CAT3606

6-Channel Low Noise Charge Pump White LED Driver

FEATURES

- Drives up to 4 main LEDs and 2 sub LEDs
- Separate control for main and sub LEDs
- Compatible with supply voltage of 3V to 5.5V
- Power efficiency up to 90%
- Output current up to 30mA per LED
- High-frequency Operation at 1MHz
- 2 modes of operation 1x and 1.5x
- White LED detect circuitry on all channels
- Shutdown current less than 1μA
- Small ceramic capacitors
- Soft start and current limiting
- Short circuit protection
- 16-lead thin QFN package, 0.8mm max height

APPLICATIONS

- Cell phone main and sub-display backlight
- Navigation
- PDAs
- Digital Cameras

DESCRIPTION

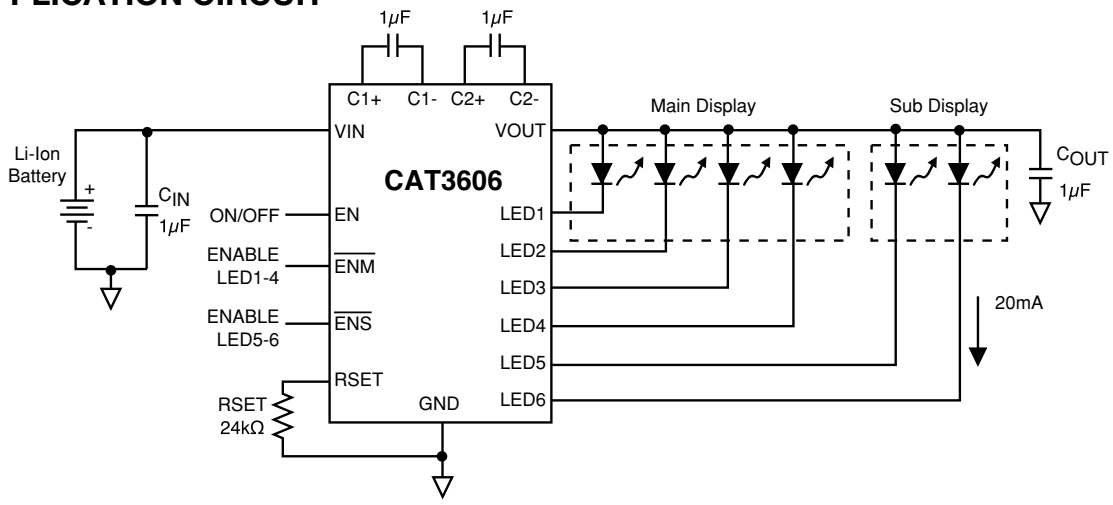
The CAT3606 controls up to four LEDs for the main display and two LEDs for the sub-display in cellular phones. The device is capable of operating in either 1x (LDO) mode or 1.5x charge pump mode. All LED pin currents are regulated and tightly matched to achieve uniformity of brightness across the LCD backlight. An external resistor (R_{SET}) sets the nominal output current.

The device can deliver as much as 20mA per channel during low voltage operation (3V), and 30mA per channel during nominal operation (3.3V). A constant high-frequency switching scheme (1MHz) provides low noise and allows the use of very small value ceramic capacitors.

A “zero” quiescent current mode can be achieved via the chip enable pin EN. The Main and Sub LEDs each have their own dedicated ON/OFF control pins ($\overline{ENM}$, $\overline{ENS}$). Dimming can be achieved using either a DC voltage to control the R_{SET} pin current, or by applying a PWM signal on the $\overline{ENM}$ and $\overline{ENS}$ pins.

The device is available in a 16-lead thin QFN package with a max height of 0.8mm.

TYPICAL APPLICATION CIRCUIT



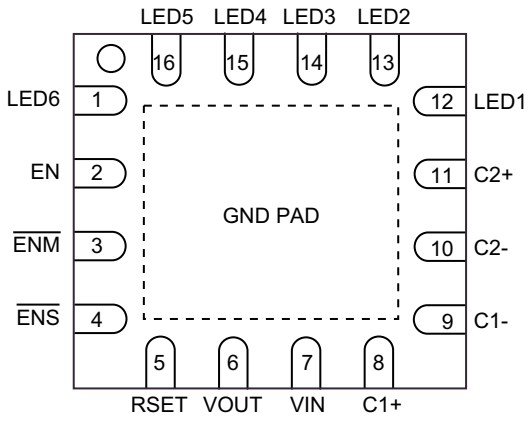
Doc. No. 5009, Rev. B

ORDERING INFORMATION

Part Number	Package	Quantity per Reel	Package Marking
CAT3606HS4	Thin QFN-16 4x4mm	2000	C366
CAT3606HV4	Thin QFN-16 4x4mm Lead Free	2000	G366

PIN CONFIGURATION

Top View



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

Note: The "exposed pad" under the package must be connected to the ground plane on the PCB.

PIN DESCRIPTIONS

Pin Number	Name	Function
1	LED6	LED6 cathode terminal
2	EN	Enable/shutdown input, active high
3	$\overline{ENM}$	Enable "main" input for LED1 to LED4, active low
4	$\overline{ENS}$	Enable "sub" input for LED5 and LED6, active low
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	LED1	LED 1 cathode terminal
13	LED2	LED 2 cathode terminal
14	LED3	LED 3 cathode terminal
15	LED4	LED 4 cathode terminal
16	LED5	LED 5 cathode terminal
PAD	GND	Ground reference

ABSOLUTE MAXIMUM RATINGS

Parameter	Rating	Unit
VIN, VOUT, LEDx voltage	-0.3 to 7.0	V
EN, $\overline{ENM}$, $\overline{ENS}$ 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
I_{OUT} Total Output Current	0 to 150	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 1x Mode, No Load 1.5x Mode, No Load		0.1 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}	LED Current Range with 6 LEDs	3.3 ≤ VIN ≤ 4.5 V 3.0 ≤ VIN ≤ 4.5 V			30 20	mA mA
I_{LED}	LED Current Range with 4 LEDs	3.0 ≤ VIN ≤ 4.5V			30	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, $\overline{ENM}$, $\overline{ENS}$			1	µA
V_{EN-CTR}	High Detect Threshold Low Detect Threshold	On Inputs EN, $\overline{ENM}$, $\overline{ENS}$	 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

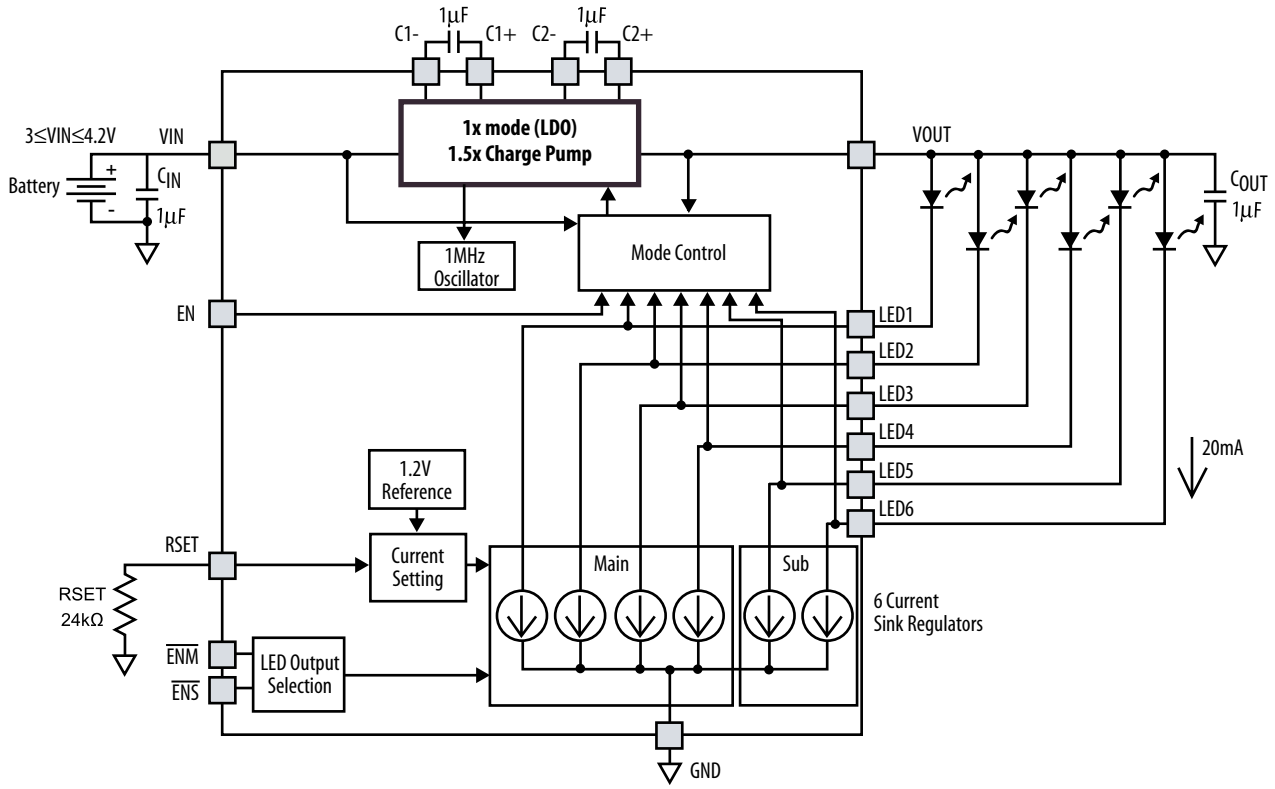


Figure 1: CAT3606 Functional Block Diagram

BASIC OPERATION

At power-up, the CAT3606 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, to boost the output voltage high enough to achieve the nominal LED current.

The above sequence 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 Main and Sub display enable pins ($\overline{ENM}$ or $\overline{ENS}$) does not affect the mode of operation.

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 enable lines $\overline{ENM}$ and $\overline{ENS}$ allow to turn On or Off a group of LEDs as shown in Table 2.

Control Lines			LED Outputs	
EN	$\overline{ENM}$	$\overline{ENS}$	Main LED1 - LED4	Sub LED5 - LED6
0	X	X	-	-
1	1	1	-	-
1	0	1	ON	-
1	1	0	-	ON
1	0	0	ON	ON

Table 2: LED Selection

Notes: 1 = logic high (or VIN)
0 = logic low (or GND)
- = LED output OFF
X = don't care

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 0.2mA. When the following equation is true on any channel, the driver turns off the LED channel:

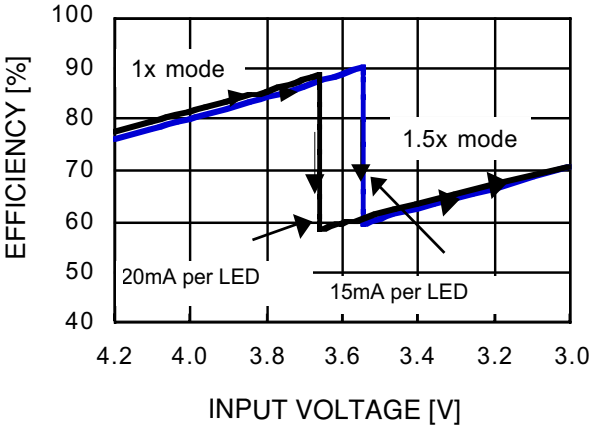
$$VOUT - V_{LED} \leq 1V \text{ (LED channel OFF)}$$

Note: The CAT3606 is designed to drive LEDs with forward voltage greater than 1V and is not compatible with resistive loads.

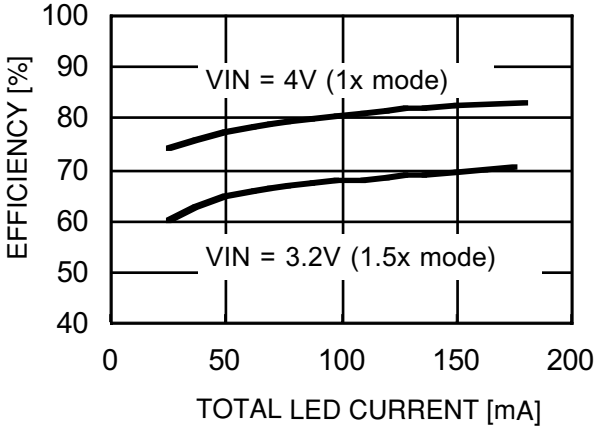
TYPICAL CHARACTERISTICS

VIN = 3.6V, EN = VIN, $\overline{ENM}$ = $\overline{ENS}$ = GND, C_{IN} = C_{OUT} = 1µF, R_{SET} = 24kΩ (20mA per LED), T_{AMB} = 25˚C, unless otherwise specified.

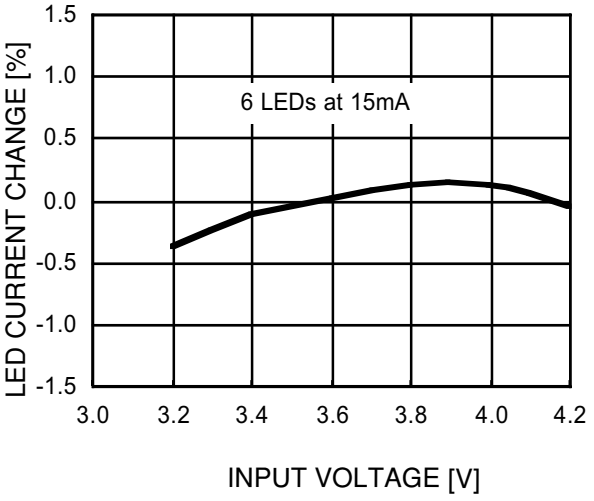
Efficiency vs. Input Voltage (6 LEDs)



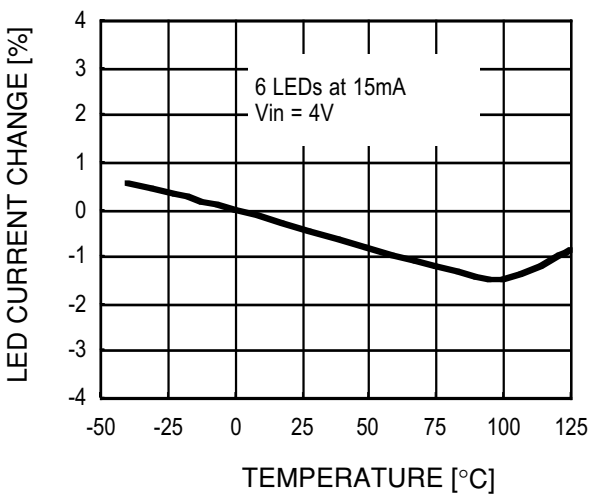
Efficiency vs. Total LED Current (6 LEDs)



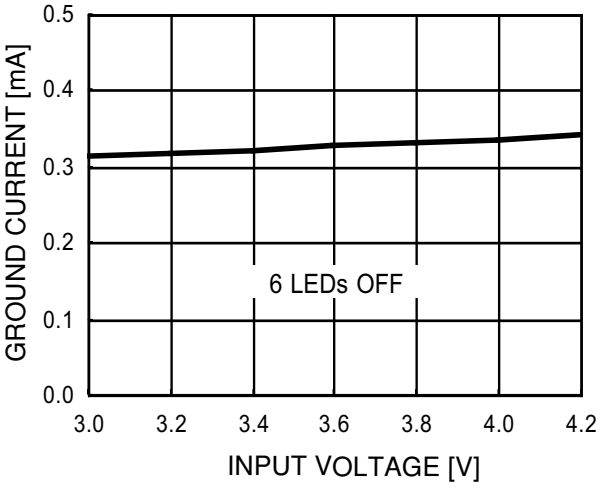
LED Current Change vs. Input Voltage



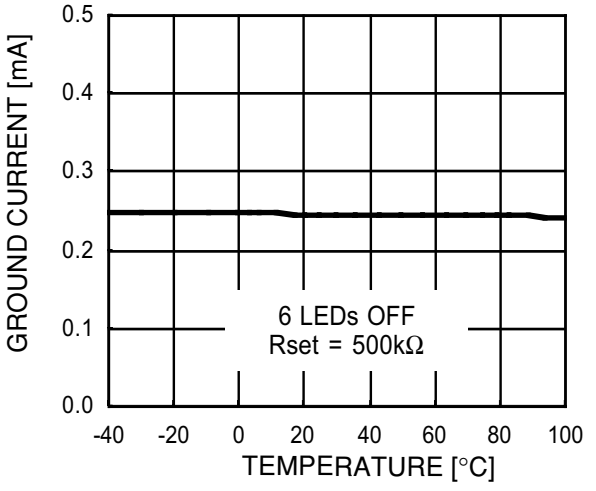
LED Current Change vs. Temperature



Ground Current vs. Input Voltage (1x mode)



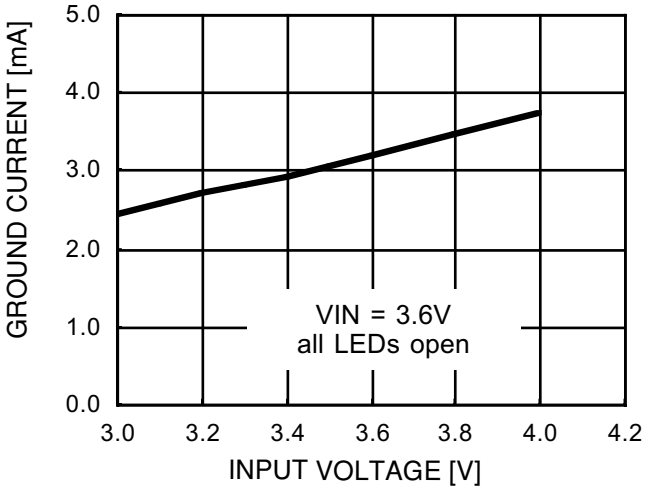
Ground Current vs. Temperature (1x mode)



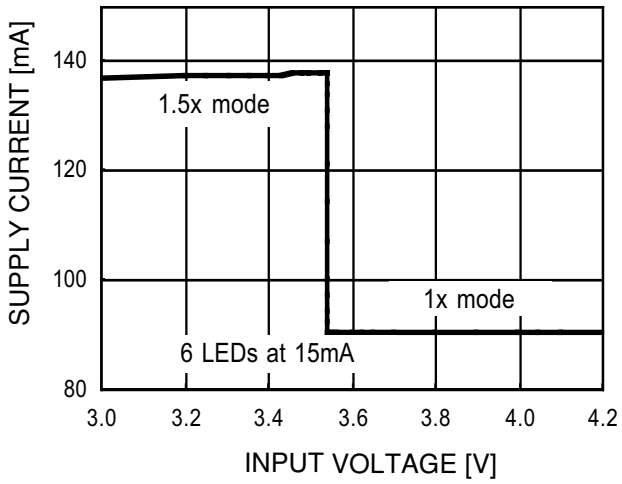
TYPICAL CHARACTERISTICS

VIN = 3.6V, EN = VIN, $\overline{ENM}$ = $\overline{ENS}$ = GND, C_{IN} = C_{OUT} = 1µF, R_{SET} = 24kΩ (20mA per LED), T_{AMB} = 25°C, unless otherwise specified.

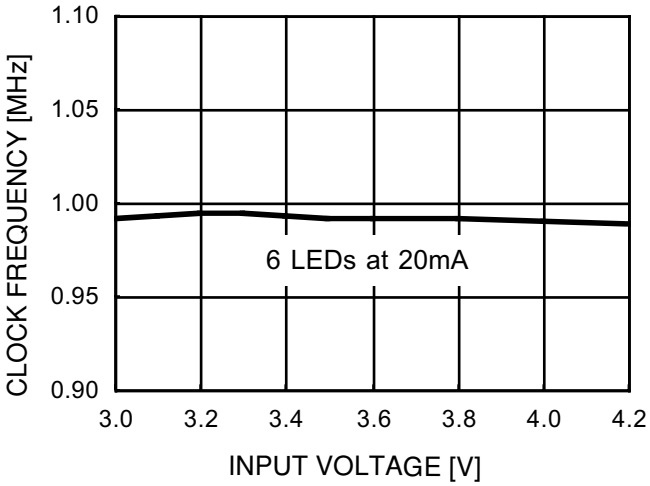
Ground Current vs. Input Voltage (1.5x mode)



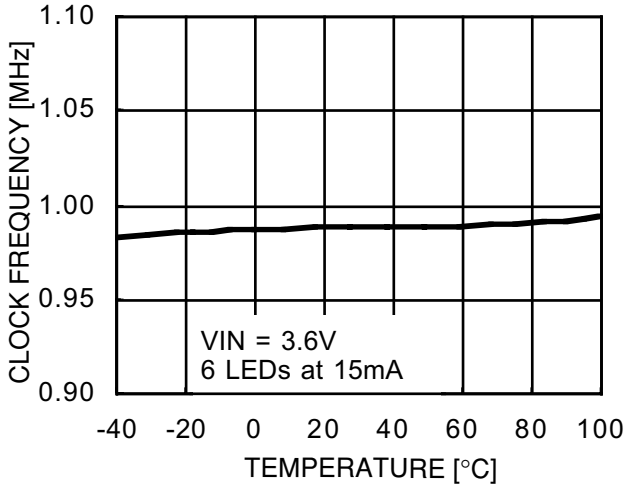
Supply Current vs. Input Voltage



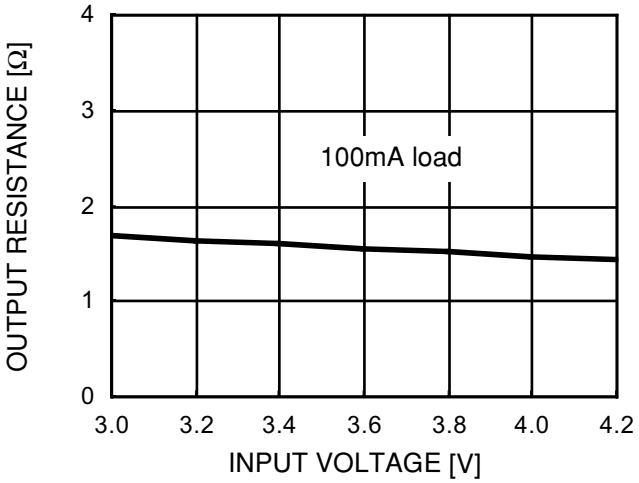
Oscillator Frequency vs. Input Voltage



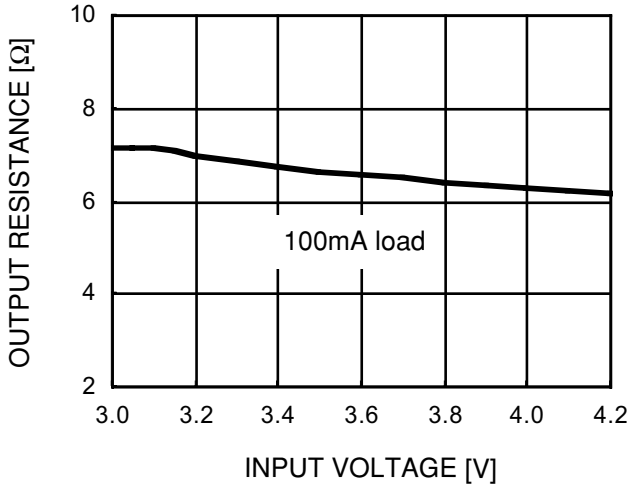
Oscillator Frequency vs. Temperature



Output Resistance vs. Input Voltage (1x mode)



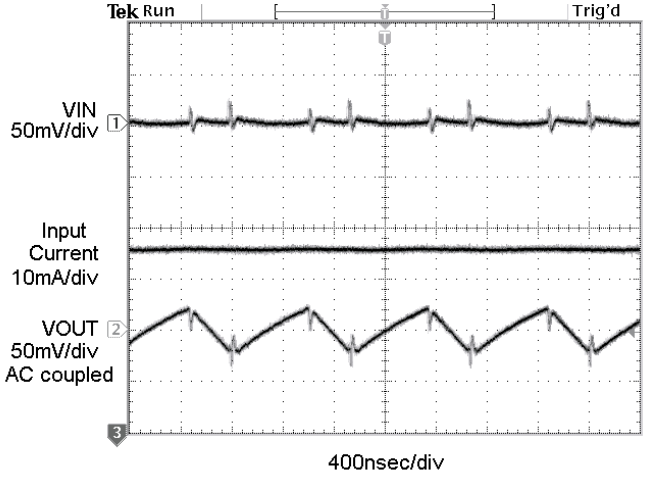
Output Resistance vs. Input Voltage (1.5x mode)



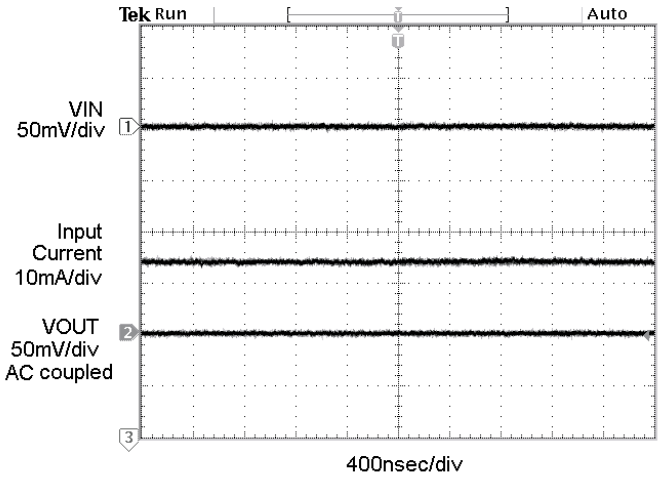
TYPICAL CHARACTERISTICS

VIN = 3.6V, EN = VIN, $\overline{ENM}$ = $\overline{ENS}$ = GND, C_{IN} = C_{OUT} = 1µF, R_{SET} = 24kΩ (20mA per LED), T_{AMB} = 25˚C, unless otherwise specified.

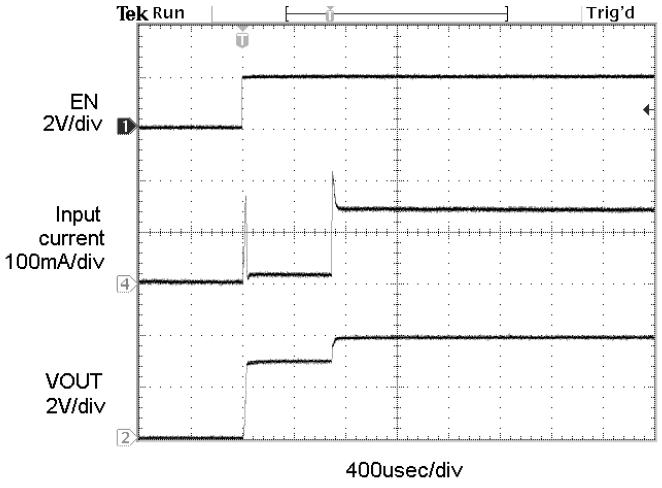
Switching Waveforms in 1.5x Mode



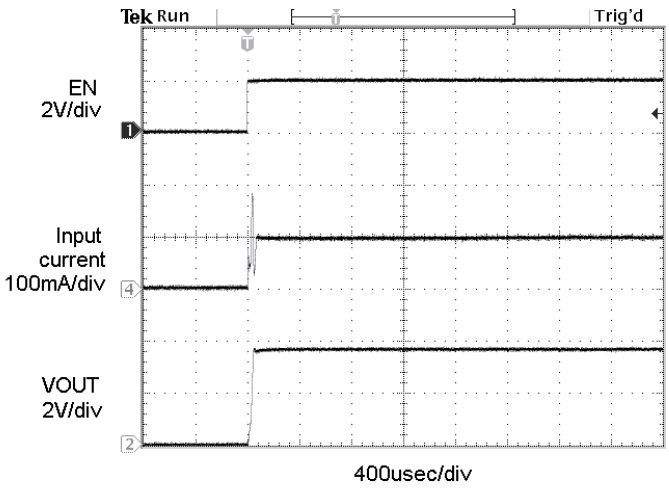
Operating Waveforms in 1x Mode



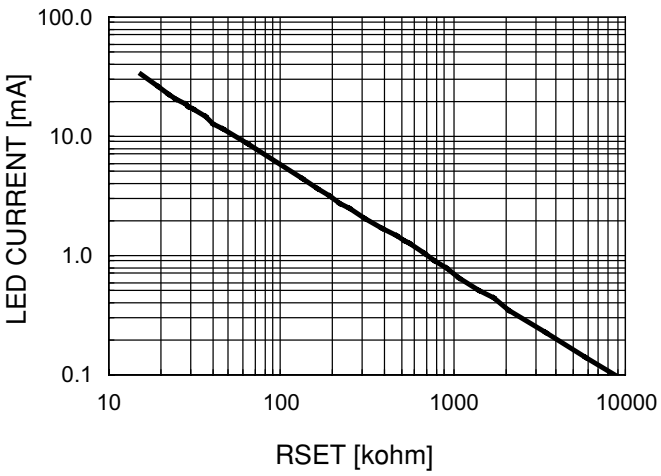
Power Up 6 LEDs at 15mA, VIN = 3V (1.5x Mode)



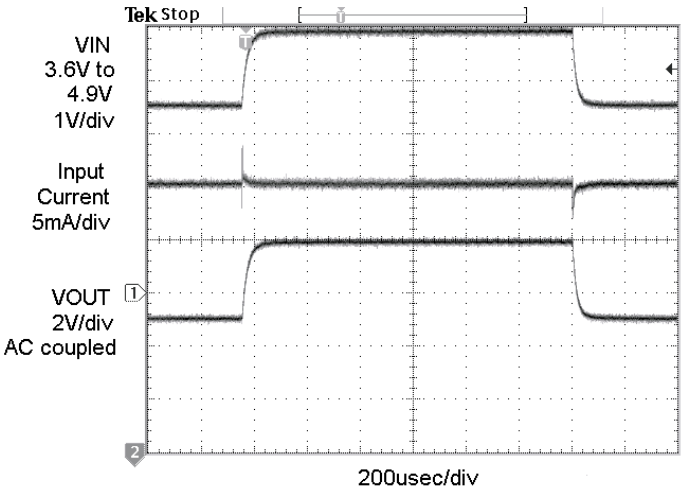
Power Up 6 LEDs at 15mA, VIN = 3.6V (1x Mode)



LED Current vs. R_{SET}



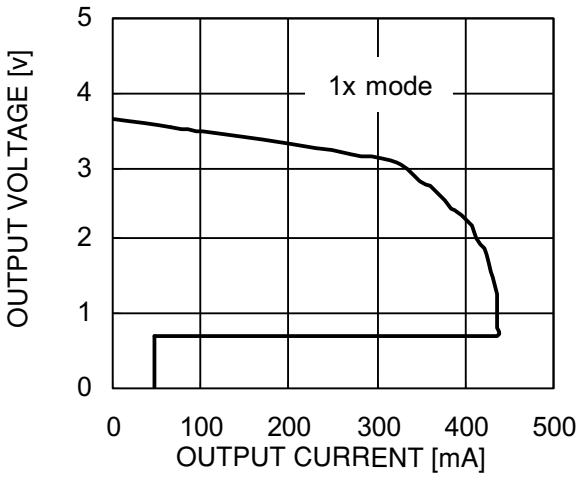
Line Transient Response in 1x Mode



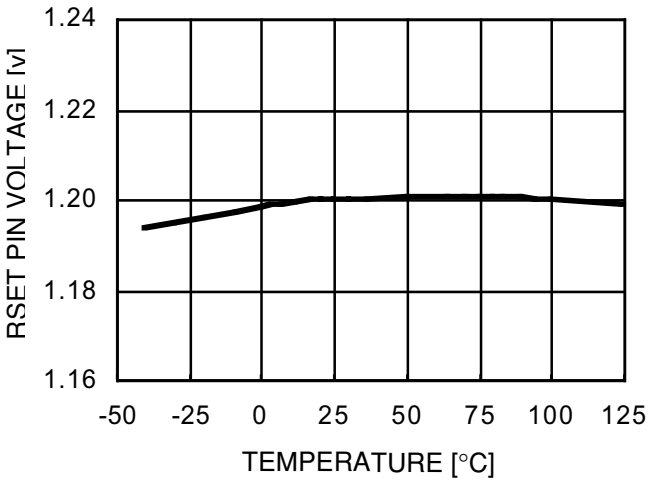
TYPICAL CHARACTERISTICS

VIN = 3.6V, EN = VIN, $\overline{ENM}$ = $\overline{ENS}$ = GND, C_{IN} = C_{OUT} = 1µF, T_{AMB} = 25˚C, unless otherwise specified.

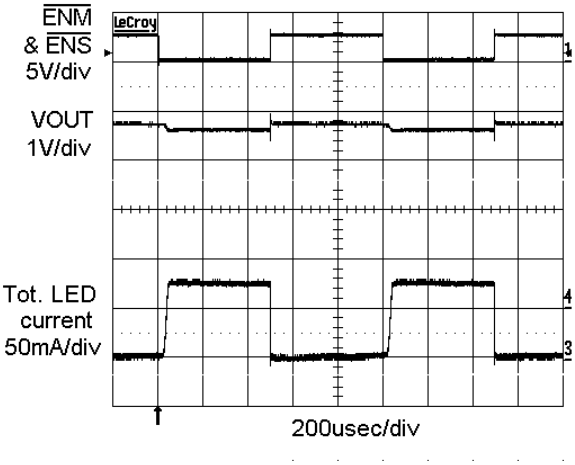
Foldback Current Limiting



RSET Pin Voltage vs. Temperature



PWM Dimming at 1kHz on $\overline{ENM}$ and $\overline{ENS}$



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) and must be connected to the ground plane underneath. The use of multiple via will improve the heat dissipation.

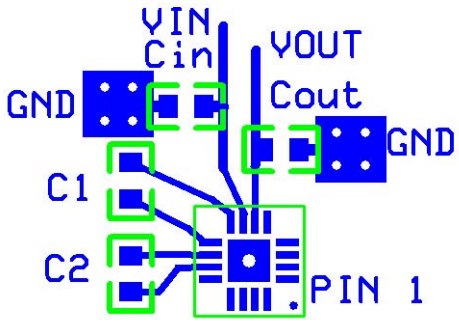
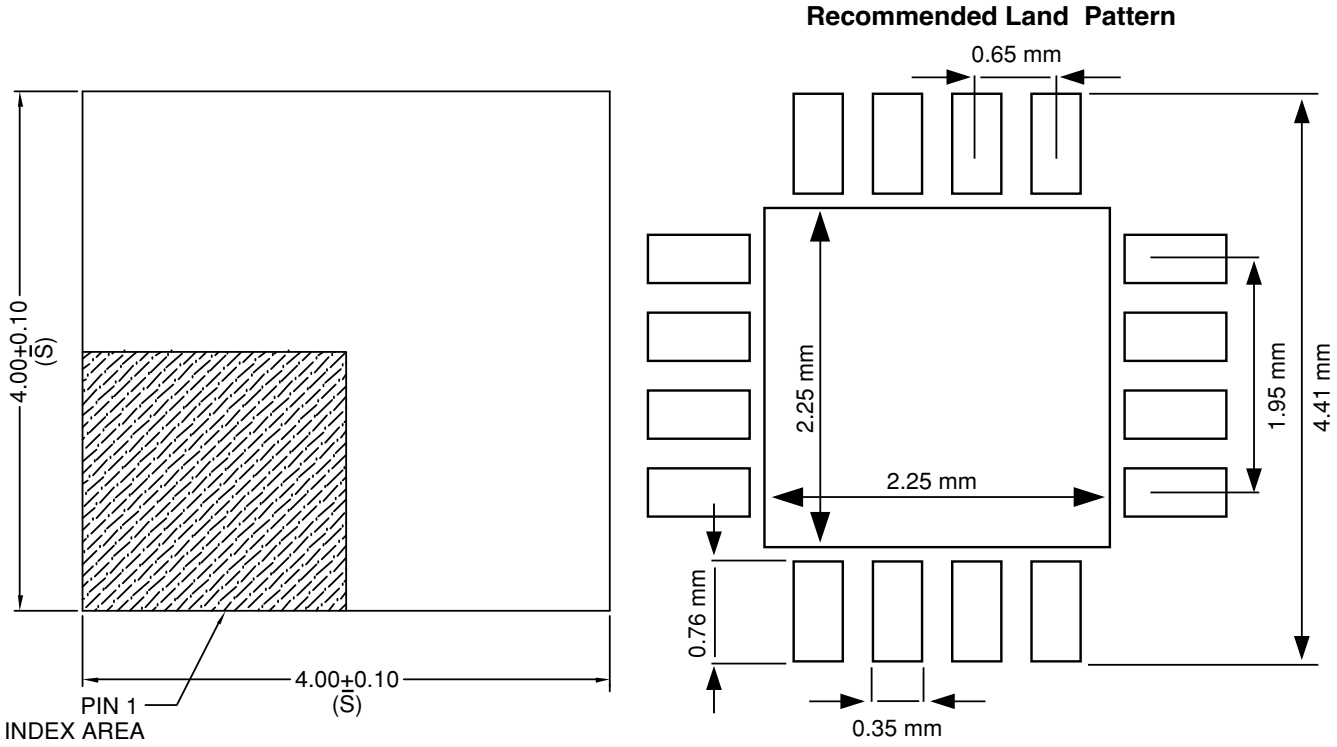
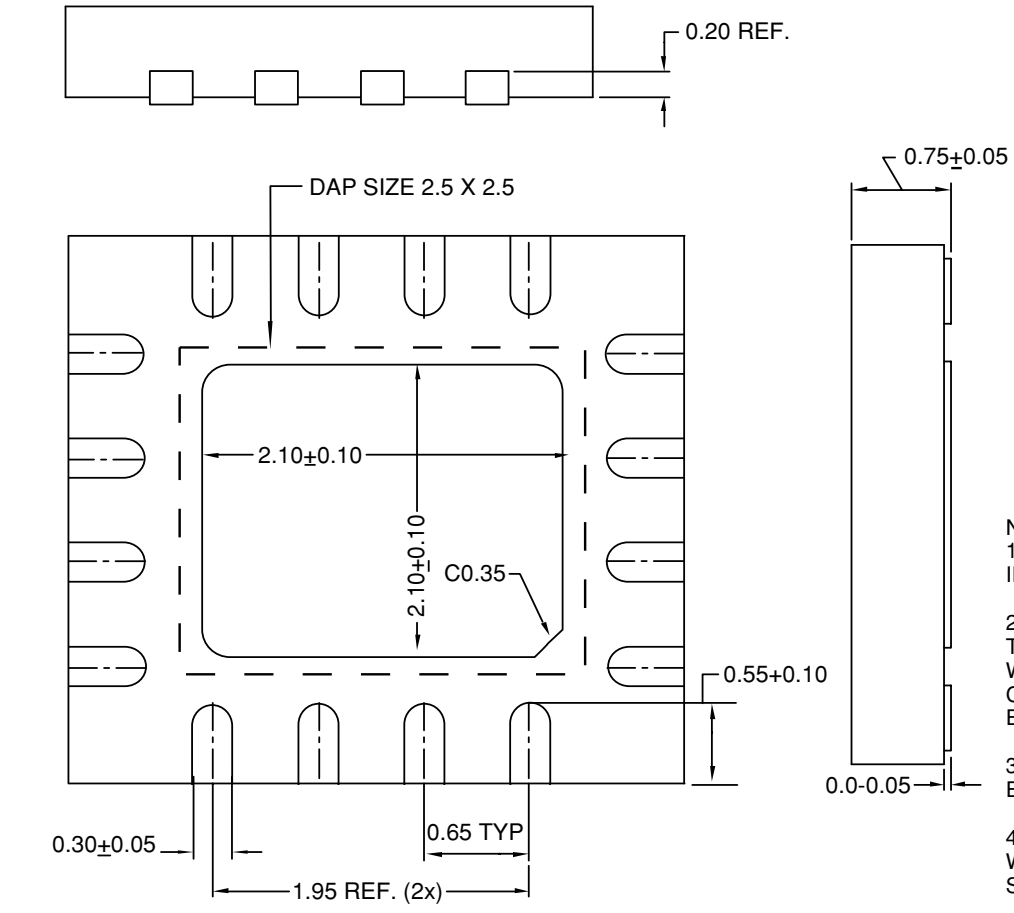


Figure 2: PCB Layout

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





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
1/21/2005	A	Initial issue
08/01/2005	B	Update LED Current Setting

Catalyst Semiconductor, Inc.
Corporate Headquarters
1250 Borregas Avenue
Sunnyvale, CA 94089
Phone: 408.542.1000
Fax: 408.542.1200
www.caalyst-semiconductor.com

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