



# 4-Channel 1-Wire LED Driver in 3 x 3mm Package



## FEATURES

- Drives up to 4 LED channels
- 1-wire EZDim™ Programmable LED Current
- Accurate 1mA Dimming Level
- Power efficiency up to 91%
- Fractional pump 1x/1.5x
- Low noise input ripple
- Fixed High Frequency Operation 1MHz
- “Zero” Current Shutdown Mode
- Soft start and current limiting
- Short circuit protection
- Thermal shutdown protection
- TDFN 12-pad 3mm x 3mm package

## APPLICATIONS

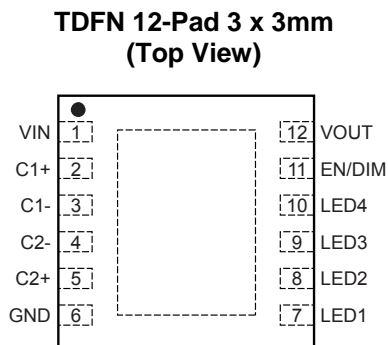
- LCD Display Backlight
- Cellular Phones
- Digital Still Cameras
- Handheld Devices

## ORDERING INFORMATION

| Part Number    | Package                | Quantity per Reel | Package Marking |
|----------------|------------------------|-------------------|-----------------|
| CAT3614HV2-T2  | TDFN-12 <sup>(1)</sup> | 2000              | HAAA            |
| CAT3614HV2-GT2 | TDFN-12 <sup>(2)</sup> | 2000              | HAAC            |

Notes: (1) Matte-Tin Plated Finish (RoHS-compliant).  
 (2) NiPdAu Plated Finish (RoHS-compliant).

## PIN CONFIGURATION



## DESCRIPTION

The CAT3614 is a high efficiency 1x/1.5x fractional charge pump with programmable dimming current in four LED channels. To ensure uniform brightness in LCD backlight applications, each LED channel delivers an accurate regulated current.

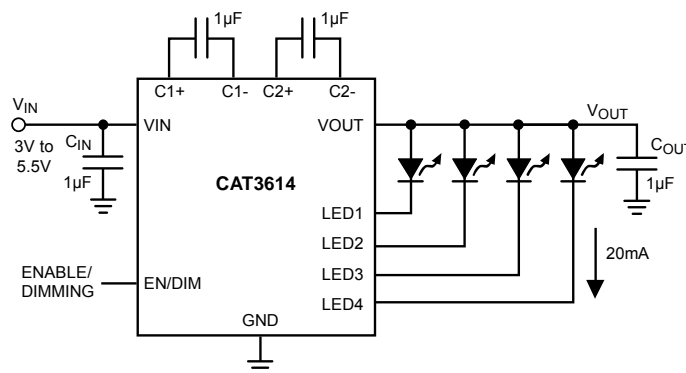
Low noise and input ripple is achieved by operating at a constant switching frequency of 1MHz which allows the use of small external ceramic capacitors. The 1x/1.5x fractional charge pump supports a wide range of input voltages from 3V to 5.5V with efficiency up to 91%, and is ideal for Li-Ion battery powered devices.

The EN/DIM logic input provides a 1-wire EZDim™ interface for dimming control of the LEDs. When enabled, a series of clock pulses reduces the LED brightness in 1mA steps on each negative going edge. Currents from 0mA to 31mA are supported.

The device is available in the tiny 12-pad TDFN 3 x 3mm package with a max height of 0.8mm.

For Ordering Information details, see page 12.

## TYPICAL APPLICATION CIRCUIT



Note: Unused LED channels must be connected to VOUT.

**ABSOLUTE MAXIMUM RATINGS**

| Parameter                           | Rating                 | Unit |
|-------------------------------------|------------------------|------|
| V <sub>IN</sub> , LEDx voltage      | 6                      | V    |
| V <sub>OUT</sub> , C1±, C2± voltage | 7                      | V    |
| EN/DIM voltage                      | V <sub>IN</sub> + 0.7V | V    |
| Storage Temperature Range           | -65 to +160            | °C   |
| Junction Temperature Range          | -40 to +150            | °C   |
| Lead Temperature                    | 300                    | °C   |

**RECOMMENDED OPERATING CONDITIONS**

| Parameter                    | Range      | Unit |
|------------------------------|------------|------|
| V <sub>IN</sub>              | 3 to 5.5   | V    |
| Ambient Temperature Range    | -40 to +85 | °C   |
| I <sub>LED</sub> per LED pin | 0 to 31    | mA   |
| Total Output Current         | 0 to 124   | mA   |

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

**ELECTRICAL OPERATING CHARACTERISTICS**

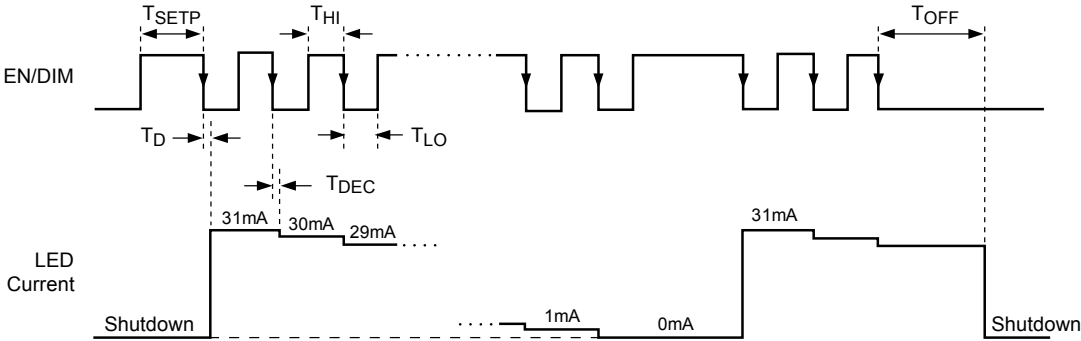
V<sub>IN</sub> = 3.6V, EN = High, ambient temperature of 25°C (over recommended operating conditions unless specified otherwise).

| Symbol   | Parameter  | Conditions   | Min       | Typ        | Max      | Unit         |
|--|--|--|-----------|------------|----------|--------------|
| I <sub>Q</sub>   | Quiescent Current  | 1x mode, no load<br>1.5x mode, no load                                   | 0.3<br>1  | 0.5<br>3   | 1<br>8   | mA<br>mA     |
| I <sub>QSHDN</sub>                                       | Shutdown Current   | V <sub>EN</sub> = 0V   |           |            | 1        | µA           |
| I <sub>LED-ACC</sub>                                     | LED Current Accuracy   | 1mA ≤ I <sub>LED</sub> ≤ 31mA  |           | ±3         | ±8       | %            |
| I <sub>LED-DEV</sub>                                     | LED Channel Matching   | (I <sub>LED</sub> - I <sub>LEDAVG</sub> ) / I <sub>LEDAVG</sub>          |           | ±3         | ±7       | %            |
| R <sub>OUT</sub>   | Output Resistance (open loop)  | 1x mode, I <sub>OUT</sub> = 100mA<br>1.5x mode, I <sub>OUT</sub> = 100mA |           | 0.4<br>2.6 | 1<br>7   | Ω<br>Ω       |
| F <sub>OSC</sub>   | Charge Pump Frequency  |  | 0.8       | 1          | 1.3      | MHz          |
| I <sub>SC_MAX</sub>                                      | Output short circuit Current Limit                                       | V <sub>OUT</sub> < 0.5V  | 30        | 60         | 100      | mA           |
| I <sub>IN_MAX</sub>                                      | Input Current Limit  | 1x mode, V <sub>OUT</sub> > 1V   | 200       | 300        | 600      | mA           |
| I <sub>ENDIM</sub><br>V <sub>HI</sub><br>V <sub>LO</sub> | EN/DIM Pin<br>• Input Leakage<br>• Logic High Level<br>• Logic Low Level |  | -1<br>1.3 |            | 1<br>0.4 | µA<br>V<br>V |
| T <sub>SD</sub>  | Thermal Shutdown   |  | 145       | 165        | 175      | °C           |
| T <sub>HYS</sub>   | Thermal Hysteresis   |  | 10        | 20         | 30       | °C           |
| V <sub>UVLO</sub>  | Undervoltage lock out (UVLO) threshold                                   |  | 1.7       | 2          | 2.4      | V            |

**RECOMMENDED EN/DIM TIMING**

For  $3V \leq V_{IN} \leq 5.5V$ , over full ambient temperature range  $-40$  to  $+85^{\circ}C$ .

| Symbol     | Parameter                   | Conditions | Min | Typ | Max | Unit    |
|------------|-----------------------------|------------|-----|-----|-----|---------|
| $T_{SETP}$ | EN/DIM setup from shutdown  |            | 10  |     |     | $\mu s$ |
| $T_{LO}$   | EN/DIM program low time     |            | 0.3 |     | 200 | $\mu s$ |
| $T_{HI}$   | EN/DIM program high time    |            | 0.3 |     |     | $\mu s$ |
| $T_{OFF}$  | EN/DIM low time to shutdown |            | 1.5 |     |     | ms      |
| $T_D$      | LED current enable          |            |     | 40  |     | $\mu s$ |
| $T_{DEC}$  | LED current decrement       |            |     | 0.1 |     | $\mu s$ |

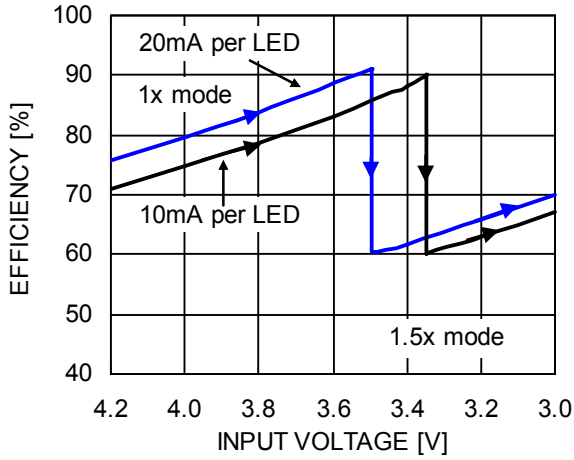


**Figure 1. LED Dimming Timing Diagram**

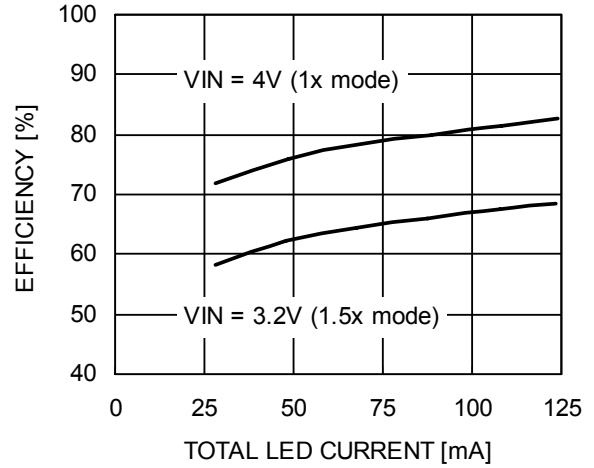
**TYPICAL CHARACTERISTICS**

$V_{IN} = 3.6V$ ,  $I_{OUT} = 80mA$  (4 LEDs at 20mA),  $C_1 = C_2 = C_{IN} = C_{OUT} = 1\mu F$ ,  $T_{AMB} = 25^\circ C$  unless otherwise specified.

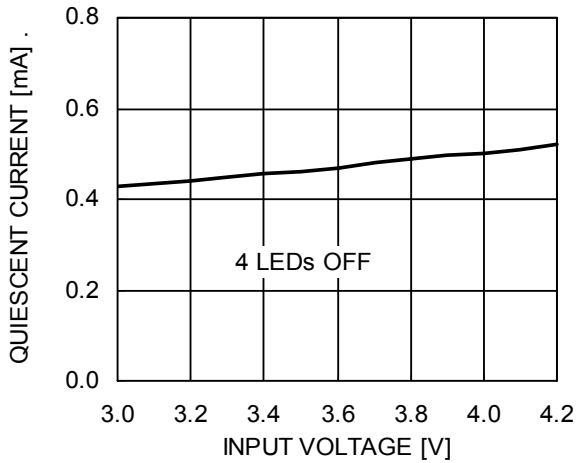
**Efficiency vs. Input Voltage (4 LEDs)**



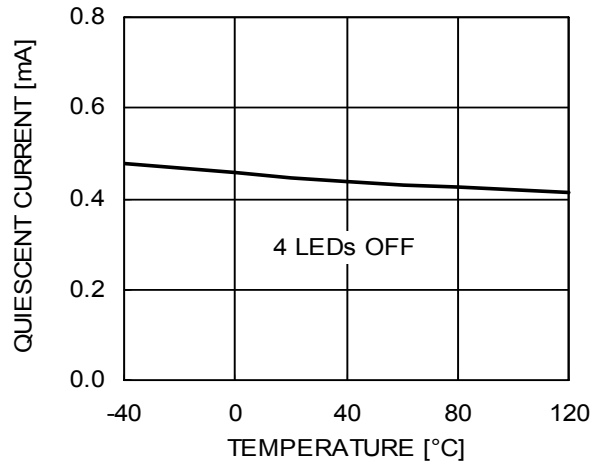
**Efficiency vs. Total LED Current (4 LEDs)**



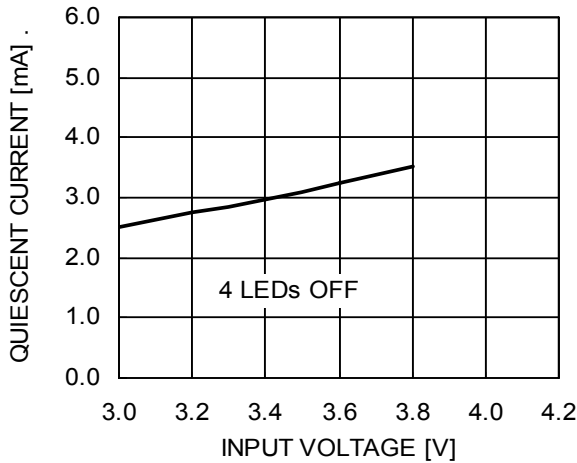
**Quiescent Current vs. Input Voltage (1x mode)**



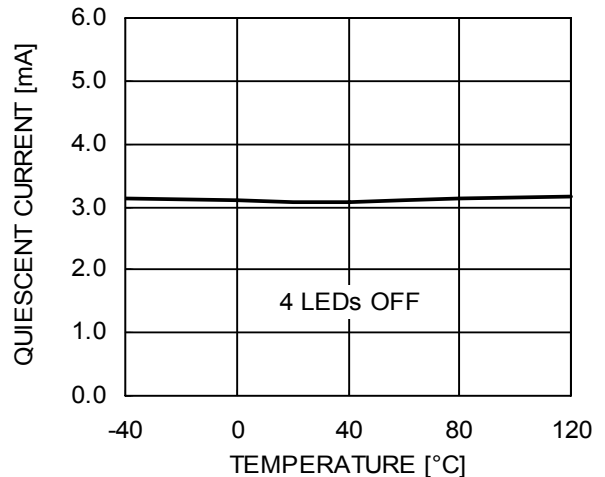
**Quiescent Current vs. Temperature (1x mode)**



**Quiescent Current vs. Input Voltage (1.5x mode)**



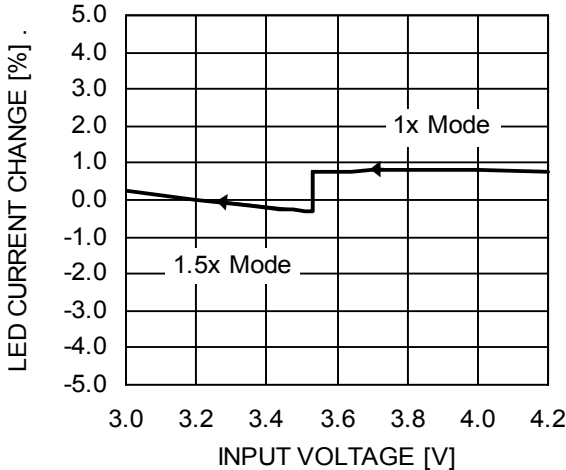
**Quiescent Current vs. Temperature (1.5x mode)**



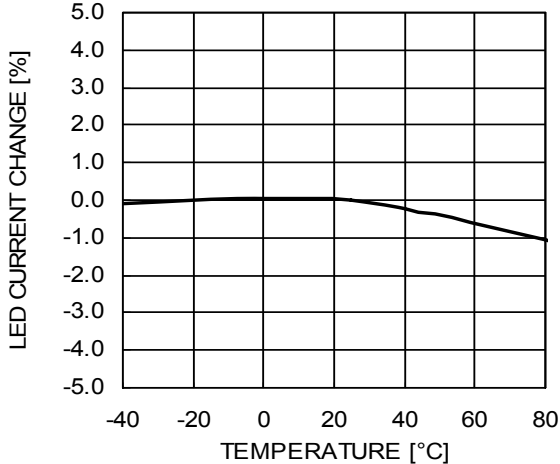
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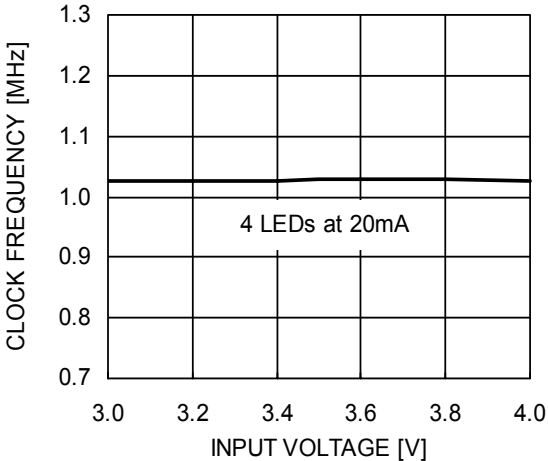
**LED Current Change vs. Input Voltage**



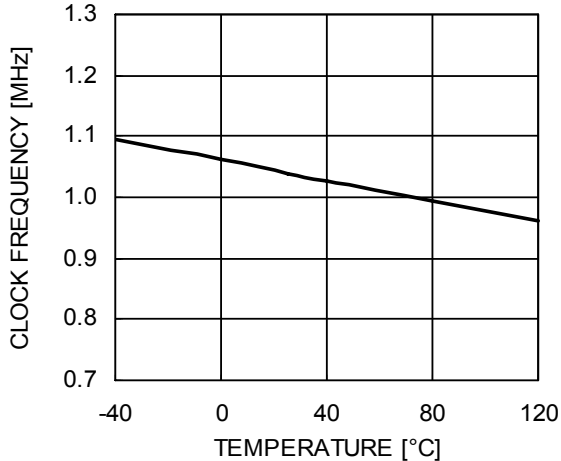
**LED Current Change vs. Temperature**



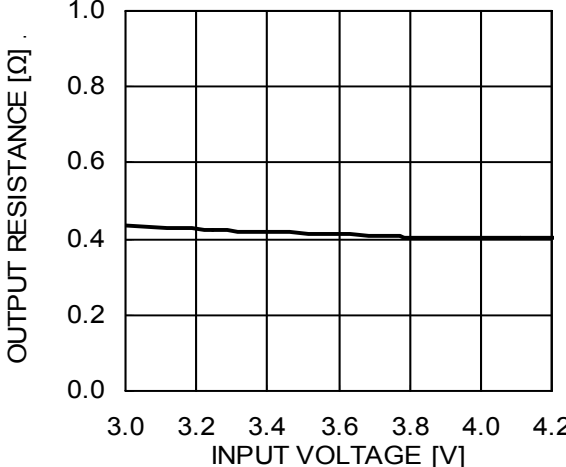
**Oscillator Frequency vs. Input Voltage**



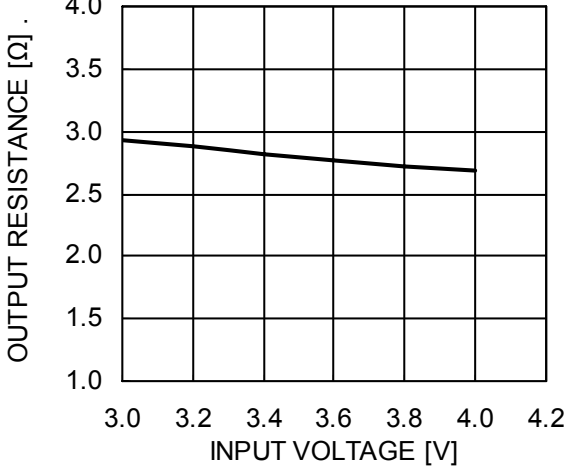
**Oscillator Frequency vs. Temperature**



**Output Resistance vs. Input Voltage (1x mode)**



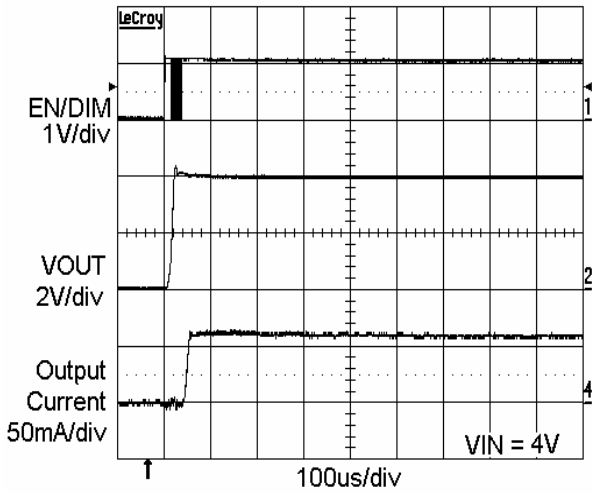
**Output Resistance vs. Input Voltage (1.5x mode)**



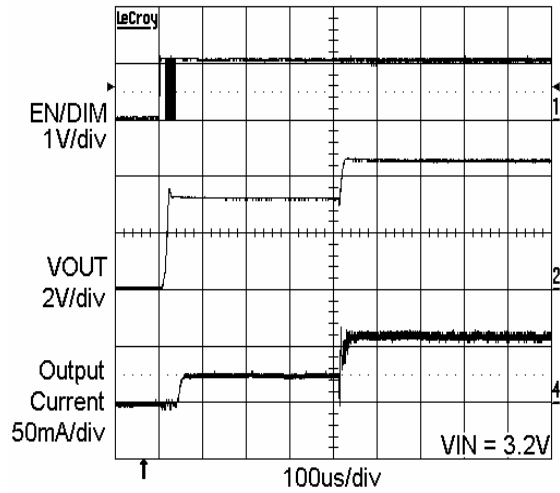
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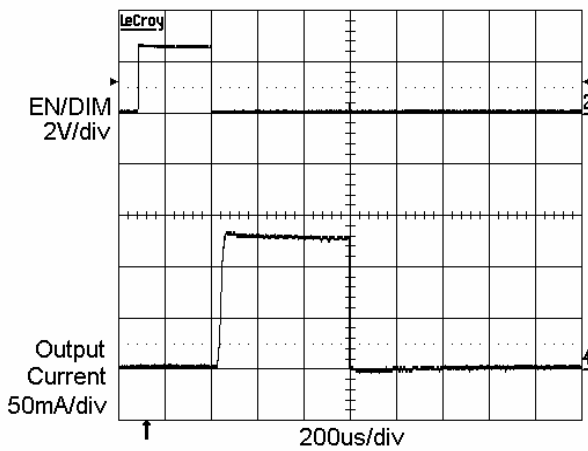
**Power Up with 4 LEDs at 15mA (1x Mode)**



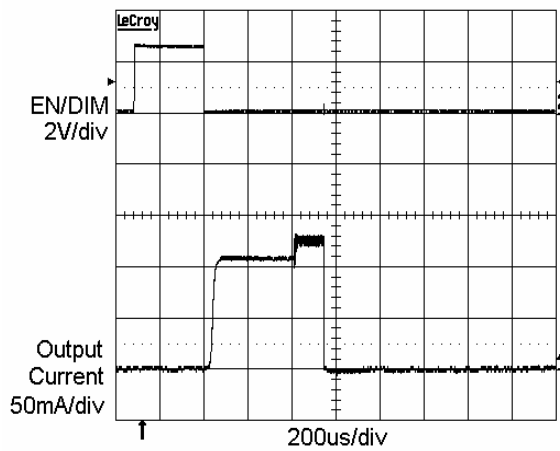
**Power Up with 4 LEDs at 15mA (1.5x Mode)**



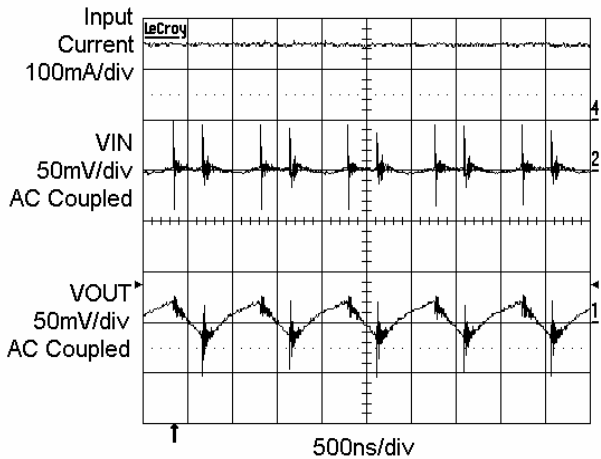
**Enable Power Down Delay (1x Mode)**



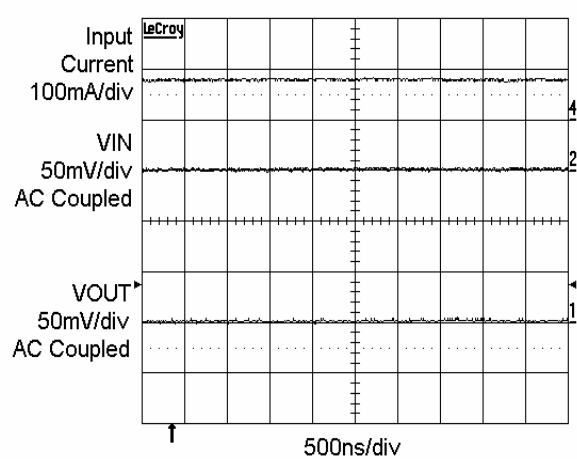
**Enable Power Down Delay (1.5x Mode)**



**Switching Waveforms in 1.5x Mode**



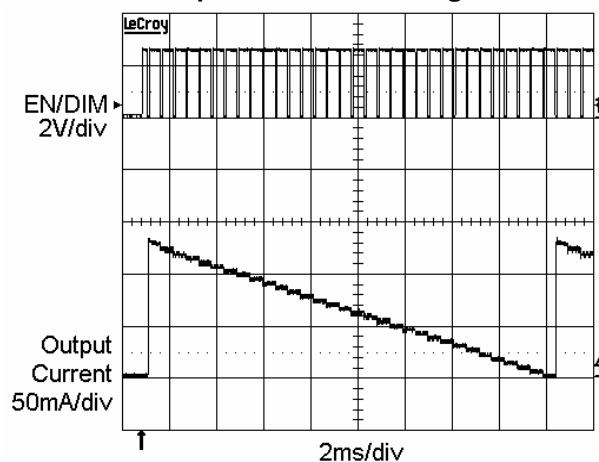
**Operating Waveforms in 1x Mode**



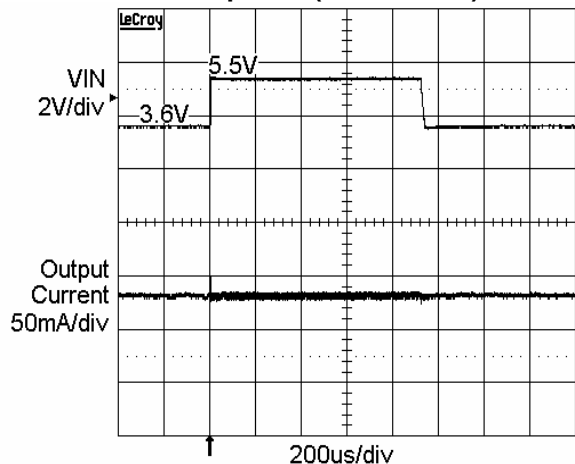
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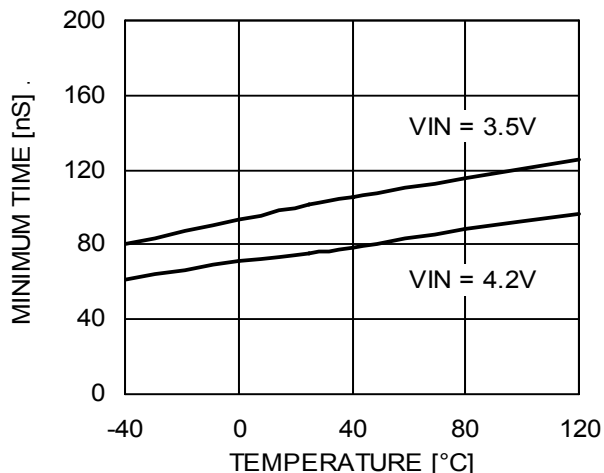
**Enable and Output Current Dimming Waveforms**



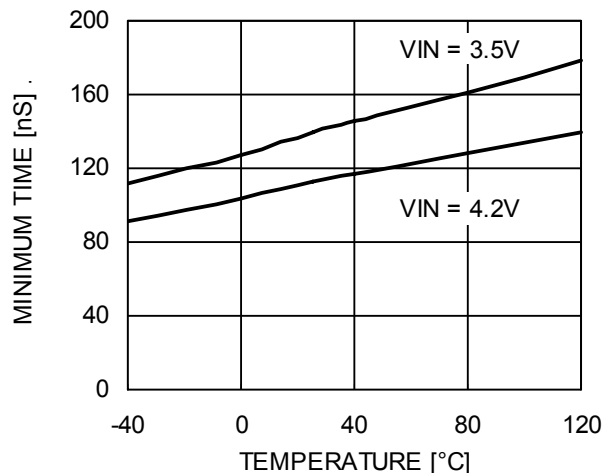
**Line Transient Response (3.6V to 5.5V) 1x Mode**



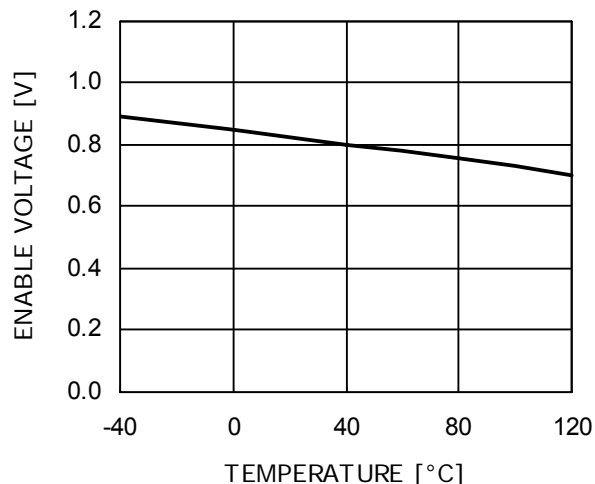
**Enable High Minimum Program Time vs. Temperature**



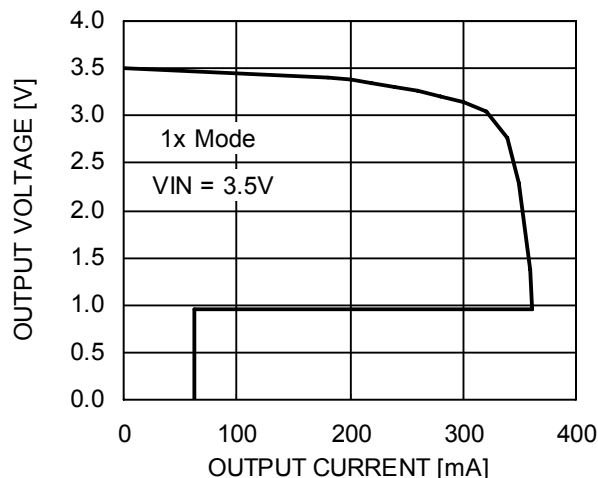
**Enable Low Minimum Program Time vs. Temperature**



**Enable Voltage Threshold vs. Temperature**



**Foldback Current Limit**



## PIN DESCRIPTIONS

| Pin # | Name   | Function  |
|-------|--------|---|
| 1     | VIN    | Supply voltage.   |
| 2     | C1+    | Bucket capacitor 1 terminal   |
| 3     | C1-    | Bucket capacitor 1 terminal   |
| 4     | C2-    | Bucket capacitor 2 terminal   |
| 5     | C2+    | Bucket capacitor 2 terminal   |
| 6     | GND    | Ground reference  |
| 7     | LED1   | LED1 cathode terminal (if not used, connect to VOUT) <sup>(1)</sup> |
| 8     | LED2   | LED2 cathode terminal (if not used, connect to VOUT) <sup>(1)</sup> |
| 9     | LED3   | LED3 cathode terminal (if not used, connect to VOUT) <sup>(1)</sup> |
| 10    | LED4   | LED4 cathode terminal (if not used, connect to VOUT) <sup>(1)</sup> |
| 11    | EN/DIM | Device enable (active high) and dimming control input               |
| 12    | VOUT   | Charge pump output connected to the LED anodes                      |
| TAB   | TAB    | Connect to GND on the PCB   |

## PIN FUNCTION

**VIN** is the supply pin for the charge pump. A small 1 $\mu$ F ceramic bypass capacitor is required between the VIN pin and ground near the device. The operating input voltage range is from 2.2V to 5.5V. Whenever the input supply falls below the undervoltage threshold (2V) all LEDs channels will be automatically disabled.

**EN/DIM** is the enable and dimming 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/DIM is initially taken high, the device becomes enabled and all LED currents remain at 0mA. The falling edge of the first pulse applied to EN/DIM sets all LED currents to their full scale of 31mA.

On each consecutive falling edge of the pulse applied to EN/DIM, the LED current is decreased by 1mA step. On the 32nd pulse, the LED current is set to zero. The next pulse on EN/DIM resets the current back to their full scale of 31mA.

To place the device into zero current shutdown mode, the EN/DIM pin must be held low for 1.5ms or more.

**VOUT** is the charge pump output that is connected to the LED anodes. A small 1 $\mu$ 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 1 $\mu$ F ceramic bucket capacitor C1.

**C2+, C2-** are connected to each side of the 1 $\mu$ F ceramic bucket capacitor C2.

**LED1 to LED4** provide the internal regulated current for each of the LED cathodes. These pins enter a high impedance zero current state whenever the device is placed in shutdown mode. In applications using less than four LEDs, all unused channels should be wired directly to VOUT. This ensures the channel is automatically disabled dissipating less than 200 $\mu$ A.

**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.

### Notes:

(1) LED1, LED2, LED3, LED4 pins should not be left floating. They should be connected to the LED cathode, or tied to VOUT pin if not used.



## BLOCK DIAGRAM

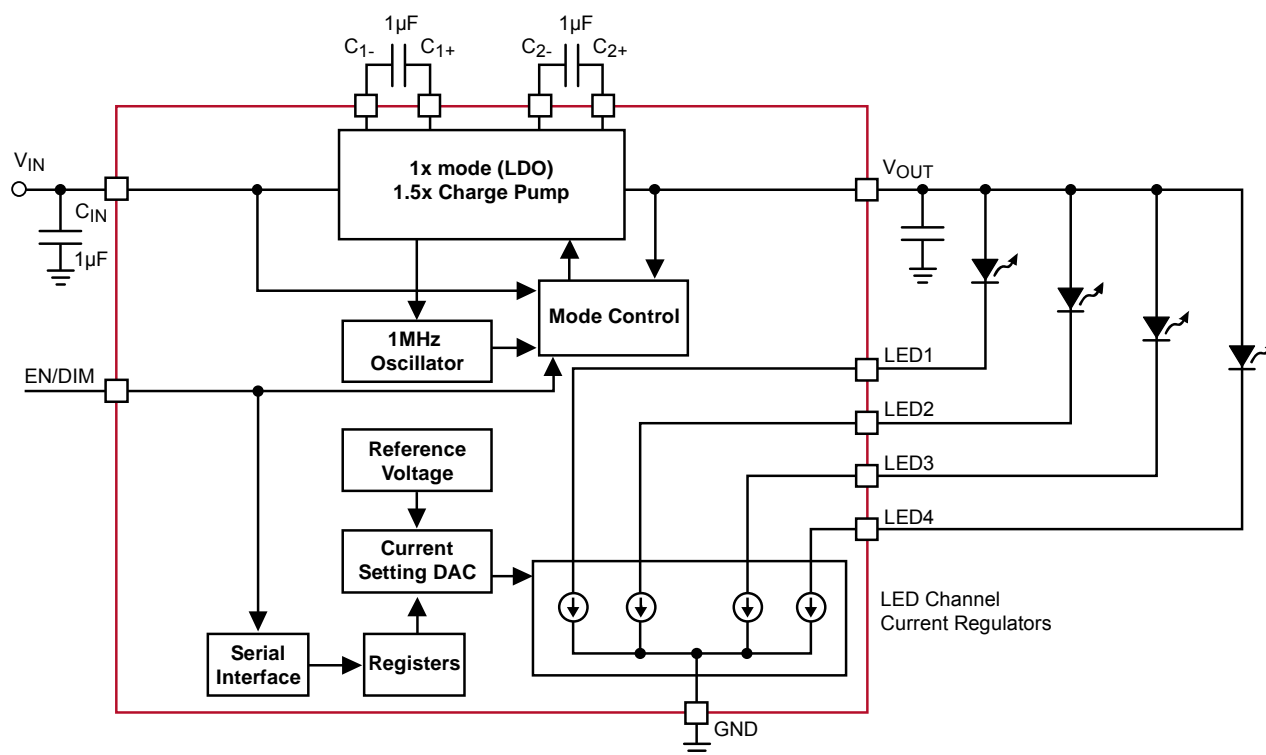


Figure 2. CAT3614 Functional Block Diagram

## BASIC OPERATION

At power-up, the CAT3614 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 input voltage is insufficient or falls to a level where the regulated currents cannot be maintained, the device automatically switches (after a fixed delay of 400µs) into 1.5x mode.

In 1.5x mode, the output is approximately equal to 1.5 times the input supply voltage (less any internal voltage losses).

The above sequence is repeated each and every time the chip is powered-up or is taken out of shutdown mode (via EN/DIM pin).

**LED Current Setting**

Figure 1 shows the timing diagram necessary at the EN/DIM input for setting the LED currents.

The EN/DIM set up time requires the signal to be held high for 10µs or longer to ensure the initialization of the driver at power-up. Each subsequent pulse on the EN/DIM (300ns to 200µs pulse duration) steps down the LED current from full scale of 31mA to zero with a 1mA resolution. Consecutive pulses should be separated by 300ns or longer. Pulsing beyond the 0mA level restores the current level back to full scale and the cycle repeats. Pulsing frequencies from 5kHz up to 1MHz can be supported during dimming operations. When the EN/DIM is held low for 1.5ms or more, the CAT3614 enters the shutdown mode and draws “zero” current.

For applications with three LEDs or less, any unused LED pins should be tied to VOUT, as shown on Figure 3.

**Protection Mode**

If an LED becomes open-circuit, the output voltage VOUT is internally limited to about 5.5V. This is to prevent the output pin from exceeding its absolute maximum rating.

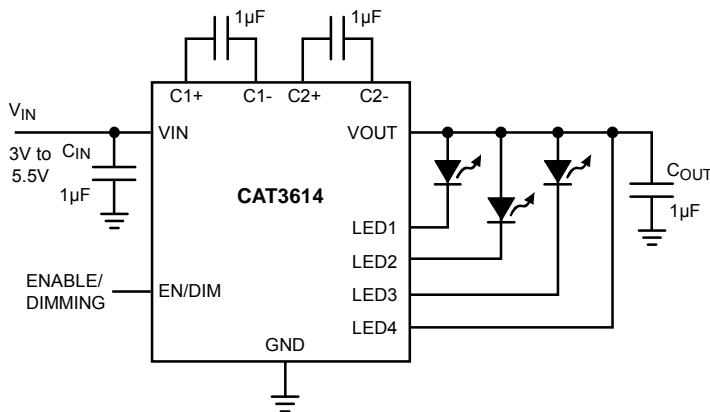
The driver enters a thermal shutdown mode as soon as the die temperature exceeds about +165°C. When the device temperature drops down by about 20°C, the device resumes normal operation.

**External Components**

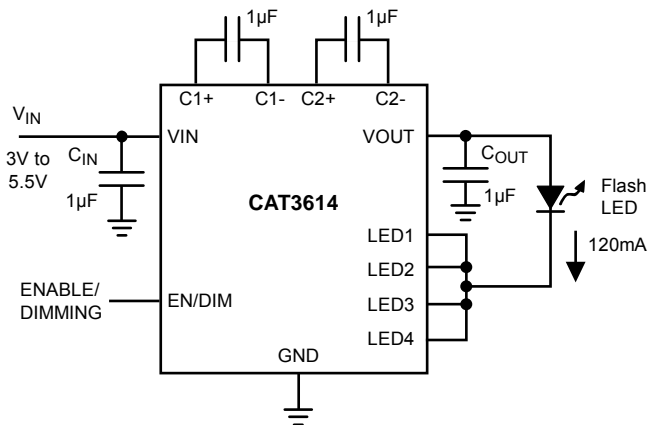
The driver requires a total of four external 1µF ceramic capacitors: two for decoupling input and output, and two for the charge pump. Both capacitor types X5R and X7R are recommended for the LED driver application. In the 1.5x charge pump mode, the input current ripple is kept very low by design, and an input bypass capacitor of 1µF is sufficient. In 1x mode, the device operating in linear mode does not introduce switching noise back onto the supply.

**Recommended Layout**

In 1.5x charge pump mode, the driver switches internally at a high frequency of 1MHz. 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 Cin and Cout can be implemented with the use of multiple vias. A copper area matching the TDFN exposed pad (GND) must be connected to the ground plane underneath. The use of multiple vias improves the package heat dissipation.



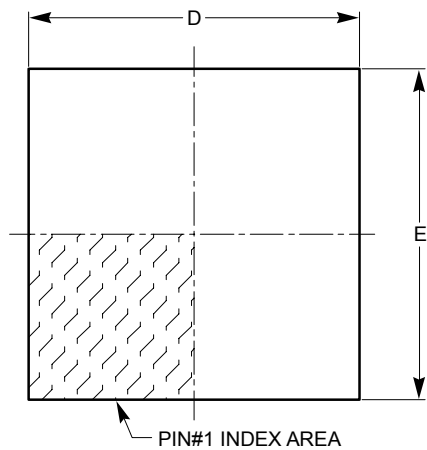
**Figure 3. Three LED Application**



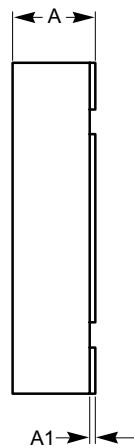
**Figure 4. Single Flash LED Application**

# PACKAGE OUTLINE DRAWING

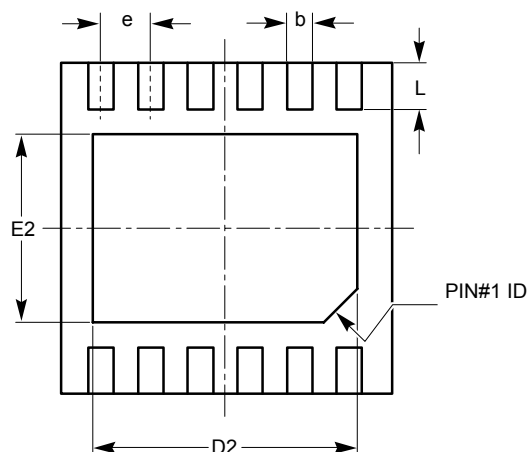
TDFN 12-Pad 3 x 3mm (HV2)<sup>(1)(2)</sup>



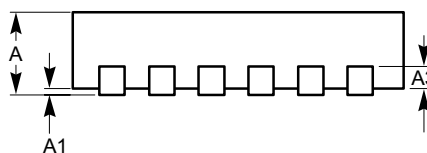
TOP VIEW



SIDE VIEW

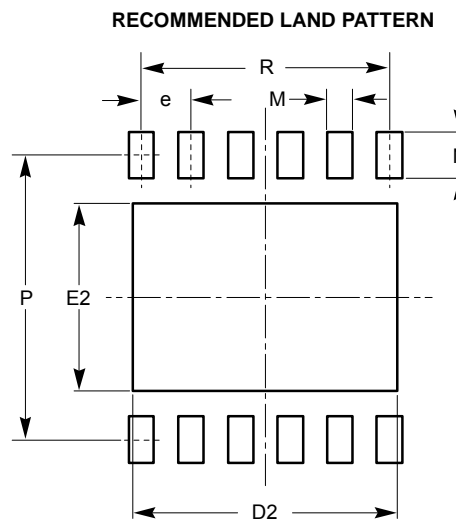


BOTTOM VIEW



FRONT VIEW

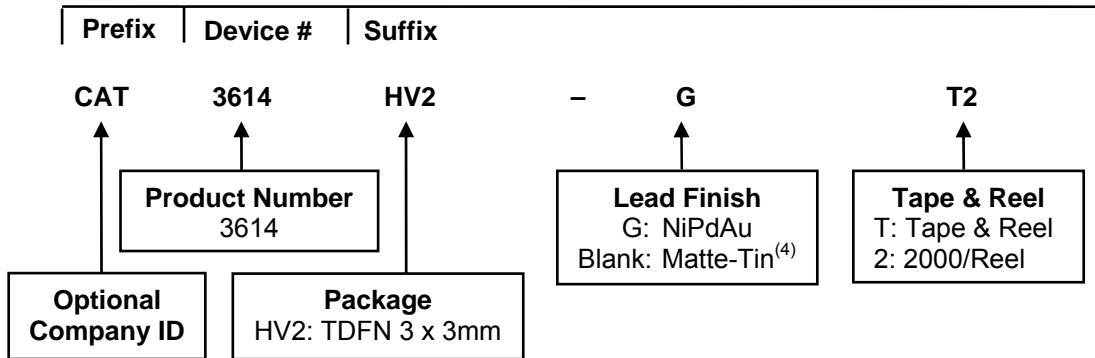
| SYMBOL | MIN      | NOM   | MAX   |
|--------|----------|-------|-------|
| A      | 0.70     | 0.75  | 0.80  |
| A1     | 0.00     | 0.02  | 0.05  |
| A3     | 0.178    | 0.203 | 0.228 |
| b      | 0.18     | 0.23  | 0.30  |
| D      | 2.90     | 3.00  | 3.10  |
| D2     | 2.30     | 2.40  | 2.50  |
| E      | 2.90     | 3.00  | 3.10  |
| E2     | 1.55     | 1.70  | 1.75  |
| e      | 0.45 BSC |       |       |
| L      | 0.30     | 0.40  | 0.50  |
| M      | 0.25     | 0.30  | 0.35  |
| N      | 0.60     | 0.70  | 0.80  |
| P      | 2.70     | 3.00  | 3.10  |
| R      | 2.25 TYP |       |       |



**Notes:**

- (1) All dimensions in millimeters.
- (2) Complies with JEDEC 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 CAT3614HV2-GT2 (TDFN, NiPdAu Plated Finish, Tape & Reel 2000).
- (4) For additional package, please contact your nearest ON Semiconductor Sales office.

## REVISION HISTORY

| Date      | Rev. | Description   |
|-----------|------|---|
| 09-Feb-06 | 00   | Initial Release   |
| 21-Jul-06 | 01   | Update Typical Application Circuit<br>Update Pin Descriptions<br>Update Electrical Operating Characteristics  |
| 07-Jan-08 | B    | Add NiPdAu lead finish<br>Add Extended Temperature Range<br>Update Package Outline Drawing<br>Add Example of Ordering Information<br>Change document number from 25095 to MD-5035 |
| 12-Nov-08 | C    | Change logo and fine print to ON Semiconductor  |

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