



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

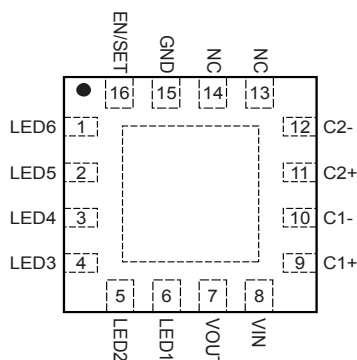
Part Number	Quantity per Reel	Package Marking
CAT3637HV3-GT2	2000 ⁽¹⁾	JAAM

Note:

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

PIN CONFIGURATION

(top view)



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.

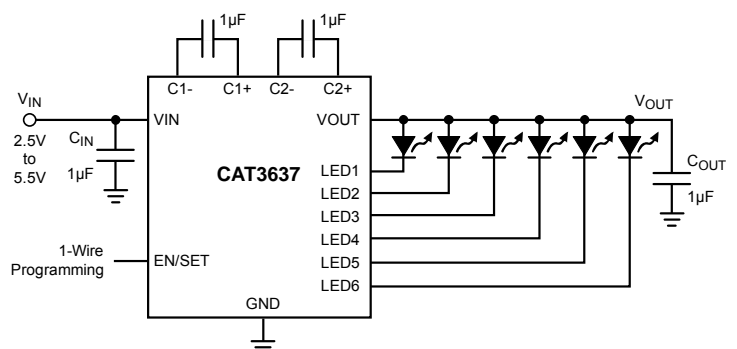
The EN/SET logic input functions as a chip enable and a digital programming interface for setting the current in the LED channels. The 1-wire pulse-programming interface supports 15 linear steps from zero current to 30mA full-brightness in 2mA steps.

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.

TYPICAL APPLICATION CIRCUIT



ABSOLUTE MAXIMUM RATINGS

Parameter	Rating	Unit
V _{IN} , LEDx, C1±, C2± voltage	6	V
V _{OUT} Voltage	7	V
EN/SET Voltage	V _{IN} + 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
V _{IN}	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 1.33x 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	$\frac{I_{LED} - I_{LEDAVG}}{I_{LED}}$		±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 -40° to $+85^{\circ}C$.

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

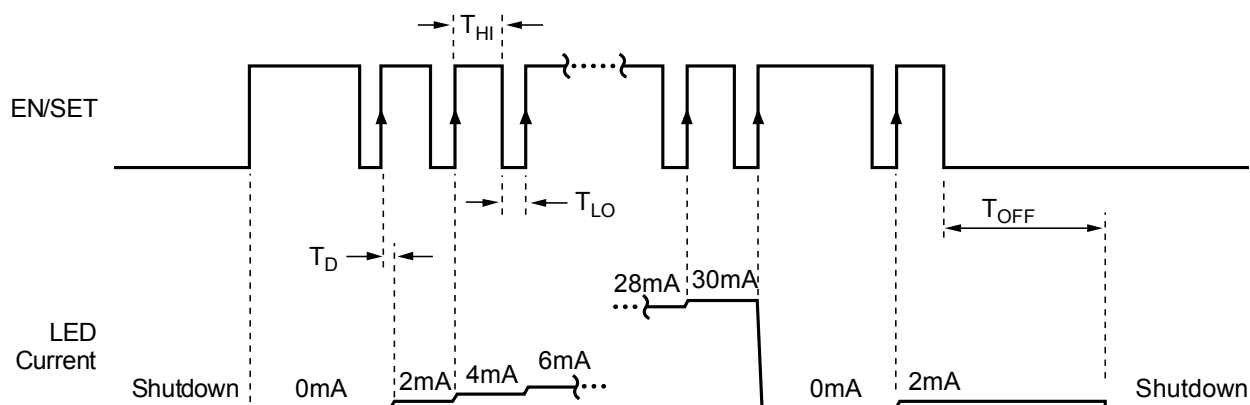
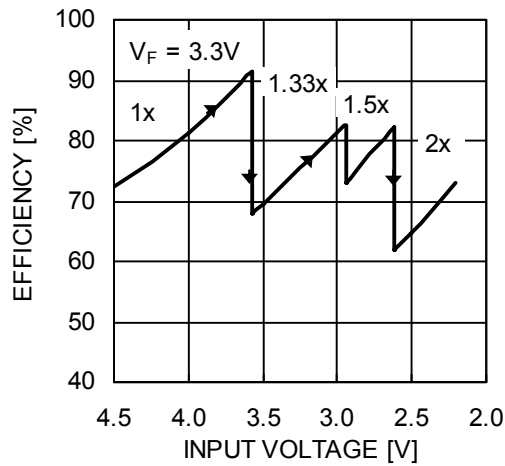


Figure 1. EN/SET One Wire Addressable Timing Diagram

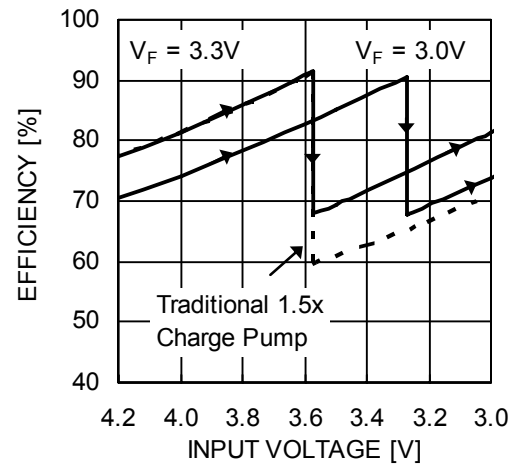
TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 3.6V$, $I_{OUT} = 120mA$ (6 LEDs at 20mA), $C_{IN} = C_{OUT} = C_1 = C_2 = 1\mu F$, $T_{AMB} = 25^\circ C$ unless otherwise specified.

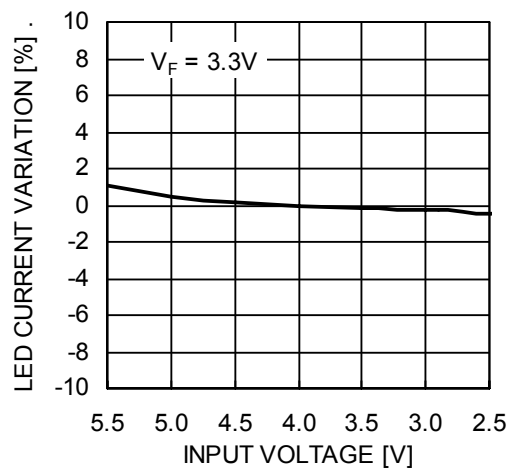
Efficiency vs. Input Voltage



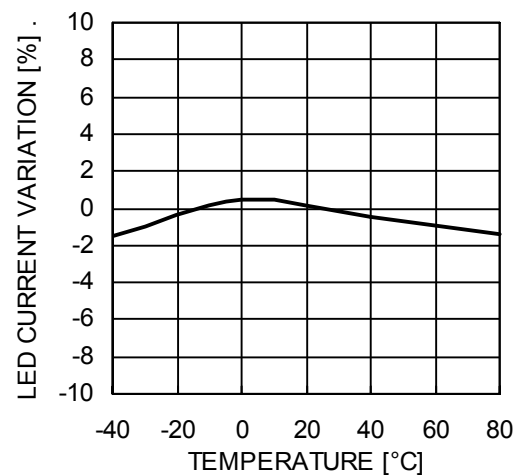
Efficiency vs. Li-Ion Voltage



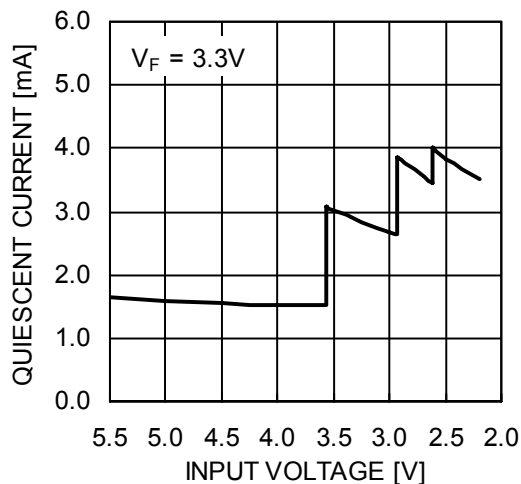
LED Current Change vs. Input Voltage



LED Current Change vs. Temperature



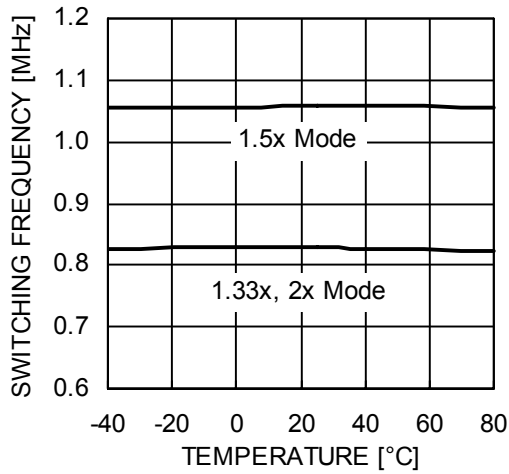
Quiescent Current vs. Input Voltage



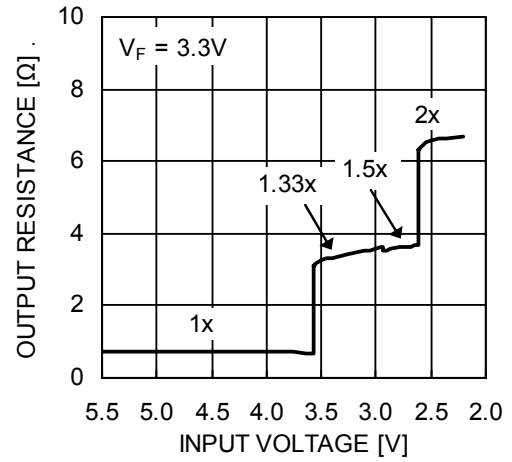
TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 3.6V$, $I_{OUT} = 120mA$ (6 LEDs at 20mA), $C_{IN} = C_{OUT} = C_1 = C_2 = 1\mu F$, $T_{AMB} = 25^\circ C$ unless otherwise specified.

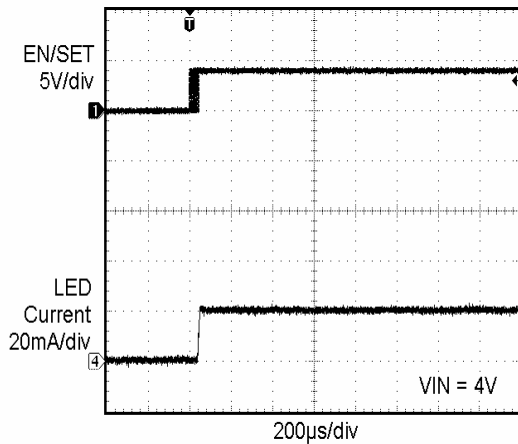
Switching Frequency vs. Temperature



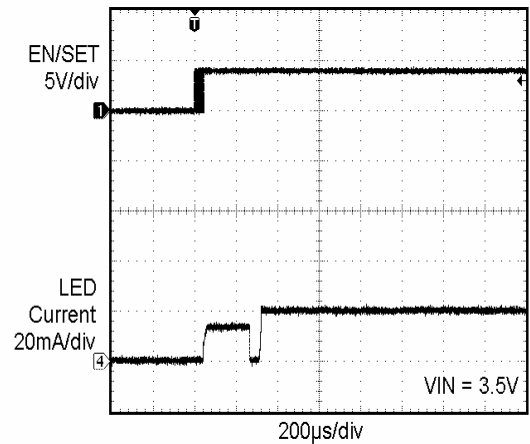
Output Resistance vs. Input Voltage



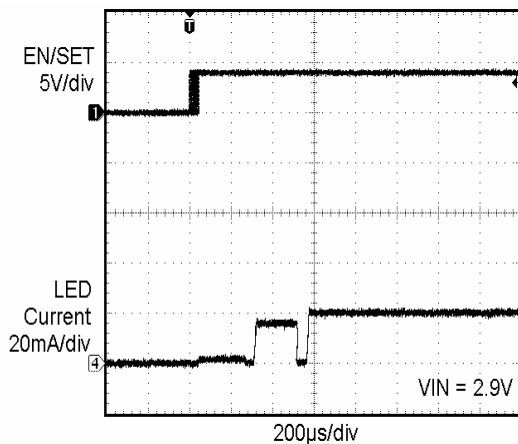
Power Up in 1x Mode



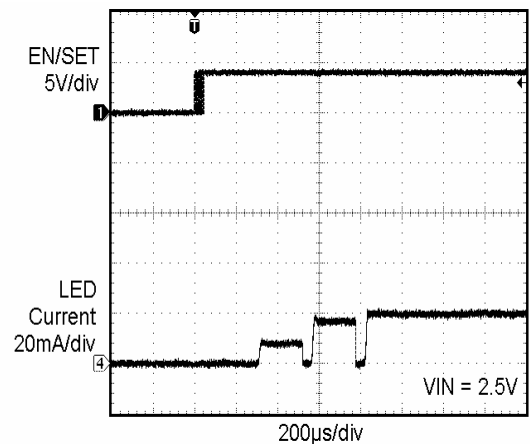
Power Up in 1.33x Mode



Power Up in 1.5x Mode



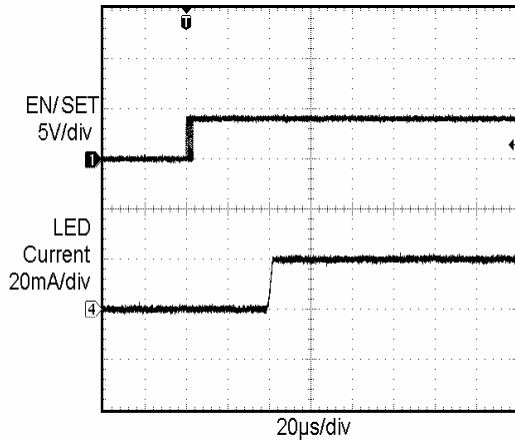
Power Up in 2x Mode



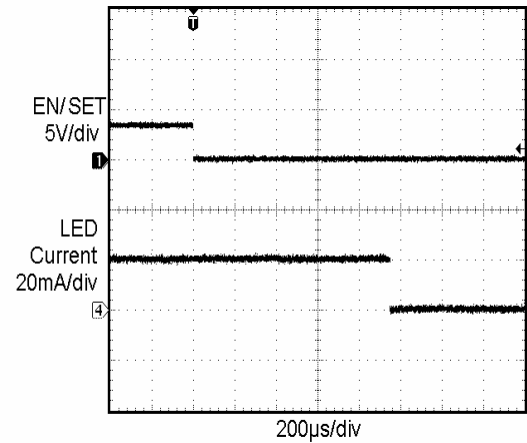
TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 3.6V$, $I_{OUT} = 120mA$ (6 LEDs at 20mA), $C_{IN} = C_{OUT} = C_1 = C_2 = 1\mu F$, $T_{AMB} = 25^\circ C$ unless otherwise specified.

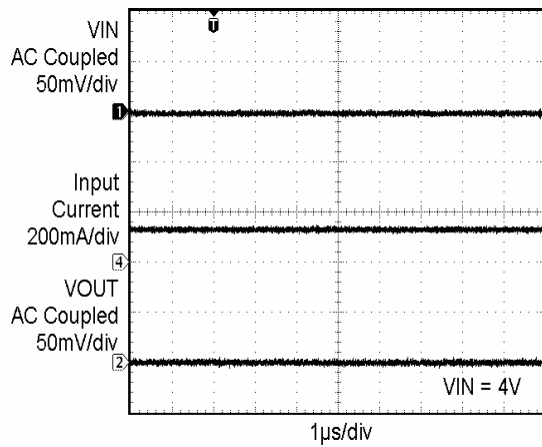
Power Up Delay (1x Mode)



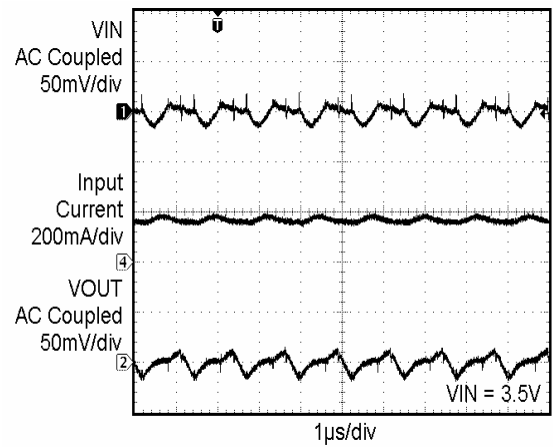
Power Down Delay (1x Mode)



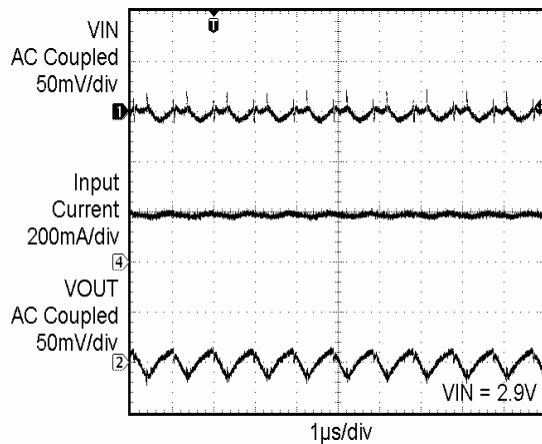
Operating Waveforms in 1x Mode



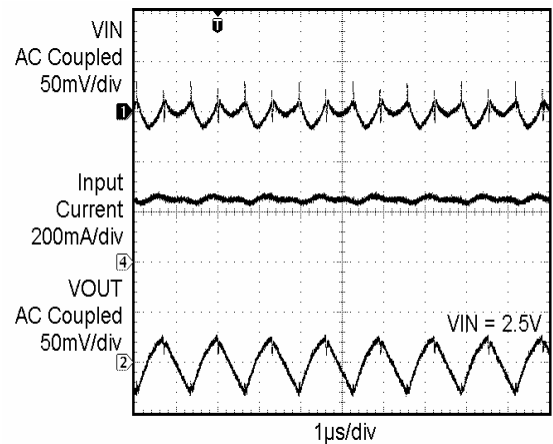
Switching Waveforms in 1.33x Mode



Switching Waveforms in 1.5x Mode



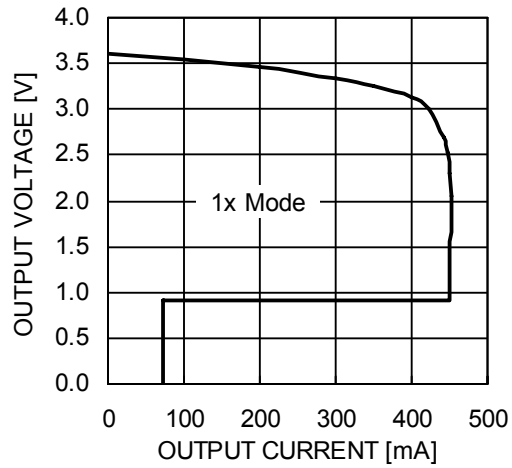
Switching Waveforms in 2x Mode



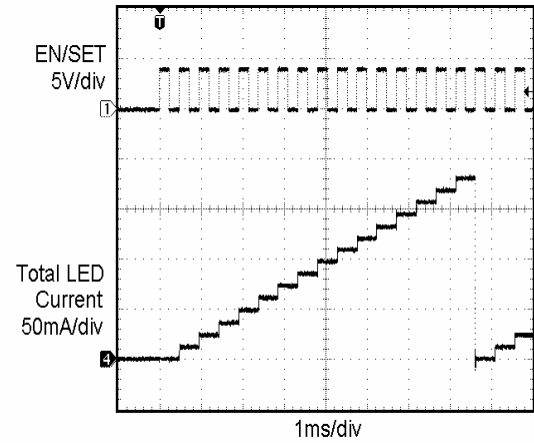
TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 3.6V$, $I_{OUT} = 120mA$ (6 LEDs at 20mA), $C_{IN} = C_{OUT} = C_1 = C_2 = 1\mu F$, $T_{AMB} = 25^\circ C$ unless otherwise specified.

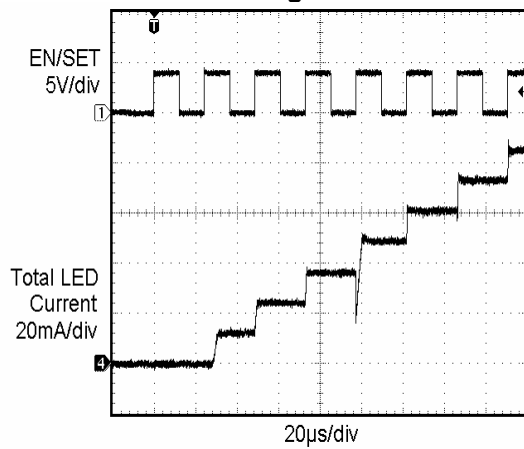
Foldback Current Limit



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 1 μ F 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 1 μ F 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

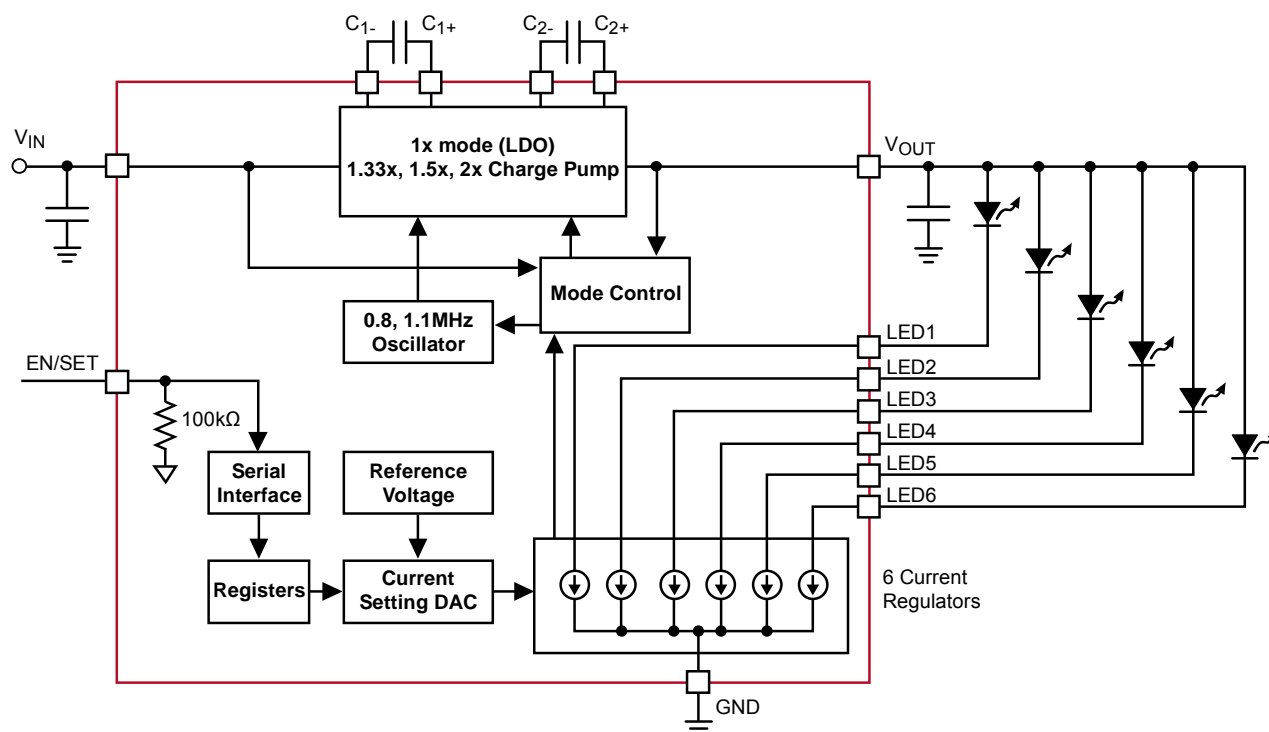


Figure 2. CAT3637 Functional Block Diagram

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 120 μ s). 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 400 μ s). 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

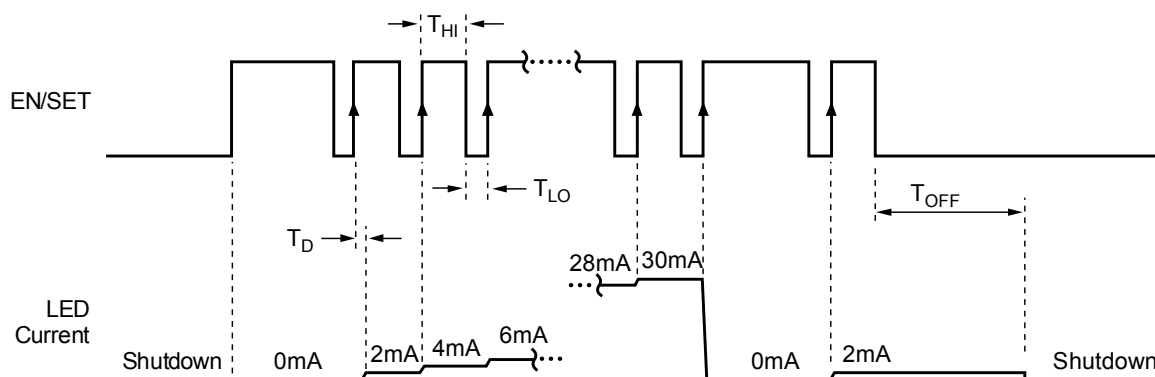
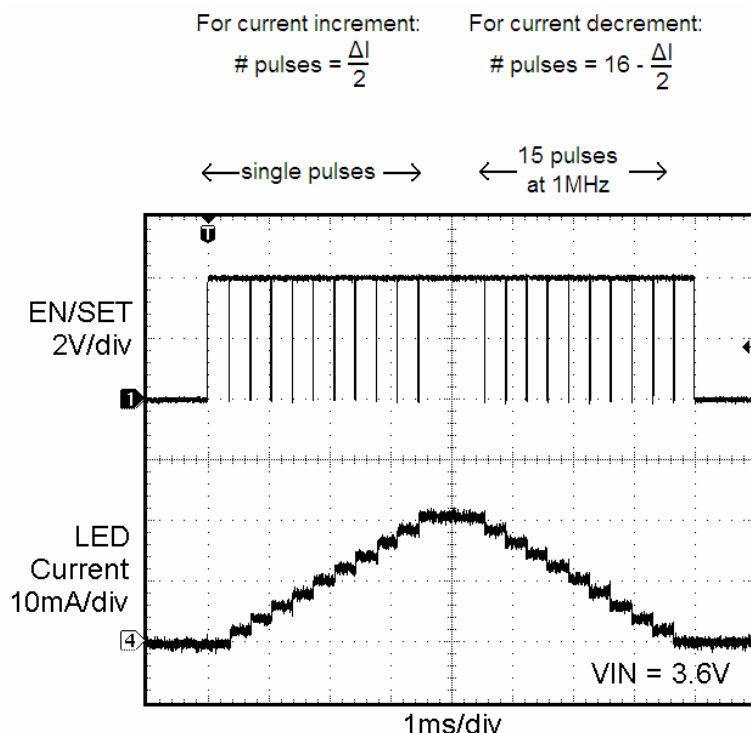


Figure 4. EN/SET Program Increasing / Decreasing LED Current by 2mA



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 200 μ A test current is placed in the channel to sense when the channel moves below $V_{OUT} - 1V$.

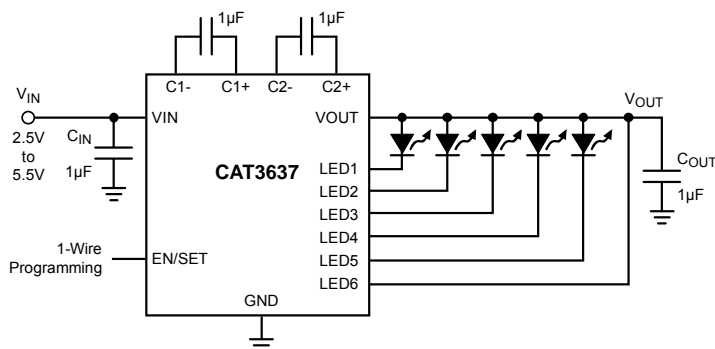


Figure 5. Five LED Application

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 1 μ F 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 1 μ F 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.

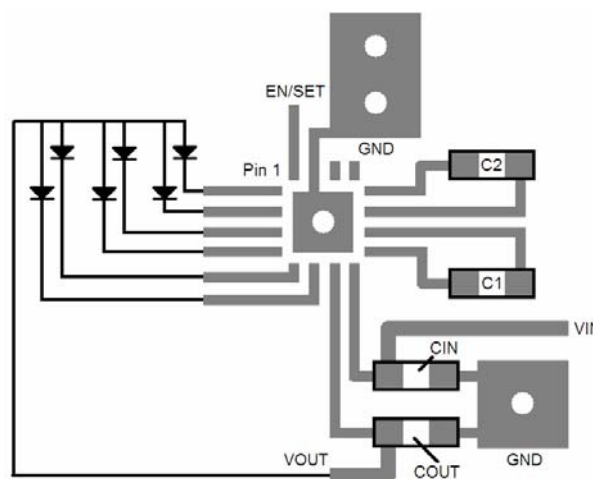
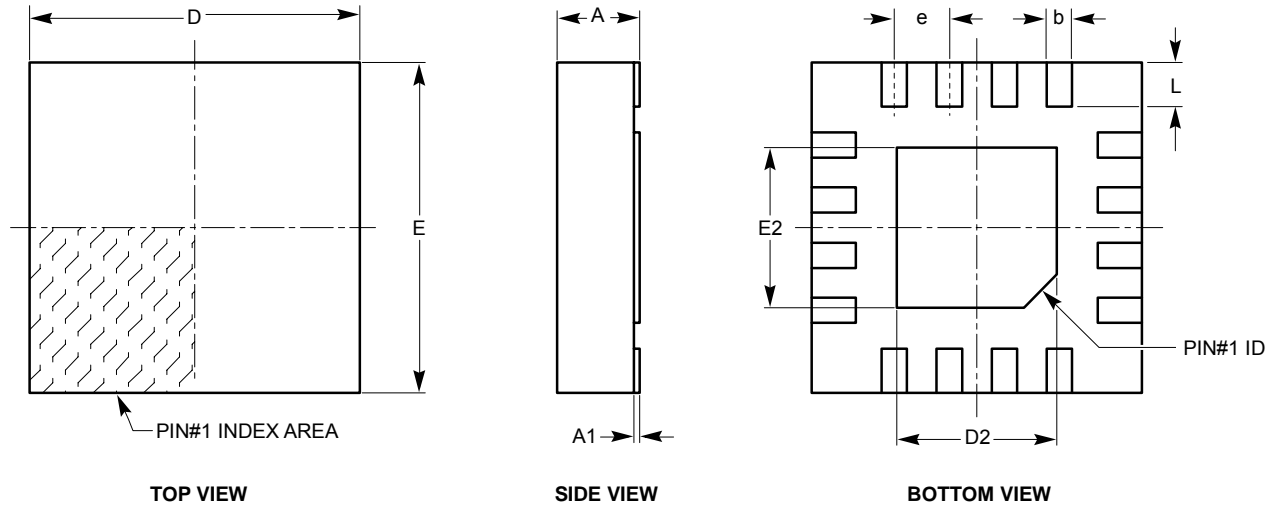
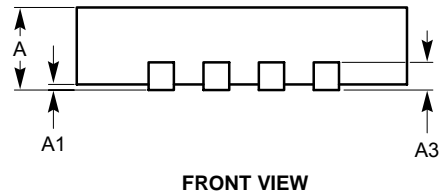


Figure 6. Recommended Layout

PACKAGE OUTLINE DRAWING

TQFN 16-Pad 3 x 3mm (HV3)⁽¹⁾⁽²⁾

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

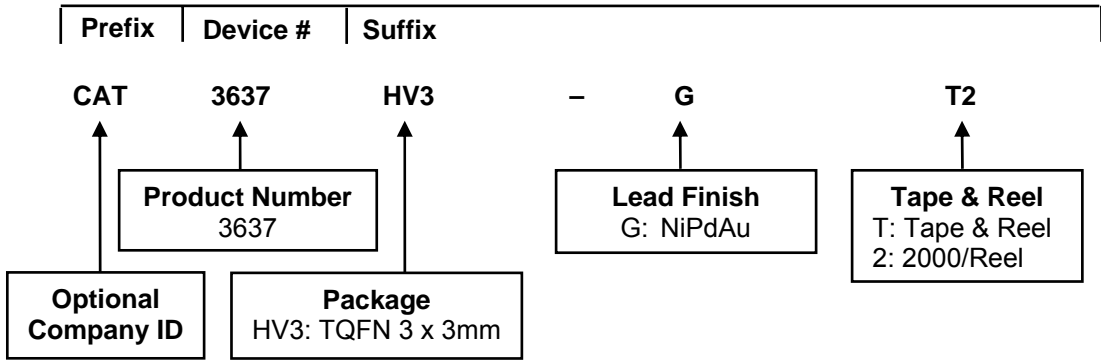


For current Tape & Reel information, download the pdf file from:
<http://www.catsemi.com/documents/tapeandreeel.pdf>

Notes:

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


EXAMPLE OF ORDERING INFORMATION



- 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 ON Semiconductor Sales office.

REVISION HISTORY

Date	Rev.	Description
07-Mar-08	A	Initial Issue
07-Aug-08	B	Changed "Quad-Mode™" to "Quad-Mode®"
12-Nov-08	C	Change logo and fine print to ON Semiconductor

ON Semiconductor and  are registered trademarks of Semiconductor Components Industries, LLC (SCILLC). SCILLC reserves the right to make changes without further notice to any products herein. SCILLC makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does SCILLC assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. "Typical" parameters which may be provided in SCILLC data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. SCILLC does not convey any license under its patent rights nor the rights of others. SCILLC products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the SCILLC product could create a situation where personal injury or death may occur. Should Buyer purchase or use SCILLC products for any such unintended or unauthorized application, Buyer shall indemnify and hold SCILLC and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that SCILLC was negligent regarding the design or manufacture of the part. SCILLC is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:

Literature Distribution Center for ON Semiconductor
P.O. Box 5163, Denver, Colorado 80217 USA
Phone: 303-675-2175 or 800-344-3860 Toll Free USA/Canada
Fax: 303-675-2176 or 800-344-3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800-282-9855 Toll Free
USA/Canada

Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910

Japan Customer Focus Center:
Phone: 81-3-5773-3850

ON Semiconductor Website: www.onsemi.com

Order Literature: <http://www.onsemi.com/orderlit>

For additional information, please contact your local
Sales Representative