ABSOLUTE MAXIMUM RATINGS

(Note 1)

V_{BAT}, CPO to GND .... −0.3V to 6V
ENM, ENC .... −0.3V to (V_{BAT} + 0.3V)
I_{CPO} (Note 2) 600mA
$I_{MLED1-4}$ 30mA
I_{CLED} (Note 2) 450mA
CPO Short-Circuit Duration .... Indefinite
Operating Temperature Range (Note 3) ... −40°C to 85°C
Storage Temperature Range .... −65°C to 125°C

PIN CONFIGURATION

TOP VIEW

C1P — 1   12 — GND
CPO — 2   11 — CLED
ENM — 3   10 — ENC
MLED1 — 4   9 — RC

Pins 16 15 14 13: C2P, V_{BAT}, C1M, C2M
Pins 5 6 7 8: MLED2, MLED3, MLED4, RM
17 (exposed pad)

UD PACKAGE
16-LEAD (3mm × 3mm) PLASTIC QFN
T_{JMAX} = 125°C, $θ_{JA}$ = 68°C/W
EXPOSED PAD (PIN 17) IS GND, MUST BE SOLDERED TO PCB
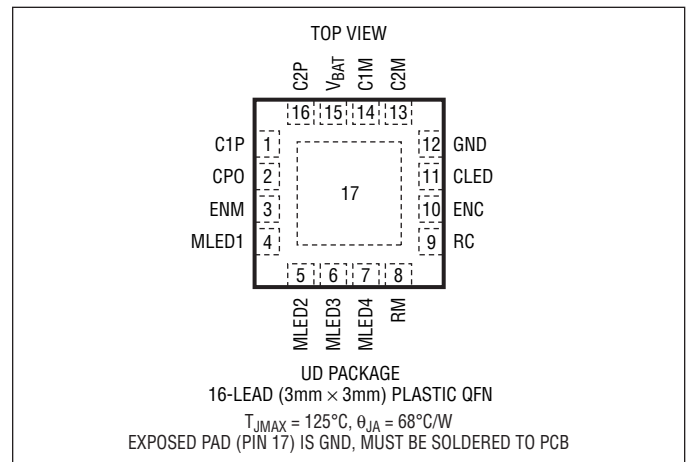
ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LTC3210EUD#PBF	LTC3210EUD#TRPBF	LBXH	16-Lead (3mm × 3mm) Plastic QFN	−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°C. V_{BAT} = 3.6V, C1 = C2 = C3 = C4 = 2.2µF, RM = 30.1k, RC = 24.3k, ENM = high, unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{BAT} Operating Voltage		●	2.9		4.5	V
I_{VBAT} Operating Current	I_{CPO} = 0, 1x Mode, MLED LSB Setting I_{CPO} = 0, 1.5x Mode I_{CPO} = 0, 2x Mode			0.375 2.5 4.5		mA mA mA
V_{BAT} Shutdown Current	ENM = ENC = LOW	●		3	6	µA
MLED1, MLED2, MLED3, MLED4 Current						
LED Current Ratio (I_{MLED}/I_{RM})	I_{MLED} = Full Scale	●	463	515	567	A/A
LED Dropout Voltage	Mode Switch Threshold, I_{MLED} = Full Scale			100		mV
LED Current Matching	Any Two Outputs, I_{MLED} = Full Scale			1		%
MLED Current, 3-Bit Exponential DAC	1 ENM Strobe (FS) 2 ENM Strobes 3 ENM Strobes 4 ENM Strobes 5 ENM Strobes 6 ENM Strobes 7 ENM Strobes (FS/64)			20 10 5 2.5 1.25 0.625 0.312		mA mA mA mA mA mA mA

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ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{BAT} = 3.6V, C1 = C2 = C3 = C4 = 2.2μF, RM = 30.1k, RC = 24.3k, ENM = high, unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Unused MLED Detection						
Test Current	MLED Tied to CPO	●	4		16	μA
Threshold Voltage	$V_{CPO} - V_{MLED}$	●	0.5		1.5	V
CLED Current						
LED Current Ratio (I_{CLED}/I_{RC})	I_{CLED} = Full Scale	●	6750	7500	8250	A/A
LED Dropout Voltage	Mode Switch Threshold, I_{CLED} = Full Scale			500		mV
CLED Current, 3-Bit Linear DAC	1 ENC Strobe (FS) 7 ENC Strobes (FS/7)			380 54		mA mA
Charge Pump (CPO)						
1x Mode Output Voltage	I_{CPO} = 0mA			V_{BAT}		V
1.5x Mode Output Voltage	I_{CPO} = 0mA			4.55		V
2x Mode Output Voltage	I_{CPO} = 0mA			5.05		V
1x Mode Output Impedance				0.5		Ω
1.5x Mode Output Impedance	V_{BAT} = 3.4V, V_{CPO} = 4.6V (Note 4)			3.15		Ω
2x Mode Output Impedance	V_{BAT} = 3.2V, V_{CPO} = 5.1V (Note 4)			3.95		Ω
CLOCK Frequency				0.8		MHz
Mode Switching Delay				0.4		ms
CPO Short Circuit Detection						
Threshold Voltage		●	0.4		1.3	V
Test Current	CPO = 0V, ENM = ENC = Low	●	10		30	mA
ENC, ENM						
V_{IL}		●			0.4	V
V_{IH}		●	1.4			V
I_{IH}	ENM = ENC = 3.6V	●	10	15	20	μA
I_{IL}	ENM = ENC = 0V	●	−1		1	μA
ENC, ENM Timing						
t_{PW}	Minimum Pulse Width	●	60			ns
t_{SD}	Low Time to Shutdown (ENC and ENM = Low)	●	50	150	250	μs
t_{EN}	Current Source Enable Time (ENC or ENM = High) (Note 5)	●	50	150	250	μs
RM, RC						
V_{RM}, V_{RC}		●	1.16	1.20	1.24	V
I_{RM}, I_{RC}		●			70	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. Assumes an operating duty cycle of ≤10% under absolute maximum conditions for durations less than 10 seconds. Maximum current for continuous operation is 300mA.
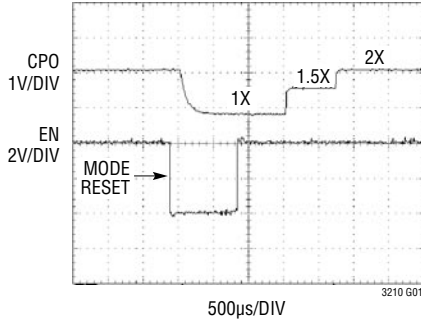
Note 3: The LTC3210E is guaranteed to meet performance specifications from 0°C to 85°C. Specifications over the −40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls.

Note 4: 1.5x mode output impedance is defined as $(1.5V_{BAT} - V_{CPO})/I_{OUT}$. 2x mode output impedance is defined as $(2V_{BAT} - V_{CPO})/I_{OUT}$.
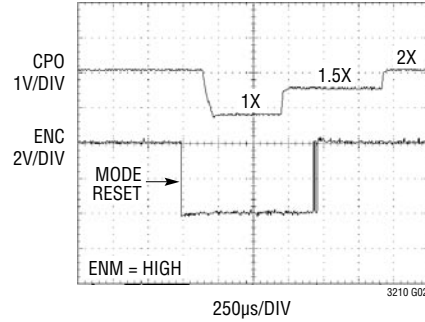
Note 5: If the part has been shut down then the initial enable time is about 100μs longer due to the bandgap enable time.

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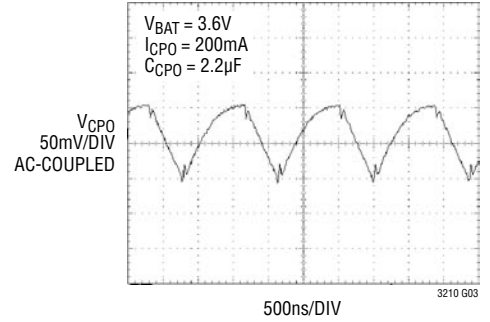# TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25°C$ unless otherwise stated.
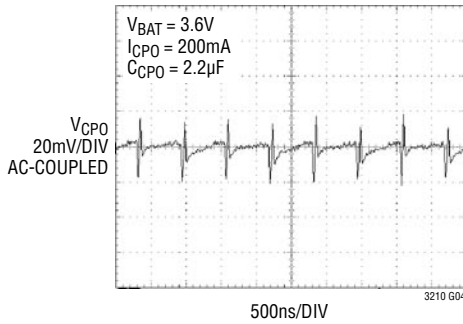
Dropout Time from Shutdown

CPO 1V/DIV
EN 2V/DIV
MODE RESET
500µs/DIV
3210 G01

Dropout Time When Enabled

CPO 1V/DIV
ENC 2V/DIV
MODE RESET
ENM = HIGH
250µs/DIV
3210 G02

1.5x CPO Ripple

$V_{BAT} = 3.6V$
$I_{CPO} = 200mA$
$C_{CPO} = 2.2µF$
V_{CPO} 50mV/DIV AC-COUPLED
500ns/DIV
3210 G03

2x CPO Ripple

$V_{BAT} = 3.6V$
$I_{CPO} = 200mA$
$C_{CPO} = 2.2µF$
V_{CPO} 20mV/DIV AC-COUPLED
500ns/DIV
3210 G04

1x Mode Switch Resistance vs Temperature

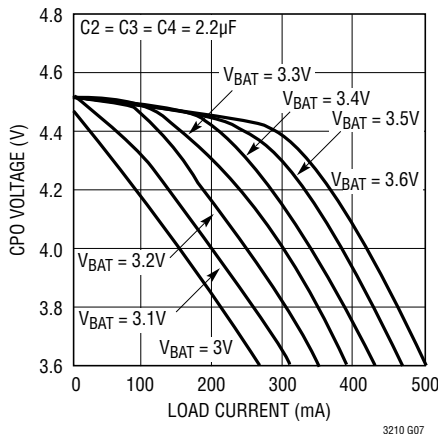$I_{CPO} = 200mA$
$V_{BAT} = 3.3V$
$V_{BAT} = 3.6V$
$V_{BAT} = 3.9V$
SWITCH RESISTANCE (Ω)
TEMPERATURE (°C)
3210 G05
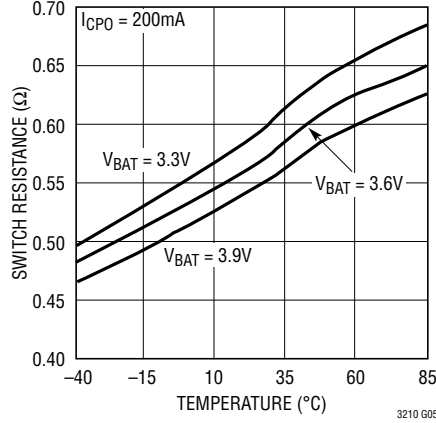
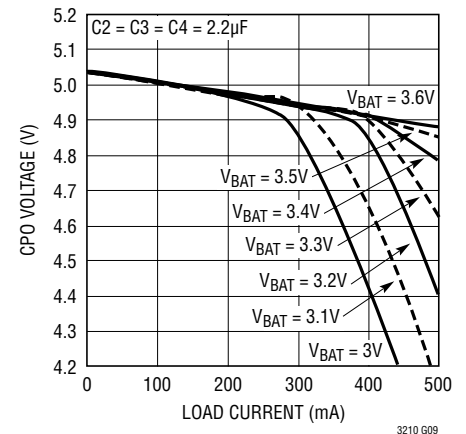**1.5x Mode Charge Pump Open-Loop Output Resistance vs Temperature $(1.5V_{BAT} - V_{CPO})/I_{CPO}$**

$V_{BAT} = 3V$
$V_{CPO} = 4.2V$
$C2 = C3 = C4 = 2.2µF$
OPEN LOOP OUTPUT RESISTANCE (Ω)
TEMPERATURE (°C)
3210 G06

1.5x Mode CPO Voltage vs Load Current

$C2 = C3 = C4 = 2.2µF$
$V_{BAT} = 3.3V$
$V_{BAT} = 3.4V$
$V_{BAT} = 3.5V$
$V_{BAT} = 3.6V$
$V_{BAT} = 3.2V$
$V_{BAT} = 3.1V$
$V_{BAT} = 3V$
CPO VOLTAGE (V)
LOAD CURRENT (mA)
3210 G07
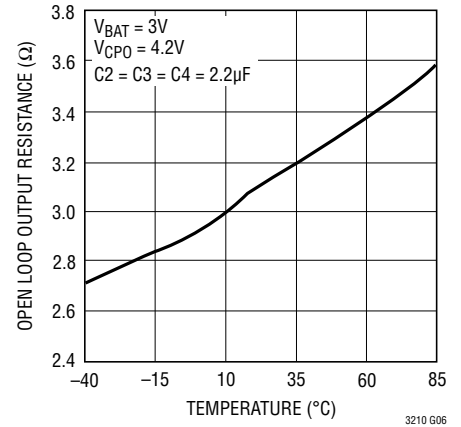
2x Mode Charge Pump Open-Loop Output Resistance vs Temperature $(2V_{BAT} - V_{CPO})/I_{CPO}$
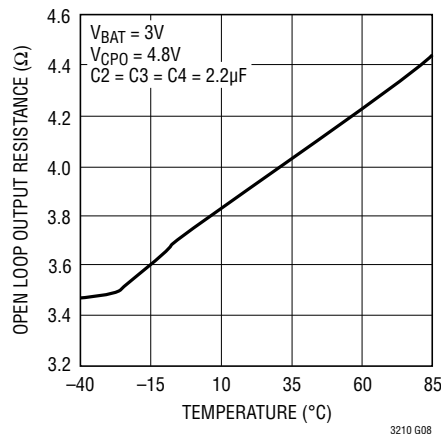
$V_{BAT} = 3V$
$V_{CPO} = 4.8V$
$C2 = C3 = C4 = 2.2µF$
OPEN LOOP OUTPUT RESISTANCE (Ω)
TEMPERATURE (°C)
3210 G08

2x Mode CPO Voltage vs Load Current

$C2 = C3 = C4 = 2.2µF$
$V_{BAT} = 3.6V$
$V_{BAT} = 3.5V$
$V_{BAT} = 3.4V$
$V_{BAT} = 3.3V$
$V_{BAT} = 3.2V$
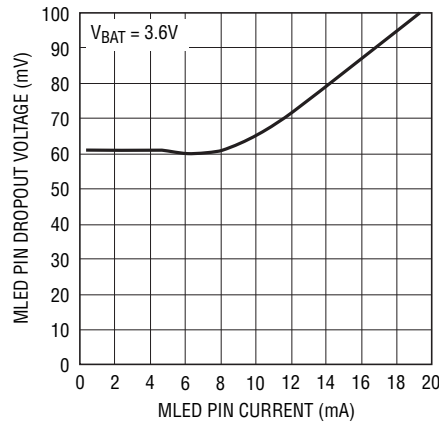$V_{BAT} = 3.1V$
$V_{BAT} = 3V$
CPO VOLTAGE (V)
LOAD CURRENT (mA)
3210 G09

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TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25°C$ unless otherwise stated.
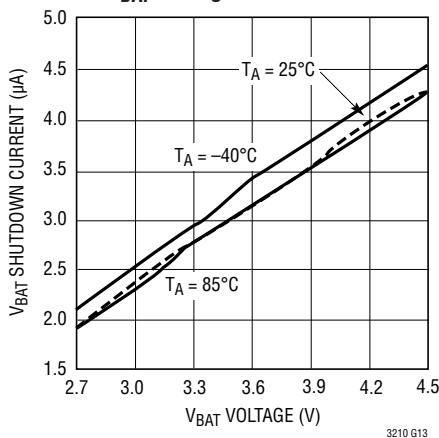
**CLED Pin Dropout Voltage
vs CLED Pin Current**

$V_{BAT} = 3.6V$

3210 G10
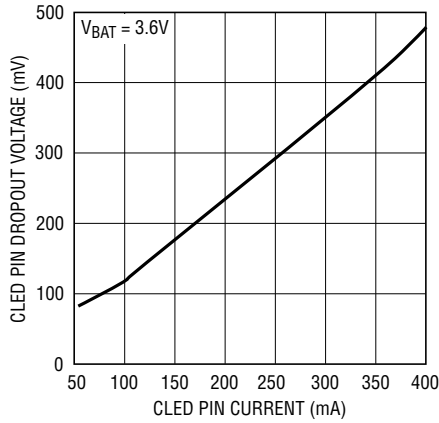
**MLED Pin Dropout Voltage
vs MLED Pin Current**

$V_{BAT} = 3.6V$

3210 G11

**Oscillator Frequency
vs V_{BAT} Voltage**

$T_A = 25°C$

$T_A = 85°C$

$T_A = -40°C$

3210 G12
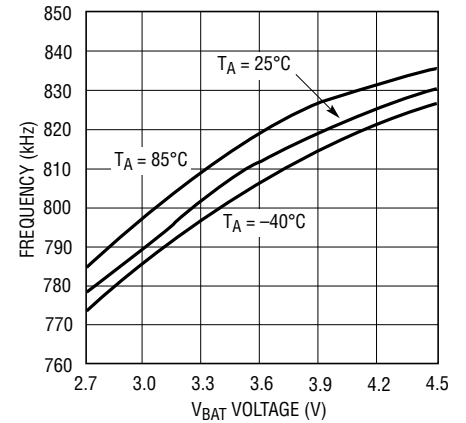
**V_{BAT} Shutdown Current
vs V_{BAT} Voltage**

$T_A = 25°C$

$T_A = -40°C$

$T_A = 85°C$

3210 G13

**1x Mode No Load V_{BAT} Current
vs V_{BAT} Voltage**

RM = 33.2k
RC = 24.3k

3210 G14
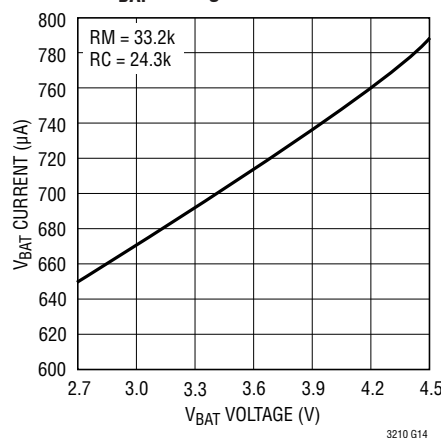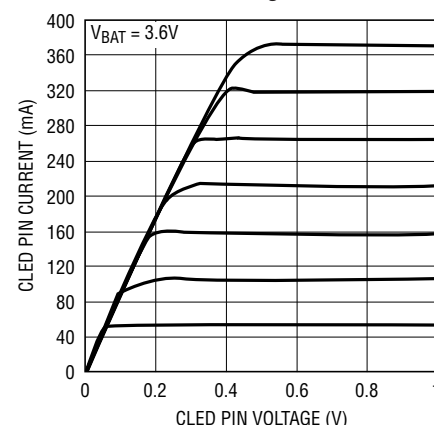
**1.5x Mode Supply Current vs I_{CPO}
($IV_{BAT} - 1.5I_{CPO}$)**

$V_{BAT} = 3.6V$

3210 G15
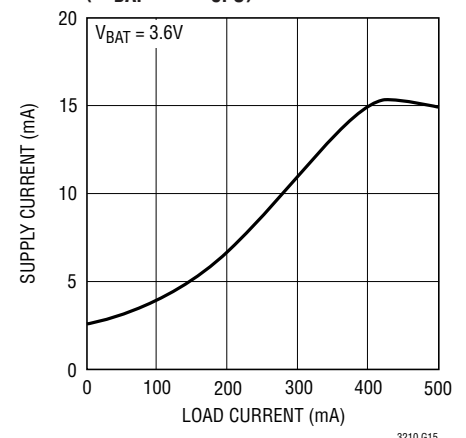
**2x Mode Supply Current vs I_{CPO}
($IV_{BAT} - 2I_{CPO}$)**

$V_{BAT} = 3.6V$

3210 G16
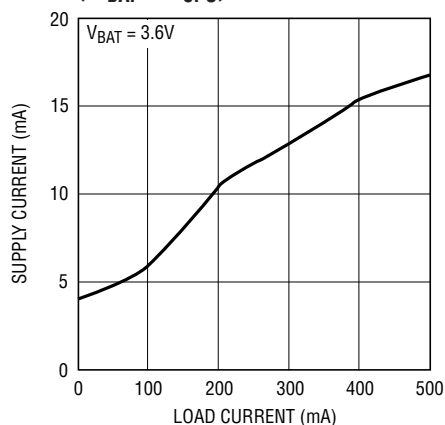
**CLED Pin Current
vs CLED Pin Voltage**

$V_{BAT} = 3.6V$

3210 G17

LINEAR
TECHNOLOGY

TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25°C$ unless otherwise stated.

**MLED Pin Current
vs MLED Pin Voltage**

3210 G18

**CLED Current
vs ENC Strobe Pulses**

3210 G19

**MLED Current
vs ENM Strobe Pulses**

3210 G20

Efficiency vs V_{BAT} Voltage

3210 G21

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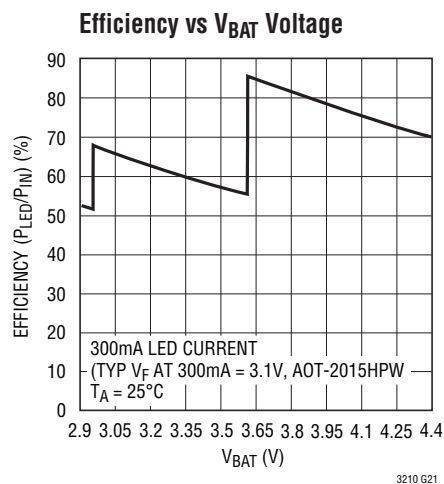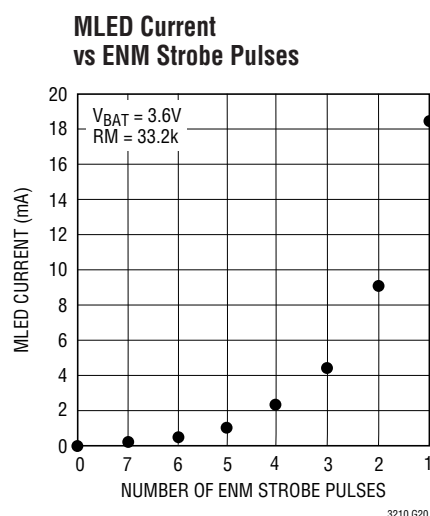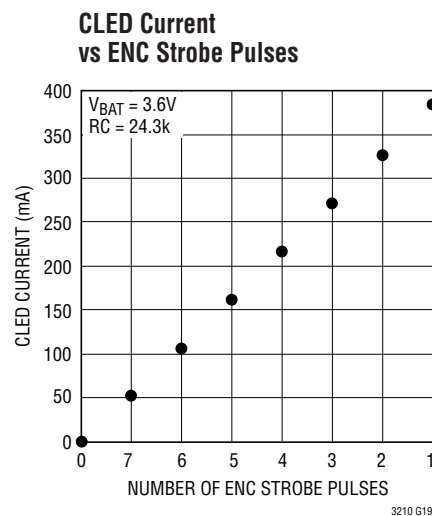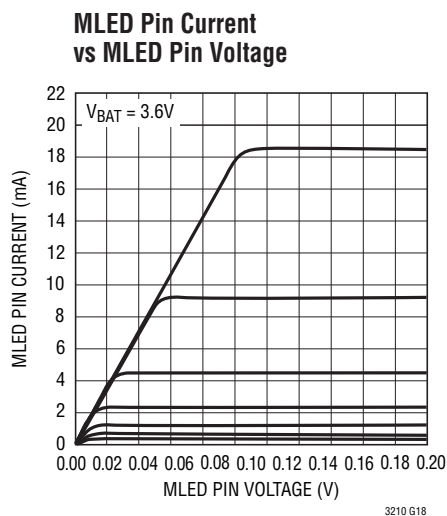
PIN FUNCTIONS

C1P, C2P, C1M, C2M (Pins 1, 16, 14, 13): Charge Pump Flying Capacitor Pins. A 2.2µF X7R or X5R ceramic capacitor should be connected from C1P to C1M and C2P to C2M.

CPO (Pin 2): Output of the Charge Pump Used to Power All LEDs. This pin is enabled or disabled using the ENM and ENC inputs. A 2.2µF X5R or X7R ceramic capacitor should be connected to ground.

ENM, ENC (Pins 3, 10): Inputs. The ENM and ENC pins are used to program the LED output currents. Each input is strobed up to 7 times to decrement the internal 3-bit DACs from full-scale to 1LSB. The counter will stop at 1 LSB if the strobing continues. The pin must be held high after the final desired positive strobe edge. The data is transferred after a 150µs (typ) delay. Holding the ENM or ENC pin low will set the LED current to 0 and will reset the counter after 150µs (typ). If both inputs are held low for longer than 150µs (typ) the part will go into shutdown. The charge pump mode is reset to 1x whenever ENC goes low or when the part is in shutdown mode.

MLED1, MLED2, MLED3, MLED4 (Pins 4, 5, 6, 7): Outputs. MLED1 to MLED4 are the MAIN current source outputs. The LEDs are connected between CPO (anodes) and MLED1-4 (cathodes). The current to each LED output is set via the ENM input, and the programming resistor connected between RM and GND. Each of the four LED outputs can be disabled by connecting the output directly to CPO. A 10µA current will flow through each directly connected LED output.

RM, RC (Pins 8, 9): LED Current Programming Resistor Pins. The RM and RC pins will servo to 1.2V. Resistors connected between each of these pins and GND are used to set the CLED and MLED current levels. Connecting a resistor 12k or less will cause the LTC3210 to enter overcurrent shutdown.

CLED (Pin 11): Output. CLED is the CAM current source output. The LED is connected between CPO (anode) and CLED (cathode). The current to the LED output is set via the ENC input, and the programming resistor connected between RC and GND.

GND (Pin 12): Ground. This pin should be connected to a low impedance ground plane.

V$_{BAT}$ (Pin 15): Supply voltage. This pin should be bypassed with a 2.2µF, or greater low ESR ceramic capacitor.

Exposed Pad (Pin 17): This pad should be connected directly to a low impedance ground plane for optimal thermal and electrical performance.

LTC3210

BLOCK DIAGRAM

3210fb
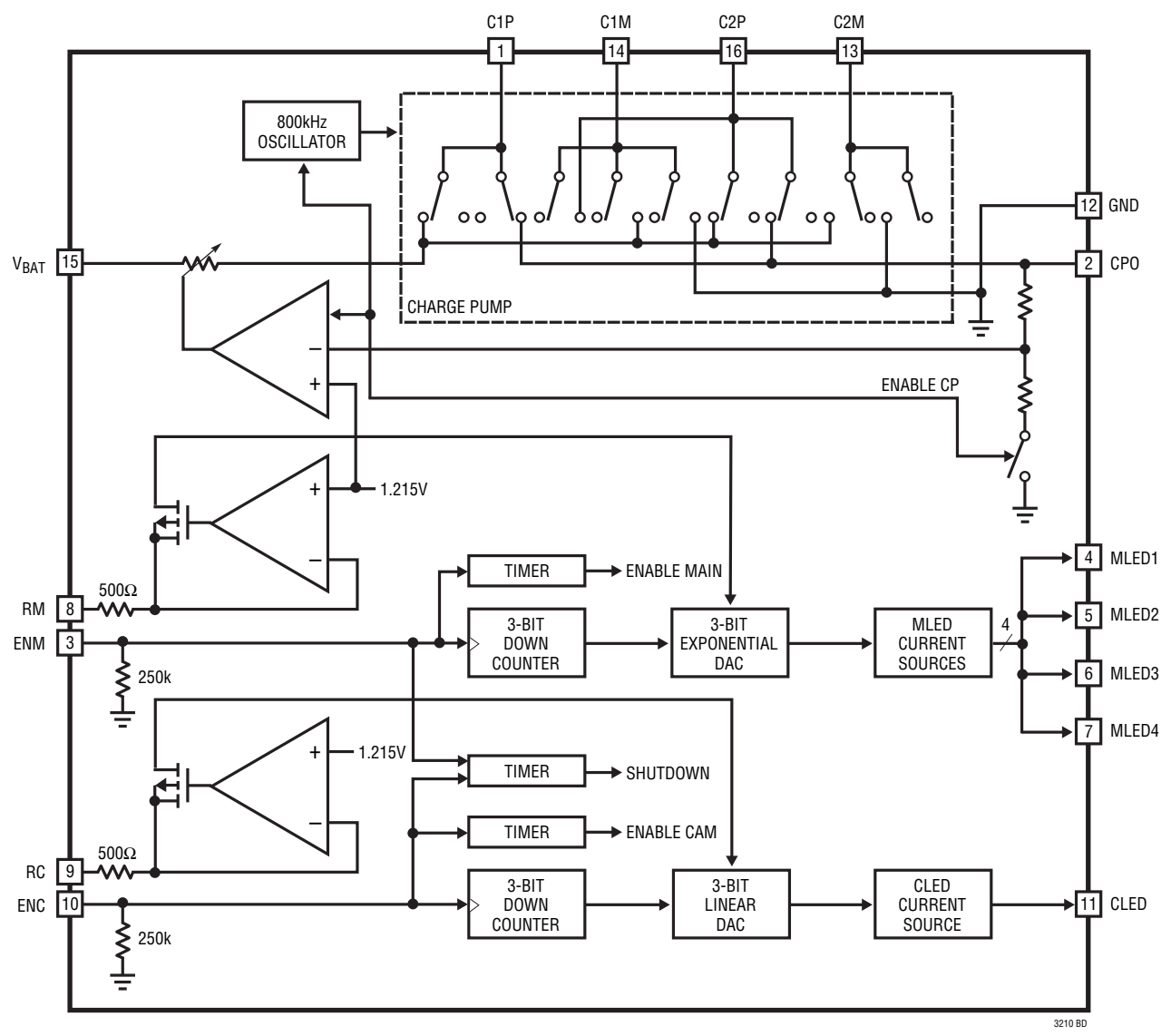
OPERATION

Power Management

The LTC3210 uses a switched capacitor charge pump to boost CPO to as much as 2 times the input voltage up to 5.1V. The part starts up in 1x mode. In this mode, V_{BAT} is connected directly to CPO. This mode provides maximum efficiency and minimum noise. The LTC3210 will remain in 1x mode until an LED current source drops out. Dropout occurs when a current source voltage becomes too low for the programmed current to be supplied. When dropout is detected, the LTC3210 will switch into 1.5x mode. The CPO voltage will then start to increase and will attempt to reach 1.5x V_{BAT} up to 4.6V. Any subsequent dropout will cause the part to enter the 2x mode. The CPO voltage will attempt to reach 2x V_{BAT} up to 5.1V. The part will be reset to 1x mode whenever the part is shut down or when ENC goes low.

A two phase nonoverlapping clock activates the charge pump switches. In the 2x mode the flying capacitors are charged on alternate clock phases from V_{BAT} to minimize input current ripple and CPO voltage ripple. In 1.5x mode the flying capacitors are charged in series during the first clock phase and stacked in parallel on V_{BAT} during the second phase. This sequence of charging and discharging the flying capacitors continues at a constant frequency of 800kHz.

LED Current Control

The MLED currents are delivered by the four programmable current sources. Eight current settings (0mA to 20mA, RM = 30.1k) are available by strobing the ENM pin. Each positive strobe edge decrements a 3-bit down counter which controls an exponential DAC. When the desired current is achieved ENM is stopped high. The output current then changes to the programmed value after 150µs (typ). The counter will stop when the LSB is reached. The output current is set to 0 when ENM is toggled low after the output has been enabled. If strobing is started within 150µs (typ), after ENM has been set low, the counter will continue to count down. After 150µs (typ) the counter is reset.

The CLED current is delivered by a programmable current source. Eight linear current settings (0mA to 380mA, RC = 24.3k) are available by strobing the ENC pin. Each positive strobe edge decrements a 3-bit down counter which controls a 3-bit linear DAC. When the desired current is reached, ENC is stopped high. The output current then changes to the programmed value after 150µs (typ). The counter will stop when the LSB is reached. The output current is set to 0 when ENC is toggled low after the output has been enabled. If strobing is started within 150µs (typ) after ENC has been set low, the counter will continue to count down. After 150µs (typ) the counter is reset.

The full-scale output current is calculated as follows:

MLED full-scale output current
$$= \bigl(1.215V/(RM + 500)\bigr) \bullet 515$$

CLED full-scale output current
$$= \bigl(1.215V/(RC + 500)\bigr) \bullet 7500$$

When both ENM and ENC are held low for 150µs (typ) the part will go into shutdown. See Figure 1 for timing information.

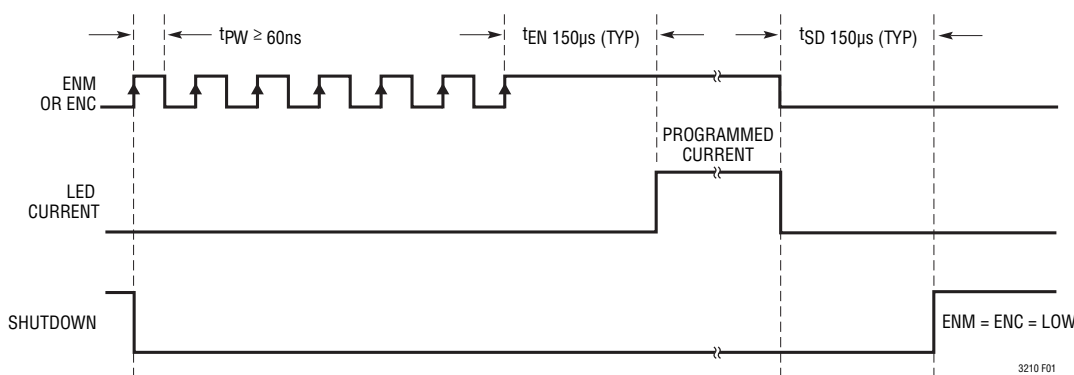ENC resets the mode to 1x on a falling edge.

Figure 1. Current Programming and Shutdown Timing Diagram

OPERATION

Soft-Start

Initially, when the part is in shutdown, a weak switch connects V_{BAT} to CPO. This allows V_{BAT} to slowly charge the CPO output capacitor to prevent large charging currents.

The LTC3210 also employs a soft-start feature on its charge pump to prevent excessive inrush current and supply droop when switching into the step-up modes. The current available to the CPO pin is increased linearly over a typical period of 150μs. Soft-start occurs at the start of both 1.5x and 2x mode changes.

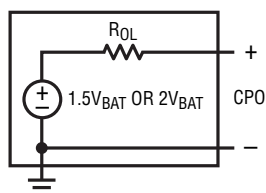### Charge Pump Strength and Regulation

Regulation is achieved by sensing the voltage at the CPO pin and modulating the charge pump strength based on the error signal. The CPO regulation voltages are set internally, and are dependent on the charge pump modes as shown in Table 1.

Table 1. Charge Pump Output Regulation Voltages

CHARGE PUMP MODE	REGULATED V_{CPO}
1.5x	4.55V
2x	5.05V

When the LTC3210 operates in either 1.5x mode or 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 effective open-loop output resistance, R_{OL} (Figure 2).

R_{OL} is dependent on a number of factors including the switching term, $1/(2f_{OSC} \cdot C_{FLY})$, internal switch resistances and the nonoverlap period of the switching circuit. However, for a given R_{OL}, the amount of current available will be directly proportional to the advantage voltage of $1.5V_{BAT}$ – CPO for 1.5x mode and $2V_{BAT}$ – CPO for 2x mode. Consider

the example of driving white LEDs from a 3.1V supply. If the LED forward voltage is 3.8V and the current sources require 100mV, the advantage voltage for 1.5x mode is 3.1V • 1.5 – 3.8V – 0.1V or 750mV. Notice that if the input voltage is raised to 3.2V, the advantage voltage jumps to 900mV— a 20% improvement in available strength.

From Figure 2, for 1.5x mode the available current is given by:

$$I_{OUT} = \frac{(1.5V_{BAT} - V_{CPO})}{R_{OL}}$$

For 2x mode, the available current is given by:

$$I_{OUT} = \frac{(2V_{BAT} - V_{CPO})}{R_{OL}}$$

Notice that the advantage voltage in this case is 3.1V • 2 – 3.8V – 0.1V = 2.3V. R_{OL} is higher in 2x mode but a significant overall increase in available current is achieved.

Typical values of R_{OL} as a function of temperature are shown in Figure 3 and Figure 4.

Shutdown Current

In shutdown mode all the circuitry is turned off and the LTC3210 draws a very low current from the V_{BAT} supply. Furthermore, CPO is weakly connected to V_{BAT}. The LTC3210 enters shutdown mode when both the ENM and ENC pins are brought low for 150μs (typ). ENM and ENC have 250k internal pull down resistors to define the shutdown state when the drivers are in a high impedance state.

Figure 2. Charge Pump Thevenin-Equivalent Circuit
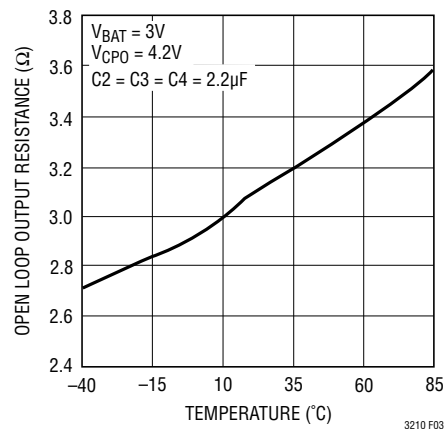
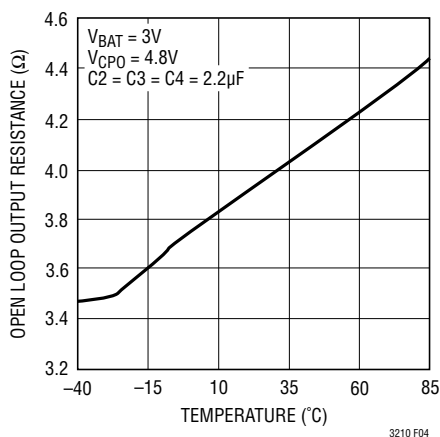Figure 3. Typical 1.5x R_{OL} vs Temperature

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OPERATION

Figure 4. Typical 2x R_{OL} vs Temperature

Thermal Protection

The LTC3210 has built-in overtemperature protection. At internal die temperatures of around 150°C thermal shutdown will occur. This will disable all of the current sources and charge pump until the die has cooled by about 15°C. This thermal cycling will continue until the fault has been corrected.

Mode Switching

The LTC3210 will automatically switch from 1x mode to 1.5x mode and subsequently to 2x mode whenever a dropout condition is detected at an LED pin. Dropout occurs when a current source voltage becomes too low for the programmed current to be supplied. The time from drop-out detection to mode switching is typically 0.4ms.

The part is reset back to 1x mode when the part is shut down (ENM = ENC = Low) or on the falling edge of ENC. An internal comparator will not allow the main switches to connect V_{BAT} and CPO in 1x mode until the voltage at the CPO pin has decayed to less than or equal to the voltage at the V_{BAT} pin.

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V_{BAT}, CPO Capacitor Selection

The style and value of the capacitors used with the LTC3210 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 CV_{BAT} 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 higher start-up current. The peak-to-peak output ripple of the 1.5x mode is approximately given by the expression:

$$V_{RIPPLE(P-P)} = \frac{I_{OUT}}{(3f_{OSC} \cdot C_{CPO})} \qquad (3)$$

Where f_{OSC} is the LTC3210 oscillator frequency or typically 800kHz and C_{CPO} is the output storage capacitor.

The output ripple in 2x mode is very small due to the fact that load current is supplied on both cycles of the clock.

Both style and value of the output capacitor can significantly affect the stability of the LTC3210. As shown in the Block Diagram, the LTC3210 uses a control loop to adjust the strength of the charge pump to match the required output current. The error signal of the loop is stored directly on the output capacitor. The output capacitor also serves as the dominant pole for the control loop. To prevent ringing or instability, it is important for the output capacitor to maintain at least 1.3µF of capacitance over all conditions.

In addition, excessive output capacitor ESR >100mΩ will tend to degrade the loop stability. Multilayer ceramic chip capacitors typically have exceptional ESR performance and when combined with a tight board layout will result in very good stability. As the value of C_{CPO} controls the amount of output ripple, the value of CV_{BAT} controls the amount of ripple present at the input pin(V_{BAT}). The LTC3210's input current will be relatively constant while the charge pump is either in the input charging phase or the output charging

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phase but will drop to zero during the clock nonoverlap times. Since the nonoverlap time is small (~35ns), these missing "notches" will result in only a small perturbation on the input power supply line. Note that a higher ESR capacitor such as tantalum will have higher input noise due to the higher ESR. Therefore, ceramic capacitors are recommended for low ESR. Input noise can be further reduced by powering the LTC3210 through a very small series inductor as shown in Figure 5. A 10nH inductor will reject the fast current notches, thereby presenting a nearly constant current load to the input power supply. For economy, the 10nH inductor can be fabricated on the PC board with about 1cm (0.4") of PC board trace.
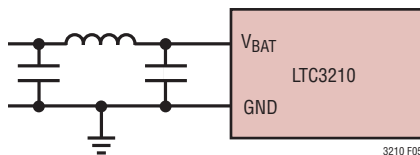

Figure 5. 10nH Inductor Used for Input Noise Reduction (Approximately 1cm of Board Trace)

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 LTC3210. 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 1.6µF of capacitance for each of the flying capacitors. 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. 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 Noise

Due to the high switching frequency and the transient currents produced by the LTC3210, 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 C1P, C2P, C1M and C2M will have high 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 LTC3210 (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 LTC3210 pins. For a high quality AC ground, it should be returned to a solid ground plane that extends all the way to the LTC3210.

The following guidelines should be followed when designing a PCB layout for the LTC3210:

- The exposed pad should be soldered to a large copper plane that is connected to a solid, low impedance ground plane using plated through-hole vias for proper heat sinking and noise protection.

- Input and output capacitors must be placed close to the part.

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APPLICATIONS INFORMATION

- The flying capacitors must be placed close to the part. The traces from the pins to the capacitor pad should be as wide as possible.

- V_{BAT}, CPO traces must be wide to minimize inductance and handle high currents.

- LED pads must be large and connected to other layers of metal to ensure proper heat sinking.

- RM and RC pins are sensitive to noise and capacitance. The resistors should be placed near the part with minimum line width.

Power Efficiency

To calculate the power efficiency (η) of a white 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 LTC3210 depends upon the mode in which it is operating. Recall that the LTC3210 operates as a pass switch, connecting V_{BAT} to CPO, until dropout is detected at the 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:

$$\eta = \frac{P_{LED}}{P_{IN}} = \frac{(V_{LED} \bullet I_{LED})}{(V_{BAT} \bullet I_{BAT})} = \frac{V_{LED}}{V_{BAT}}$$

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 LTC3210 is negligible and the expression above is valid.

Once dropout is detected at any LED pin, the LTC3210 enables the charge pump in 1.5x mode.

In 1.5x boost mode, the efficiency is similar to that of a linear regulator with an effective input voltage of 1.5 times the actual input voltage. This is because the input current for a 1.5x charge pump is approximately 1.5 times the load current. In an ideal 1.5x charge pump, the power efficiency would be given by:

$$\eta_{IDEAL} = \frac{P_{LED}}{P_{IN}} = \frac{(V_{LED} \bullet I_{LED})}{(V_{BAT} \bullet (1.5) \bullet I_{LED})} = \frac{V_{LED}}{(1.5 \bullet V_{BAT})}$$

Similarly, 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:
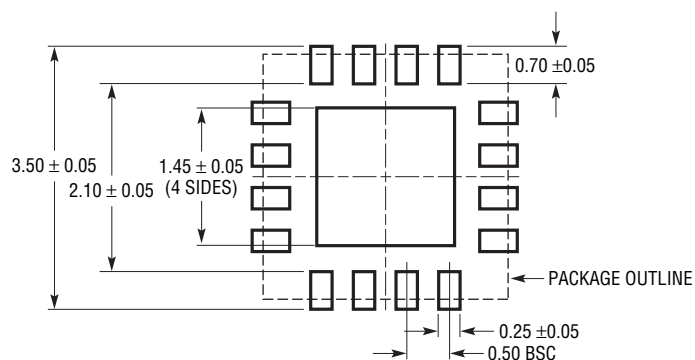
$$\eta_{IDEAL} = \frac{P_{LED}}{P_{IN}} = \frac{(V_{LED} \bullet I_{LED})}{(V_{BAT} \bullet (2) \bullet I_{LED})} = \frac{V_{LED}}{(2 \bullet V_{BAT})}$$
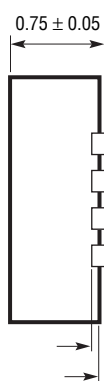
Thermal Management

For higher input voltages and maximum output current, there can be substantial power dissipation in the LTC3210. If the junction temperature increases above approximately 150°C the thermal shut down 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

UD Package
16-Lead Plastic QFN (3mm × 3mm)
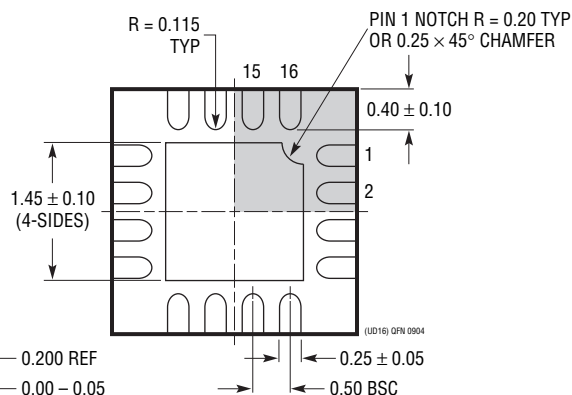(Reference LTC DWG # 05-08-1691)

3.50 ± 0.05

2.10 ± 0.05

1.45 ± 0.05
(4 SIDES)

0.70 ±0.05

PACKAGE OUTLINE

0.25 ±0.05

0.50 BSC

RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS

3.00 ± 0.10
(4 SIDES)

PIN 1
TOP MARK
(NOTE 6)

0.75 ± 0.05

1.45 ± 0.10
(4-SIDES)

0.200 REF

0.00 – 0.05

BOTTOM VIEW—EXPOSED PAD

R = 0.115
TYP

PIN 1 NOTCH R = 0.20 TYP
OR 0.25 × 45° CHAMFER

15   16

0.40 ± 0.10

1

2

(UD16) QFN 0904

0.25 ± 0.05

0.50 BSC
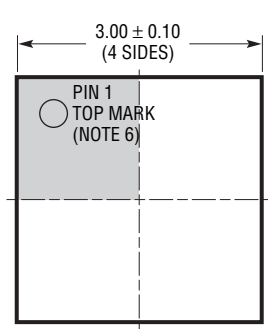
NOTE:
1. DRAWING CONFORMS TO JEDEC PACKAGE OUTLINE MO-220 VARIATION (WEED-2)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE
   MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION
   ON THE TOP AND BOTTOM OF PACKAGE

REVISION HISTORY (Revision history begins at Rev B)

REV	DATE	DESCRIPTION	PAGE NUMBER
B	6/10	Update to Note 3	3

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LINEAR TECHNOLOGY

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LTC3210

TYPICAL APPLICATION

3-LED MAIN, One LED Camera

3210 TA02
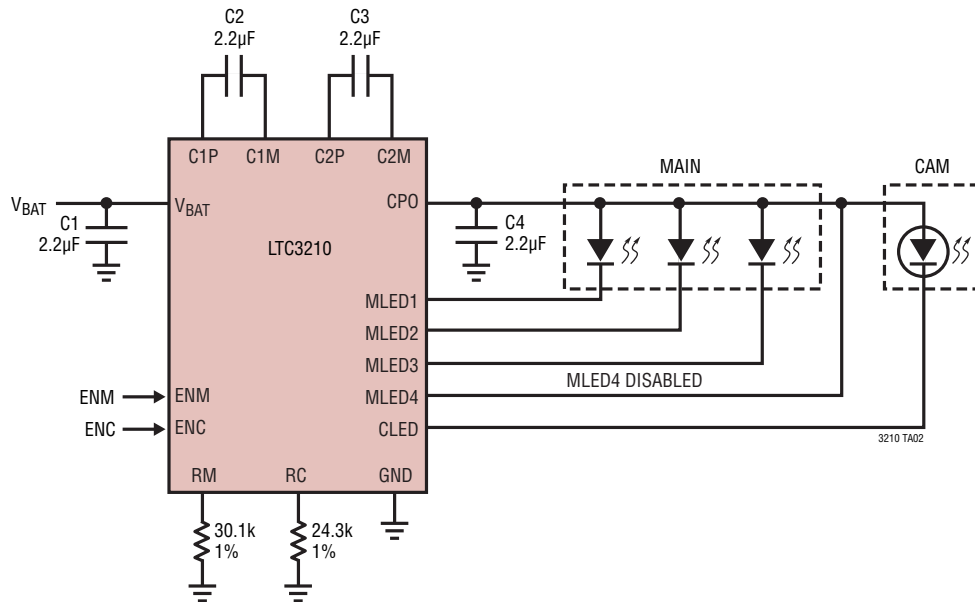
RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1618	Constant Current, 1.4MHz, 1.5A Boost Converter	V_{IN}: 1.6V to 18V, $V_{OUT(MAX)}$ = 36V, I_Q = 1.8mA, I_{SD} <1µA, MS Package
LTC3205	250mA, 1MHz, Multi-Display LED Controller	V_{IN}: 2.8V to 4.5V, $V_{OUT(MAX)}$ = 5.5V, I_Q = 50µA, I_{SD} <1µA, QFN Package
LTC3206	400mA, 800kHz, Multi-Display LED Controller	V_{IN}: 2.8V to 4.5V, $V_{OUT(MAX)}$ = 5.5V, I_Q = 50µA, I_{SD} <1µA, QFN Package
LTC3208	High Current Software Configurable Multi-Display LED Controller	V_{IN}: 2.9V to 4.5V, V_{OUT} = 5.1V, I_Q = 250µA, I_{SD} <1µA, 17 Current Sources (MAIN, SUB, RGB, CAM, AUX), 5 × 5 QFN Package
LTC3209-1/ LTC3209-2	600mA Main/Camera/AUX LED Controller	V_{IN}: 2.9V to 4.5V, I_Q = 400µA, Up to 94% Efficiency, 4mm × 4mm QFN-20 Package
LTC3210-1	MAIN/CAM LED Controller with 64-Step Brightness Control	V_{IN}: 2.9V to 4.5V, I_Q = 400µA, 3-Bit DAC Brightness Control for MAIN and CAM LEDs, 3mm × 3mm QFN Package
LTC3214	500mA Camera LED Charge Pump	V_{IN}: 2.9V to 4.5V, Single Output, 3 × 3 DFN Package
LTC3215	700mA Low Noise High Current LED Charge Pump	V_{IN}: 2.9V to 4.4V, $V_{OUT(MAX)}$ = 5.5V, I_Q = 300µA, I_{SD} <2.5µA, DFN Package
LTC3216	1A Low Noise High Current LED Charge Pump with Independent Flash/Torch Current Control	V_{IN}: 2.9V to 4.4V, $V_{OUT(MAX)}$ = 5.5V, I_Q = 300µA, I_{SD} <2.5µA, DFN Package
LTC3217	600mA Low Noise Multi-LED Camera Light	V_{IN}: 2.9V to 4.4V, I_Q = 400µA, Four 100mA Outputs, QFN Package
LTC3440/LTC3441	600mA/1.2A I_{OUT}, 2MHz/1MHz, Synchronous Buck-Boost DC/DC Converter	V_{IN}: 2.4V to 5.5V, $V_{OUT(MAX)}$ = 5.25V, I_Q = 25µA/50µA, I_{SD} <1µA, MS/DFN Packages
LTC3443	600mA/1.2A I_{OUT}, 600kHz, Synchronous Buck-Boost DC/DC Converter	V_{IN}: 2.4V to 5.5V, $V_{OUT(MAX)}$ = 5.25V, I_Q = 28µA, I_{SD} <1µA, DFN Package
LTC3453	1MHz, 800mA Synchronous Buck-Boost High Power LED Driver	$V_{IN(MIN)}$: 2.7V to 5.5V, $V_{IN(MAX)}$: 2.7V to 4.5V, I_Q = 2.5mA, I_{SD} <6µA, QFN Package
LT3467/LT3467A	1.1A (I_{SW}), 1.3/2.1MHz, High Efficiency Step-Up DC/DC Converters with Integrated Soft-Start	V_{IN}: 2.4V to 16V, $V_{OUT(MAX)}$ = 40V, I_Q = 1.2mA, I_{SD} <1µA, ThinSOT Package
LT3479	3A, 42V, 3.5MHz Boost Converter	V_{IN}: 2.5V to 24V, $V_{OUT(MAX)}$ = 40V, I_Q = 2µA, I_{SD} <1µA DFN, TSSOP Packages

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