CAT3637

6-Channel Programmable High Efficiency Quad-Mode™ LED Driver

FEATURES

- **High efficiency 1.33x charge pump**
- **Quad-Mode charge pump: 1x, 1.33x, 1.5x, 2x**
- **Drives 6 LEDs between 30mA and 0mA each**
- **1-wire EZDim™ interface with 2mA step**
- **Power efficiency up to 92%**
- **Low noise input ripple in all modes**
- **"Zero" current shutdown mode**
- **Soft start and current limiting**
- **Short circuit protection**
- **Thermal shutdown protection**
- **Tiny 3mm x 3mm, 16-pad TQFN package**

APPLICATIONS

- **LCD Display Backlight**
- **Cellular Phones**
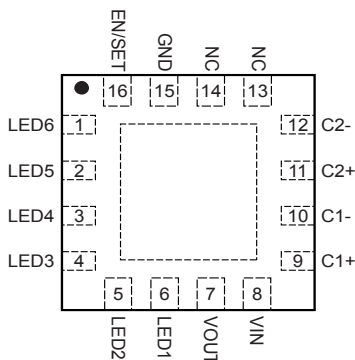- **Digital Still Cameras**
- **Handheld Devices**

ORDERING INFORMATION

Part Number	Quantity per Reel	Package Marking
CAT3637HV3-GT2	2000 [1]	JAAM

Note:

(1) NiPdAu Plated Finish (RoHS-compliant)
     16-lead TQFN 3mm x 3mm Package

DESCRIPTION

The CAT3637 is a high efficiency Quad-Mode fractional charge pump that can drive up to six LEDs programmable by a 1-wire digital interface. The inclusion of a 1.33x fractional charge pump mode increases device efficiency by up to 10% over traditional 1.5x charge pumps with no added external capacitors.

Low noise input ripple is achieved by operating at a constant switching frequency which allows the use of small external ceramic capacitors. The multi-fractional charge pump supports a wide range of input voltages from 2.5V to 5.5V.

The EN/SET logic input functions as a chip enable and a digital programming interface for setting the current in the LED channels. The 1-wire pulse-programming interface supports 15 linear steps from zero current to 30mA full-brightness in 2mA steps.

The device is available in a tiny 16-pad TQFN 3 x 3mm package with a maximum height of 0.8mm.

Catalyst Semiconductor's Quad-Mode 1.33x, charge pump switching architecture is patented.

For Ordering Information details, see page 13.

PIN CONFIGURATION

(top view)

TYPICAL APPLICATION CIRCUIT

1
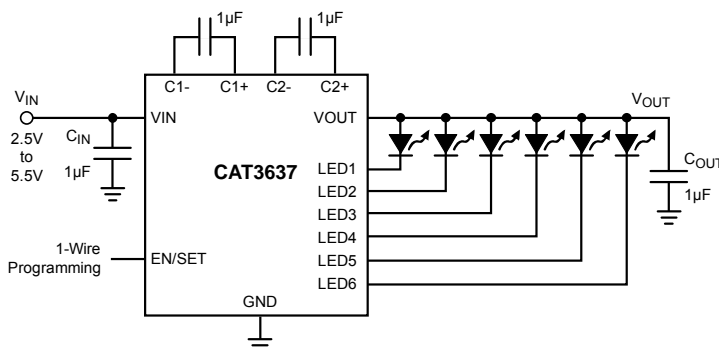
ABSOLUTE MAXIMUM RATINGS

Parameter	Rating	Unit
VIN, LEDx, C1±, C2± voltage	6	V
VOUT Voltage	7	V
EN/SET Voltage	VIN + 0.7V	V
Storage Temperature Range	–65 to +160	°C
Junction Temperature Range[(1)]	–40 to +150	°C
Lead Temperature	300	°C

RECOMMENDED OPERATING CONDITIONS

Parameter	Range	Unit
VIN	2.5 to 5.5	V
Ambient Temperature Range[(1)]	–40 to +85	°C
I_{LED} per LED pin	0 to 30	mA
Total Output Current	0 to 180	mA

ELECTRICAL OPERATING CHARACTERISTICS

(over recommended operating conditions unless specified otherwise) V_{IN} = 3.6V, EN = High, T_{AMB} = 25°C

Symbol	Name	Conditions	Min	Typ	Max	Units
I_Q	Quiescent Current	1x mode, V_{IN} = 4.2V 1.33 x mode, V_{IN} = 3.3V 1.5x mode, V_{IN} = 2.8V 2x mode, V_{IN} = 2.5V		1.5 2.8 3.7 3.8		mA mA mA mA
I_{QSHDN}	Shutdown Current	V_{EN} = 0V			1	µA
$I_{LED-ACC}$	LED Current Accuracy	2mA ≤ I_{LED} ≤ 30mA		±3		%
$I_{LED-DEV}$	LED Channel Matching	$\dfrac{I_{LED} - I_{LEDAVG}}{I_{LED}}$		±1		%
R_{OUT}	Output Resistance (open loop)	1x mode, I_{OUT} = 120mA 1.33x mode, I_{OUT} = 120mA 1.5x mode, I_{OUT} = 120mA 2x mode, I_{OUT} = 120mA		0.5 3.5 3.5 6		Ω Ω Ω Ω
F_{OSC}	Charge Pump Frequency	1.33x and 2x mode 1.5x mode	0.6 0.8	0.8 1.1	1.1 1.4	MHz MHz
I_{SC_MAX}	Output short circuit Current Limit	V_{OUT} < 0.5V		80		mA
LED_{TH}	1x to 1.33x or 1.33x to 1.5x or 1.5x to 2x Transition Thresholds at any LEDx pin			150		mV
V_{HYS}	1.33x to 1x Transition Hysteresis	V_{IN} - Highest LED V_F		400		mV
T_{DF}	Mode Transition Filter Delay			120		µs
I_{IN_MAX}	Input Current Limit	V_{OUT} > 1V		450		mA
$R_{EN/DIM}$ V_{HI} V_{LO}	EN/DIM Pin • Internal Pull-down Resistor • Logic High Level • Logic Low Level		 1.3	100	 0.4	kΩ V V
T_{SD}	Thermal Shutdown			150		°C
T_{HYS}	Thermal Hysteresis			20		°C
V_{UVLO}	Undervoltage lockout (UVLO) threshold			2		V

Typical application circuit with external components is shown on page 1.

Notes:
(1) Package thermal resistance is below 50°C/W when mounted on FR4 board.

RECOMMENDED EN/SET TIMING

For $2.5 \leq V_{IN} \leq 5.5V$, over full ambient temperature range -40º to +85ºC.

Symbol	Name	Conditions	Min	Typ	Max	Units
T_{LO}	EN/SET program low time		0.2		100	µs
T_{HI}	EN/SET program high time		0.2			µs
T_{OFF}	EN/SET low time to shutdown		1.5			ms
T_D	LED current settling time			10		µs
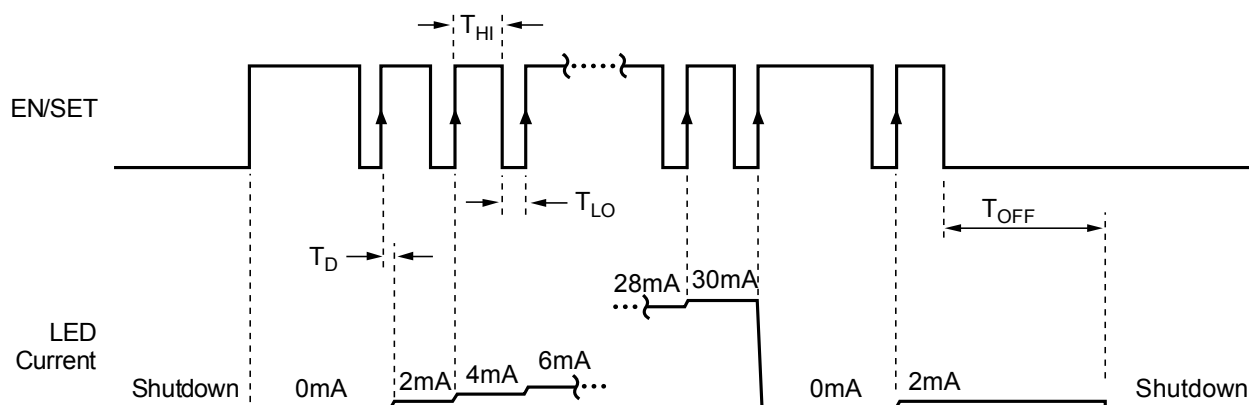
Figure 1. EN/SET One Wire Addressable Timing Diagram

TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 3.6V, I_{OUT} = 120mA (6 LEDs at 20mA), C_{IN} = C_{OUT} = C_1 = C_2 = 1μF, T_{AMB} = 25°C unless otherwise specified.

Efficiency vs. Input Voltage
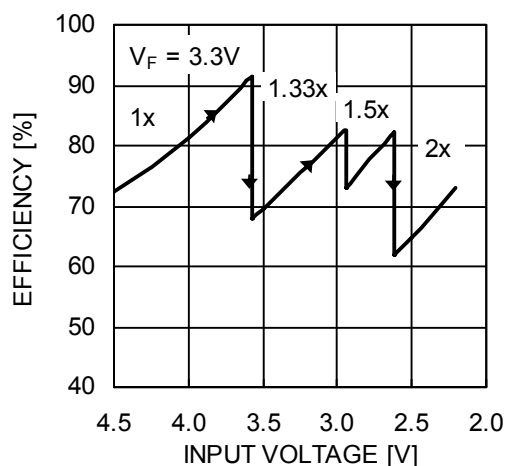
Efficiency vs. Li-Ion Voltage
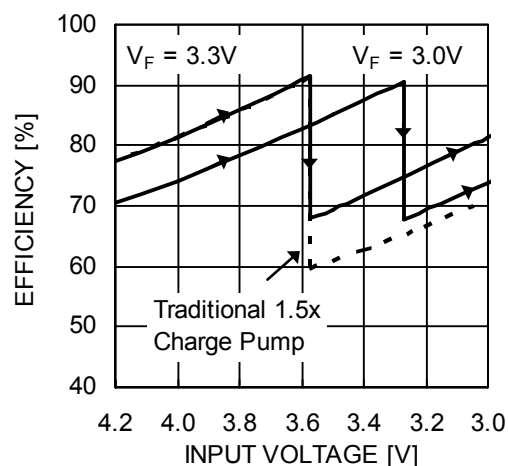
LED Current Change vs. Input Voltage
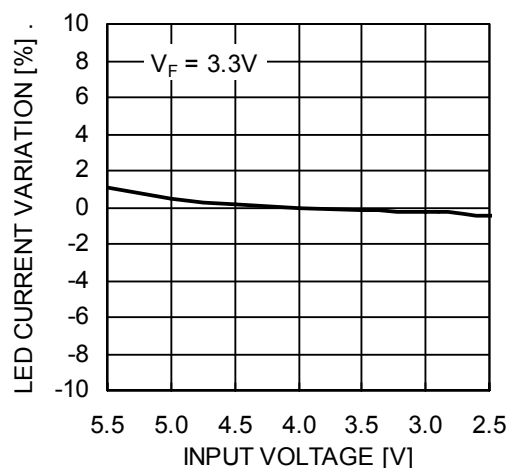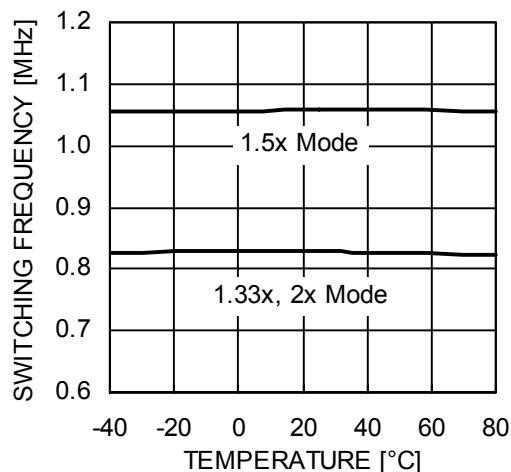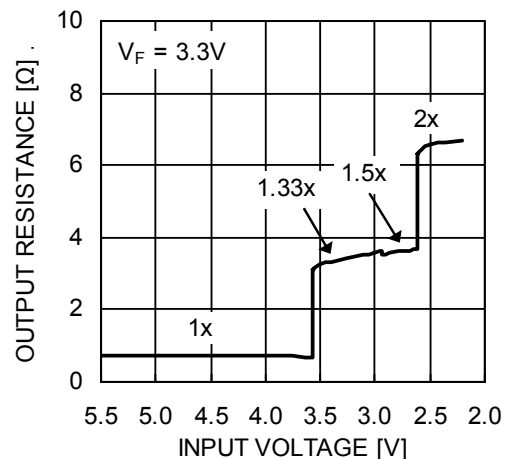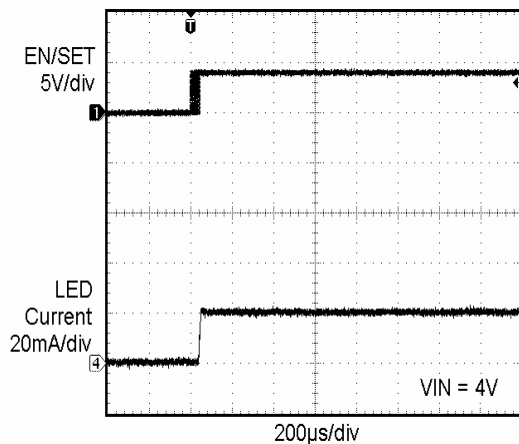
LED Current Change vs. Temperature
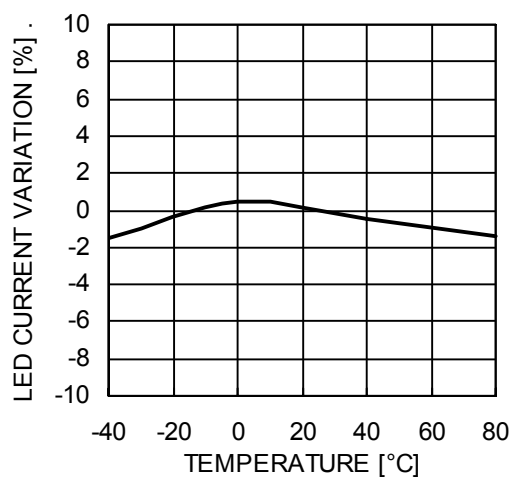
Quiescent Current vs. Input Voltage
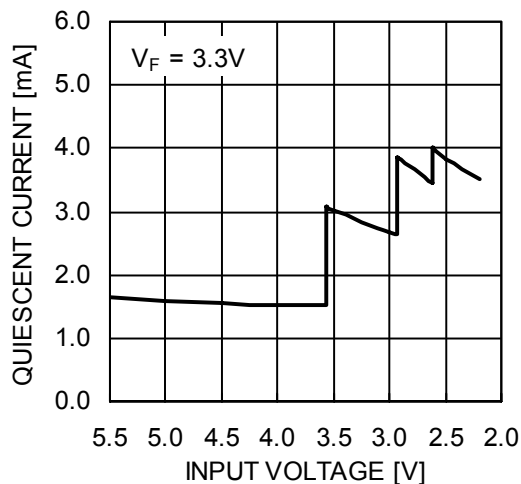
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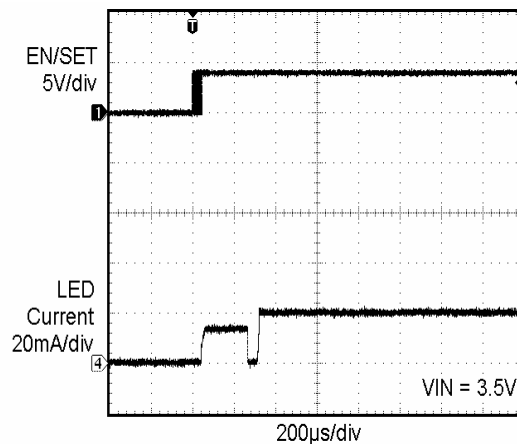
Switching Frequency vs. Temperature
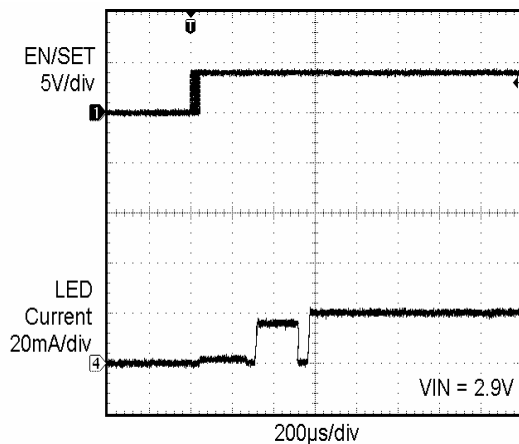

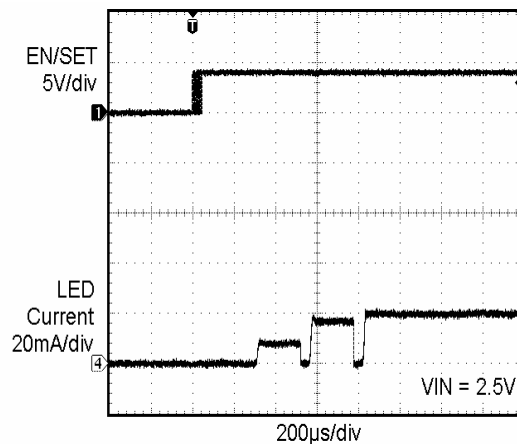**Output Resistance vs. Input Voltage**

Power Up in 1x Mode

Power Up in 1.33x Mode
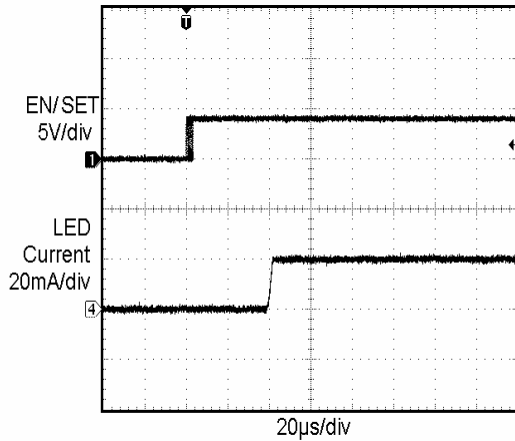

Power Up in 1.5x Mode
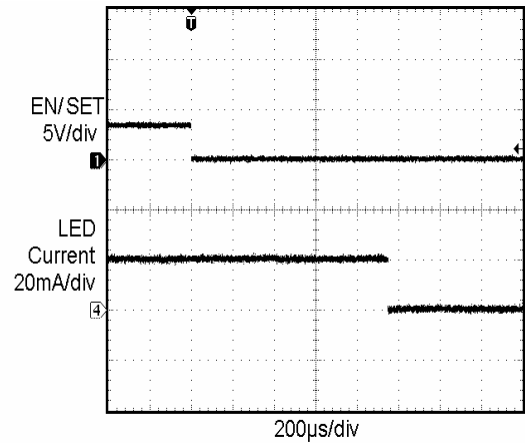

Power Up in 2x Mode

TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 3.6V, I_{OUT} = 120mA (6 LEDs at 20mA), C_{IN} = C_{OUT} = C_1 = C_2 = 1µF, T_{AMB} = 25°C unless otherwise specified.
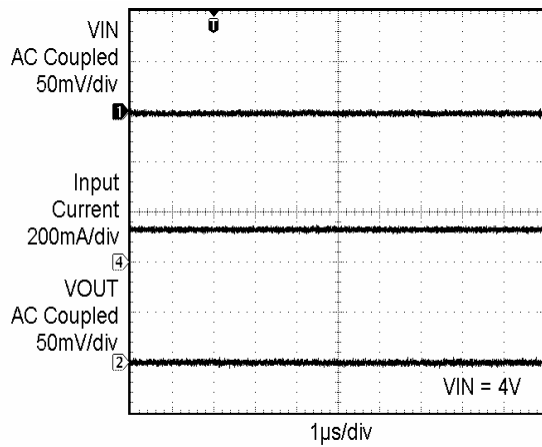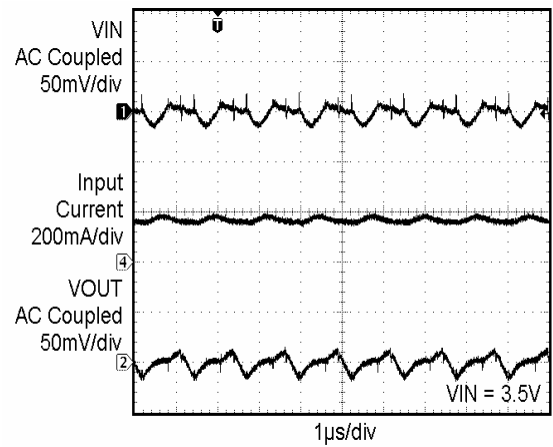
Power Up Delay (1x Mode)

EN/SET
5V/div

LED
Current
20mA/div

20µs/div

Power Down Delay (1x Mode)

EN/SET
5V/div

LED
Current
20mA/div

200µs/div

Operating Waveforms in 1x Mode

VIN
AC Coupled
50mV/div

Input
Current
200mA/div

VOUT
AC Coupled
50mV/div

VIN = 4V

1µs/div

Switching Waveforms in 1.33x Mode

VIN
AC Coupled
50mV/div

Input
Current
200mA/div

VOUT
AC Coupled
50mV/div

VIN = 3.5V

1µs/div

Switching Waveforms in 1.5x Mode

VIN
AC Coupled
50mV/div

Input
Current
200mA/div

VOUT
AC Coupled
50mV/div

VIN = 2.9V

1µs/div
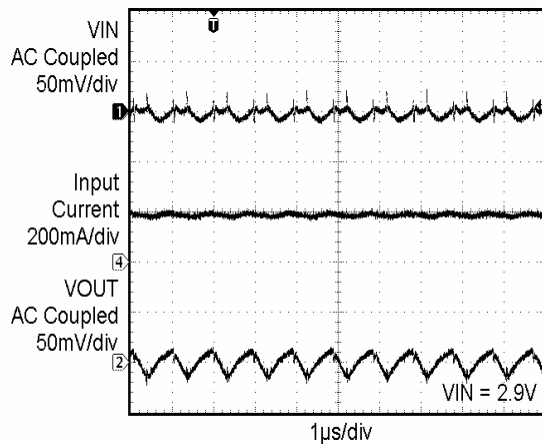
Switching Waveforms in 2x Mode
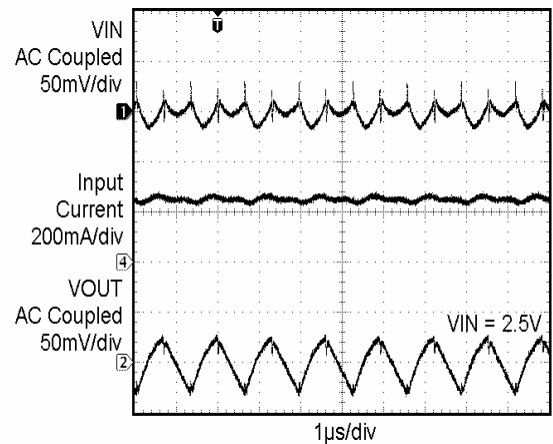
VIN
AC Coupled
50mV/div

Input
Current
200mA/div

VOUT
AC Coupled
50mV/div

VIN = 2.5V

1µs/div
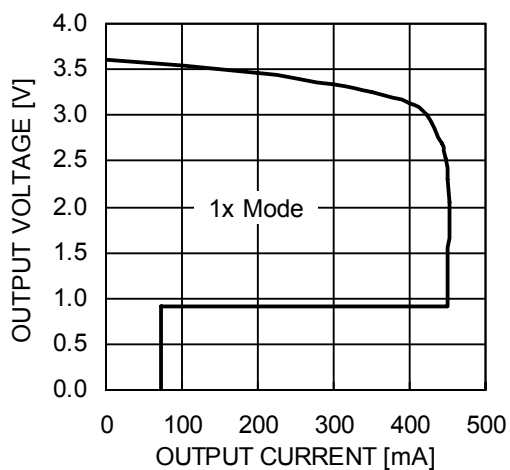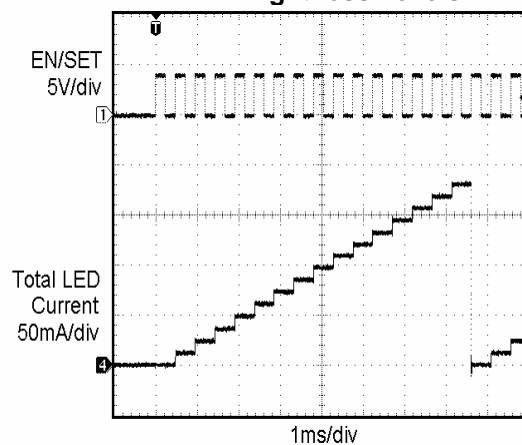
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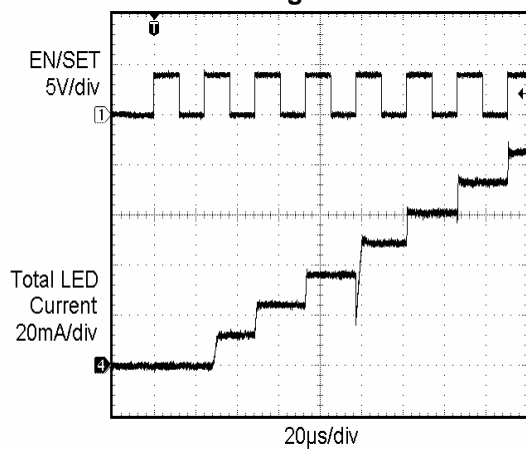
Foldback Current Limit

LED Brightness Levels

LED Settling Time

PIN DESCRIPTION

Pin #	Name	Function
1	LED6	LED6 cathode terminal
2	LED5	LED5 cathode terminal
3	LED4	LED4 cathode terminal
4	LED3	LED3 cathode terminal
5	LED2	LED2 cathode terminal
6	LED1	LED1 cathode terminal
7	VOUT	Charge pump output, connect to LED anodes
8	VIN	Charge pump input, connect to battery or supply
9	C1+	Bucket capacitor 1, positive terminal
10	C1-	Bucket capacitor 1, negative terminal
11	C2+	Bucket capacitor 2, positive terminal
12	C2-	Bucket capacitor 2, negative terminal
13/14	NC	No connect
15	GND	Ground reference
16	EN/SET	Device enable (active high) and 1 wire control input
TAB	TAB	Connect to GND on the PCB

PIN FUNCTION

VIN is the supply pin for the charge pump. A small 1µF ceramic bypass capacitor is required between the VIN pin and ground near the device. The operating input voltage range is from 2.5V to 5.5V. Whenever the input supply falls below the under-voltage threshold (2V) all the LED channels will be automatically disabled and the device register are reset to default values.

EN/SET is the enable and one wire addressable control logic input for all LED channels. Guaranteed levels of logic high and logic low are set at 1.3V and 0.4V respectively. When EN/SET is initially taken high, the device becomes enabled and all LED currents remain at 0mA. To place the device into zero current mode, the EN/SET pin must be held low for more than 1.5ms.

VOUT is the charge pump output that is connected to the LED anodes. A small 1µF ceramic bypass capacitor is required between the VOUT pin and ground near the device.

GND is the ground reference for the charge pump. The pin must be connected to the ground plane on the PCB.

C1+, C1- are connected to each side of the ceramic bucket capacitor C1.

C2+, C2- are connected to each side of the ceramic bucket capacitor C2.

LED1 to LED6 provide the internal regulated current for each of the LED cathodes. These pins enter high-impedance zero current state whenever the device is placed in shutdown mode.

TAB is the exposed pad underneath the package. For best thermal performance, the tab should be soldered to the PCB and connected to the ground plane.

SIMPLIFIED BLOCK DIAGRAM

Figure 2. CAT3637 Functional Block Diagram

BASIC OPERATION

At power-up, the CAT3637 starts operating in 1x mode where the output will be approximately equal to the input supply voltage (less any internal voltage losses). If the output voltage is sufficient to regulate all LED currents, the device remains in 1x operating mode.

If the output voltage is insufficient or falls to a level where the regulated current cannot be maintained, the device automatically switches into 1.33x mode (after a fixed delay time of about 120μs). In 1.33x mode, the output voltage is approximately equal to 1.33 times the input supply voltage (less any internal voltage losses).

If the output voltage is still insufficient or falls to a level where the regulated currents cannot be maintained, the device will automatically switch to the 1.5x mode (after a fixed delay time of about 400μs). In 1.5x mode, the output is approximately equal to 1.5 times the input supply voltage (less any internal voltage losses).

If the output voltage is still insufficient to drive the LEDs, it will automatically switch into 2x mode where the output is approximately equal to 2 times the input supply voltage (less any internal voltage losses).

If the device detects a sufficient output voltage to drive all LED currents in 1x mode, it will revert back to 1x mode. This only applies for changing back to the 1x mode.

LED Current Setting

The current in each of the six LED channels is programmed through the 1-wire EN/SET digital control input. At the initial power-up and once the EN/SET is set high, the LED current remains at zero in all channels. On the first EN/SET pulse (positive edge), the current is set to 2mA in all channels. On each consecutive pulse, the current is incremented by 2mA. On the 15th pulse, the current is equal to the full scale of 30mA. On the following pulse (16th pulse), the current goes back to zero and the previous sequence can be repeated. The EN/SET pin can be pulsed at high frequency 15 times to decrement the current by 2mA or to program the current from 0mA to 30mA. The maximum EN/SET signal frequency for programming the LED current is 2.5MHz.

To power-down the device and turn-off all current sources, the EN/SET input should be kept low for a duration T_{OFF} of 1.5ms or more. The driver typically powers-down with a delay of about 1ms.

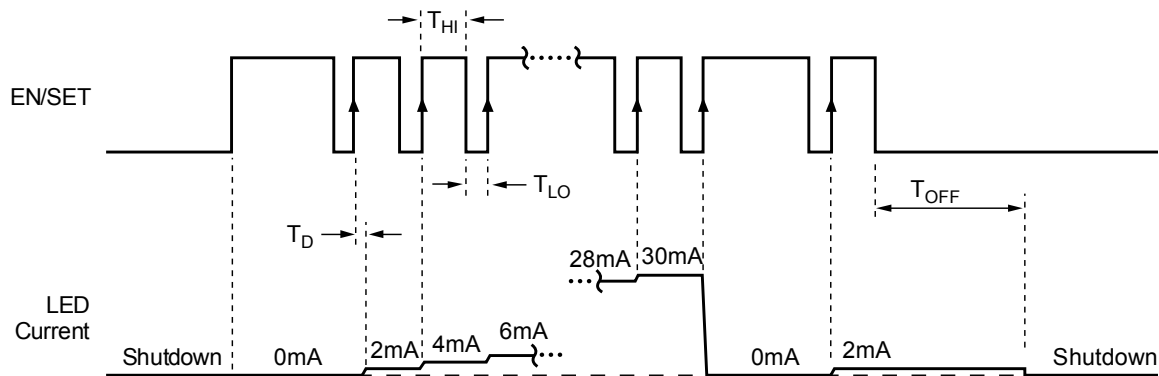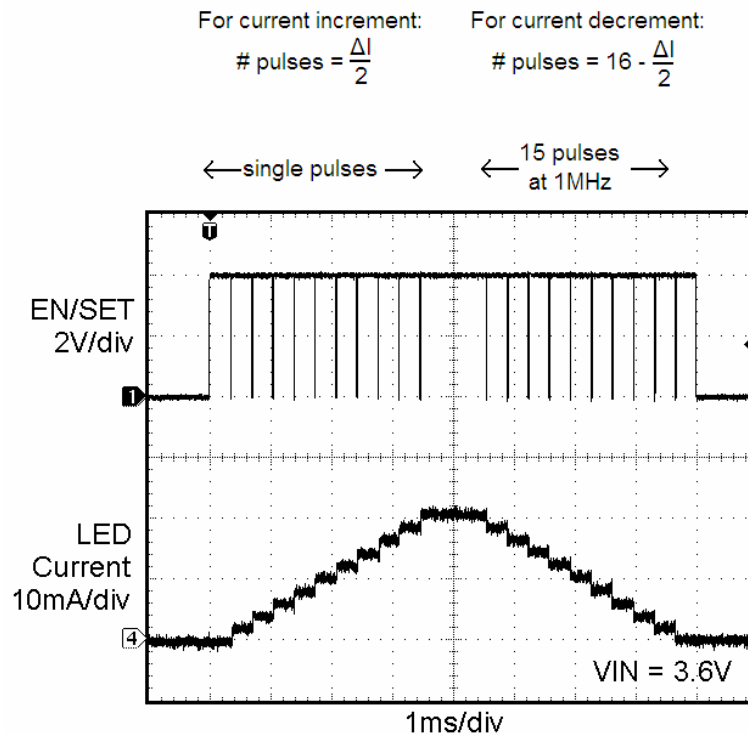**Figure 3. EN/SET One Wire Addressable Timing Diagram**

Figure 4. EN/SET Program Increasing / Decreasing LED Current by 2mA

For current increment:

$$\# \text{ pulses} = \frac{\Delta I}{2}$$

For current decrement:

$$\# \text{ pulses} = 16 - \frac{\Delta I}{2}$$

Unused LED Channels

For applications with 5 LEDs or less, unused LEDs can be disabled by connecting the LED pin directly to VOUT, as shown on Figure 4. If LED pin voltage is within 1V of VOUT, then the channel is switched off and a 200µA test current is placed in the channel to sense when the channel moves below VOUT – 1V.
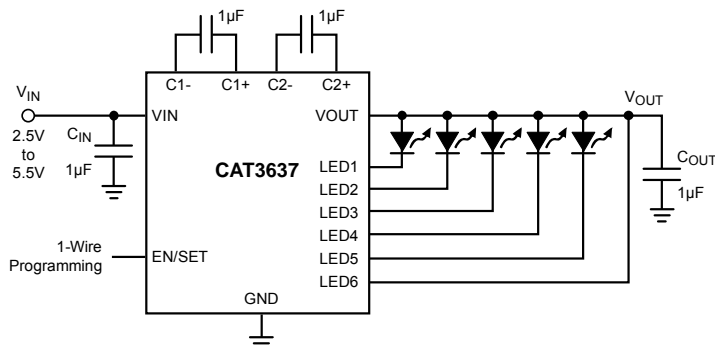

Figure 5. Five LED Application

Protection Mode

If an LED is disconnected, the output voltage VOUT automatically limits at about 5.5V. This is to prevent the output pin from exceeding its absolute maximum rating.

If the die temperature exceeds +150°C the driver will enter a thermal protection shutdown mode. When the device temperature drops by about 20°C the device will resume normal operation.

LED Selection

LEDs with forward voltages (V_F) ranging from 1.3V to 5.0V may be used with the CAT3637. Selecting LEDs with lower V_F is recommended in order to improve the efficiency by keeping the driver in 1x mode longer as the battery voltage decreases.

For example, if a white LED with a V_F of 3.3V is selected over one with V_F of 3.5V, the CAT3637 will stay in 1x mode for lower supply voltage of 0.2V. This helps improve the efficiency and extends battery life.

External Components

The driver requires two external 1µF ceramic capacitors for decoupling input, output, and for the charge pump. Both capacitors type X5R and X7R are recommended for the LED driver application. In all charge pump modes, the input current ripple is kept very low by design and an input bypass capacitor of 1µF is sufficient.

In 1x mode, the device operates in linear mode and does not introduce switching noise back onto the supply.

Recommended Layout

In charge pump mode, the driver switches internally at a high frequency. It is recommended to minimize trace length to all four capacitors. A ground plane should cover the area under the driver IC as well as the bypass capacitors. Short connection to ground on capacitors C_{IN} and C_{OUT} can be implemented with the use of multiple via. A copper area matching the TQFN exposed pad (TAB) must be connected to the ground plane underneath. The use of multiple via improves the package heat dissipation.
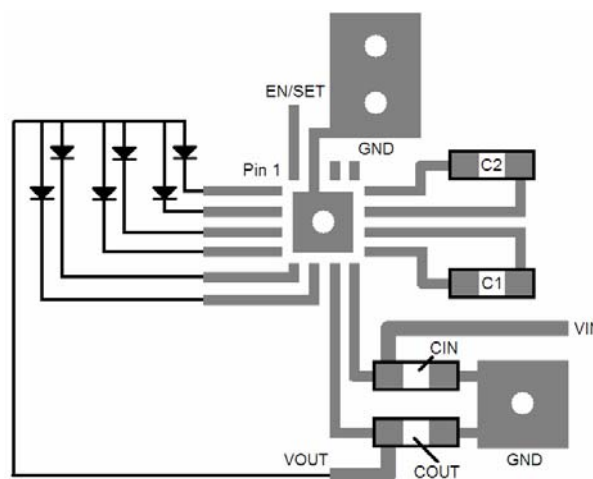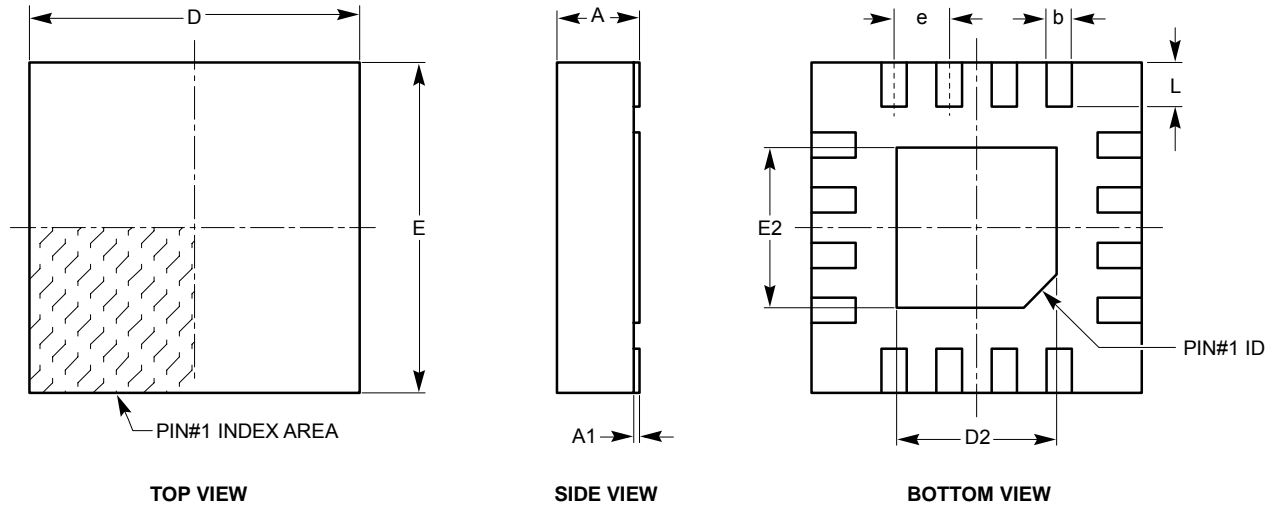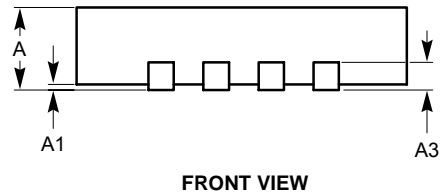

Figure 6. Recommended Layout

PACKAGE OUTLINE DRAWINGS

TQFN 16-Pad 3 x 3mm (HV3)[1][2]

TOP VIEW

PIN#1 INDEX AREA

SIDE VIEW

BOTTOM VIEW

PIN#1 ID

FRONT VIEW

SYMBOL	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A3	0.20 REF		
b	0.18	0.25	0.30
D	2.90	3.00	3.10
D2	1.40	–	1.80
E	2.90	3.00	3.10
E2	1.40	–	1.80
e	0.50 BSC		
L	0.30	0.40	0.50

For current Tape & Reel information, download the pdf file from:
http://www.catsemi.com/documents/tapeandreel.pdf

Notes:
(1) All dimensions are in millimeters.
(2) Complies with JEDEC standard MO-229.

EXAMPLE OF ORDERING INFORMATION

Prefix	Device #	Suffix

CAT 3637 HV3 – G   T2

Product Number
3637

Optional Company ID

Package
HV3: TQFN 3 x 3mm

Lead Finish
G: NiPdAu

Tape & Reel
T: Tape & Reel
2: 2000/Reel
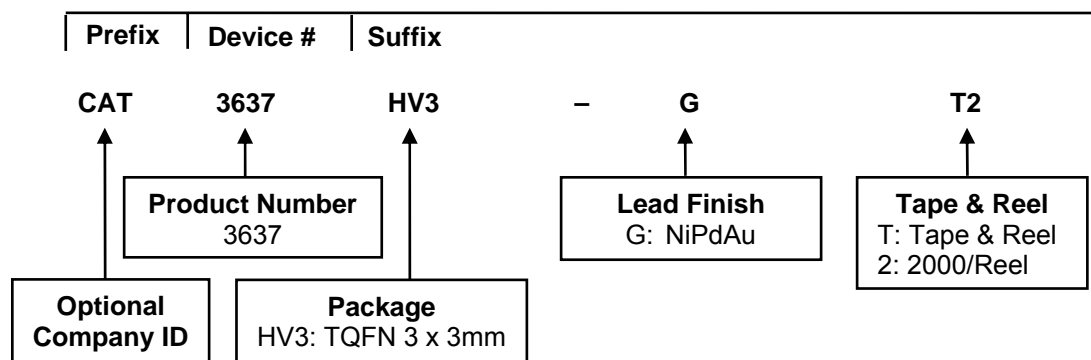
Notes:
(1) All packages are RoHS-compliant (Lead-free, Halogen-free).
(2) The standard lead finish is NiPdAu.
(3) The device used in the above example is a CAT3637HV3–GT2 (TQFN, NiPdAu, Tape & Reel, 2000 pcs / Reel).
(4) For additional package and temperature options, please contact your nearest Catalyst Semiconductor Sales office.

REVISION HISTORY

Date	Rev.	Reason
03/07/2008	A	Initial Issue