}$ x 75/256 ~ $V_{SBIAS}$ x 104/256 | $V_{SBIAS}$ x 144/256 ~ $V_{SBIAS}$ x 155/256 |
| Dh | $V_{SBIAS}$ x 105/256 ~ $V_{SBIAS}$ x 144/256 | $V_{SBIAS}$ x 156/256 ~ $V_{SBIAS}$ x 168/256 |
| Eh | $V_{SBIAS}$ x 145/256 ~ $V_{SBIAS}$ x 199/256 | $V_{SBIAS}$ x 169/256 ~ $V_{SBIAS}$ x 181/256 |
| Fh | $V_{SBIAS}$ x 200/256 ~ $V_{SBIAS}$ x 255/256 | $V_{SBIAS}$ x 182/256 ~ $V_{SBIAS}$ x 255/256 |

## Table 2. LED Current Conversion

| BRIGHTNESS | INITIAL | CURRENT (mA) | BRIGHTNESS | INITIAL | CURRENT (mA) |
|---|---|---|---|---|---|
| 0 | 0Fh | 1.6 | 8 | 89h | 13.8 |
| 1 | 1Eh | 3.1 | 9 | 98h | 15.3 |
| 2 | 2Dh | 4.6 | A | A7h | 16.8 |
| 3 | 3Ch | 6.1 | B | B6h | 18.3 |
| 4 | 4Ch | 7.7 | C | C6h | 19.9 |
| 5 | 5Bh | 9.2 | D | D5h | 21.4 |
| 6 | 6Ah | 10.7 | E | E4h | 22.9 |
| 7 | 79h | 12.2 | F | F9h | 25.0 |

### The Operation of ALC Function

Table 3 shows the various conditions on the main WLED_ current for LCD backlight.

### Sensor Interface

As a default value, 3V is applied from the BIAS pin. The sensed voltage at the SENSE pin is transformed into digital data by the embedded 8-bit ADC.

### A/D Conversion

The detection of ambient light condition is performed in periodic time steps (4 options). BIAS and ADC are turned off except when reading the ambient light condition. The sensor is also turned off in between measurements. This leads to lower power consumption. For the first 64ms, the ambient light data is discarded because the data might be inaccurate information in startup period. For

## Table 3. ALC Function

| ALC ON/OFF | MAIN WLED_ ON/OFF | ALC BLOCK | LCD BACKLIGHT CURRENT |
|---|---|---|---|
| 0 | 0 | OFF | OFF |
| 0 | 1 | | Setup by main LED current* |
| 1 | 0 | ON | OFF |
| 1 | 1 | | Setup by ambient light data† |

**The ALC for WLED backlight is disabled in this mode. It means the current for the LCD backlight is set up by the main LED current value using either I²C or CAI.*

*†The ALC for WLED backlight is enabled in this mode. It means the current for the LCD backlight is set up by the ambient light data from 0h to Fh.*

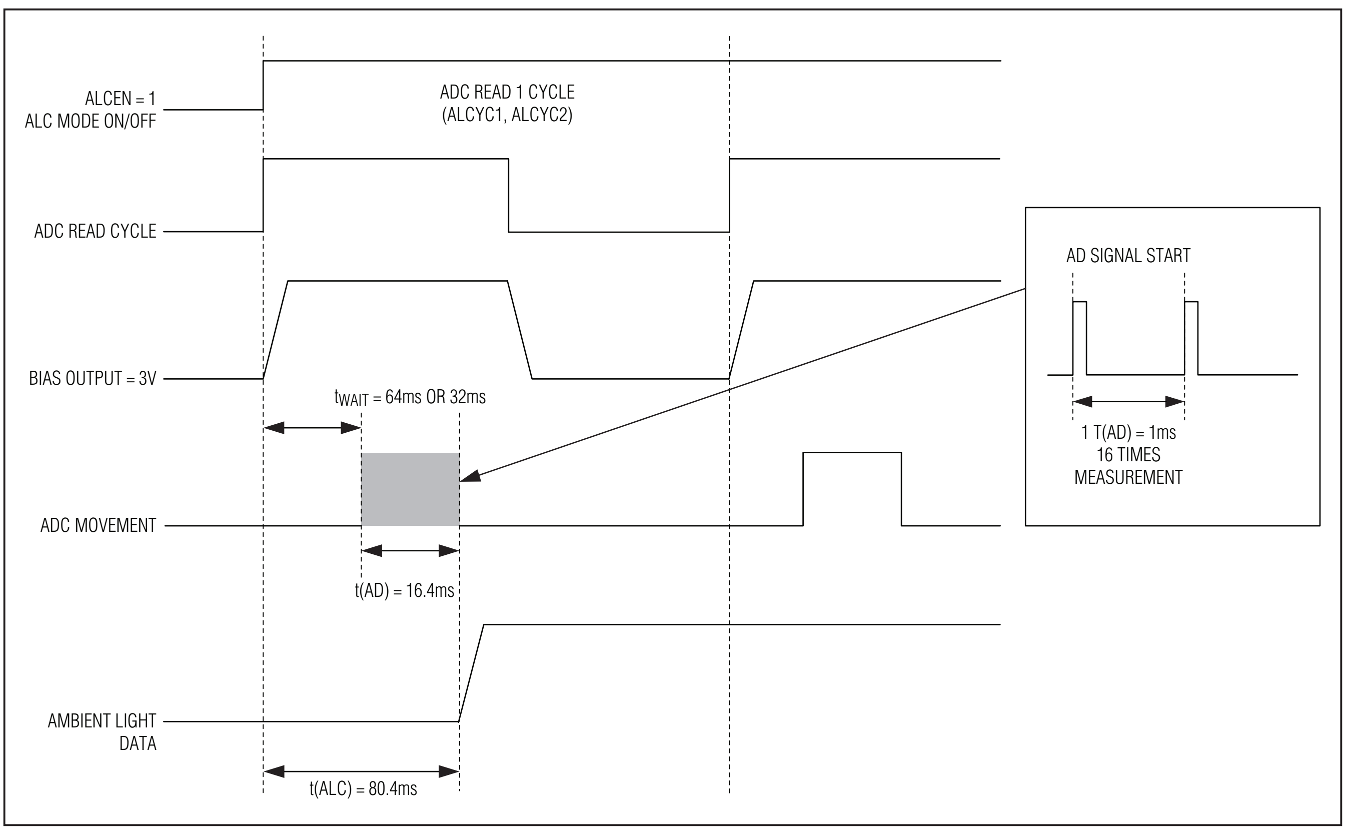



*Figure 5. ALC A/D Conversion*

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

the next 16.4ms, the internal digital logic block tries to read the ambient light condition 16 times and calculate the average data. This read data is automatically saved in Register 0Dh.

### *Up/Down Slope Control*

The up/down slope control is sometimes necessary for dimming the main WLED_ in a natural way. The up (dark to bright), down (bright to dark) main WLED current transition speeds are set individually.

The default value of the up/down slope is 0s. It is programmable by the settings of control bits in Register 0Ah. The up/down slope time is per 0.1mA increment; for example, if the $I_{LED1}$ current is 0mA and the up slope time is set to 2.048ms. After reading the ambient light condition and getting $I_{LED2}$ with 20mA, the total time from $I_{LED1}$ to $I_{LED2}$ is 0.4096s [(20mA/0.1mA) x 2.048ms = 0.4096s].

### *ADC Data Offset Adjustment*

The accuracy of the ALC control circuitry can be calibrated in each IC using the ADC data offset adjustment register. This offset adjustment can correct for parameter variation in the IC and in the external light sensor. This adjustment is performed with bits 3–0 in Register 0Ch.

Table 4 shows all possibilities of dimming control for both main WLEDs and KEY.

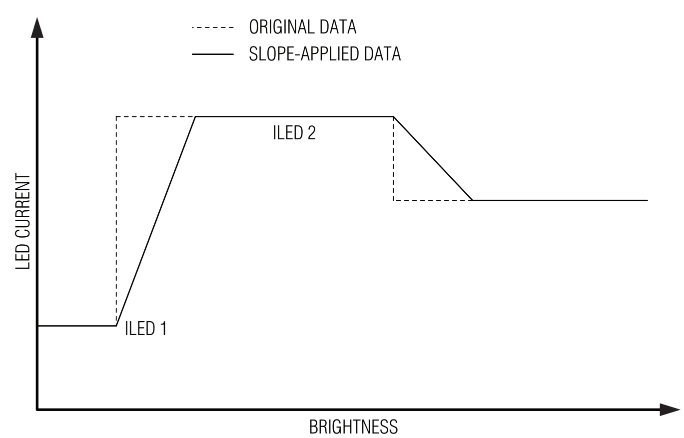



*Figure 6. LED Current vs. Brightness*

## Table 4. Summary of Dimming Control for Main WLEDs and KEY

| | | $I^2C$ | ALC | CAI (PWM) | PWM (500Hz) | $I^2C$ + ALC | $I^2C$ + CAI | ALC + CAI | $I^2C$ + CAI + ALC |
|---|---|---|---|---|---|---|---|---|---|
| **MAIN WHITE LEDS** | **DIMMING** | Yes (default) | Yes | Yes | No | No | Yes | Yes | No |
| | **UP/ DOWN SLOPE CONTROL** | Available | Available | Not available | Not available | Not available | Not available | Not available | Not available |
| **KEY** | **ON/OFF** | Yes (default) | Yes | No | Yes | No | No | No | No |
| | **DUTY TRANSITION CONTROL TIME** | Not available | Not available | Not available | Available | Not available | Not available | Not available | Not available |

### KEY (Keypad Backlight) ON/OFF Control Operation

The keypad lighting is controlled by 3 methods, which are all exclusive of each other.

These are:

- ALC
- PWM
- $I^2C$ command

If KBALC (bit 1 of 00h) is set to 1, then ALC for keypad is ON, otherwise, it is off.

If KYPWM (bit 0 of 03h) is set to 1, PWM for keypad is ON, otherwise, it is off.

If KYI2C (bit 5 of 02h) is set to 1, $I^2C$ for keypad is ON, otherwise, it is off.

The ambient light level at which the key backlight is turned off can be set in register 0Fh. The default ambient light is Ah. There is also a programmable hysteresis level, accessed through $I^2C$ in the 0Fh register. The default hysteresis width is 3h. See Figure 7.

There is a built in PWM that has a 500Hz operation frequency. The dimming can be adjusted by duty ratio (set KYDT_ bit in register 0Eh).

The KEY output is simply a 1 bit value representing ON or OFF function.

### Keypad Backlight ON/OFF Operation by ALC

To link the keypad backlight ON/OFF control to the ALC, the register bit, KBALC, at register 00h, should be set to 1 (see Table 5).

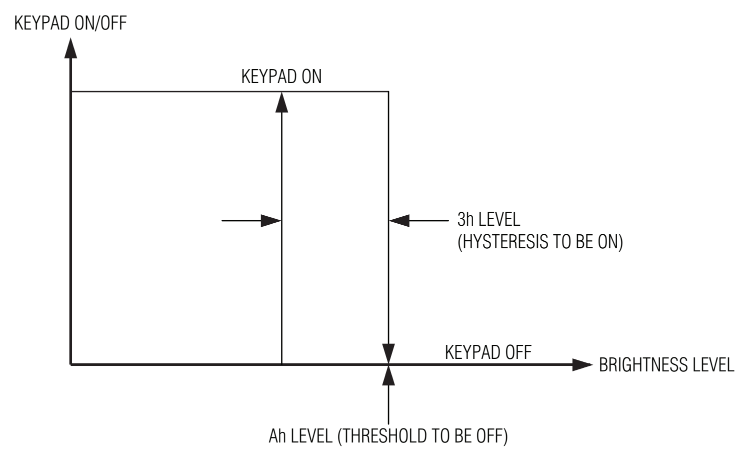



*Figure 7. KEY On/Off Hysteresis*

## Table 5. Keypad Backlight On/Off by ALC

| ALCEN | KBALC | MAIN WLEDs IN ALC MODE | ALC BLOCK | KEY BACKLIGHT |
|---|---|---|---|---|
| 0 | 0 | No | OFF | OFF |
| 0 | 1 | | | ON/OFF by $I^2C$ or PWM* |
| 1 | 0 | Yes | ON | ON/OFF by $I^2C$ or PWM** |
| 1 | 1 | Yes | ON | ON/OFF depends on ALC data level*** |

**The ALC block is disabled in this mode. In this condition, keypad backlight is activated and controlled by either internal PWM operation (500Hz) or $I^2C$.*

***The ALC block is enabled in this mode. However KBALC bit is still set to 0. Therefore, the on/off control should be either $I^2C$ or internal 500Hz PWM.*

****The ALC block is enabled in this mode. ALC has priority over both internal PWM and $I^2C$ in case KBALC bit is set to 1. This means that the activation of the key backlight depends on the preprogrammed on/off threshold and hysteresis width.*

The ambient light level at which the key backlight is turned off can be set in register 0Fh. The default ambient light level is Ah, which is bright enough for the user to recognize the numbers on the keypad. At this time, the key output is held off. There is also a programmable hysteresis level, accessed through I2C in the 0Fh register. The default hysteresis width is 3h. The key output is held high on any hysteresis value minus 1h. For example, if the hysteresis is set to 3h, in this default condition, the key output is held low at Ah level and then high at 6h level.

### Keypad Backlight ON/OFF Operation by PWM

There is a built-in PWM signal operating at a frequency of 500Hz. The on/off can be adjusted by duty cycle ratio (set KYDT_ bit in Register 0Eh). 16 different duty values of PWM are available in register 0Eh. In addition, fade-in and fade-out can also be set up with the KYSL_ bits in the 0Eh register.

### Keypad Backlight ON/OFF Operation by I2C Command

There is a dedicated register bit (KYI2C at 02h, see Table 15) to both enable and disable the KEY function. This I2C on/off is the default for KEY.

### Control of Duty Transition Time Control in Internal PWM Mode (500Hz)

The internal 500Hz PWM can set up the duty transition control time by the register (KYSL1 and KYSL2 at 0Eh).

Figure 8 shows the duty transition in slope-applied mode.

### Low-Drop Output (LDO) Operation

The linear regulators are designed for low-input, low-dropout, low quiescent current to maximize battery life. All LDOs are controlled through the serial interface, minimizing the requirements of control lines to the MAX8930.

Each of the LDOs are turned on or off through the setting of the control bits in the On/Off Control register, 00h. For each LDO, it is possible to set the output voltage and enable/disable the active pulldown resistor (1kΩ typ) during power-off. This is done in the 03h and 04h registers. For optimized battery life, there are two external supply voltage inputs, PV3 for LDO1 and LDO2 and PV4 for LDO3. This allows the input voltage of the LDO to be supplied from a lower voltage power rail, resulting in higher efficiency operation and longer battery life. LDO3 is a low $V_{IN}$ LDO ($V_{IN}$ = 1.7V to 5.5V). The input voltage, $V_{PV3}$ and $V_{PV4}$ must be greater than the selected LDO1 to LDO3 voltages.

### GPO Operation

Three LDO outputs have the option of being converted to GPO outputs through an I2C command. Figure 9 shows the external connections. The register, 24h, is responsible for this setup. In GPO mode, the output capacitors should be removed in advance, otherwise, there is some delay in both turn-on and turn-off mode.

### Component Selection

Use only ceramic capacitors with an X5R, X7R, or better dielectric. See the Table 6 for a list of recommended parts. Connect a 1µF and 2.2µF ceramic capacitor between LDO1, LDO2, and LDO3 and PGND3, respectively, for 200mA applications. The LDO output capacitor's equivalent series resistance (ESR) affects stability and output noise. Use output capacitors with an ESR of 0.1Ω or less to ensure stability and optimum transient

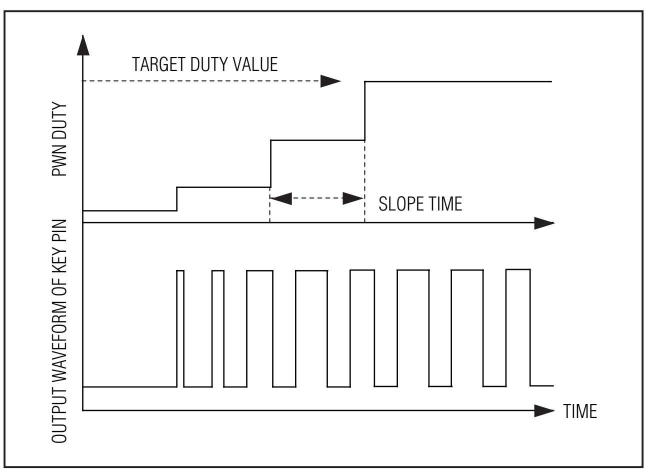



*Figure 8. Slope Time-In Internal PWM Mode (500Hz)*

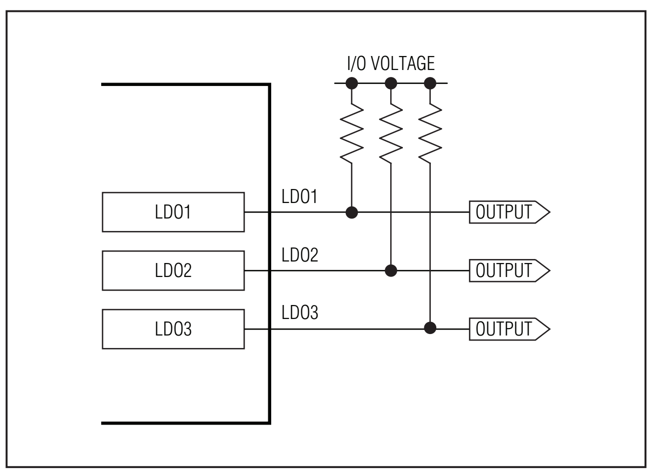



*Figure 9. LDO GPO Configuration*

## Table 6. Recommended Capacitors

| DESIGNATION | VALUE (µF) | MANUFACTURER | PART NUMBER | DESCRIPTION |
|---|---|---|---|---|
| $C_{PV3}$ | 2.2 | TDK | C2012X5R0J225M | 2.2µF ±20%, 6.3V X5R ceramic capacitor |
| $C_{PV4}$ (in case of external supply) | 2.2 | TDK | C2012X5R0J225M | 2.2µF ±20%, 6.3V X5R ceramic capacitor |
| $C_{LDO1}$ | 1 | TDK | C1005X5R0J105M | 1µF ±20%, 6.3V X5R ceramic capacitor |
| $C_{LDO2}$ | 1 | TDK | C1005X5R0J105M | 1µF ±20%, 6.3V X5R ceramic capacitor |
| $C_{LDO3}$ | 2.2 | TDK | C1005X5R0J225M | 2.2µF ±20%, 6.3V X5R ceramic capacitor |

response. Connect $C_{LDO}$ as close as possible to the MAX8930 to minimize the impact of PCB trace inductance.

### Step-Up DC-DC Converter Operation

The step-up DC-DC converter operates from a 2.7V to 5.5V supply. The MAX8930 includes an internal high-voltage nMOSFET switch with low on-resistance and a synchronous rectifier to reduce losses and achieve higher efficiency. A true-shutdown feature disconnects the battery from the load and reduces the supply current to 0.05µA. This DC-DC converter provides adjustable output voltage from 13.0V to 16.5V with 0.5V steps. The adjustment bits are located in the 04h register.

#### Control Scheme

The step-up DC-DC features a minimum off-time, current-limited control scheme operating in discontinuous conduction mode. An internal p-channel MOSFET switch connects PV5 to SW to provide power to the inductor when the converter is operating. When the converter is shut down, this switch disconnects the input supply from the inductor. To boost the output voltage, an n-channel MOSFET switch turns on and allows the inductor current to ramp up to the current limit. Once the inductor current reaches the current limit, the switch turns off and the inductor current flows through synchronous rectifier (pMOS) to supply the output voltage. The switching frequency varies depending on the load and input and output voltage and can be up to 750kHz.

#### Setting the Output Voltage

The output voltage of the step-up converter is set by bit, boost1 to boost3, in Register 04h. The output voltage can be adjusted from 13.0V to 16.5V in 0.5V increments.

#### Shutdown

If Bit 6, SUEN, in Register 00h is set to 0, the step-up converter enters shutdown. During shutdown, the output is disconnected from the input, and LX enters a high-impedance state. The capacitance and load at the output determine the rate at which $V_{OUT}$ decays.

#### Soft-Start

The step-up converter uses two soft-start mechanisms. When the true-shutdown feature is used, the gate of the internal synchronous turns on slowly to prevent inrush current. This takes approximately 0.04ms (typ). When SW is fully turned on, the internal n-channel switch begins boosting the input to set the output voltage.

#### Protection Features

The step-up converter has protection features designed to make it extremely robust to application errors. If the output capacitor in the application is missing, the converter protects the internal switch from being damaged.

## Table 7. Protection Features

| APPLICATION FAULTS | PROTECTION |
|---|---|
| Output Shorted to Ground | True off-switch detects short, opens when current reaches the synchronous rectifier current limit, and restarts soft-start. This protects the inductor and the synchronous rectifier. |
| Output Capacitor Missing | LX may boost one or two times before the internal FB voltage exceeds the trip point. In the rare case where the capacitive loading and external loading on OUT is small enough that the energy in one cycle can slew it more than 22V, the internal OVP operates at the typical threshold value, 18.5V. |

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

### Inductor Selection

Smaller inductance values typically offer smaller physical size for a given series resistance or saturation current. The inductor's saturation current rating should be greater than the peak switching current. Recommended inductor values range from 10µH to 100µH (e.g., 22µH, VLF3010AT-220MR33-1, TDK).

### Capacitor Selection

Small, ceramic surface-mount capacitors with X7R or X5R temperature characteristics are recommended due to their small size, low cost, low equivalent series resistance (ESR), and low equivalent series inductance (ESL). If nonceramic capacitors are used, it is important that they have low ESR to reduce the output ripple voltage and peak-to-peak load transient voltage.

### $\overline{\text{CHG}}$ Charge-Indicator Output

$\overline{\text{CHG}}$ is an open-drain output that indicates charger status and can be used with an LED. $\overline{\text{CHG}}$ goes low during charging when the bit of $\overline{\text{CHG}}$ at 02h is 1. $\overline{\text{CHG}}$ goes high impedance when the bit of $\overline{\text{CHG}}$ at 02h is 0. When this function is used in conjunction with a microprocessor (µP), connect a pullup resistor between $\overline{\text{CHG}}$ and the logic I/O voltage to indicate charge status to the µP.

### I²C Interface

The slave address for MAX8930 is EC/Dh in write/read mode.

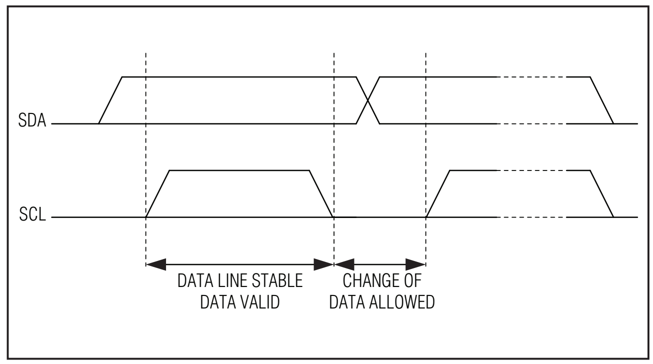



*Figure 10. SDA and SCL Bit Transfer*

## Table 8. Recommended Inductors

| DESIGNATION | VALUE (µH) | DCR (Ω) | MANUFACTURER | PART | CURRENT (mA) |
|---|---|---|---|---|---|
| $L_{SW}$ | 22 | 1.5 | TDK | VLF3010AT-220MR33-1 | 330 |
| | 22 | 4.0 | Panasonic | ELJPC220KF | 160 |
| | 22 | 1.0 | Taiyo Yuden | LB2016-220 | 105 |
| | 22 | 5.0 | Taiyo Yuden | LEM2520-220 | 125 |
| | 47 | 2.2 | Sumida | CMD4D11-47 | 180 |
| | 68 | 3.3 | Taiyo Yuden | LEMC3225-680 | 120 |

## Table 9. Recommended Capacitors

| DESIGNATION | VALUE (µF) | MANUFACTURER | PART | DESCRIPTION |
|---|---|---|---|---|
| $C_{PV5}$ | 1 | TDK | C2012X5R0J105M | 1µF ±20%, 6.3V X5R ceramic capacitor |
| $C_{OUT}$ | 1 | Taiyo Yuden | TMK316BJ105KL | 1µF ±20%, 25V X7R ceramic capacitor |

## Table 10. Slave Address

| A7 | A6 | A5 | A4 | A3 | A2 | A1 | R/W |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1/0 |

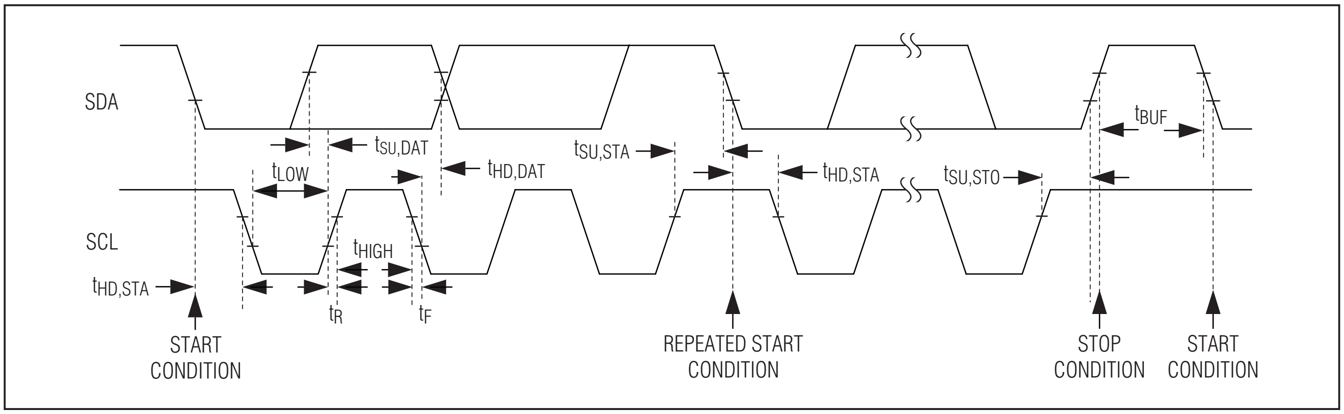



*Figure 11. START and STOP Conditions*

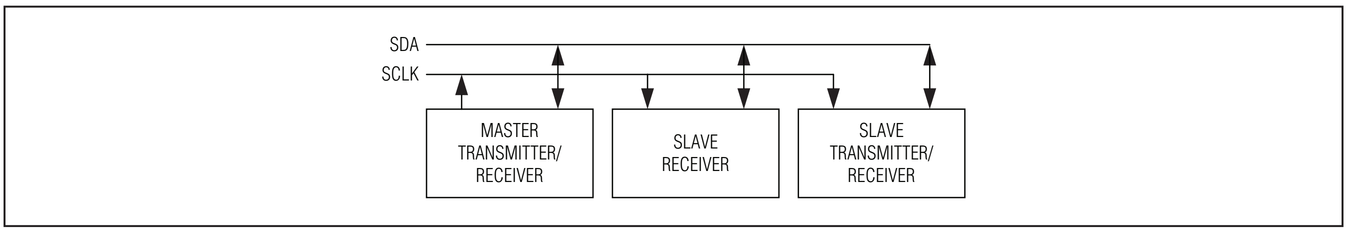



*Figure 12. I²C Master and Slave Configuration*

### I²C Bit Transfer

One data bit is transferred for each clock pulse. The data on SDA must remain stable during the high portion of the clock pulse as changes in data during this time are interpreted as a control signal.

### I²C START and STOP Conditions

Both SDA and SCL remain high when the bus is not busy. A high-to-low transition of SDA, while SCL is high is defined as the START (S) condition. A low-to-high transition of the data line while SCL is high is defined as the STOP (P) condition.

### I²C System Configuration

A device on the I²C bus that generates a message is called a transmitter and a device that receives the message is a receiver. The device that controls the message is the master and the devices that are controlled by the master are called slaves.

### I²C Acknowledge

The number of data bytes between the START and STOP conditions for the transmitter and receiver are unlimited. Each 8-bit byte is followed by an acknowledge bit. The acknowledge bit is a high-level signal put on DATA by the transmitter during which time the master generates an extra acknowledge related clock pulse. A slave receiver that is addressed must generate an acknowledge after each byte it receives. Also, a master receiver must generate an acknowledge after each byte it receives that has been clocked out of the slave transmitter.

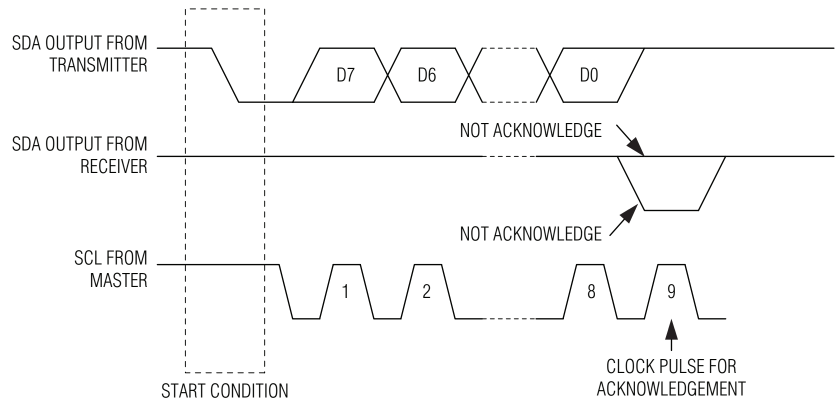



*Figure 13. I²C Acknowledge*

The device that acknowledges must pull down the SDA line during the acknowledge clock pulse, so that the SDA line is stable low during the high period of the acknowledge clock pulse (setup and hold times must also be met). A master receiver must signal an end of data to the transmitter by not generating an acknowledge on the last byte that has been clocked out of the slave. In this case, the transmitter must leave SDA high to enable the master to generate a STOP condition.

### *Current Level for 8 WLEDs and 3 RGB LEDs*

The total 11 LEDs (8 WLEDs and 3 RGB LEDs) have linear scale current dimming by 0.1mA step as follows.

## Table 11. LED Current Levels

| BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 | LED CURRENT (mA) |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.3 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0.4 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0.5 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.6 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0.7 |
| — | — | — | — | — | — | — | — | — |
| — | — | — | — | — | — | — | — | — |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 25.5 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 25.6 |

## Table 12. Register Map

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 | FUNCTION |
|---|---|---|---|---|---|---|---|---|---|---|
| 00h | 00 | RESET | SUEN | LDO1 | LDO2 | LDO3 | Main WLED | KBALC | ALCEN | On/off control for boost, LDO1, LDO2, LDO3, main WLED_, ALC |
| 01h | 00 | WLED7 | WLED6 | WLED5 | Sub7 | Sub6 | Sub5 | RGB slope | LED slope | On/off control for backlight-related LEDs |
| 02h | 26 | CAI | $\overline{CHG}$ | KYI2C | WLED8 | Sub8 | x | MAIN I2C | HLCAI | On/off control for dimming-related signal, bias output |
| 03h | 6C | LDO10 | LDO11 | LDO12 | x | LDO20 | LDO21 | LDO22 | KYPWM | Output program for LDO1 and LDO2 |
| 04h | BA | LDO 30 | LDO 31 | LDO1ADIS | LDO2ADIS | LDO3ADIS | Boost1 | Boost2 | Boost3 | Output program for LDO3 and boost |
| 05h | 01 | IMLED7 | IMLED6 | IMLED5 | IMLED4 | IMLED3 | IMLED2 | IMLED1 | IMLED0 | 256 steps current scale for main WLEDs |
| 06h | 01 | ISLED7 | ISLED6 | ISLED5 | ISLED4 | ISLED3 | ISLED2 | ISLED1 | ISLED0 | 256 steps current scale for sub WLED5 |
| 07h | 01 | ISLED7 | ISLED6 | ISLED5 | ISLED4 | ISLED3 | ISLED2 | ISLED1 | ISLED0 | 256 steps current scale for sub WLED6 |
| 08h | 01 | ISLED7 | ISLED6 | ISLED5 | ISLED4 | ISLED3 | ISLED2 | ISLED1 | ISLED0 | 256 steps current scale for sub WLED7 |

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## Table 12. Register Map (continued)

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 | FUNCTION |
|---|---|---|---|---|---|---|---|---|---|---|
| 09h | 01 | ISLED7 | ISLED6 | ISLED5 | ISLED4 | ISLED3 | ISLED2 | ISLED1 | ISLED0 | 256 steps current scale for sub WLED8 |
| 0Ah | 00 | x | DSLP3 | DSLP2 | DSLP1 | x | USLP3 | USLP2 | USLP1 | Slope control for main WLEDs in step-up/down |
| 0Bh | 00 | x | DSLP3 | DSLP2 | DSLP1 | x | USLP3 | USLP2 | USLP1 | Slope control for RGB in step-up/down |
| 0Ch | 10 | SBIAS | LSTY | ALCYC1 | ALCYC2 | OST1 | OST2 | OST3 | OST4 | Control for ALC-related functions |
| 0Dh | — | ALDA1 | ALDA2 | ALDA3 | ALDA4 | x | x | x | TWAIT | Read the ADC data based on ambient condition |
| 0Eh | 00 | KYSL1 | KYSL2 | x | KYDT0 | KYDT1 | KYDT2 | KYDT3 | KYDT4 | Control for PWM slope and duty |
| 0Fh | A8 | KYHS1 | KYHS2 | KYTH1 | KYTH2 | KYTH3 | KYTH4 | x | x | Control for hysteresis width and on/off |
| 10h | 0F | CADA07 | CADA06 | CADA05 | CADA04 | CADA03 | CADA02 | CADA01 | CADA00 | Current level of 0h |
| 11h | 1E | CADA17 | CADA16 | CADA15 | CADA14 | CADA13 | CADA12 | CADA11 | CADA10 | Current level of 1h |
| 12h | 2D | CADA27 | CADA26 | CADA25 | CADA24 | CADA23 | CADA22 | CADA21 | CADA20 | Current level of 2h |
| 13h | 3C | CADA37 | CADA36 | CADA35 | CADA34 | CADA33 | CADA32 | CADA31 | CADA30 | Current level of 3h |
| 14h | 4C | CADA47 | CADA46 | CADA45 | CADA44 | CADA43 | CADA42 | CADA41 | CADA40 | Current level of 4h |
| 15h | 5B | CADA57 | CADA56 | CADA55 | CADA54 | CADA53 | CADA52 | CADA51 | CADA50 | Current level of 5h |

## Table 12. Register Map (continued)

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 | FUNCTION |
|---|---|---|---|---|---|---|---|---|---|---|
| 16h | 6A | CADA67 | CADA66 | CADA65 | CADA64 | CADA63 | CADA62 | CADA61 | CADA60 | Current level of 6h |
| 17h | 79 | CADA77 | CADA76 | CADA75 | CADA74 | CADA73 | CADA72 | CADA71 | CADA70 | Current level of 7h |
| 18h | 89 | CADA87 | CADA86 | CADA85 | CADA84 | CADA83 | CADA82 | CADA81 | CADA80 | Current level of 8h |
| 19h | 98 | CADA97 | CADA96 | CADA95 | CADA94 | CADA93 | CADA92 | CADA91 | CADA90 | Current level of 9h |
| 1Ah | A7 | CADAA7 | CADAA6 | CADAA5 | CADAA4 | CADAA3 | CADAA2 | CADAA1 | CADAA0 | Current level of Ah |
| 1Bh | B6 | CADAB7 | CADAB6 | CADAB5 | CADAB4 | CADAB3 | CADAB2 | CADAB1 | CADAB0 | Current level of Bh |
| 1Ch | C6 | CADAC7 | CADAC6 | CADAC5 | CADAC4 | CADAC3 | CADAC2 | CADAC1 | CADAC0 | Current level of Ch |
| 1Dh | D5 | CADAD7 | CADAD6 | CADAD5 | CADAD4 | CADAD3 | CADAD2 | CADAD1 | CADAD0 | Current level of Dh |
| 1Eh | E4 | CADAE7 | CADAE6 | CADAE5 | CADAE4 | CADAE3 | CADAE2 | CADAE1 | CADAE0 | Current level of Eh |
| 1Fh | F9 | CADAF7 | CADAF6 | CADAF5 | CADAF4 | CADAF3 | CADAF2 | CADAF1 | CADAF0 | Current level of Fh |
| 20h | 00 | RGBEN | x | x | RI2C | GI2C | BI2C | HLRGB | x | Control for on/off of RGB |
| 21h | 01 | RLED7 | RLED6 | RLED5 | RLED4 | RLED3 | RLED2 | RLED1 | RLED0 | Current level for Red |
| 22h | 01 | GLED7 | GLED6 | GLED5 | GLED4 | GLED3 | GLED2 | GLED1 | GLED0 | Current level for Green |
| 23h | 01 | BLED7 | BLED6 | BLED5 | BLED4 | BLED3 | BLED2 | BLED1 | BLED0 | Current level for Blue |
| 24h | 00 | GPO1 | GPO2 | x | GPLD1 | GPLD2 | GPLD3 | GPWD8 | x | On/off for GPO |

*x = Don't care.*

*POR = Default state at reset and initial startup condition.*

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## Table 13. On/Off Register 1 for Boost, LDO1, LDO2, LDO3, Main WLED, and ALC

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 00 | 00 | RESET | SUEN | LDO1 | LDO2 | LDO3 | Main WLED | KB ALC | ALC EN |

| NAME | POR | R/W | DESCRIPTION |
|---|---|---|---|
| RESET | 0 | R/W | 1: IC is reset, back to POR status<br>0: Reset is off |
| SUEN | 0 | R/W | 1: Boost output is on<br>0: Boost output is off |
| LDO1 | 0 | R/W | 1: LDO1 output is on<br>0: LDO1 output is off |
| LDO2 | 0 | R/W | 1: LDO2 output is on<br>0: LDO2 output is off |
| LDO3 | 0 | R/W | 1: LDO3 output is on<br>0: LDO3 output is off |
| Main WLED | 0 | R/W | 1: Main WLEDs are on<br>0: Main WLEDs are off |
| KBALC | 0 | R/W | 1: ALC for keypad is on<br>0: ALC for keypad is off |
| ALCEN | 0 | R/W | 1: ALC function for main WLEDs is on<br>0: ALC function is off |

## Table 14. On/Off Register 2 for Backlight-Related WLED5, WLED6, WLED7 and RGB

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 01 | 00 | WLED7 | WLED6 | WLED5 | Sub7 | Sub6 | Sub5 | RGB Slope | LED Slope |

| NAME | POR | R/W | DESCRIPTION |
|---|---|---|---|
| WLED7 | 0 | R/W | 1: WLED7 output is on<br>0: WLED7 output is off |
| WLED6 | 0 | R/W | 1: WLED6 output is on<br>0: WLED6 output is off |
| WLED5 | 0 | R/W | 1: WLED5 output is on<br>0: WLED5 output is off |
| SUB7 | 0 | R/W | 1: WLED7 belongs to main group<br>0: WLED7 belongs to subgroup |
| SUB6 | 0 | R/W | 1: WLED6 belongs to main group<br>0: WLED6 belongs to subgroup |
| SUB5 | 0 | R/W | 1: WLED5 belongs to main group<br>0: WLED5 belongs to subgroup |
| RGB Slope | 0 | R/W | 1: Dimming slope for RGB LED is on<br>0: Dimming slope is off |
| LED Slope | 0 | R/W | 1: Dimming slope for main WLED_ is on<br>0: Dimming slope is off |

## Table 15. On/Off Register 3

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 02 | 26 | CAI | CHG | KYI2C | WLED8 | SUB8 | TWAIT | MAIN I$^2$C | HLCAI |

| NAME | POR | R/W | DESCRIPTION |
|---|---|---|---|
| CAI | 0 | R/W | 1: CAI Dimming for main WLEDs is on<br>0: Off |
| CHG | 0 | R/W | 1: nMOS for charging indicator is on<br>0: Off |
| KYI2C | 1 | R/W | 1: I$^2$C for keypad is on<br>0: I$^2$C for keypad is off |
| WLED8 | 0 | R/W | 1: WLED8 output is on<br>0: WLED8 output is off |
| SUB8 | 0 | R/W | 1: WLED8 belongs to main group<br>0: WLED8 belongs to subgroup |
| TWAIT | 1 | R/W | 1: 64ms waiting time for ALC calculation<br>0: 32ms |
| MAINI2C | 1 | R/W | 1: I$^2$C dimming for main WLEDs is ON<br>0: I$^2$C dimming for main WLEDs is OFF |
| HLCAI | 0 | R/W | 1: Active low for main WLED_ activated<br>0: Active high to be ON |

## Table 16. LDO1 and LDO2 Register

| ADDRESS (HEX) | POR (HEX) | R/W | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 03 | 4A | R/W | LDO10 | LDO11 | LDO12 | Reserved | LDO20 | LDO21 | LDO22 | KYPWM |

DESCRIPTION

| LDO10 | LDO11 | LDO12 | LDO1 VOLTAGE (V) |
|---|---|---|---|
| 0 | 0 | 0 | 2.3 |
| 0 | 0 | 1 | 2.5 |
| 0 | 1 | 0 | 2.6 (default) |
| 0 | 1 | 1 | 2.7 |
| 1 | 0 | 0 | 2.8 |
| 1 | 0 | 1 | 2.9 |
| 1 | 1 | 0 | 3.0 |
| 1 | 1 | 1 | 3.1 |
| **LDO20** | **LDO21** | **LDO22** | **LDO2 VOLTAGE (V)** |
| 0 | 0 | 0 | 2.3 |
| 0 | 0 | 1 | 2.5 |
| 0 | 1 | 0 | 2.6 |
| 0 | 1 | 1 | 2.7 |
| 1 | 0 | 0 | 2.8 |
| 1 | 0 | 1 | 2.9 (default) |
| 1 | 1 | 0 | 3.0 |
| 1 | 1 | 1 | 3.1 |

| NAME | POR | DESCRIPTION |
|---|---|---|
| KYPWM | 0 | 1: PWM for keypad is on. 0: PWM for keypad is off |

## Table 17. LDO3, Step-Up, LDO1, LDO2, and LDO3 Active Discharge Function Register

| ADDRESS (HEX) | POR (HEX) | R/W | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 04 | BA | R/W | LDO30 | LDO31 | LDO1 ADIS | LDO2 ADIS | LDO3 ADIS | Boost1 | Boost2 | Boost3 |

**DESCRIPTION**

| LDO30 | LDO31 | LDO3 voltage |
|---|---|---|
| 0 | 0 | 1.2V |
| 0 | 1 | 1.5V |
| 1 | 0 | 1.8V (default) |
| 1 | 1 | 2.5V |

| NAME | POR | DESCRIPTION |
|---|---|---|
| LDO1ADIS | 1 | 1: Enable LDO1 active discharge<br>0: Disable LDO1 active discharge |
| LDO2ADIS | 1 | 1: Enable LDO2 active discharge<br>0: Disable LDO2 active discharge |
| LDO3ADIS | 1 | 1: Enable LDO3 active discharge<br>0: Disable LDO3 active discharge |

| BOOST1 | BOOST2 | BOOST3 | OUTPUT (V) |
|---|---|---|---|
| 0 | 0 | 0 | 13.0 |
| 0 | 0 | 1 | 13.5 |
| 0 | 1 | 0 | 14.0 (default) |
| 0 | 1 | 1 | 14.5 |
| 1 | 0 | 0 | 15.0 |
| 1 | 0 | 1 | 15.5 |
| 1 | 1 | 0 | 16.0 |
| 1 | 1 | 1 | 16.5 |

## Table 18. Dimming Current Register for Main WLEDs

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 05 | 01 | IMLED7 | IMLED6 | IMLED5 | IMLED4 | IMLED3 | IMLED2 | IMLED1 | IMLED0 |

| NAME | POR | R/W | DESCRIPTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IMLED7 | 0 | R/W | BIT | | | | | | | | COMMENTS |
| IMLED6 | 0 | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| IMLED5 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Minimum current = 0.1mA |
| IMLED4 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2mA set as default |
| IMLED3 | 0 | R/W | • | • | • | • | • | • | • | • | • |
| IMLED2 | 0 | R/W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Maximum LED current = 25.6mA |
| IMLED1 | 0 | R/W | 256 steps from 0.1 to 25.6mA by 0.1mA step by binary value increment | | | | | | | | |
| IMLED0 | 1 | R/W | | | | | | | | | |

## Table 19. Dimming Current Register for Sub WLED5

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 06 | 01 | ISLED7 | ISLED6 | ISLED5 | ISLED4 | ISLED3 | ISLED2 | ISLED1 | ISLED0 |

| NAME | POR | R/W | DESCRIPTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ISLED7 | 0 | R/W | BIT | | | | | | | | COMMENTS |
| ISLED6 | 0 | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| ISLED5 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Minimum current = 0.1mA |
| ISLED4 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2mA set as default |
| ISLED3 | 0 | R/W | • | • | • | • | • | • | • | • | • |
| ISLED2 | 0 | R/W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Maximum LED current = 25.6mA |
| ISLED1 | 0 | R/W | 256 steps from 0.1 to 25.6mA by 0.1mA step by binary value increment | | | | | | | | |
| ISLED0 | 1 | R/W | | | | | | | | | |

## Table 20. Dimming Current Register for Sub WLED6

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 07 | 01 | ISLED7 | ISLED6 | ISLED5 | ISLED4 | ISLED3 | ISLED2 | ISLED1 | ISLED0 |

| NAME | POR | R/W | DESCRIPTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ISLED7 | 0 | R/W | BIT | | | | | | | | COMMENTS |
| ISLED6 | 0 | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| ISLED5 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Minimum current = 0.1mA |
| ISLED4 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2mA set as default |
| ISLED3 | 0 | R/W | • | • | • | • | • | • | • | • | • |
| ISLED2 | 0 | R/W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Maximum LED current = 25.6mA |
| ISLED1 | 0 | R/W | 256 steps from 0.1 to 25.6mA by 0.1mA step by binary value increment | | | | | | | | |
| ISLED0 | 1 | R/W | | | | | | | | | |

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## Table 21. Dimming Current Register for Sub WLED7

| ADDRESS (HEX) | POR (HEX) | | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 08 | 01 | | ISLED7 | ISLED6 | ISLED5 | ISLED4 | ISLED3 | ISLED2 | ISLED1 | ISLED0 |
| **NAME** | **POR** | **R/W** | **DESCRIPTION** | | | | | | | |
| ISLED7 | 0 | R/W | **BIT** | | | | | | | **COMMENTS** |
| ISLED6 | 0 | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| ISLED5 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Minimum current = 0.1mA |
| ISLED4 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2mA set as default |
| ISLED3 | 0 | R/W | • | • | • | • | • | • | • | • | • |
| ISLED2 | 0 | R/W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Maximum LED current = 25.6mA |
| ISLED1 | 0 | R/W | 256 steps from 0.1 to 25.6mA by 0.1mA step by binary value increment | | | | | | | | |
| ISLED0 | 1 | R/W | | | | | | | | | |

## Table 22. Dimming Current Register for Sub WLED8

| ADDRESS (HEX) | POR (HEX) | | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 09 | 01 | | ISLED7 | ISLED6 | ISLED5 | ISLED4 | ISLED3 | ISLED2 | ISLED1 | ISLED0 |
| **NAME** | **POR** | **R/W** | **DESCRIPTION** | | | | | | | |
| ISLED7 | 0 | R/W | **BIT** | | | | | | | **COMMENTS** |
| ISLED6 | 0 | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| ISLED5 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Minimum current = 0.1mA |
| ISLED4 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2mA set as default |
| ISLED3 | 0 | R/W | • | • | • | • | • | • | • | • | • |
| ISLED2 | 0 | R/W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Maximum LED current = 25.6mA |
| ISLED1 | 0 | R/W | 256 steps from 0.1 to 25.6mA by 0.1mA step by binary value increment | | | | | | | | |
| ISLED0 | 1 | R/W | | | | | | | | | |

## Table 23. Slope Control Register for Main WLEDs

| ADDRESS (HEX) | POR (HEX) | | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0A | 00 | | Reserved | DSLP3 | DSLP2 | DSLP1 | Reserved | USLP3 | USLP2 | USLP1 |
| **NAME** | **POR** | **R/W** | **DESCRIPTION** | | | | | | | |
| DSLP3 | 0 | R/W | Slope control for ramp down and up has 8 steps, respectively (see details in Table 25) | | | | | | | |
| DSLP2 | 0 | R/W | | | | | | | | |
| DSLP1 | 0 | R/W | | | | | | | | |
| USLP4 | 0 | R/W | | | | | | | | |
| USLP4 | 0 | R/W | | | | | | | | |
| USLP3 | 0 | R/W | | | | | | | | |

## Table 24. Slope Control Register for RGB LED

| ADDRESS (HEX) | POR (HEX) | | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0B | 00 | | Reserved | DSLP3 | DSLP2 | DSLP1 | Reserved | USLP3 | USLP2 | USLP1 |
| **NAME** | **POR** | **R/W** | **DESCRIPTION** | | | | | | | |
| DSLP3 | 0 | R/W | Slope control for ramp down and up has 8 steps, respectively (see details in Table 25) | | | | | | | |
| DSLP2 | 0 | R/W | | | | | | | | |
| DSLP1 | 0 | R/W | | | | | | | | |
| USLP4 | 0 | R/W | | | | | | | | |
| USLP4 | 0 | R/W | | | | | | | | |
| USLP3 | 0 | R/W | | | | | | | | |

## Table 25. Ramp-Up/Down Transition Time in 0.1mA Step

| BIT | | | | | | | COMMENTS |
|---|---|---|---|---|---|---|---|
| 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 0 | 0 | 0 | — | • | • | • | 0 seconds (default) |
| 0 | 0 | 1 | — | • | • | • | 0.016ms ($2^4$ x 1Fs) |
| 0 | 1 | 0 | — | • | • | • | 0.068ms ($2^6$ x 1Fs) |
| 0 | 1 | 1 | — | • | • | • | 0.128ms ($2^7$ x 1Fs) |
| 1 | 0 | 0 | — | • | • | • | 0.256ms ($2^8$ x 1Fs) |
| 1 | 0 | 1 | — | • | • | • | 0.512ms ($2^9$ x 1Fs) |
| 1 | 1 | 0 | — | • | • | • | 1.024ms ($2^{10}$ x 1Fs) |
| 1 | 1 | 1 | — | • | • | • | 2.048ms ($2^{11}$ x 1Fs) |
| • | • | • | — | 0 | 0 | 0 | 0 seconds (default) |
| • | • | • | — | 0 | 0 | 1 | 0.016ms ($2^4$ x 1Fs) |
| • | • | • | — | 0 | 1 | 0 | 0.068ms ($2^6$ x 1µs) |
| • | • | • | — | 0 | 1 | 1 | 0.128ms ($2^7$ x 1µs) |
| • | • | • | — | 1 | 0 | 0 | 0.256ms ($2^8$ x 1µs) |
| • | • | • | — | 1 | 0 | 1 | 0.512ms ($2^9$ x 1µs) |
| • | • | • | — | 1 | 1 | 0 | 1.024ms ($2^{10}$ x 1µs) |
| • | • | • | — | 1 | 1 | 1 | 2.048ms ($2^{11}$ x 1µs) |

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## Table 26. ALC Control Register 1

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 0C | 10 | SBIAS | LSTY | ALCYC1 | ALCYC2 | OST1 | OST2 | OST3 | OST4 |

| NAME | POR | R/W | DESCRIPTION |
|---|---|---|---|
| SBIAS | 0 | R/W | 1: Measurement cycle is synchronized<br>0: Always on |
| LSTY | 0 | R/W | 1: LOG type of light sensor is connected<br>0: Linear type sensor |
| ALCYC1 | 0 | R/W | The measurement cycle<br>00: 0.52s; 01: 1.05s<br>10: 1.57s; 11: 2.10s |
| ALCYC2 | 1 | | |
| OST_ | 0 | R/W | Optimize the offset of ADC data |

| OST1 | OST2 | OST3 | OST4 | OFFSET VALUE |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | Non-offset (default) |
| 0 | 0 | 0 | 1 | +1 LSB |
| 0 | 0 | 1 | 0 | +2 LSB |
| 0 | 0 | 1 | 1 | +3 LSB |
| 0 | 1 | 0 | 0 | +4 LSB |
| 0 | 1 | 0 | 1 | +5 LSB |
| 0 | 1 | 1 | 0 | +6 LSB |
| 0 | 1 | 1 | 1 | +7 LSB |
| 1 | 0 | 0 | 0 | -8 LSB |
| 1 | 0 | 0 | 1 | -7 LSB |
| 1 | 0 | 1 | 0 | -6 LSB |
| 1 | 0 | 1 | 1 | -5 LSB |
| 1 | 1 | 0 | 0 | -4 LSB |
| 1 | 1 | 0 | 1 | -3 LSB |
| 1 | 1 | 1 | 0 | -2 LSB |
| 1 | 1 | 1 | 1 | -1 LSB |

## Table 27. ALC Control Register 2

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 0D | 00 | ALDA1 | ALDA2 | ALDA3 | ALDA4 | Reserved | Reserved | Reserved | Reserved |

| NAME | POR | R/W | DESCRIPTION |
|---|---|---|---|
| ALDA_ | | R | 16 different levels based on ambient light conditions |

| ALDA1 | ALDA2 | ALDA3 | ALDA4 | AMBIENT LIGHT CONDITION |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0h level |
| 0 | 0 | 0 | 1 | 1h level |
| 0 | 0 | 1 | 0 | 2h level |
| 0 | 0 | 1 | 1 | 3h level |
| 0 | 1 | 0 | 0 | 4h level |
| 0 | 1 | 0 | 1 | 5h level |
| 0 | 1 | 1 | 0 | 6h level |
| 0 | 1 | 1 | 1 | 7h level |
| 1 | 0 | 0 | 0 | 8h level |
| 1 | 0 | 0 | 1 | 9h level |
| 1 | 0 | 1 | 0 | Ah level |
| 1 | 0 | 1 | 1 | Bh level |
| 1 | 1 | 0 | 0 | Ch level |
| 1 | 1 | 0 | 1 | Dh level |
| 1 | 1 | 1 | 0 | Eh level |
| 1 | 1 | 1 | 1 | Fh level |

## Table 28. Keypad Control Register

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 0E | 00 | KYSL1 | KYSL2 | Reserved | KYDT0 | KYDT1 | KYDT2 | KYDT3 | KYDT4 |

| NAME | POR | R/W | DESCRIPTION |
|---|---|---|---|
| KYSL_ | 0 | R/W | PWM slope time is the transition time for stepping to the next duty ratio (both up and down) |

| KYSL1 | KYSL2 | PWM SLOPE RISING TIME (ms) |
|---|---|---|
| 0 | 0 | 0 (default) |
| 0 | 1 | 32 |
| 1 | 0 | 64 |
| 1 | 1 | 128 |

| NAME | POR | R/W | DESCRIPTION |
|---|---|---|---|
| KYDT_ | 0 | R/W | Duty is set by the active-high period |

| KYDT0 | KYDT0 | KYDT2 | KYDT3 | KYDT4 | Duty ratio |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0% (default) |
| 0 | 0 | 0 | 0 | 1 | 6.25% |
| 0 | 0 | 0 | 1 | 0 | 12.5% |
| 0 | 0 | 0 | 1 | 1 | 18.75% |
| 0 | 0 | 1 | 0 | 0 | 25.0% |
| 0 | 0 | 1 | 0 | 1 | 31.25% |
| 0 | 0 | 1 | 1 | 0 | 37.5% |
| 0 | 0 | 1 | 1 | 1 | 43.75% |
| 0 | 1 | 0 | 0 | 0 | 50.0% |
| 0 | 1 | 0 | 0 | 1 | 56.25% |
| 0 | 1 | 0 | 1 | 0 | 62.5% |
| 0 | 1 | 0 | 1 | 1 | 68.75% |
| 0 | 1 | 1 | 0 | 0 | 75.0% |
| 0 | 1 | 1 | 0 | 1 | 81.25% |
| 0 | 1 | 1 | 1 | 0 | 87.5% |
| 0 | 1 | 1 | 1 | 1 | 93.75% |
| 1 | 0 | 0 | 0 | 0 | 100% |

### Table 29. Keypad Control Register for ALC

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 0F | A8 | KYHS1 | KYHS2 | KYTH1 | KYTH2 | KYTH3 | KYTH4 | Reserved | Reserved |

| NAME | POR | R/W | DESCRIPTION |
|---|---|---|---|
| KYHS_ | 10 | R/W | The hysteresis values between ON and OFF.<br>The value should meet the following equation.<br>The value of KYTH_ - the value of KYHS_ > 1 |

| KYHS1 | KYHS2 | Hysteresis values |
|---|---|---|
| 0 | 0 | No hysteresis |
| 0 | 1 | 2h |
| 1 | 0 | 3h |
| 1 | 1 | 4h |

| NAME | POR | R/W | DESCRIPTION |
|---|---|---|---|
| KYTH_ | — | R/W | Determine the OFF time based on ambient light condition |

| KYTH1 | KYTH2 | KYTH3 | KYTH4 | Keypad off | KYTH1 |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0h off | 0 |
| 0 | 0 | 0 | 1 | 1h off | 0 |
| 0 | 0 | 1 | 0 | 2h off | 0 |
| 0 | 0 | 1 | 1 | 3h off | 0 |
| 0 | 1 | 0 | 0 | 4h off | 0 |
| 0 | 1 | 0 | 1 | 5h off | 0 |
| 0 | 1 | 1 | 0 | 6h off | 0 |
| 0 | 1 | 1 | 1 | 7h off | 0 |
| 1 | 0 | 0 | 0 | 8h off | 1 |
| 1 | 0 | 0 | 1 | 9h off | 1 |
| 1 | 0 | 1 | 0 | Ah off | 1 |
| 1 | 0 | 1 | 1 | Bh off | 1 |
| 1 | 1 | 0 | 0 | Ch off | 1 |
| 1 | 1 | 0 | 1 | Dh off | 1 |
| 1 | 1 | 1 | 0 | Eh off | 1 |
| 1 | 1 | 1 | 1 | Fh off | 1 |

## Table 30. Control Register in ACL 1–16

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 10~1F | — | CADA*7 | CADA*6 | CADA*5 | CADA*4 | CADA*3 | CADA*2 | CADA*1 | CADA*0 |

| NAME | POR | R/W | DESCRIPTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | BIT | | | | | | | | COMMENTS |
| | | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| CADA* | — | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Minimum current = 0.1mA |
| | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2mA set as default |
| | | | • | • | • | • | • | • | • | • | • |
| | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Maximum LED current = 25.6mA |
| | | | 256 steps from 0.1 to 25.6mA by 0.1mA step by binary value increment | | | | | | | | |

*Refers to 0~F

## Table 31. RGB LED On/Off Control Register

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 00 | RGBEN | Reserved | Reserved | RI2C | GI2C | BI2C | HLRGB | Reserved |

| NAME | POR | R/W | DESCRIPTION |
|---|---|---|---|
| RGBEN | 0 | R/W | 1: RGB LED is on by $I^2C$<br>0: RGB LED is ON by play pin |
| RI2C | 0 | R/W | 1: RED LED is ON by $I^2C$<br>0: Off |
| GI2C | 0 | R/W | 1: Green LED is ON by $I^2C$<br>0: Off |
| BI2C | 0 | R/W | 1: Blue LED is ON by $I^2C$<br>0: Off |
| HLRGB | 0 | R/W | 1: Active low for RGB LED activated<br>0: Active high for RGB LED ON |

## Table 32. Red LED Dimming Current Control Register

| ADDRESS (HEX) | POR (HEX) | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|
| 21 | 01 | RLED7 | RLED6 | RLED5 | RLED4 | RLED3 | RLED2 | RLED1 | RLED0 |

| NAME | POR | R/W | DESCRIPTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RLED7 | 0 | R/W | BIT | | | | | | | | COMMENTS |
| RLED6 | 0 | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| RLED5 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Minimum current = 0.1mA |
| RLED4 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2mA set as default |
| RLED3 | 0 | R/W | • | • | • | • | • | • | • | • | • |
| RLED2 | 0 | R/W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Maximum LED current = 25.6mA |
| RLED1 | 0 | R/W | 256 steps from 0.1 to 25.6mA by 0.1mA step by binary value increment | | | | | | | | |
| RLED0 | 1 | R/W | | | | | | | | | |

## Table 33. Green LED Dimming Current Control Register

| ADDRESS (HEX) | POR (HEX) | | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 01 | | GLED7 | GLED6 | GLED5 | GLED4 | GLED3 | GLED2 | GLED1 | GLED0 |
| **NAME** | **POR** | **R/W** | **DESCRIPTION** | | | | | | | |
| GLED7 | 0 | R/W | **BIT** | | | | | | | **COMMENTS** |
| GLED6 | 0 | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| GLED5 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Minimum current = 0.1mA |
| GLED4 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2mA set as default |
| GLED3 | 0 | R/W | • | • | • | • | • | • | • | • | • |
| GLED2 | 0 | R/W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Maximum LED current = 25.6mA |
| GLED1 | 0 | R/W | 256 steps from 0.1 to 25.6mA by 0.1mA step by binary value increment | | | | | | | | |
| GLED0 | 1 | R/W | | | | | | | | | |

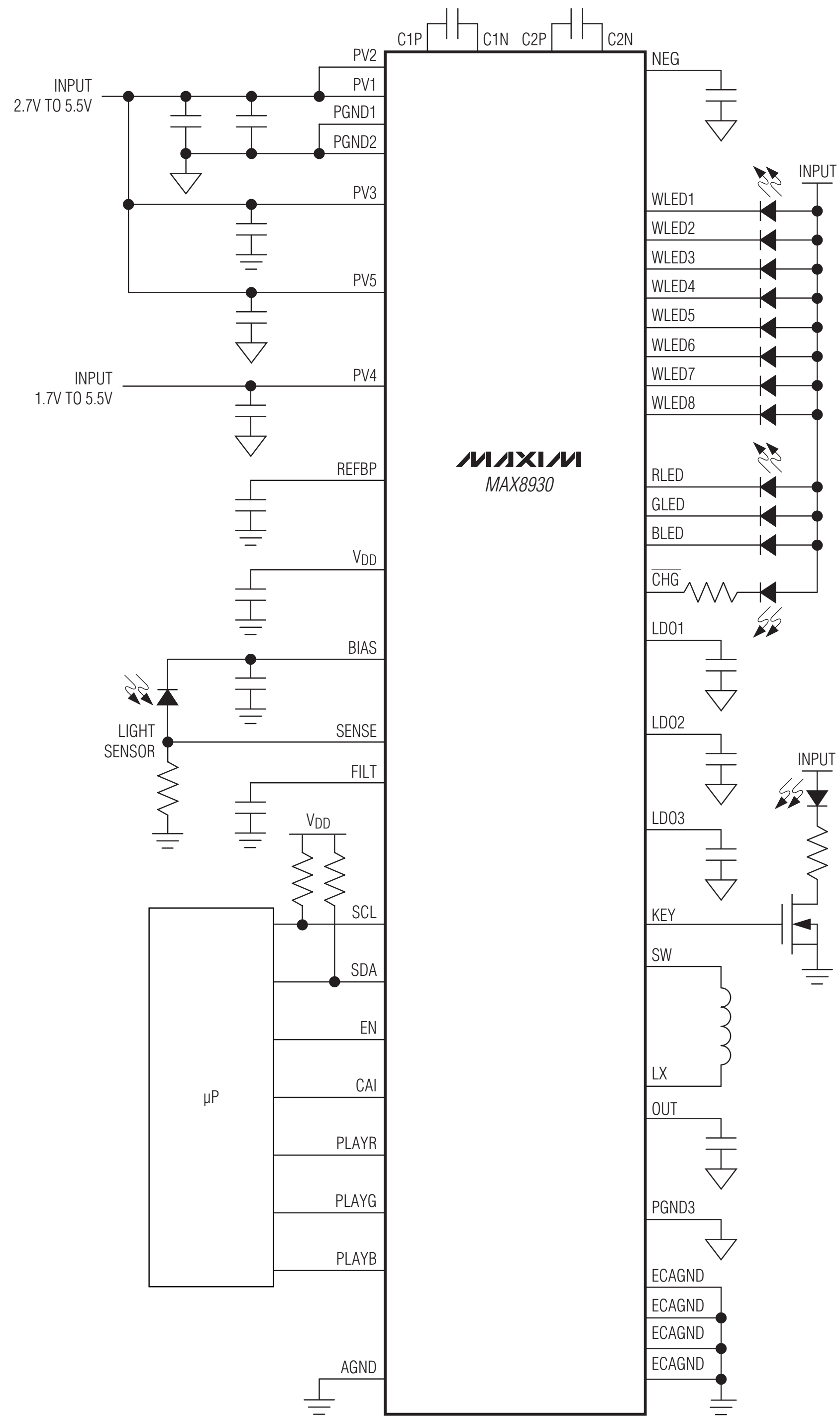
## Table 34. Blue LED Dimming Current Control Register

| ADDRESS (HEX) | POR (HEX) | | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 01 | | BLED7 | BLED6 | BLED5 | BLED4 | BLED3 | BLED2 | BLED1 | BLED0 |
| **NAME** | **POR** | **R/W** | **DESCRIPTION** | | | | | | | |
| BLED7 | 0 | R/W | **BIT** | | | | | | | **COMMENTS** |
| BLED6 | 0 | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BLED5 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Minimum current = 0.1mA |
| BLED4 | 0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.2mA set as default |
| BLED3 | 0 | R/W | • | • | • | • | • | • | • | • | • |
| BLED2 | 0 | R/W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Maximum LED current = 25.6mA |
| BLED1 | 0 | R/W | 256 steps from 0.1 to 25.6mA by 0.1mA step by binary value increment | | | | | | | | |
| BLED0 | 1 | R/W | | | | | | | | | |

## Table 35. On/Off Control Register

| ADDRESS (HEX) | POR (HEX) | | BIT 7 | BIT 6 | BIT 5 | BIT 4 | BIT 3 | BIT 2 | BIT 1 | BIT 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 00 | | GPO1 | Reserved | Reserved | GPLD1 | GPLD2 | GPLD3 | Reserved | Reserved |
| **NAME** | **POR** | **R/W** | **DESCRIPTION** | | | | | | | |
| GPO1 | 0 | R/W | 1: GPO mode<br>0: LDO Mode for LDO1, LDO2, LDO3 | | | | | | | |
| GPLD1 | 0 | R/W | 1: Output low for LDO1 (power SW on)<br>0: Output high (power SW off) | | | | | | | |
| GPLD2 | 0 | R/W | 1: Output low for LDO2 (power SW on)<br>0: Output high (Power SW off) | | | | | | | |
| GPLD3 | 0 | R/W | 1: Output low for LDO3 (power SW on)<br>0: Output high (power SW off) | | | | | | | |

## Typical Operating Circuit



## PCB Layout

Good PCB layout is essential for optimizing performance. Use large traces for the power-supply inputs to minimize losses due to parasitic trace resistance and route heat away from the device. Good design minimizes excessive EMI on the switching paths and voltage gradients in the ground plane, resulting in a stable and well regulated charge pump. Connect all capacitors as close as possible to the IC and keep their traces short, direct, and wide. Keep noisy traces, as short as possible. Connect AGND, PGND1, PGND2, and PGND3 to the common ground plane.

## Chip Information

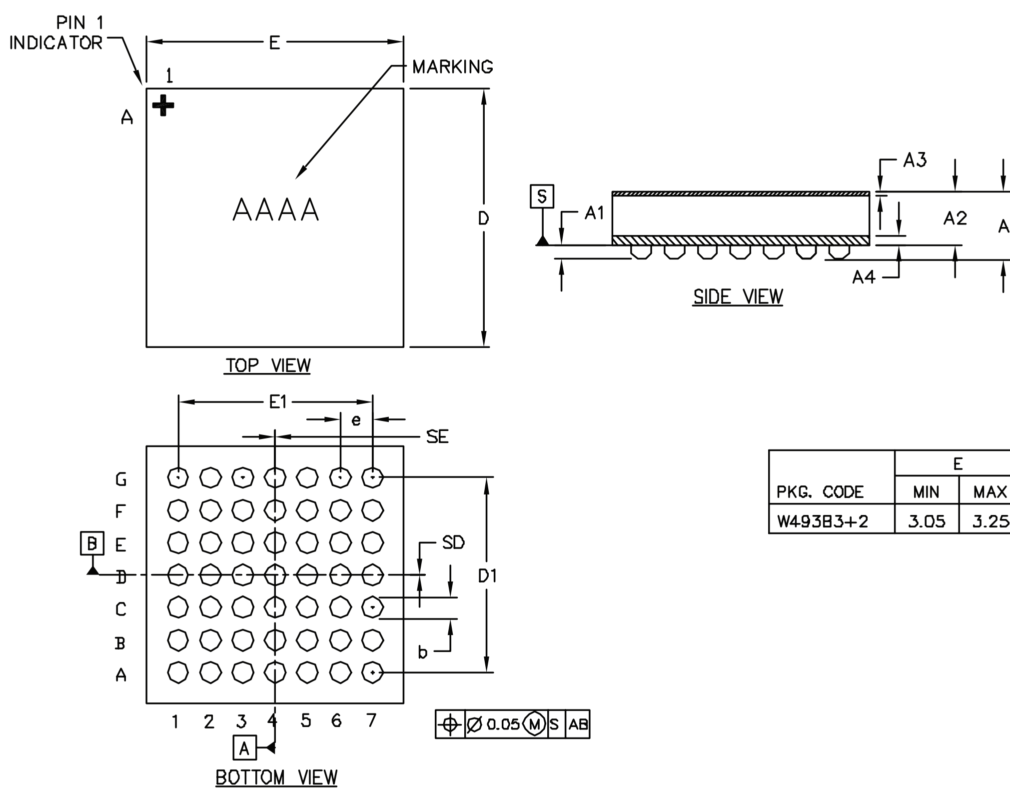
PROCESS: BiCMOS

# WLED Charge Pump, RGB, OLED Boost, LDOs with ALC and CAI

## Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO. |
|---|---|---|
| 49 WLP | W493B3+2 | 21-0441 |




| COMMON DIMENSIONS | |
|---|---|
| A | 0.64±0.05 |
| A1 | 0.21±0.03 |
| A2 | 0.43 REF |
| A3 | 0.025 BASIC |
| A4 | 0.07 BASIC |
| b | ø0.26±0.03 |
| D1 | 2.40 |
| E1 | 2.40 |
| e | 0.40 BASIC |
| SD | 0.00 BASIC |
| SE | 0.00 BASIC |

| PKG. CODE | E | | D | | DEPOPULATED BUMPS |
|---|---|---|---|---|---|
| | MIN | MAX | MIN | MAX | |
| W493B3+2 | 3.05 | 3.25 | 3.05 | 3.25 | NONE |

NOTES:
1. Terminal pitch is defined by terminal center to center value.
2. Outer dimension is defined by center lines between scribe lines.
3. All dimensions in millimeters.
4. Marking shown is for package orientation reference only.
5. Tolerance is ± 0.02mm unless specified otherwise.
6. All dimensions apply to PbFree (+) package codes only.

–DRAWING NOT TO SCALE–

MAXIM

TITLE: PACKAGE OUTLINE
49 BUMPS, WLP PKG. 0.4mm PITCH

| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0443 | A | 1/1 |

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