CATALYST
SEMICONDUCTOR, INC.

CAT3604
4-Channel Regulated Charge Pump White LED Driver

HALOGEN FREE
LEAD FREE ™
RoHS Compliance

FEATURES

- **Drives individually up to 4 LEDs**
- **Output current up to 30mA per LED**
- **Digital control On/Off of each LED**
- **Compatible with supply voltage of 3V to 5.5V**
- **Power efficiency up to 93%**
- **2 modes of operation 1x and 1.5x**

- **Automatic short circuit detect/disable**
- **High-frequency Operation at 1MHz**
- **Low value ceramic capacitors**
- **"604" compatible pinout**
- **Soft start and current limiting**
- **Thin QFN 16-lead package, 4x4mm, 0.8mm max height**

APPLICATIONS

- **Color LCD and keypad Backlighting**
- **Cellular Phones**
- **Handheld Devices**

- **Digital Cameras**
- **PDAs**
- **Portable MP3 players**

DESCRIPTION

The CAT3604 is a charge pump operating in either 1x (LDO) mode or 1.5x fractional mode regulating current through each of the 4 LED pins. Operation at a fixed high frequency of 1MHz typical allows the use of very small value ceramic capacitors.

The CAT3604 drives white light-emitting diodes (LEDs) connected in parallel and provides tightly matched regulated current to achieve uniformity of brightness in LCD backlighting applications. An external resistor R_{SET} controls the output current level. LED currents of up to 30mA are supported over a range of input supply voltages from 3V to

5.5V, making the device ideal for battery-powered applications.

LED dimming can be accomplished by several methods including using a DC voltage to set the R_{SET} pin current, applying a PWM signal on the Control signals, or adding a switched resistor in parallel with R_{SET}. The Enable input pin allows the device to be placed in power-down mode with "zero" quiescent current.

The CAT3604 features short circuit and overcurrent limiting protection. The device is available in a 16-lead thin QFN package with a max height of 0.8mm.
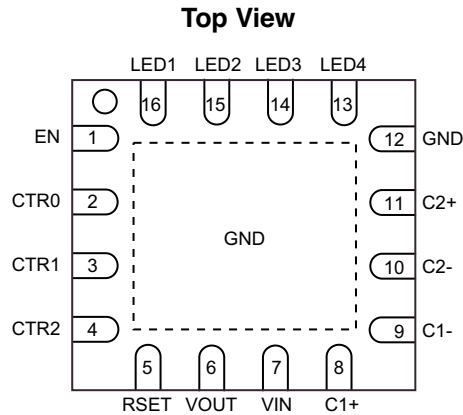
TYPICAL APPLICATION

Doc. No. 5008, Rev. I
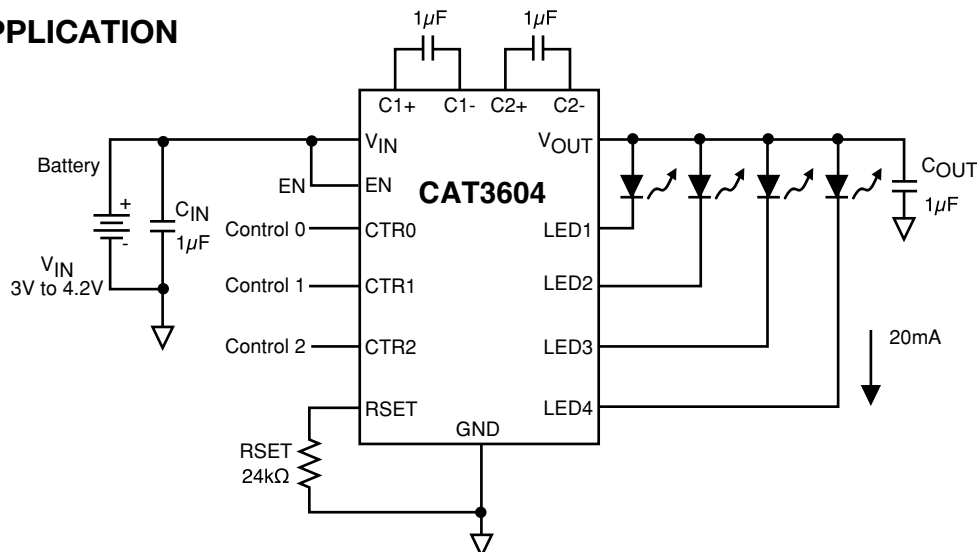
ORDERING INFORMATION

Part Number	Package	Quantity per Reel	Package Marking
CAT3604HS4-TE13	Thin QFN-16 4x4mm	2000	C364
CAT3604HV4-TE13	Thin QFN-16 4x4mm Lead Free	2000	G364

PIN CONFIGURATION

Top View

LED1 LED2 LED3 LED4

EN 1
CTR0 2
CTR1 3
CTR2 4

16 15 14 13

GND

12 GND
11 C2+
10 C2-
9 C1-

5 6 7 8
RSET VOUT VIN C1+

16-lead Thin QFN (4mm x 4mm)

Note: The package exposed pad is electrically connected inside the package to GND and to pin 12.

PIN DESCRIPTIONS

Pin Number	Name	Function
1	EN	Enable input, active HIGH
2	CTR0	Digital control input 0
3	CTR1	Digital control input 1
4	CTR2	Digital control input 2
5	RSET	The LED output current is set by the current sourced out of the RSET pin
6	VOUT	Charge pump output connected to the LED anodes
7	VIN	Supply voltage
8	C1+	Bucket capacitor 1 terminal
9	C1-	Bucket capacitor 1 terminal
10	C2-	Bucket capacitor 2 terminal
11	C2+	Bucket capacitor 2 terminal
12	GND	Ground reference
13	LED4	LED 4 cathode terminal
14	LED3	LED 3 cathode terminal
15	LED2	LED 2 cathode terminal
16	LED1	LED 1 cathode terminal
Pad	GND Pad	Ground reference

ABSOLUTE MAXIMUM RATINGS

Parameter	Rating	Unit
VIN, VOUT, LEDx voltage	-0.3 to 7.0	V
EN, CTRx voltage	-0.3 to VIN	V
RSET voltage	-0.3 to VIN	V
RSET current	±1	mA
Ambient Temperature Range	-40 to +85	°C
Storage Temperature Range	-65 to +160	°C
Lead Temperature	300	°C

ESD Ratings
  Human Body Model (HBM)
  Machine Model (MM) (note 1)
	2000
	200
		V
		V

Note 1:   Machine model is with 200pF capacitor discharged directly into each pin.

RECOMMENDED OPERATING CONDITIONS

Parameter	Rating	Unit
VIN	3.0 to 5.5	V
Ambient Temperature Range	-40 to +85	°C
Input/Output/Bucket Capacitors	1 ±20% typical	µF
I_{LED} per LED pin	0 to 30	mA

ELECTRICAL OPERATING CHARACTERISTICS

Limits over recommended operating conditions unless specified otherwise. Typical values at T_A = 25°C, VIN = 3.5V, I_{RSET} = 5µA

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_Q	Quiescent Current	V_{EN} = 0V Shutdown Mode 1x Mode, No Load 1.5x Mode, No Load		0.05 0.3 2.6	1 1 5	µA mA mA
V_{RSET}	RSET Regulated Voltage		1.17	1.2	1.23	V
I_{LED}	Programmed LED Current	I_{RSET} = 5µA I_{RSET} = 37µA I_{RSET} = 78µA		2.4 15.0 30.0		mA mA mA
$I_{LED-ACC}$	LED Current Accuracy	0.5mA < I_{LED} < 3mA 3mA < I_{LED} < 30mA		±15 ±5		% %
$I_{LED-DEV}$	LED Channel Matching	$(I_{LED} - I_{LEDAVG}) / I_{LEDAVG}$		±3		%
R_{OUT}	Output Resistance (Open Loop)	1x Mode 1.5x Mode, I_{OUT} = 100mA		1.4 6.5	2.5 10	Ω Ω
f_{OSC}	Charge Pump Frequency		0.8	1.0	1.3	MHz
$T_{DROPOUT}$	1x to 1.5x Mode Transition Dropout Delay		0.4	0.6	0.9	ms
I_{EN-CTR}	Input Leakage Current	On Inputs EN, CTR0, 1 & 2		0.001	1	µA
V_{EN-CTR}	High Detect Threshold Low Detect Threshold	On Inputs EN, CTR0, 1 & 2	 0.4	0.8 0.7	1.3	V V
I_{SC}	Input Current Limit	VOUT = GND	30	45	60	mA
I_{LIM}	Maximum Input Current	VOUT > 1V	200	400	600	mA

BLOCK DIAGRAM

Figure 1: CAT3604 Functional Block Diagram

BASIC OPERATION

At power-up, the CAT3604 starts operation in 1x mode. If it is able to drive the programmed LED current, it continues in 1x mode. If the battery voltage drops to a level where the LED current cannot be met, the driver automatically switches into 1.5x mode. The 1.5x charge pump will boost the output voltage accordingly to achieve the nominal LED current.

The operating mode is reinitialized each and every time the chip is powered up or is taken out of shutdown mode (via EN pin). The use of the control pins (CTR0, CTR1, CTR2) does not reconfigure the mode of operation.

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LED CURRENT SETTING

The LED current is set by the external resistor R_{SET} connected between the RSET pin and ground. Table 1 lists various LED currents and the associated R_{SET} resistor value for standard 1% precision surface mount resistors.

LED Current (mA)	R_{SET} (kΩ)
1	649
2	287
5	102
10	49.9
15	32.4
20	23.7
30	15.4

Table 1. RSET Resistor Selection

The digital control lines CTR0, CTR1 adn CTR2 allow to turn On or Off a combition of LEDs as shown in Table 2.

SHORT CIRCUIT DETECT/DISABLE

The unused LED channels can also be turned off by connecting the respective LED pins to VOUT. In which case, the corresponding LED driver is disabled and the typical LED sink current is only about 20μA. When the following equation is true on any channel, the driver turns off the LED channel:

$$VOUT - V_{LED} \leq 1V \text{ (LED channel OFF)}$$

Note: The CAT3604 is designed to drive LEDs with forward voltage greater than 1V and is not compatible with resistive loads.

Control Lines			LED Outputs			
CTR2	CTR1	CTR0	LED4	LED3	LED2	LED1
0	0	0	-	-	-	ON
0	0	1	-	-	ON	-
0	1	0	-	ON	-	-
0	1	1	ON	-	-	-
1	0	0	-	-	ON	ON
1	0	1	-	ON	ON	ON
1	1	0	ON	ON	ON	ON
1	1	1	-	-	-	-

Table 2: LED Selection

Notes: 1 = logic high (or VIN)
        0 = logic low (or GND)
        - = LED output OFF

TYPICAL CHARACTERISTICS

V_{IN} = 3.6V, EN = V_{IN}, C_{IN} = C_{OUT} = 1μF, R_{SET} = 24kΩ, T_{AMB} = 25°C, unless otherwise specified.

Efficiency vs. Input Voltage (4 LEDs)
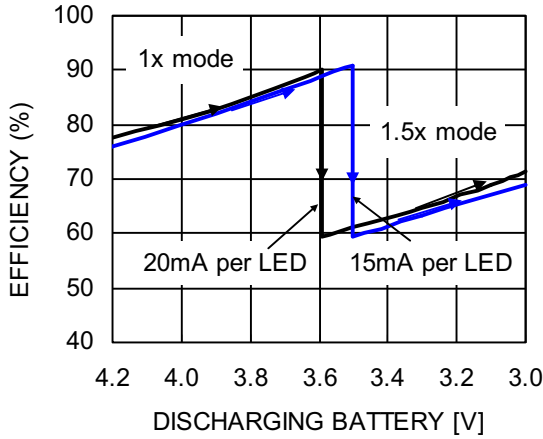
Efficiency vs. Total LED Current (4 LEDs)
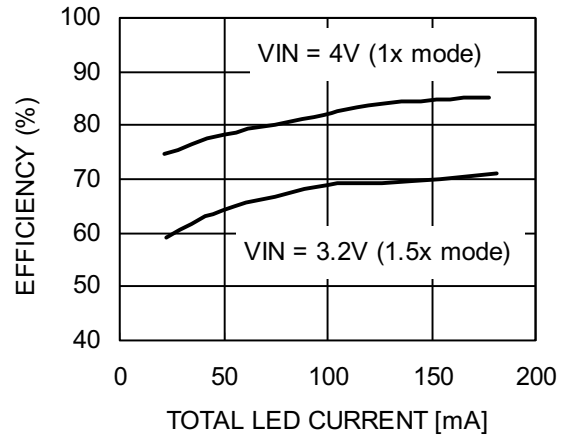
LED Current vs. Input Voltage
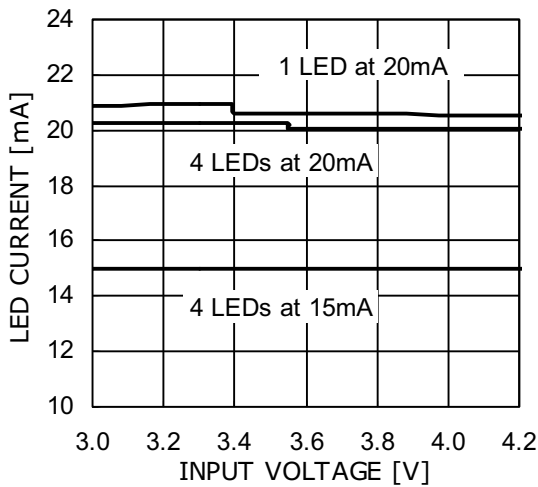
LED Current vs. Temperature
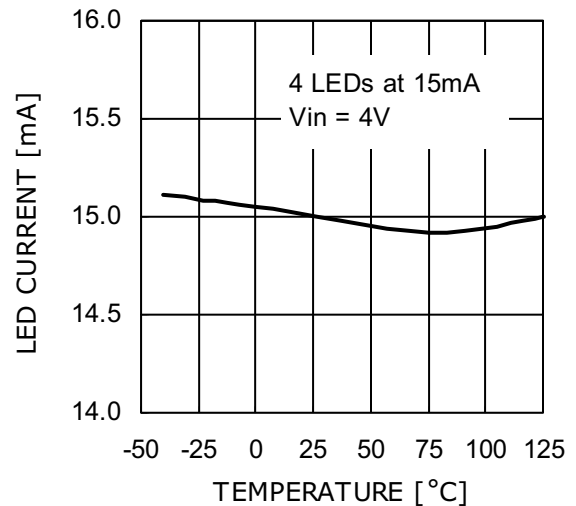
Ground Current vs. Input Voltage (1x mode)
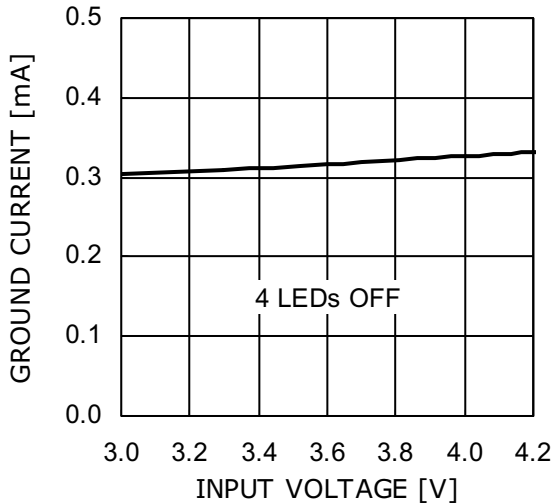
Ground Current vs. Temperature (1x mode)
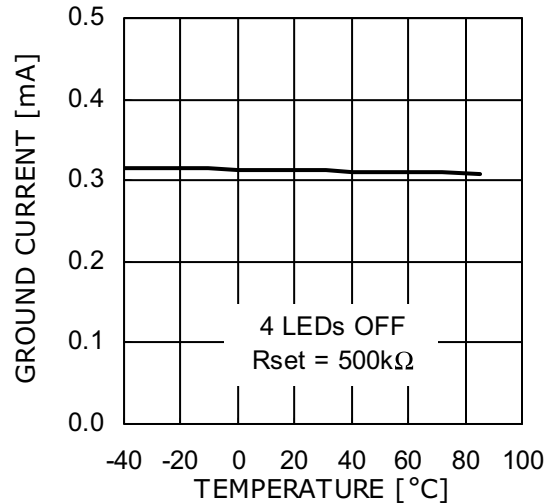
TYPICAL CHARACTERISTICS

V_{IN} = 3.6V, EN = V_{IN}, C_{IN} = C_{OUT} = 1µF, R_{SET} = 24kΩ, T_{AMB} = 25˚C, unless otherwise specified.

Ground Current vs. Input Voltage (1.5x mode)
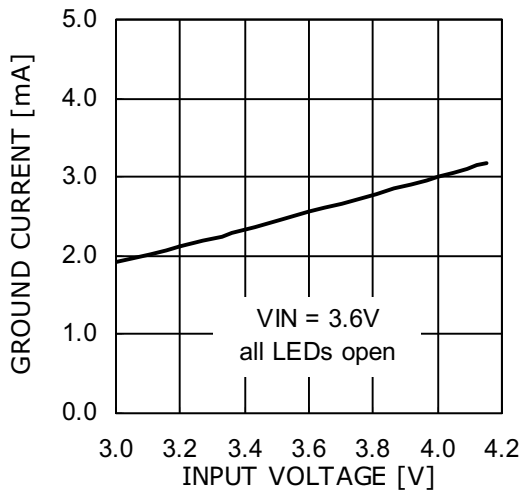
Supply Current vs. Input Voltage
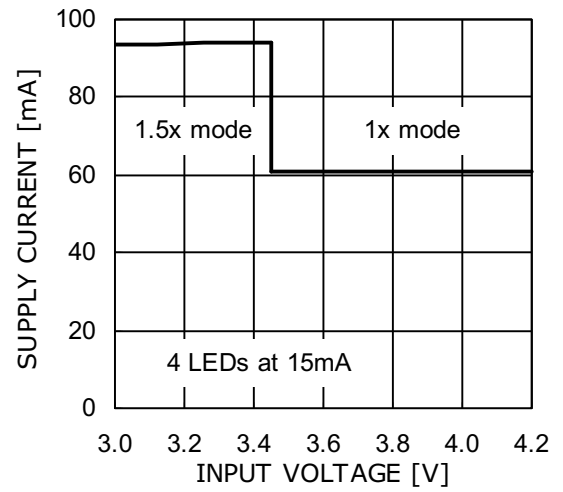
Oscillator Frequency vs. Input Voltage
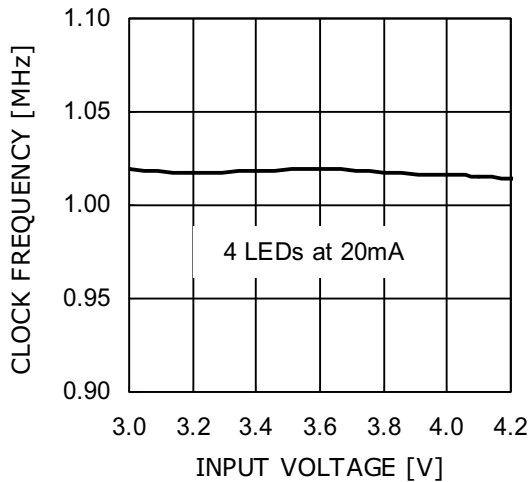
Oscillator Frequency vs. Temperature
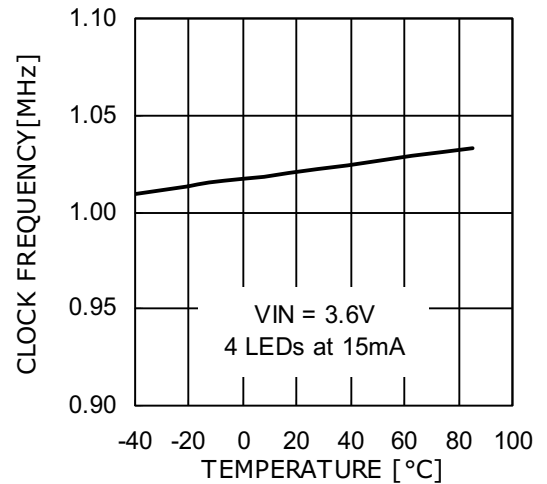
Output Resistance vs. Input Voltage (1x mode)
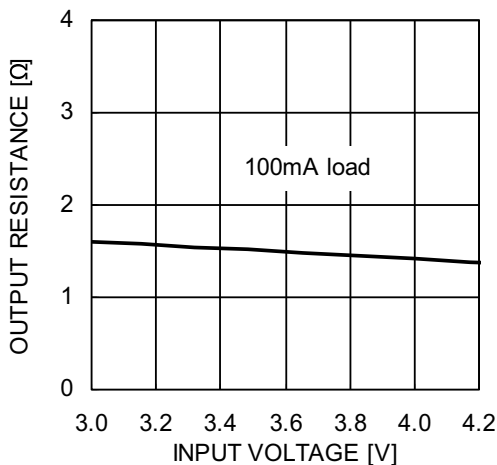
Output Resistance vs. Input Voltage (1.5x mode)
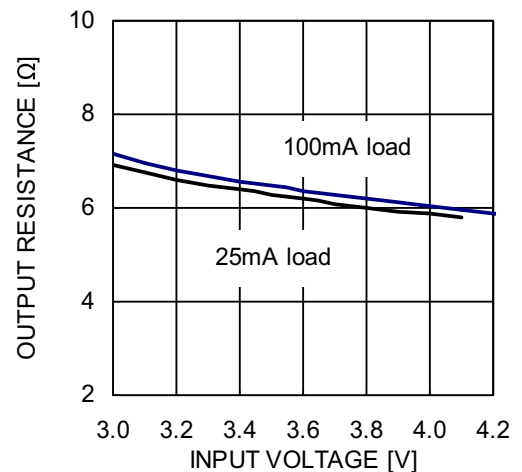
TYPICAL CHARACTERISTICS

V_{IN} = 3.6V, EN = V_{IN}, C_{IN} = C_{OUT} = 1µF, R_{SET} = 24kΩ, T_{AMB} = 25˚C, unless otherwise specified.

Switching Waveforms in 1.5x Mode
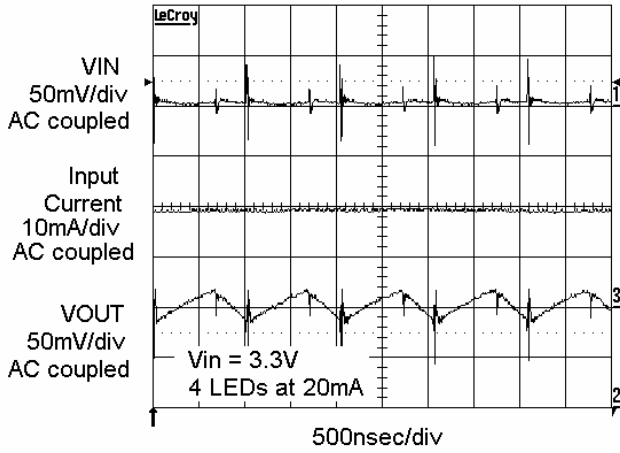
Operating Waveforms in 1x Mode
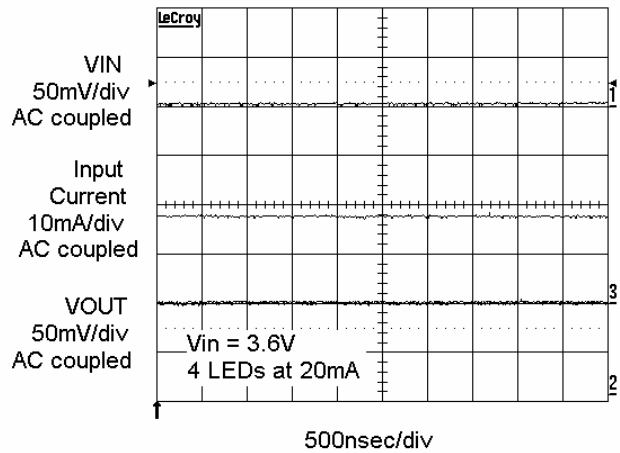
Power Up 4 LEDs at 15mA, Vin = 3V (1.5x Mode)
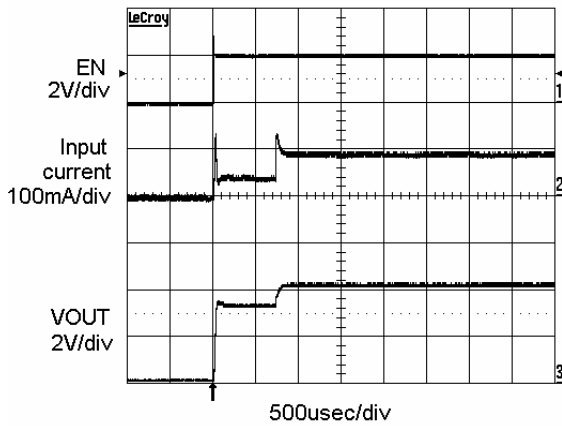
Power Up 4 LEDs at 15mA, Vin = 3.6V (1x Mode)
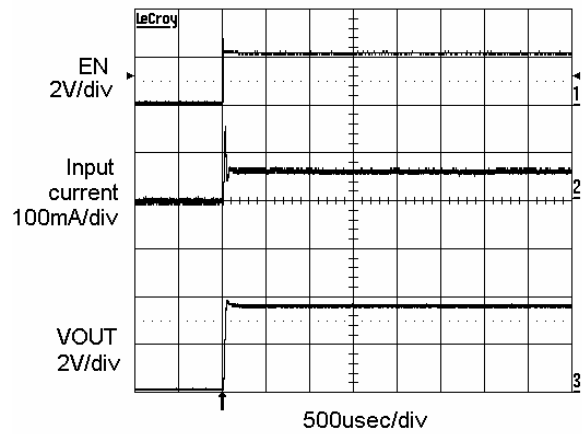
LED Current vs. R_{SET}
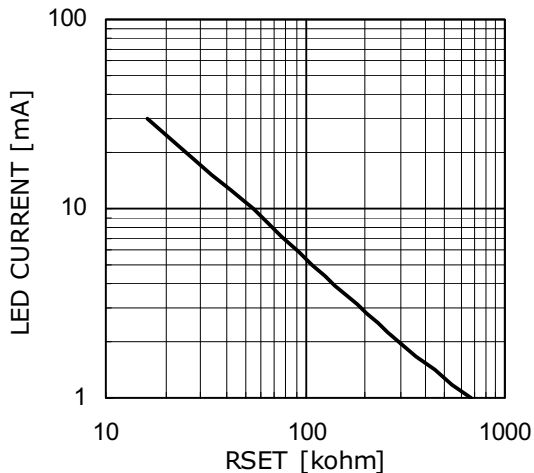
Line Transient Response in 1x Mode
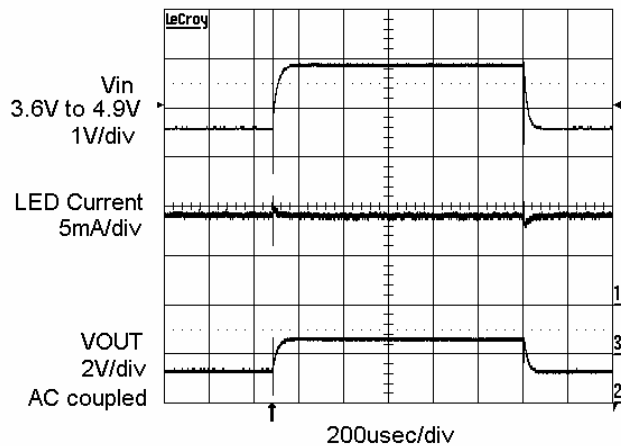
TYPICAL CHARACTERISTICS

V_{IN} = 3.6V, EN = V_{IN}, C_{IN} = C_{OUT} = 1µF, unless otherwise specified.

Foldback Current Limiting
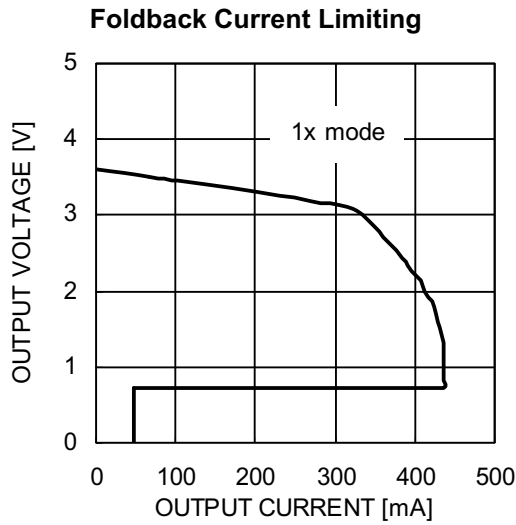
RECOMMENDED LAYOUT

When the driver is in the 1.5x charge pump mode, the 1MHz switching frequency operation requires to minimize trace length and impedance to ground on all 4 capacitors. A ground plane should cover the area on the bottom side of the PCB opposite to the IC and the bypass capacitors. Capacitors Cin and Cout require short connection to ground which can be done with multiple vias as shown on Figure 2. A square copper area matches the QFN16 exposed pad (GND) which is connected by a trace to the pin 12 pad (GND). A large via (metalized hole) centered in the square pad provides a low impedance connection to the ground plane on the opposite side of the PCB and allows the heat dissipated by the driver IC to spread out resulting in excellent thermal performance.
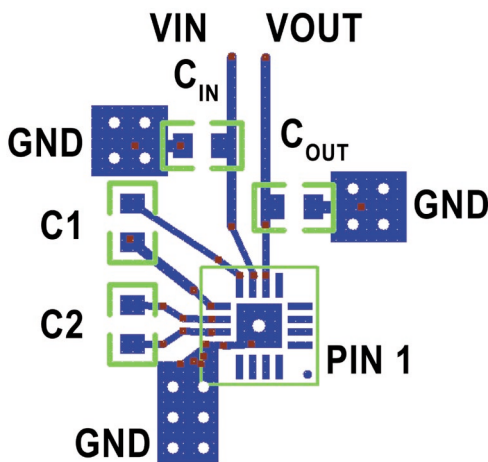
Figure 2: PCB Layout
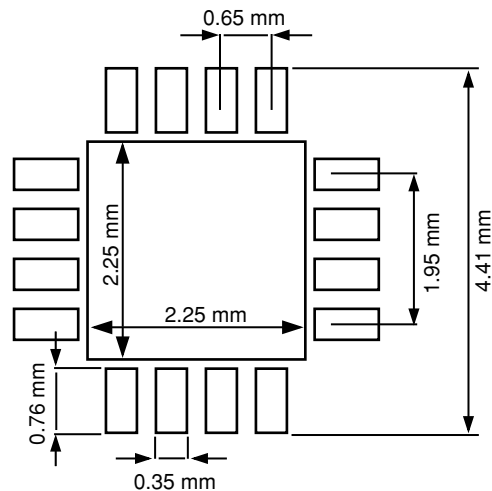
Figure 3: Recommended QFN 16 Package Land Pattern

PACKAGE DRAWING AND DIMENSIONS
THIN QFN 16-LEAD 4MM X 4MM

Recommended Land Pattern

0.65 mm

2.25 mm

2.25 mm

1.95 mm

4.41 mm

0.76 mm

0.35 mm

4.00±0.10 (S)

4.00±0.10 (S)

PIN 1
INDEX AREA

0.20 REF.

DAP SIZE 2.5 X 2.5

0.75±0.05

2.10±0.10

2.10±0.10

C0.35

0.55+0.10

0.30±0.05

0.65 TYP

1.95 REF. (2x)

0.0-0.05
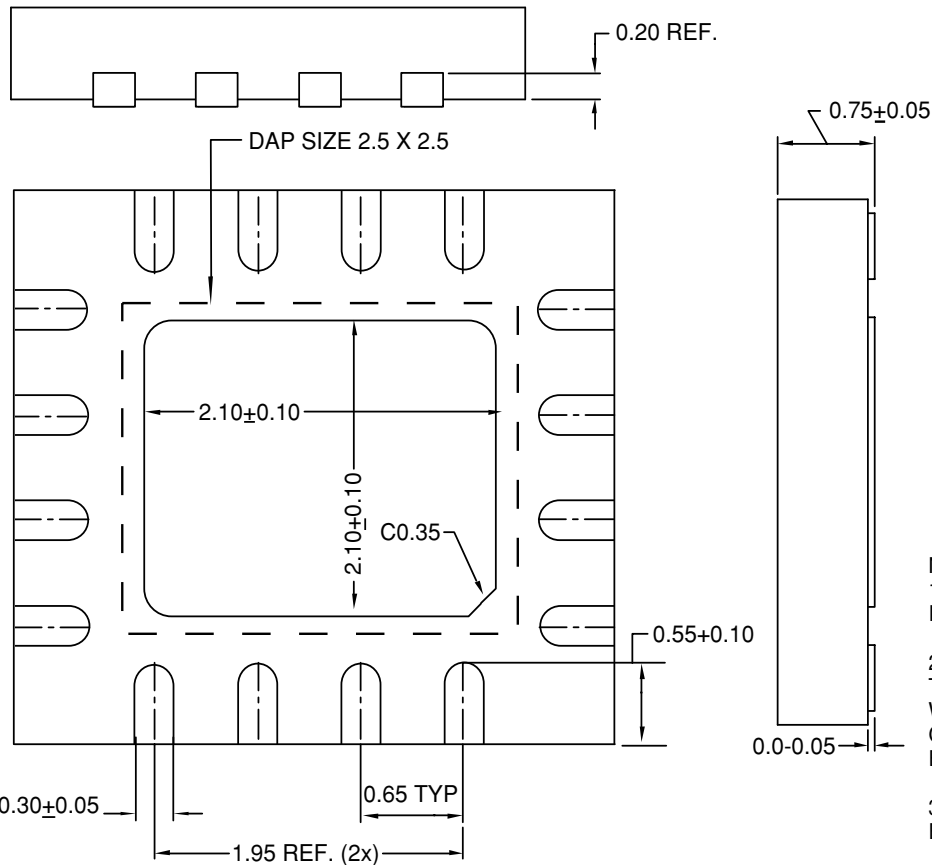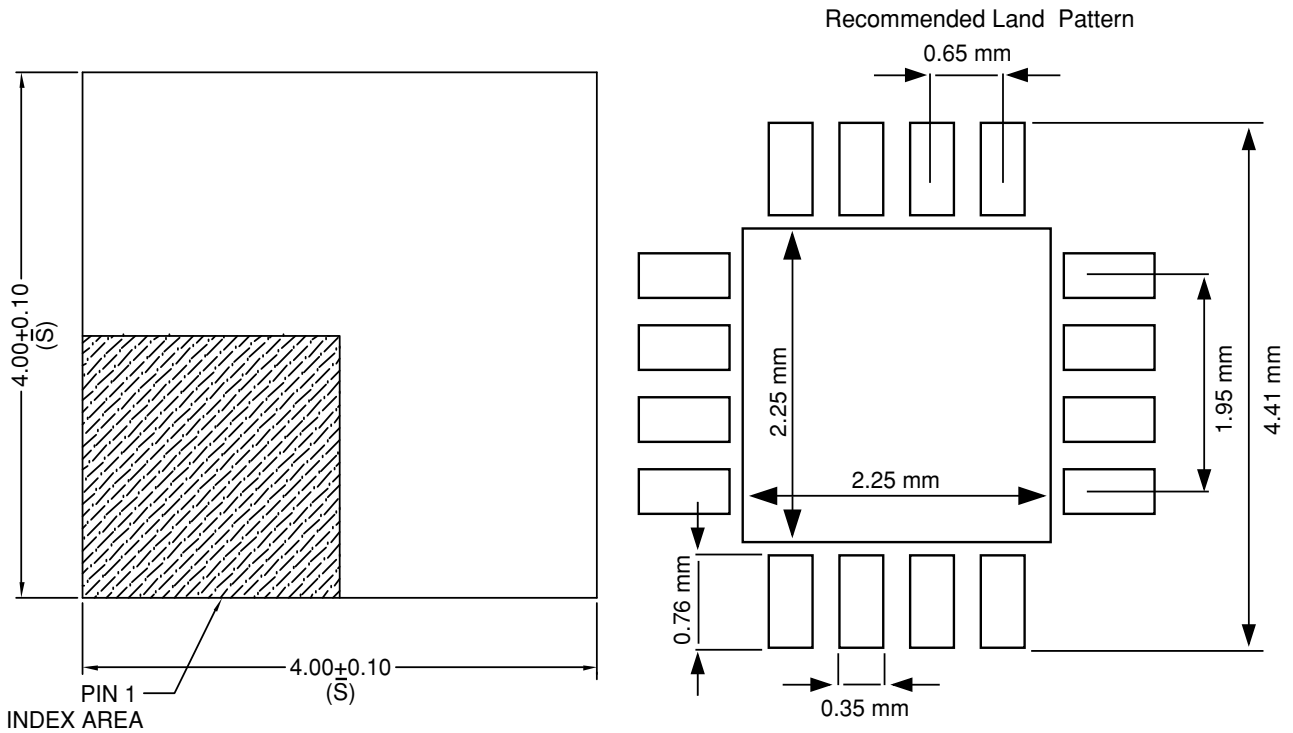
NOTE:
1. ALL DIMENSIONS ARE
IN mm. ANGLES IN DEGREES.

2. COPLANARITY APPLIES
TO THE EXPOSED PAD AS
WELL AS THE TERMINALS.
COPLANARITY SHALL NOT
EXCEED 0.08mm.

3. WARPAGE SHALL NOT
EXCEED 0.10mm.

4. PACKAGE LENGTH/PACKAGE
WIDTH ARE CONSIDERED AS
SPECIAL CHARACTERISTIC. (S)

REVISION HISTORY

Date	Rev.	Reason
8/19/2004	A	Initial issue
9/21/2004	B	Minor Changes
9/22/2004	C	Added Green package in all areas
9/29/2004	D	Minor Changes
1/4/2005	E	Added QFN land pattern (figure 3)
1/21/2005	F	Minor Changes
04/15/2005	G	Update Features Update Short Circuit Detect/Disable
06/06/2005	H	Update Ordering Information
07/15/2005	I	Update Basic Operation