

# 700 mA Quad Channel Constant Current LED Driver

## CAT4104

### Description

The CAT4104 provides four matched low dropout current sinks to drive high-brightness LED strings up to 175 mA per channel. The LED channel current is set by an external resistor connected to the RSET pin. The LED pins are compatible with high voltage up to 25 V supporting applications with long strings of LEDs.

The EN/PWM logic input supports the device enable and high frequency external Pulse Width Modulation (PWM) dimming control.

Thermal shutdown protection is incorporated in the device to disable the LED outputs whenever the die temperature exceeds 150°C.

The device is available in the 8-pad TDFN 2 mm x 3 mm package and the SOIC 8-Lead 150 mil wide package.

### Features

- 4 Matched LED Current Sinks up to 175 mA
- Up to 25 V Operation on LED Pins
- Low Dropout Current Source (0.4 V at 175 mA)
- LED Current Set by External Resistor
- High Frequency PWM Dimming via EN/PWM
- “Zero” Current Shutdown Mode
- Thermal Shutdown Protection
- TDFN 8-pad 2 x 3 mm and SOIC 8-lead Packages
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant

### Applications

- Automotive Lighting
- General and Architectural Lighting
- LCD Backlight

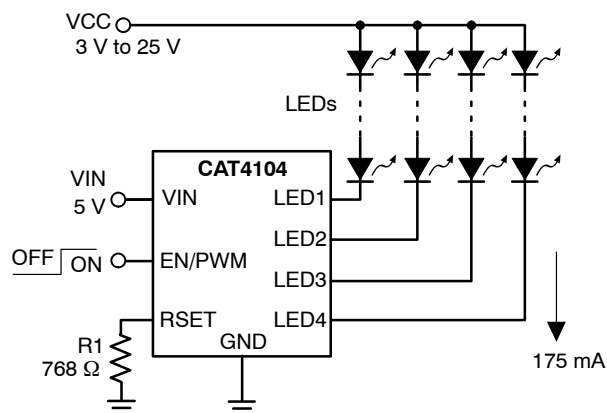


Figure 1. Typical Application Circuit

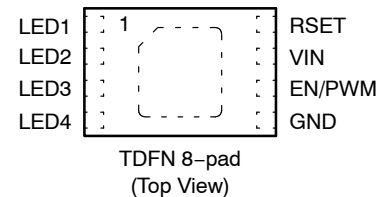
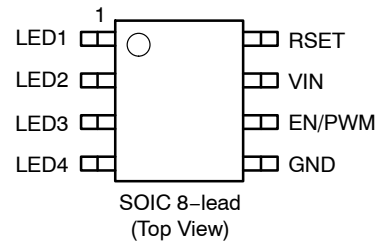


SOIC-8  
V SUFFIX  
CASE 751BD

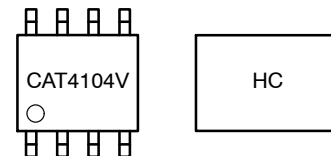


TDFN-8  
VP SUFFIX  
CASE 511AK

### PIN CONNECTIONS



### MARKING DIAGRAMS



CAT4104V = CAT4104V  
HC = CAT4104VP2

### ORDERING INFORMATION

| Device                     | Package             | Shipping              |
|----------------------------|---------------------|-----------------------|
| CAT4104V-GT3<br>(Note 1)   | SOIC-8<br>(Pb-Free) | 3,000/<br>Tape & Reel |
| CAT4104VP2-GT3<br>(Note 1) | TDFN-8<br>(Pb-Free) | 3,000/<br>Tape & Reel |

1. Lead Finish is NiPdAu

**Table 1. ABSOLUTE MAXIMUM RATINGS**

| Parameter                       | Rating      | Unit |
|---------------------------------|-------------|------|
| VIN, RSET, EN/PWM Voltages      | –0.3 to 6   | V    |
| LED1, LED2, LED3, LED4 Voltages | –0.3 to 25  | V    |
| Storage Temperature Range       | –65 to +160 | °C   |
| Junction Temperature Range      | –40 to +150 | °C   |
| Lead Temperature                | 300         | °C   |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

**Table 2. RECOMMENDED OPERATING CONDITIONS**

| Parameter                                    | Rating           | Unit |
|----------------------------------------------|------------------|------|
| VIN                                          | 3.0 to 5.5       | V    |
| Voltage applied to LED1 to LED4, outputs off | up to 25         | V    |
| Voltage applied to LED1 to LED4, outputs on  | up to 6 (Note 2) | V    |
| Ambient Temperature Range                    | –40 to +85       | °C   |
| ILED per LED pin                             | 10 to 175        | mA   |

2. Keeping LEDx pin voltage below 6 V in operation is recommended to minimize thermal dissipation in the package.

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

**Table 3. ELECTRICAL OPERATING CHARACTERISTICS** (Min and Max values are over the recommended operating conditions unless specified otherwise. Typical values are at VIN = 5.0 V, TAMB = 25°C.)

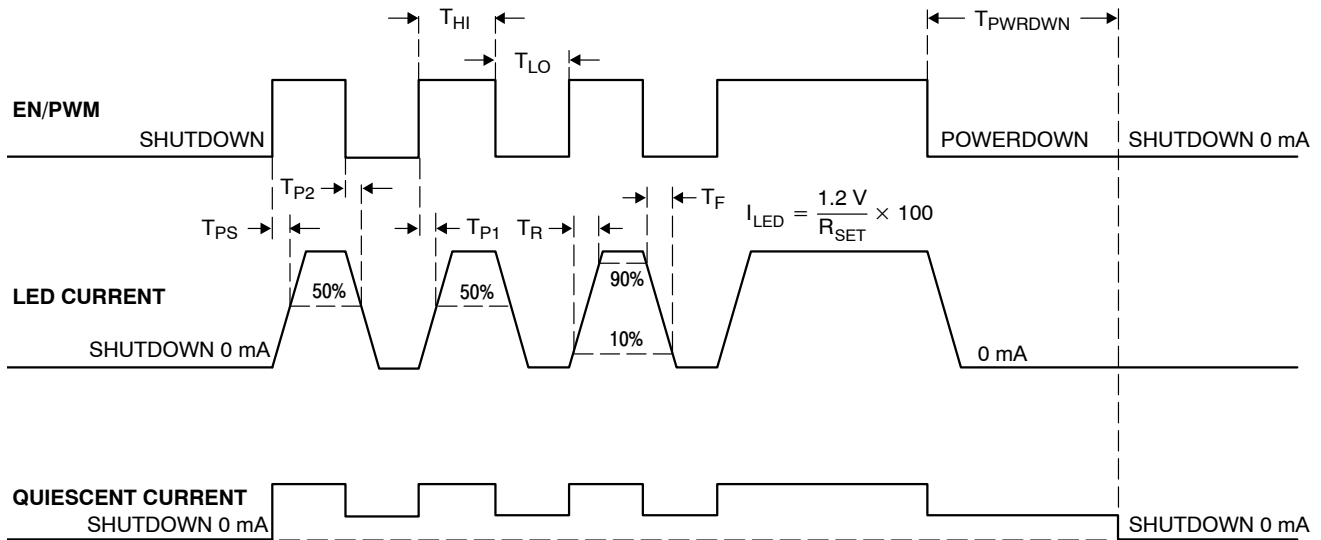
| Symbol                | Name                                                                                     | Conditions                                         | Min  | Typ      | Max  | Units        |
|-----------------------|------------------------------------------------------------------------------------------|----------------------------------------------------|------|----------|------|--------------|
| ILED-ACC              | LED Current Accuracy                                                                     | $\frac{I_{LEDNOM} - I_{LED}}{I_{LEDNOM}}$          |      | ±2       |      | %            |
| ILED-DEV              | LED Channel Matching                                                                     | $\frac{I_{LED} - I_{LEDAVG}}{I_{LEDAVG}}$ (Note 3) | –5   | ±1       | +5   | %            |
| VDOUT                 | Dropout Voltage                                                                          | ILED = 175 mA                                      |      | 400      |      | mV           |
| VRSET                 | RSET Pin Voltage                                                                         |                                                    | 1.17 | 1.2      | 1.23 | V            |
| IQ                    | Quiescent Current                                                                        | No LED, RSET = Float<br>No LED, RSET = 770 Ω       |      | 0.6<br>6 |      | mA           |
| IQSHDN                | Shutdown Current                                                                         | VEN = 0 V                                          |      |          | 1    | μA           |
| REN/PWM<br>VHI<br>VLO | EN/PWM Pin<br>– Internal pull-down resistance<br>– Logic High Level<br>– Logic Low Level |                                                    | 1.3  | 200      | 0.4  | kΩ<br>V<br>V |
| TSD                   | Thermal Shutdown                                                                         |                                                    |      | 150      |      | °C           |
| THYS                  | Thermal Hysteresis                                                                       |                                                    |      | 20       |      | °C           |
| ILED/IRSET            | RSET to LED Current gain ratio                                                           | 25 mA LED current                                  |      | 100      |      |              |
| VUVLO                 | Undervoltage lockout (UVLO) threshold                                                    |                                                    |      | 2.0      |      | V            |

3. Min and Max values are tested for ILED = 50 mA, VIN = 3.5 V, VLEDx = 0.4 V, TAMB = 25°C.

## CAT4104

**Table 4. RECOMMENDED EN/PWM TIMING** (Min and Max values are over the recommended operating conditions unless specified otherwise. Typical values are at VIN = 5.0 V, TAMB = 25°C.)

| Symbol              | Name                                                          | Conditions                                            | Min | Typ        | Max | Units |
|---------------------|---------------------------------------------------------------|-------------------------------------------------------|-----|------------|-----|-------|
| T <sub>PS</sub>     | Turn-On time, EN/PWM rising to I <sub>LED</sub> from shutdown | I <sub>LED</sub> = 175 mA<br>I <sub>LED</sub> = 80 mA |     | 1.5<br>1.3 |     | μs    |
| T <sub>P1</sub>     | Turn-On time, EN/PWM rising to I <sub>LED</sub>               | I <sub>LED</sub> = 175 mA                             |     | 600        |     | ns    |
| T <sub>P2</sub>     | Turn-Off time, EN/PWM falling to I <sub>LED</sub>             | I <sub>LED</sub> = 175 mA<br>I <sub>LED</sub> = 80 mA |     | 400<br>300 |     | ns    |
| T <sub>R</sub>      | LED rise time                                                 | I <sub>LED</sub> = 175 mA<br>I <sub>LED</sub> = 80 mA |     | 700<br>440 |     | ns    |
| T <sub>F</sub>      | LED fall time                                                 | I <sub>LED</sub> = 175 mA<br>I <sub>LED</sub> = 80 mA |     | 360<br>320 |     | ns    |
| T <sub>LO</sub>     | EN/PWM low time                                               |                                                       | 1   |            |     | μs    |
| T <sub>HI</sub>     | EN/PWM high time                                              |                                                       | 5   |            |     | μs    |
| T <sub>PWRDWN</sub> | EN/PWM low time to shutdown delay                             |                                                       |     | 4          | 8   | ms    |



**Figure 2. CAT4104 EN/PWM Timing**

### EN/PWM OPERATION

The EN/PWM pin has two primary functions. One function enables and disables the device. The other function turns the LED channels on and off for PWM dimming control. The device has a very fast turn-on time (from EN/PWM rising to LED on) and allows “instant on” when dimming LED using a PWM signal.

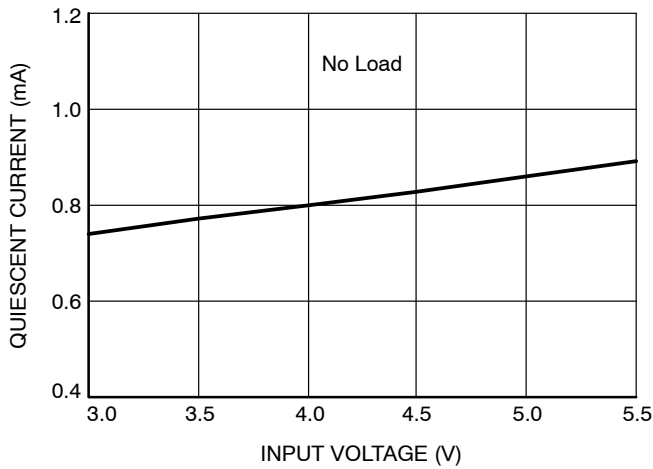
Accurate linear dimming is compatible with PWM frequencies from 100 Hz to 5 kHz for PWM duty cycle down to 1%. PWM frequencies up to 50 kHz can be supported for duty cycles greater than 10%.

When performing a combination of low frequencies and small duty cycles, the device may enter shutdown mode. This has no effect on the dimming accuracy, because the turn-on time T<sub>PS</sub> is very short, in the range of 1 μs.

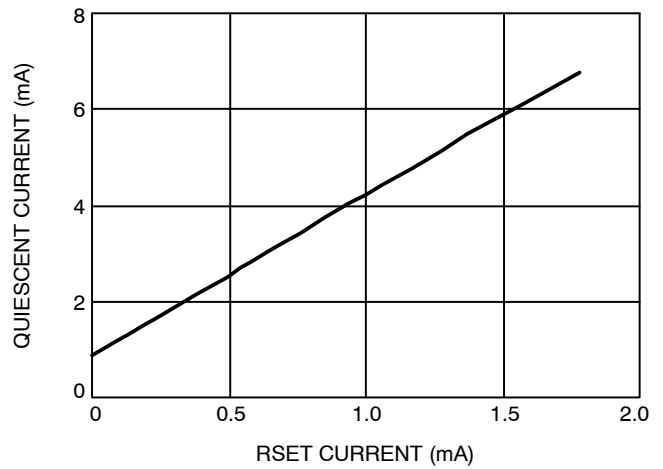
To ensure that PWM pulses are recognized, pulse width low time T<sub>LO</sub> should be longer than 1 μs. The CAT4104 enters a “zero current” shutdown mode after a 4 ms delay (typical) when EN/PWM is held low.

# TYPICAL PERFORMANCE CHARACTERISTICS

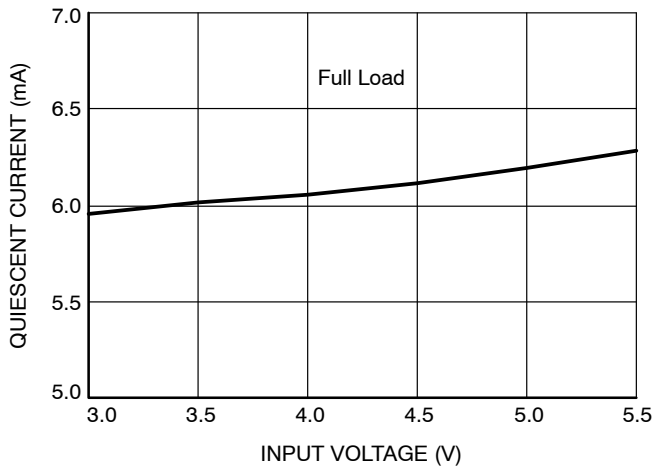
(VIN = 5 V, VCC = 5 V, LED FORWARD VOLTAGE = 3.5 V, CIN = 1 MF, TAMB = 25°C UNLESS OTHERWISE SPECIFIED.)



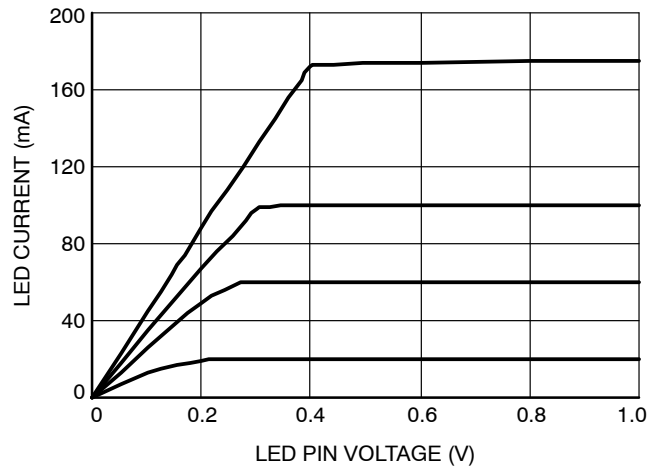
**Figure 3. Quiescent Current vs. Input Voltage (RSET Open)**



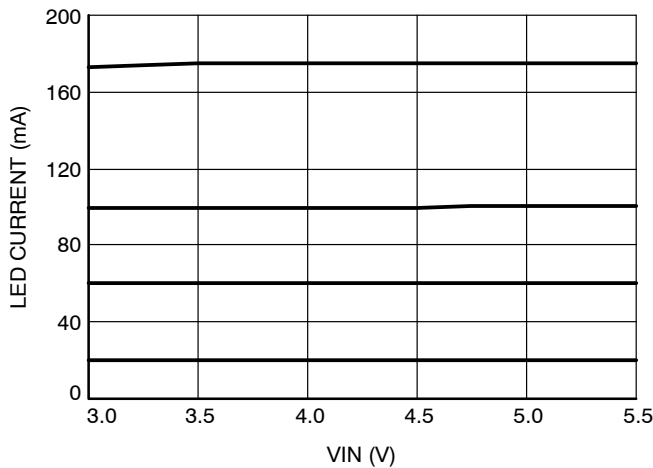
**Figure 4. Quiescent Current vs. RSET Current**



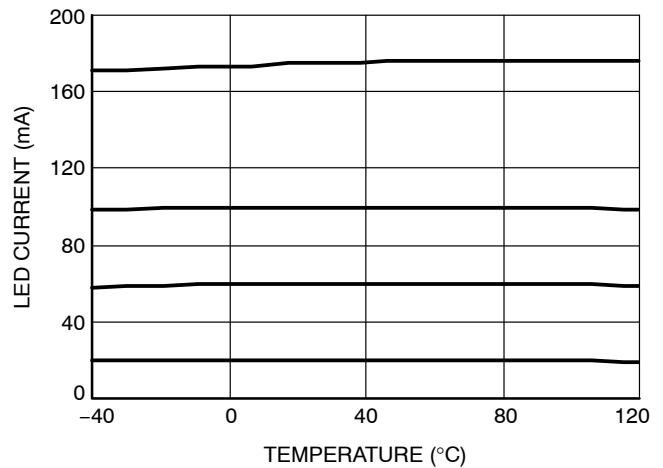
**Figure 5. Quiescent Current vs. Input Voltage (Full Load)**



**Figure 6. LED Dropout vs. LED Pin Voltage**



**Figure 7. LED Line Regulation**



**Figure 8. LED Current Change vs. Temperature**

# TYPICAL PERFORMANCE CHARACTERISTICS

(VIN = 5 V, VCC = 5 V, LED FORWARD VOLTAGE = 3.5 V, CIN = 1 MF, TAMB = 25°C UNLESS OTHERWISE SPECIFIED.)

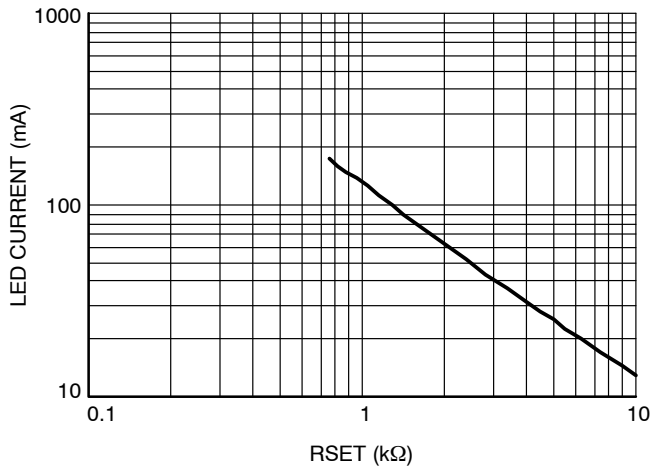


Figure 9. LED Current vs. RSET Resistor

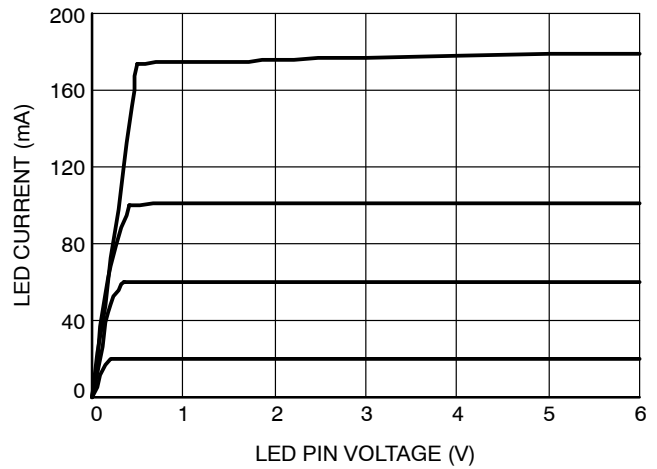


Figure 10. LED Current vs. LED Pin Voltage

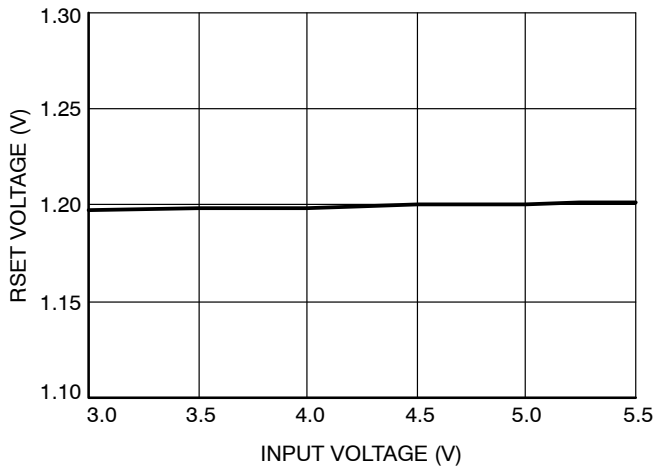


Figure 11. RSET Pin Voltage vs. Input Voltage

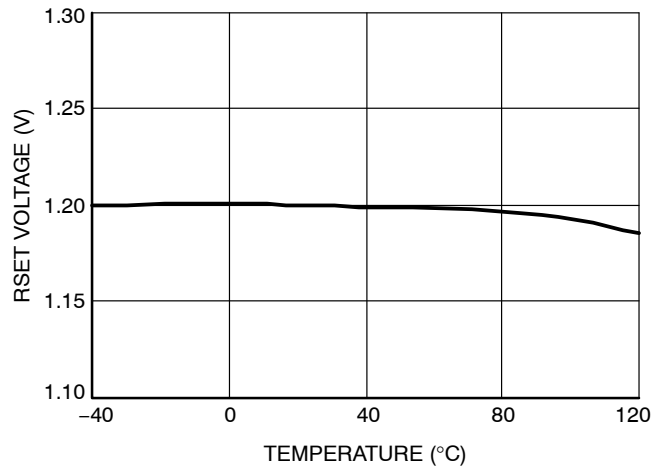


Figure 12. RSET Pin Voltage vs. Temperature

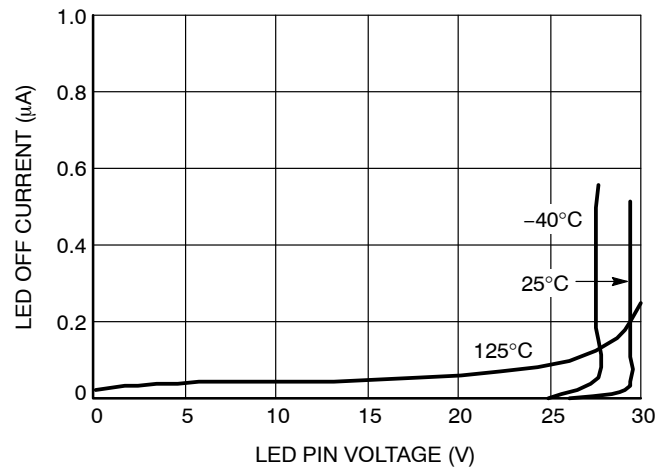
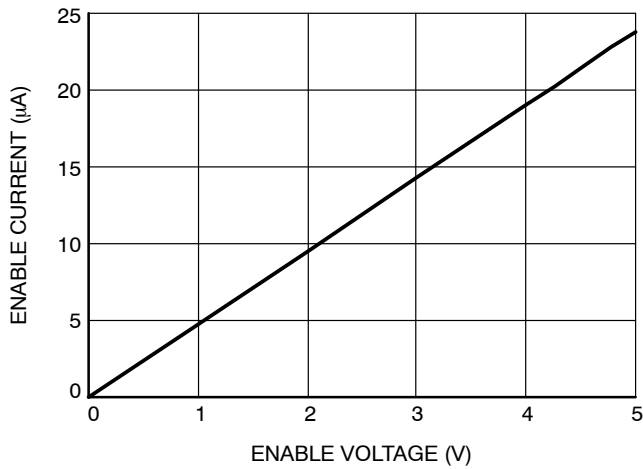


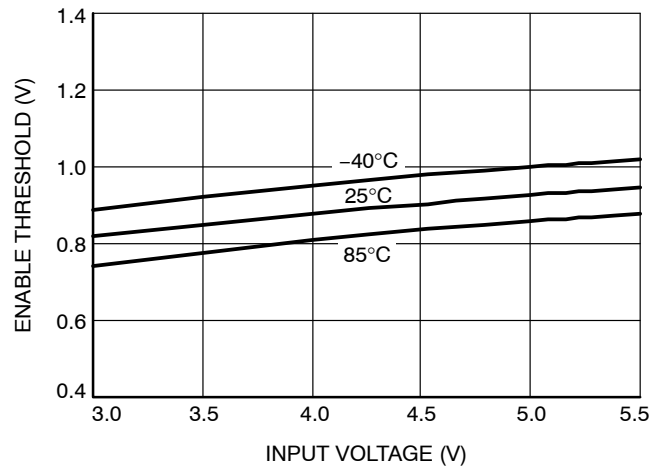
Figure 13. LED Off Current vs. LED Pin Voltage

**TYPICAL PERFORMANCE CHARACTERISTICS**

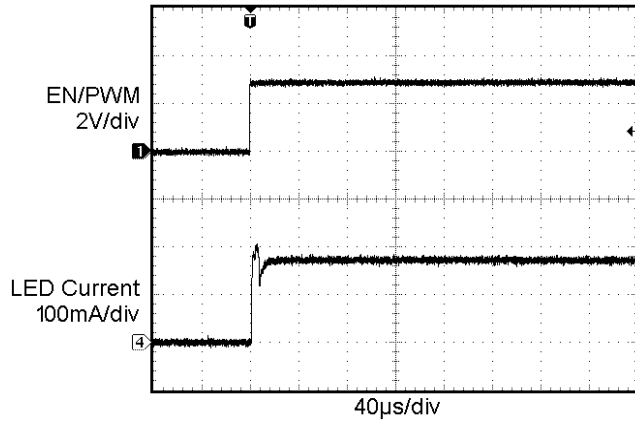
(VIN = 5 V, VCC = 5 V, LED FORWARD VOLTAGE = 3.5 V, CIN = 1 MF, TAMB = 25°C UNLESS OTHERWISE SPECIFIED.)



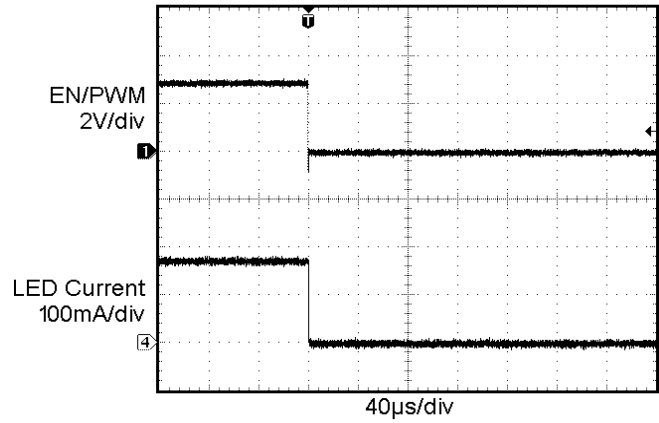
**Figure 14. EN/PWM Pull-down Current vs.  $V_{EN/PWM}$**



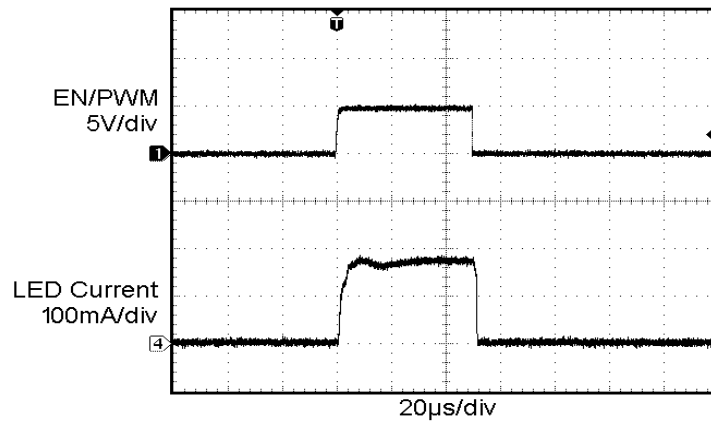
**Figure 15. EN/PWM Threshold vs. VIN**



**Figure 16. Power Up from Shutdown**



**Figure 17. Power Down**



**Figure 18. PWM 200 Hz, 1% Duty Cycle**

Table 5. PIN DESCRIPTIONS

| Name   | Pin<br>SOIC 8-Lead | Pin<br>TDFN 8-Lead | Function                                 |
|--------|--------------------|--------------------|------------------------------------------|
| LED1   | 1                  | 1                  | LED1 cathode terminal                    |
| LED2   | 2                  | 2                  | LED2 cathode terminal                    |
| LED3   | 3                  | 3                  | LED3 cathode terminal                    |
| LED4   | 4                  | 4                  | LED4 cathode terminal                    |
| GND    | 5                  | 5 and TAB          | Ground reference                         |
| EN/PWM | 6                  | 6                  | Device enable input and PWM control      |
| VIN    | 7                  | 7                  | Device supply pin                        |
| RSET   | 8                  | 8                  | LED current set pin for the LED channels |

### PIN FUNCTION

**VIN** is the supply pin for the device. A small 0.1  $\mu$ F ceramic bypass capacitor is optional for noisy environments. Whenever the input supply falls below the under-voltage threshold, all LED channels are automatically disabled.

**EN/PWM** is the enable and one wire dimming input for all LED channels. Guaranteed levels of logic high and logic low are set at 1.3 V and 0.4 V respectively. When EN/PWM is initially taken high, the device becomes enabled and all LED currents are set at a gain of 100 times the current in RSET. To place the device into zero current shutdown mode, the EN/PWM pin must be held low for 4 ms typical.

**LED1 to LED4** provide individual regulated currents for each of the LED cathodes. These pins enter a high

impedance zero current state whenever the device is placed in shutdown mode.

**RSET** pin is connected to an external resistor to set the LED channel current. The ground side of the external resistor should be star connected to the GND of the PCB. The pin source current mirrors the current to the LED sinks. The voltage at this pin is regulated to 1.2 V.

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

**TAB** (TDFN 8-Lead Only) 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.

# CAT4104

## BLOCK DIAGRAM

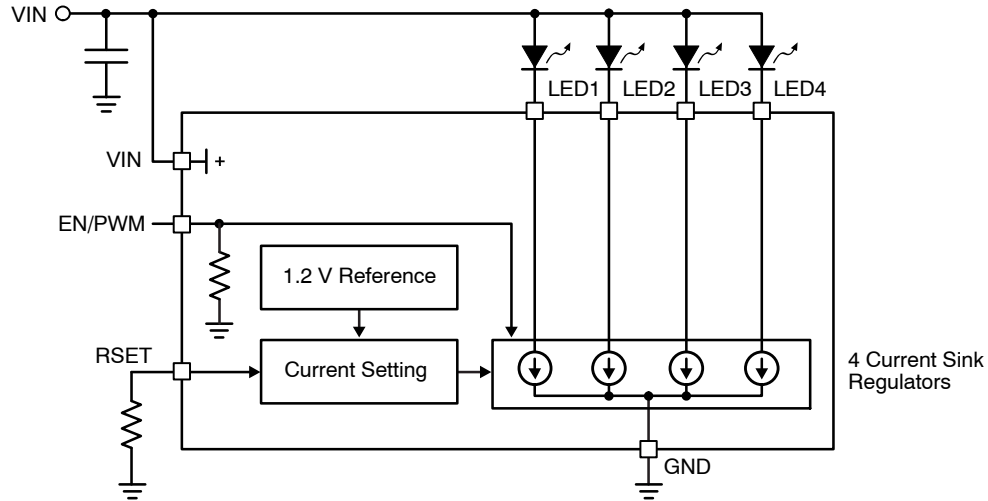


Figure 19. CAT4104 Functional Block Diagram

## BASIC OPERATION

The CAT4104 has four tightly matched current sinks to regulate LED current in each channel. The LED current in the four channels is mirrored from the current flowing through the RSET pin according to the following formula:

$$R(K\Omega) = 117 \times I \text{ (mA)}^{-0.978} + 0.05$$

Table 6 shows standard resistor values for RSET and the corresponding LED current.

Table 6. RSET RESISTOR SETTINGS

| LED Current [mA] | RSET [kΩ] |
|------------------|-----------|
| 20               | 6.34      |
| 60               | 2.10      |
| 100              | 1.27      |
| 175              | 0.768     |

Tight current regulation for all channels is possible over a wide range of input voltages and LED voltages due to independent current sensing circuitry on each channel.

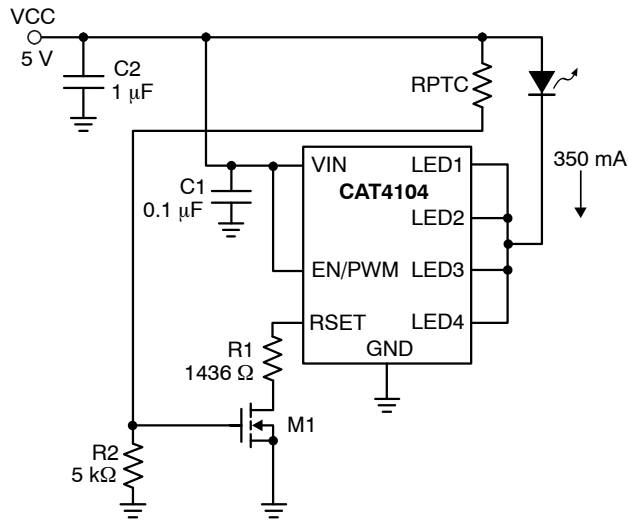
Each LED channel needs a minimum of 400 mV headroom to sink constant regulated current up to 175 mA. If the input supply falls below 2 V, the under-voltage lockout circuit disables all LED channels. Any unused LED channels should be left open.

For applications requiring more than 175 mA current, LED channels can be tied together to sink up to a total of 700 mA from the one device.

The LED channels can withstand voltages up to 25 V. This makes the device ideal for driving long strings of high power LEDs from a high voltage source.



## CAT4104



**Figure 23. LED Current Derating**

### Power Dissipation

The power dissipation ( $P_D$ ) of the CAT4104 can be calculated as follows:

$$P_D = (V_{IN} \times I_{IN}) + \Sigma(V_{LEDN} \times I_{LEDN})$$

where  $V_{LEDN}$  is the voltage at the LED pin, and  $I_{LEDN}$  is the LED current. Combinations of high  $V_{LEDN}$  voltage and high ambient temperature can cause the CAT4104 to enter thermal shutdown. In applications where  $V_{LEDN}$  is high, a resistor can be inserted in series with the LED string to lower the power dissipation  $P_D$ .

Thermal dissipation of the junction heat consists primarily of two paths in series. The first path is the junction to the case ( $\theta_{JC}$ ) thermal resistance which is defined by the package style, and the second path is the case to ambient ( $\theta_{CA}$ ) thermal resistance, which is dependent on board layout. The overall junction to ambient ( $\theta_{JA}$ ) thermal resistance is equal to:

$$\theta_{JA} = \theta_{JC} + \theta_{CA}$$

For a given package style and board layout, the operating junction temperature  $T_J$  is a function of the power dissipation  $P_D$ , and the ambient temperature, resulting in the following equation:

$$T_J = T_{AMB} + P_D(\theta_{JC} + \theta_{CA}) = T_{AMB} + P_D \theta_{JA}$$

When mounted on a double-sided printed circuit board with two square inches of copper allocated for “heat spreading”, the resulting  $\theta_{JA}$  is about 90°C/W for the TDFN-8 package, and 160°C/W for the SOIC-8 package.

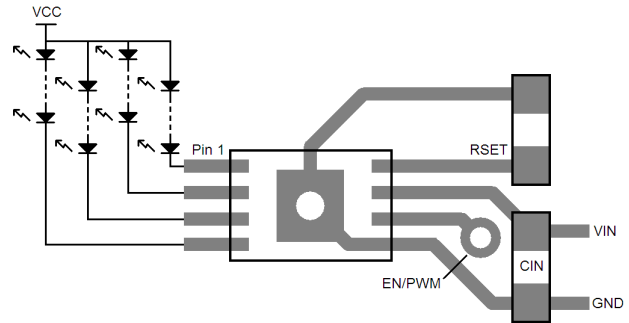
For example, at 60°C ambient temperature, the maximum power dissipation for the TDFN-8 is calculated as follow:

$$P_{Dmax} = \frac{T_{Jmax} - T_{AMB}}{\theta_{JA}} = \frac{150 - 60}{90} = 1 \text{ W}$$

### Recommended Layout

A small ceramic capacitor should be placed as close as possible to the driver VIN pin. The RSET resistor should have a Kelvin connection to the GND pin of the CAT4104.

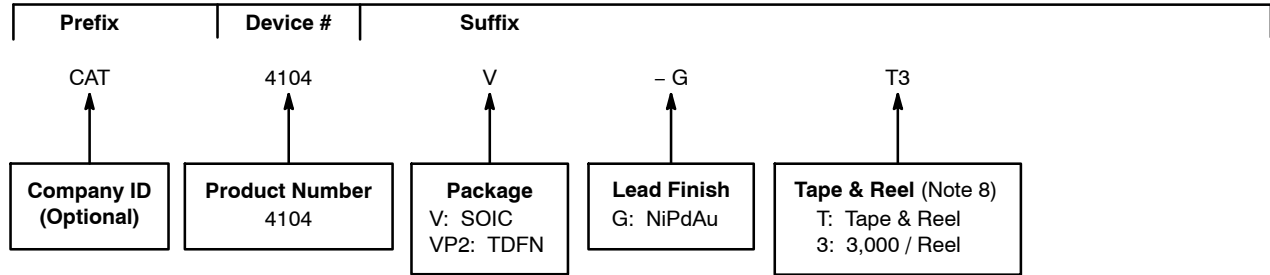
The board layout should provide good thermal dissipation through the PCB. In the case of the CAT4104VP2 in the TDFN package, a via can be used to connect the center tab to a large ground plane underneath as shown on Figure 24.



**Figure 24. CAT4104 Recommended Layout**

# CAT4104

## EXAMPLE OF ORDERING INFORMATION (NOTE 6)



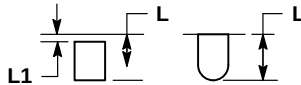
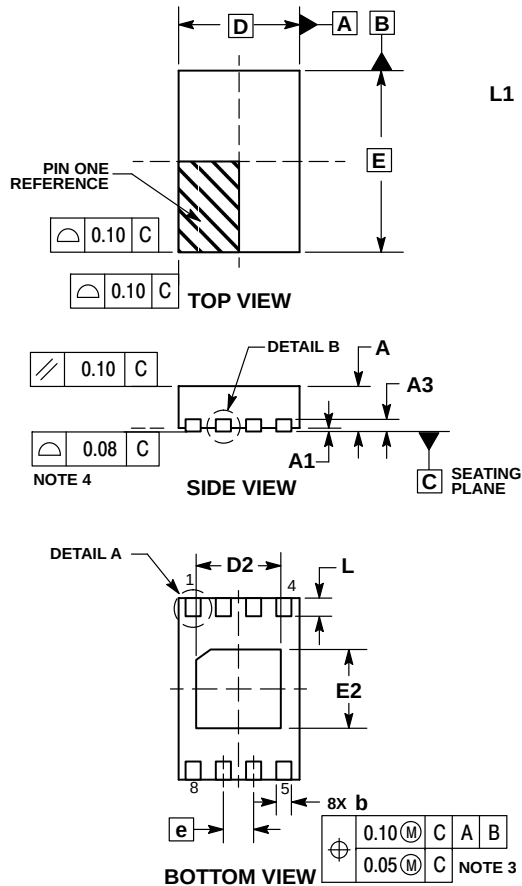
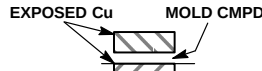
4. All packages are RoHS-compliant (Lead-free, Halogen-free).
5. The standard plated finish is NiPdAu.
6. The device used in the above example is a CAT4104V-GT3 (SOIC, NiPdAu, Tape & Reel, 3,000/Reel).
7. For additional temperature options, please contact your nearest ON Semiconductor Sales office.
8. For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.



SCALE 2:1

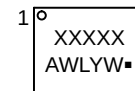
**TDFN8, 2x3, 0.5P**  
**CASE 511AK**  
**ISSUE B**

DATE 18 MAR 2015


**DETAIL A**  
**ALTERNATE**  
**CONSTRUCTIONS**

**DETAIL B**  
**ALTERNATE**  
**CONSTRUCTION**
**NOTES:**

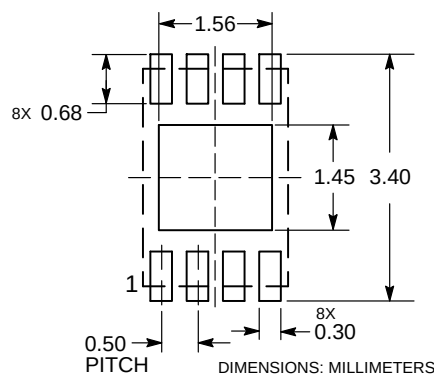
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.25MM FROM THE TERMINAL TIP.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

| DIM | MILLIMETERS |      |
|-----|-------------|------|
|     | MIN         | MAX  |
| A   | 0.70        | 0.80 |
| A1  | 0.00        | 0.05 |
| A3  | 0.20 REF    |      |
| b   | 0.20        | 0.30 |
| D   | 2.00 BSC    |      |
| D2  | 1.30        | 1.50 |
| E   | 3.00 BSC    |      |
| E2  | 1.20        | 1.40 |
| e   | 0.50 BSC    |      |
| L   | 0.20        | 0.40 |
| L1  | ---         | 0.15 |

**GENERIC**  
**MARKING DIAGRAM\***


XXXXX = Specific Device Code  
A = Assembly Location  
WL = Wafer Lot  
Y = Year  
W = Work Week  
▪ = Pb-Free Package

\*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "▪", may or may not be present.

**RECOMMENDED**  
**SOLDERING FOOTPRINT\***


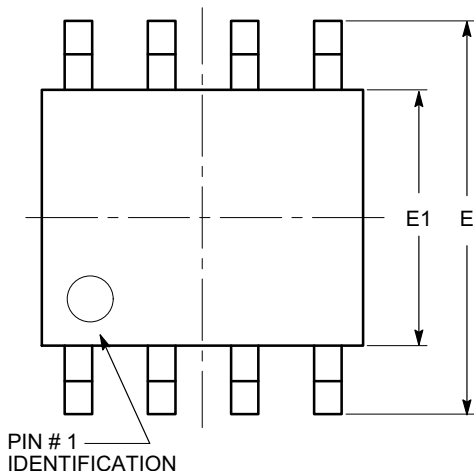
\*For additional information on our Pb-Free strategy and soldering details, please download the onsemi Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

|                         |                         |                                                                                                                                                                                     |
|-------------------------|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DOCUMENT NUMBER:</b> | <b>98AON34336E</b>      | Electronic versions are uncontrolled except when accessed directly from the Document Repository.<br>Printed versions are uncontrolled except when stamped "CONTROLLED COPY" in red. |
| <b>DESCRIPTION:</b>     | <b>TDFN8, 2X3, 0.5P</b> | <b>PAGE 1 OF 1</b>                                                                                                                                                                  |

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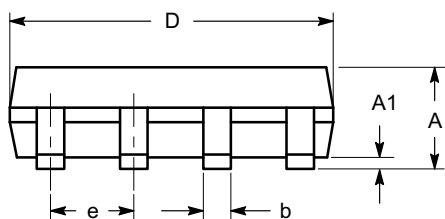
**SOIC-8, 150 mils**  
CASE 751BD  
ISSUE O

DATE 19 DEC 2008

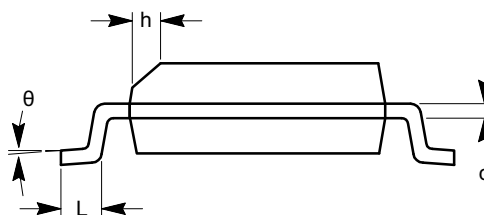


**TOP VIEW**

| SYMBOL   | MIN      | NOM | MAX  |
|----------|----------|-----|------|
| A        | 1.35     |     | 1.75 |
| A1       | 0.10     |     | 0.25 |
| b        | 0.33     |     | 0.51 |
| c        | 0.19     |     | 0.25 |
| D        | 4.80     |     | 5.00 |
| E        | 5.80     |     | 6.20 |
| E1       | 3.80     |     | 4.00 |
| e        | 1.27 BSC |     |      |
| h        | 0.25     |     | 0.50 |
| L        | 0.40     |     | 1.27 |
| $\theta$ | 0°       |     | 8°   |



**SIDE VIEW**



**END VIEW**

**Notes:**

- (1) All dimensions are in millimeters. Angles in degrees.
- (2) Complies with JEDEC MS-012.

|                         |                         |                                                                                                                                                                                     |
|-------------------------|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
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