

FEATURES

- **Power and Current Control for Driving RGB LEDs**
- **Individually Programmable Current Sources**
- **1x or 2x Mode, Low Noise, Constant Frequency Charge Pump**
- **Single Wire Enable Control for All LEDs**
- White Mode Adjusts R, G, B Currents for White Light
- 25mA Maximum LED Current
- V_{IN} Range: 2.7V to 5.5V
- Automatic Soft-Start, Mode Switching and Output Disconnect in Shutdown Mode
- Available in 12-Lead (3mm × 2mm) DFN Package

APPLICATIONS

- Cellular Phones
- Media Players
- RGB Back Lights

LT, LTC and LTM are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners. Protected by U.S. Patents, including 6411531.

DESCRIPTION

The LTC[®]3212 is a low noise charge pump RGB LED driver capable of driving three LEDs up to 25mA each from a 2.7V to 5.5V input. Low external part count (one flying capacitor, two bypass capacitors and one to three programming resistors) makes the LTC3212 ideally suited for small, battery-powered applications.

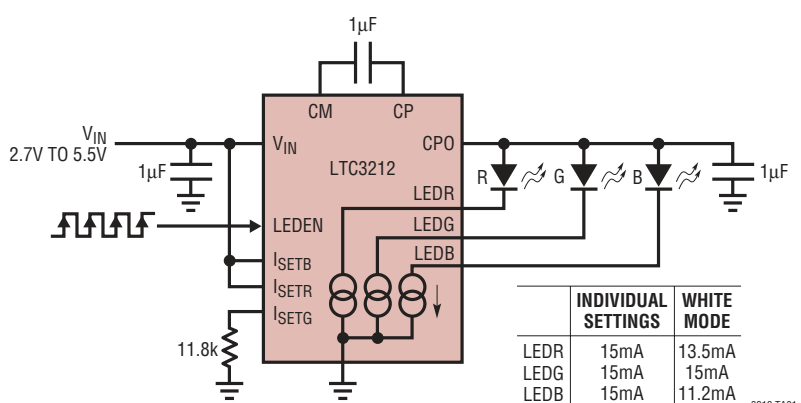
Built-in soft-start circuitry prevents excessive inrush current during start-up and mode switching. High switching frequency enables the use of small external capacitors. The charge pump shuts down to a high impedance mode to prevent LED leakage while the LTC3212 is off.

Each LED may be individually turned on or off via a single pin interface. The current through the LEDs may be individually programmed with resistors or may share a single programming resistor. White mode adjusts the red, green and blue LED current ratios for a white light when all three LEDs are programmed to be on.

LED currents are regulated using internal low dropout current sources. Automatic mode switching optimizes efficiency by monitoring the LED current drivers and switches mode only when dropout is detected. The part is available in a 3mm × 2mm 12-lead DFN package.

TYPICAL APPLICATION

RGB Power Supply and Current Control



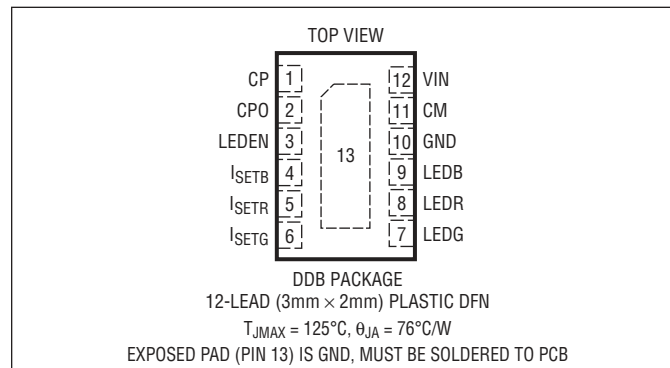
LTC3212

ABSOLUTE MAXIMUM RATINGS

(Note 1)

V_{IN} to GND	–0.3V to 6V
CPO to GND	–0.3V to 6V
LEDEN	–0.3V to $V_{IN} + 0.3V$
I_{CPO} (Note 2)	75mA
$I_{LED(R,G,B)}$ (Note 2)	30mA
CPO Short-Circuit Duration	Indefinite
Operating Temperature Range (Notes 3, 4)	–40°C to 85°C
Storage Temperature Range	–65°C to 125°C

PIN CONFIGURATION



ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LTC3212EDDB#PBF	LTC3212EDDB#TR	LCWMM	12-Lead (3mm × 2mm) Plastic DFN	–40°C to 85°C

Consult LTC Marketing for parts specified with wider operating temperature ranges.

Consult LTC Marketing for information on non-standard lead based finish parts.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandreel/>

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^{\circ}C$. $V_{IN} = 3.6V$.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{IN} Operating Voltage	●	2.7		5.5	V
I_{VIN} Operating Current	$I_{CPO} = 0mA$, 1x Mode $I_{CPO} = 0mA$, 2x Mode		0.4 2.0		mA mA
V_{IN} Shutdown Current	LEDEN = Low		3	8	μA
LED Current					
Current Ratio (I_{LEDG}/I_{SETG})	$I_{SETG} = 78\mu A$	173	192	210	A/A
Current Ratio (I_{LEDB}/I_{SETB})	$I_{SETB} = 78\mu A$	173	192	210	A/A
Current Ratio (I_{LEDB}/I_{SETG})	White Mode, $I_{SETG} = 78\mu A$	128	144	160	A/A
Current Ratio (I_{LEDR}/I_{SETR})	$I_{SETR} = 78\mu A$	173	192	210	A/A
Current Ratio (I_{LEDR}/I_{SETG})	White Mode, $I_{SETG} = 78\mu A$	154	171	186	A/A
I_{LED} Dropout Voltage (V_{ILED})	Mode Switching Theshold, $I_{LED} = 15mA$		150		mV
t_{EN}	Current Source Enable Time (LEDEN = High) (Note 5)	●		400	μs
Mode Switching Delay		50	120	250	μs
Charge Pump (CPO)					
Charge Pump Output Voltage Clamp			5.1		V
1x Mode Output Impedance	(Notes 6, 7)		5		Ω

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. $V_{IN} = 3.6\text{V}$.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS	
2x Mode Output Impedance	(Notes 6, 7)		25			Ω	
CLK Frequency			650	900	1275	kHz	
LEDEN							
High Level Input Voltage (V _{IH})		●	1.4			V	
Low Level Input Voltage (V _{IL})		●	0.4			V	
Input Current (I _{IH})	LEDEN = 3.6V		3			10	μA
Input Current (I _{IL})			−1			1	μA
t _{PWH}	High Pulse Width	●	0.08				μs
t _{PWL}	Low Pulse Width	●	0.08			20	μs
t _{SD}	Low Time to Shutdown (LEDEN = Low)	●	350				μs
I _{SET} (R,G,B)							
V _{ISET}			864	925	985		mV
I _{ISET}			140				μA

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: Based on long-term current density limitations.

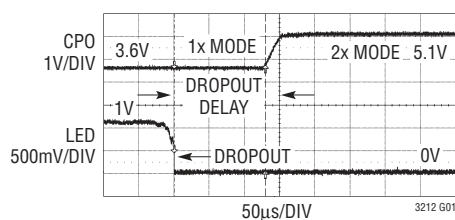
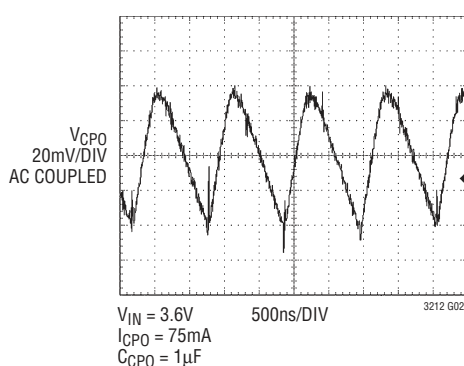
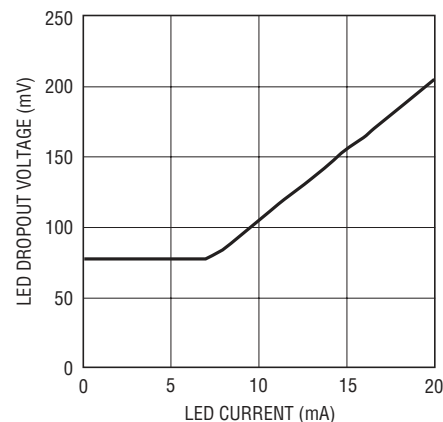
Note 3: The LTC3212E is guaranteed to meet performance specifications from 0°C to 85°C . Specifications over the -40°C to 85°C ambient operating temperature range are assured by design, characterization and correlation with statistical process controls

Note 4: This IC includes overtemperature protection that is intended to protect the device during momentary overload conditions. Junction temperature will exceed 125°C when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may impair device reliability.

Note 5: If the LTC3212 has been shut down, then the initial enable time is longer due to the bandgap settling time and the CPO output capacitor soft-start time.

Note 6: 1x mode output impedance is defined as $(V_{IN} - V_{CPO})/I_{OUT}$. 2x mode output impedance is defined as $(2V_{IN} - V_{CPO})/I_{OUT}$.

Note 7: Guaranteed by design.

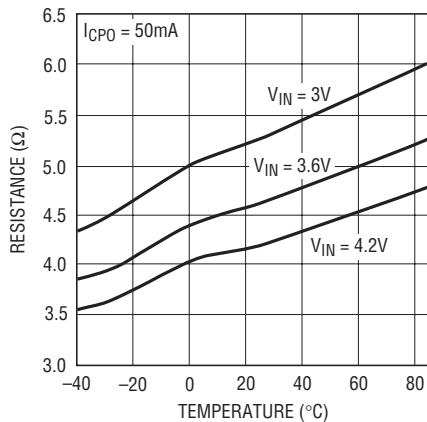
TYPICAL PERFORMANCE CHARACTERISTICS**Dropout Time****2x Mode CPO Ripple****LED Pin Dropout Voltage vs LED Pin Current**

3212 G03

3212fb

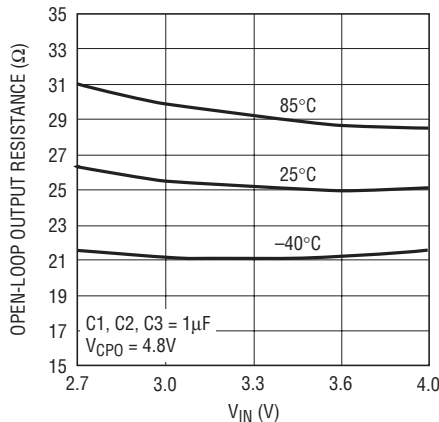
TYPICAL PERFORMANCE CHARACTERISTICS

**1x Mode Charge Pump
Resistance vs Temperature**



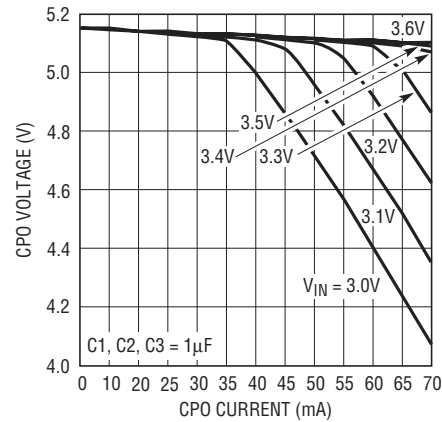
3212 G04

**2x Mode CPO Open-Loop Output
Resistance**



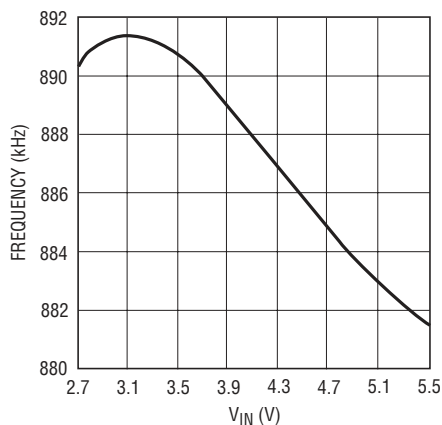
3212 G05

**2x Mode CPO Voltage
vs CPO Current**



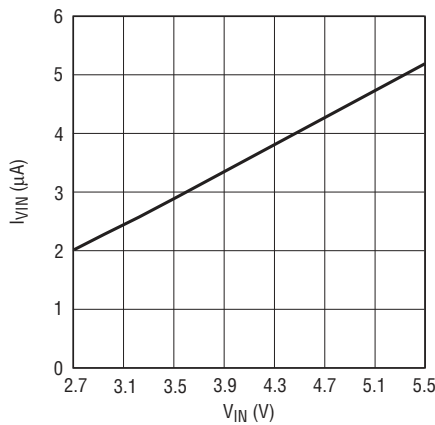
3212 G06

**Oscillator Frequency
vs VIN Voltage**



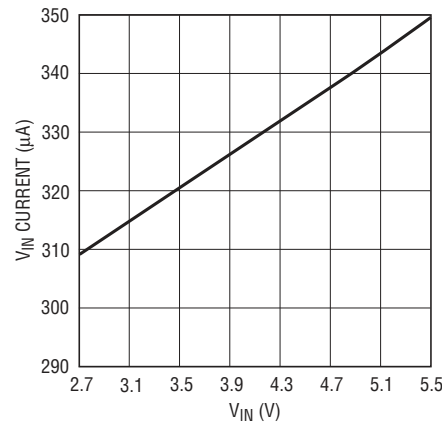
3212 G07

**VIN Shutdown Current
vs VIN Voltage**



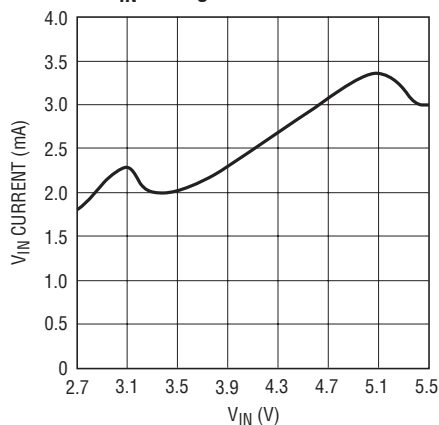
3212 G08

**1x Mode No-Load VIN Current
vs VIN Voltage**



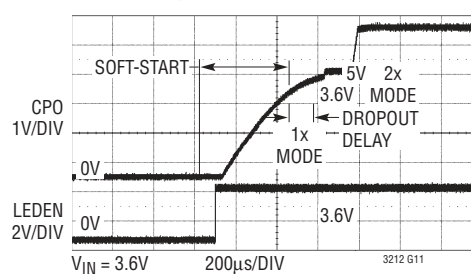
3212 G09

**2x Mode VIN Current
vs VIN Voltage**



3212 G10

Start-Up and Mode Switch



3212 G11

PIN FUNCTIONS

CP, CM (Pins 1, 11): Charge Pump Flying Capacitor Pins. A 1 μ F X5R or X7R ceramic capacitor should be connected from CP to CM.

CPO (Pin 2): CPO is the output of the charge pump. A 1 μ F X5R or X7R ceramic capacitor is required from CPO to GND. While operating, this pin will supply current to the LEDs and while in shutdown mode this pin will be high impedance.

LEDEN (Pin 3): The LEDEN pin is used to program, enable and shut down the part. A 3 μ A internal current source pulls this pin to ground.

I_{SETB}, I_{SETR}, I_{SETG} (Pins 4, 5, 6): LED current programming resistor pins. A resistor connected between a pin and GND is used to set the LED current. A resistor from I_{SETG} to GND is required. Resistors on I_{SETR} and I_{SETB} are optional. If I_{SETR} and/or I_{SETB} is not connected to a resistor I_{SETR}'s and/or I_{SETB}'s respective output(s) will be

automatically programmed by the resistor connected to I_{SETG}. If I_{SETR} or I_{SETB} is unused the pin should be connected to V_{IN}.

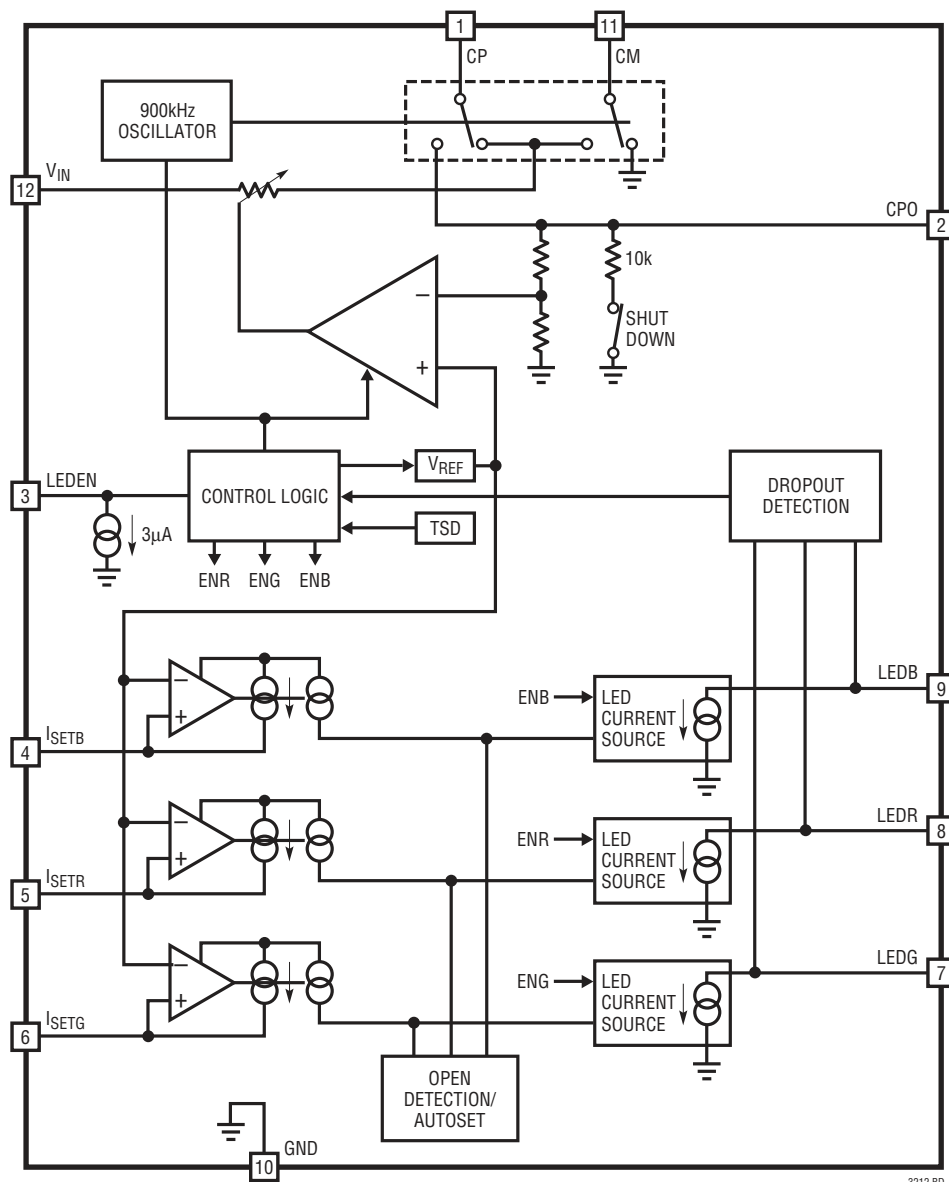
LEDG, LEDR, LEDB (Pins 7, 8, 9): These pins are the LED current output pins. The LEDs are connected from either the charge pump or V_{IN} (anode) to LED (R, G, B) (cathode).

GND (Pin 10): This pin should be connected directly to a low impedance ground plane.

V_{IN} (Pin 12): Supply voltage for the LTC3212. V_{IN} should be bypassed with a low impedance ceramic capacitor to GND of at least 1 μ F of capacitance.

Exposed Pad (Pin 13): GND. The Exposed Pad must be soldered to a low impedance ground plane for optimum performance.

BLOCK DIAGRAM



3212 BD

OPERATION

The LTC3212 uses a switched capacitor charge pump to power three LEDs with a programmable regulated current. The part powers up into 1x mode. In this mode V_{IN} is directly connected to CPO. When powering up into 1x mode, the LTC3212 charges the CPO capacitor to near V_{IN} before directly connecting V_{IN} to CPO. This prevents a large in-rush current. 1x mode provides maximum efficiency and minimum noise. The LTC3212 will remain in this mode until one of the LED current source drivers

begins to drop out of regulation. When this drop out occurs the LTC3212 will switch to 2x mode after a soft-start period. The part will return to 1x mode when the part is shut down and reprogrammed.

The current delivered through the LED load is controlled by an internal programmable low dropout current source. The current is programmed by resistors connected between the $I_{SET(R,G,B)}$ pins and GND.

3212fb

OPERATION

An overcurrent shutdown mode on the I_{SET} pins will prevent damage to the part and the LED by shutting down the LED drivers. Choosing an R_{SET} value of 5.9k or greater will ensure that the part stays out of this mode. When in normal operating mode current, regulation is achieved by controlling an active current source.

In shutdown mode all internal circuitry is turned off and the LTC3212 draws very little current from the V_{IN} supply. The LTC3212 enters shutdown mode after the LEDEN pin is brought low for 350 μ s.

Short-Circuit Protection

When LEDEN is brought high, the part will connect V_{IN} to CPO through a weak pull-up until CPO has charged to near V_{IN} . After the LTC3212 detects that the CPO voltage is near the V_{IN} voltage, it then enables 1x mode. If the CPO is shorted or falls below approximately 1V, then the LTC3212 is disabled. After falling below 1V the LTC3212 will use the weak pull-up to charge CPO to near V_{IN} before re-enabling the chip.

Soft-Start

To prevent excessive inrush during start-up and mode switching, the LTC3212 employs built-in soft-start circuitry. Soft-start is achieved by increasing the current available to the CPO capacitor over a period of approximately 100 μ s.

Charge Pump Strength

When the LTC3212 operates in 2x mode, the charge pump can be modeled as a Thevenin equivalent circuit to determine the amount of current available from the effective input voltage and the effective open-loop output resistance, R_{OL} .

R_{OL} is dependent on a number of factors including the oscillator frequency, flying capacitor values and switch resistances. From Figure 1 we can see that the maximum output current in 2x mode is proportional to:

$$\frac{2V_{IN} - CPO}{R_{OL}}$$

LED Current Programming

The LTC3212 includes three accurate, programmable current sources that are capable of driving LED currents up to 25mA continuously. The current is programmed using an external resistor for each channel. The equation for each external resistance is:

$$R_{SETG} = \frac{177.6}{I_{LEDG}}$$

$$R_{SETB} = \frac{177.6}{I_{LEDB}}$$

$$R_{SETR} = \frac{177.6}{I_{LEDR}}$$

Alternatively, if either the I_{SETR} or I_{SETB} pins are connected to V_{IN} , the respective LEDR and/or LEDB current will automatically use the R_{SETG} resistor and be set to:

$$I_{LEDR} = \frac{177.6}{R_{SETG}}$$

$$I_{LEDB} = \frac{177.6}{R_{SETG}}$$

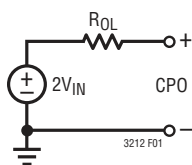


Figure 1. CPO Equivalent Open-Loop

OPERATION

White Mode

The LTC3212 has a white mode that automatically scales the current in the red, green and blue LEDs to a preset mix when selected. This allows the currents programmed with the external resistors to be set independently of the ratio needed for white light, increasing the flexibility of programming other colors. The intensity of the white is set by the resistor on I_{SETG}. The ratio used for white mode is:

$$I_{LEDG} = \frac{177.6}{R_{SETG}}$$

$$I_{LEDR} = \frac{159.8}{R_{SETG}}$$

$$I_{LEDB} = \frac{133.2}{R_{SETG}}$$

Enable

Each LED driver output may be programmed on or off by pulsing the LEDEN pin while enabling the LTC3212. An internal counter and decoder selects the output configuration from the number of pulses. This counter is

clocked by the rising edges of the LEDEN signal. Refer to Figure 2 for timing details. The outputs are programmed using Table 1.

Table 1. LED Programming

PULSES	R	G	B
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7+	White Mode		

Mode Switching

The LTC3212 will automatically switch from 1x to 2x mode whenever it detects a LED driver is entering dropout. The part will wait approximately 140μs before switching to 2x mode. This delay will act as filtering to prevent the part from incorrectly switching to 2x mode due to a momentary glitch on the V_{IN} supply. The mode may be reset by entering shutdown mode and reprogramming.

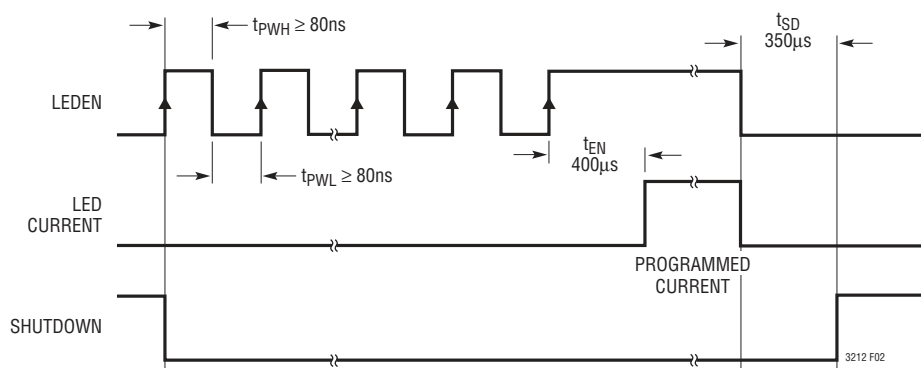


Figure 2. LED Selection and Shutdown Timing Diagram

APPLICATIONS INFORMATION

V_{IN} , CPO Capacitor Selection

The style and value of the capacitors used with the LTC3212 determine several important parameters such as regulator control loop stability, output ripple, charge pump strength and minimum start-up time.

To reduce noise and ripple, it is recommended that low equivalent series resistance (ESR) ceramic capacitors are used for both C_{VIN} and C_{CPO} . Tantalum and aluminum capacitors are not recommended due to high ESR.

The value of C_{CPO} directly controls the amount of output ripple for a given load current. Increasing the size of C_{CPO} will reduce output ripple at the expense of longer start-up time. The peak-to-peak output ripple of the 2x mode is approximately given by the expression:

$$V_{RIPPLE-P} = \frac{I_{OUT}}{2f_{OSC} \cdot C_{CPO}}$$

where f_{OSC} is the LTC3212 oscillator frequency or typically 900kHz and C_{CPO} is the output storage capacitor.

Flying Capacitor Selection

Warning: Polarized capacitors such as tantalum or aluminum should never be used for the flying capacitors since their voltage can reverse upon start-up of the LTC3212. Ceramic capacitors should always be used for the flying capacitors.

The flying capacitors control the strength of the charge pump. In order to achieve the rated output current it is necessary to have at least 0.6μF of capacitance for flying capacitor. Capacitors of different materials lose their capacitance with higher temperature and voltage at different rates. For example, a ceramic capacitor made of X7R material will retain most of its capacitance from -40°C to 85°C whereas a Z5U or Y5V style capacitor will lose considerable capacitance over that range. Z5U and Y5V capacitors may also have a very poor voltage coefficient causing them to lose 60% or more of their capacitance when the rated

voltage is applied. Therefore, when comparing different capacitors, it is often more appropriate to compare the amount of achievable capacitance for a given case size rather than comparing the specified capacitance value. For example, over rated voltage and temperature conditions, a 1μF, 10V, Y5V ceramic capacitor in a 0603 case may not provide any more capacitance than a 0.22μF, 10V, X7R available in the same case. The capacitor manufacturer's data sheet should be consulted to determine what value of capacitor is needed to ensure minimum capacitances at all temperatures and voltages.

Table 2 shows a list of ceramic capacitor manufacturers and how to contact them:

Table 2. Recommended Capacitor Vendors

AVX	www.avxcorp.com
Kemet	www.kemet.com
Murata	www.murata.com
Taiyo Yuden	www.t-yuden.com
Vishay	www.vishay.com

Layout Considerations and Switching Noise

The LTC3212 has been designed to minimize EMI. However due to its high switching frequency and the transient currents produced by the LTC3212, careful board layout is necessary. A true ground plane and short connections to all capacitors will improve performance and ensure proper regulation under all conditions.

The flying capacitor pins CP and CM will have 5ns to 10ns edge rate waveforms. The large dv/dt on these pins can couple energy capacitively to adjacent PCB runs. Magnetic fields can also be generated if the flying capacitors are not close to the LTC3212 (i.e., the loop area is large). To decouple capacitive energy transfer, a Faraday shield may be used. This is a grounded PCB trace between the sensitive node and the LTC3212 pins. For a high quality AC ground, it should be returned to a solid ground plane that extends all the way to the LTC3212.

APPLICATIONS INFORMATION

Power Efficiency

To calculate the power efficiency (η) of an LED driver chip, the LED power should be compared to the input power. The difference between these two numbers represents lost power whether it is in the charge pump or the current sources. Stated mathematically, the power efficiency is given by:

$$\eta = \frac{P_{LED}}{P_{IN}}$$

The efficiency of the LTC3212 depends upon the mode in which it is operating. Recall that the LTC3212 operates as a pass switch, connecting V_{IN} to CPO, until dropout is detected at an I_{LED} pin. This feature provides the optimum efficiency available for a given input voltage and LED forward voltage. When it is operating as a switch, the efficiency is approximated by:

$$\eta = \frac{P_{LED}}{P_{IN}} = \frac{V_{LED} \cdot I_{LED}}{V_{BAT} \cdot I_{BAT}} = \frac{V_{LED}}{V_{BAT}}$$

since the input current will be very close to the sum of the LED currents.

At moderate to high output power, the quiescent current of the LTC3212 is negligible and the expression above is valid.

Once dropout is detected at any LED pin, the LTC3212 enables the charge pump in 2x mode.

In 2x boost mode, the efficiency is similar to that of a linear regulator with an effective input voltage of 2 times the actual input voltage. In an ideal 2x charge pump, the power efficiency would be given by:

$$\eta_{IDEAL} = \frac{P_{LED}}{P_{IN}} = \frac{V_{LED} \cdot I_{LED}}{V_{BAT} \cdot 2 \cdot I_{LED}} = \frac{V_{LED}}{2 \cdot V_{BAT}}$$

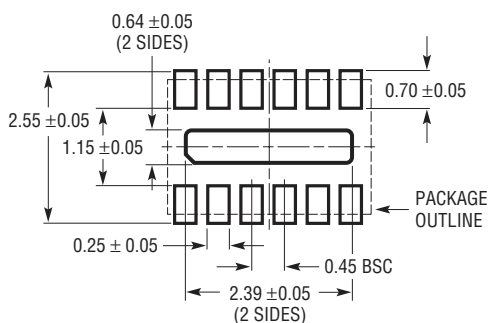
In some applications it may be possible to increase the efficiency of the LTC3212. If any of the LED's maximum forward voltage is less than the minimum V_{IN} supply voltage minus I_{LED} dropout voltage then the charge pump is not needed to drive that LED. This is often the case with the red LED due to its lower forward voltage. Its anode may be connected directly to V_{IN} , bypassing the charge pump's losses in 2x mode.

Thermal Management

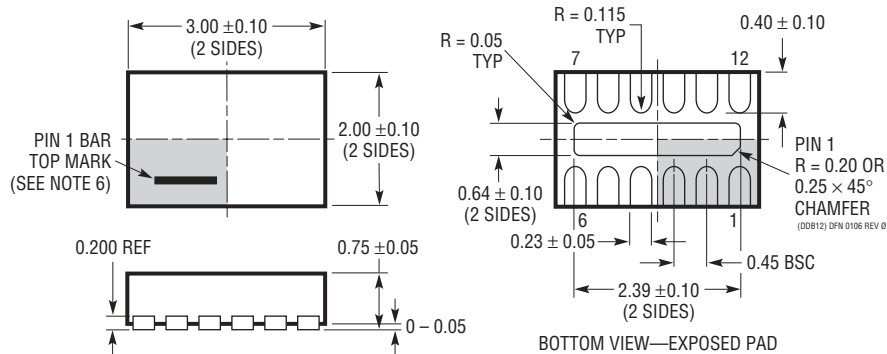
If the junction temperature increases above approximately 140°C the thermal shutdown circuitry will automatically deactivate the output current sources and charge pump. To reduce maximum junction temperature, a good thermal connection to the PC board is recommended. Connecting the Exposed Pad to a ground plane and maintaining a solid ground plane under the device will reduce the thermal resistance of the package and PC board considerably.

PACKAGE DESCRIPTION

DDB Package 12-Lead Plastic DFN (3mm × 2mm) (Reference LTC DWG # 05-08-1723 Rev 0)



RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS
APPLY SOLDER MASK TO AREAS THAT ARE NOT SOLDERED

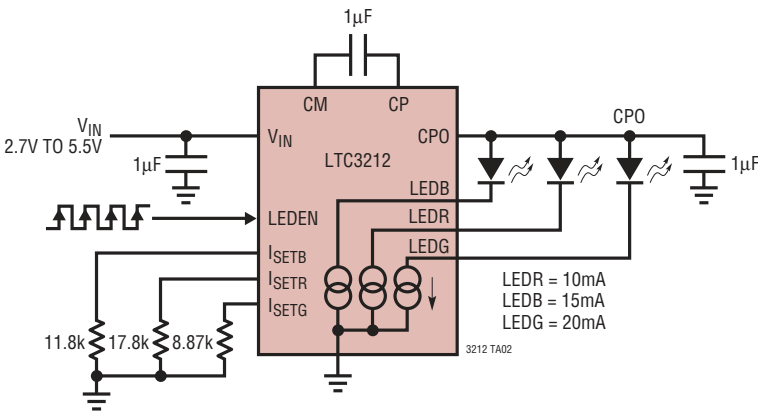


NOTE:

1. DRAWING IS NOT A JEDEC PACKAGE OUTLINE
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON THE TOP AND BOTTOM OF PACKAGE

TYPICAL APPLICATION

Three Independent Programming Resistors (10mA, 15mA, 20mA)



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC3200-5	Low Noise, 2MHz Regulated Charge Pump White LED Driver	Up to 6 White LEDs, V_{IN} : 2.7V to 4.5V, $V_{OUT(MAX)}$ = 5V, I_Q = 8mA, $I_{SD} \leq 1\mu A$, ThinSOT Package
LTC3201	Low Noise, 1.7MHz Regulated Charge Pump White LED Driver	Up to 6 White LEDs, V_{IN} : 2.7V to 4.5V, $V_{OUT(MAX)}$ = 5V, I_Q = 6.5mA, $I_{SD} \leq 1\mu A$, 10-Lead MS Package
LTC3202	Low Noise, 1.5MHz Regulated Charge Pump White LED Driver	Up to 8 White LEDs, V_{IN} : 2.7V to 4.5V, $V_{OUT(MAX)}$ = 5V, I_Q = 5mA, $I_{SD} \leq 1\mu A$, 10-Lead MS Package
LTC3205	Multidisplay LED Controller	92% Efficiency, V_{IN} : 2.8V to 4.5V, I_Q = 50µA, $I_{SD} \leq 1\mu A$, 4mm × 4mm QFN Package
LTC3206	I ² C Multidisplay LED Controller	92% Efficiency, 400mA Continuous Output Current; Up to 11 White LEDs in 4mm × 4mm QFN Package
LTC3208	High Current Software Configurable Multidisplay LED Controller	95% Efficiency, V_{IN} : 2.9V to 4.5V, 1A Output Current; Up to 17 LEDs for 5 Displays, 5mm × 5mm QFN Package
LTC3209	600mA MAIN/Camera LED Controller	Up to 8 LEDs, 94% Efficiency, V_{IN} : 2.9V to 4.5V, 1x/1.5x/2x Boost Modes, 4mm × 4mm QFN Package
LTC3210/ LTC3210-1	500mA MAIN/Camera LED Controller	Up to 5 LEDs, 95% Efficiency, V_{IN} : 2.9V to 4.5V, 1x/1.5x/2x Boost Modes, Exponential Brightness Control, “-1” Version Has 64-Step Linear Brightness Control, 3mm × 3mm QFN Package
LTC3210-2	MAIN/CAM LED Controller with 32-Step Brightness Control	Drives 4 MAIN LEDs, 3mm × 3mm QFN Package
LTC3210-3	MAIN/CAM LED Controller with 32-Step Brightness Control	Drives 3 MAIN LEDs, 3mm × 3mm QFN Package
LTC3214	500mA Camera LED Charge Pump	93% Efficiency, V_{IN} : 2.9V to 4.4V, 1x/1.5x/2x Boost Modes, 3mm × 3mm DFN Package
LTC3215	700mA High Current, Low Noise, White LED Driver	93% Efficiency, V_{IN} : 2.9V to 4.4V, 1x/1.5x/2x Boost Modes, 3mm × 3mm DFN Package
LTC3216	1A High Current, Low Noise, White LED Driver	93% Efficiency, V_{IN} : 2.9V to 4.4V, 1x/1.5x/2x Boost Modes, Independent Low/High Current Programming
LTC3217	600mA Low Noise Multi-LED Camera Light Charge Pump	Up to 4 LEDs, 92% Efficiency, V_{IN} : 2.9V to 4.5V, 1x/1.5x/2x Boost Modes, Independent Torch and Flash I_{SET} and Enable Pins, 3mm × 3mm QFN Package
LT3465/ LT3465A	1.2MHz/2.4MHz White LED Boost Converters with Internal Schottky	Up to 6 White LEDs, V_{IN} : 12.7V to 16V, $V_{OUT(MAX)}$ = 34V, I_Q = 1.9mA, $I_{SD} < 1\mu A$, ThinSOT Package

ThinSOT is a trademark of Linear Technology Corporation.