# 3-Channel Constant-Current RGB LED Driver with Individual PWM Dimming

## FEATURES

- **3 independent current sinks up to 175mA rated 25V**
- **LED Current set by external low power control resistors**
- **Individual PWM control per channel**
- **Low dropout current source (0.4V at 175mA)**
- **Output Enable input for dimming**
- **"Zero" current shutdown mode**
- **3V to 5.5V logic supply**
- **Thermal shutdown protection**
- **RoHS-compliant 16-lead SOIC package**

## APPLICATIONS

- **Multi-color LED, Architectural Lighting**
- **LED signs and displays**
- **LCD backlight**

## ORDERING INFORMATION

| Part Number | Package | Quantity per Reel | Package Marking |
|---|---|---|---|
| CAT4109V-GT2 | SOIC-16* | 2,000 | CAT4109V |

* Lead Finish NiPdAu

## DESCRIPTION

The CAT4109 is a 3-channel constant-current LED driver, requiring no inductor. LED channel currents up to 175mA are programmed independently via separate external resistors. Low output voltage operation of 0.4V at 175mA allows for more power efficient designs across wider supply voltage range. The three LED pins are compatible with high voltage up to 25V supporting applications with long strings of LEDs.

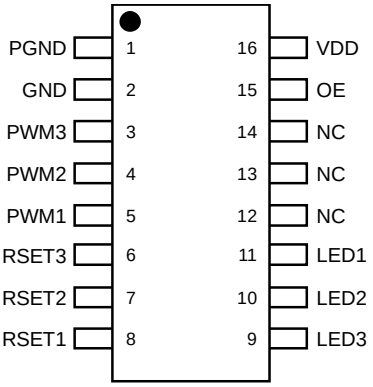
Three independent control inputs PWM1, PWM2, PWM3, control respectivelly LED1, LED2, LED3 channels. The device also includes an output enable (OE) control pin to disable all three channels independently of the PWMx input states.

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

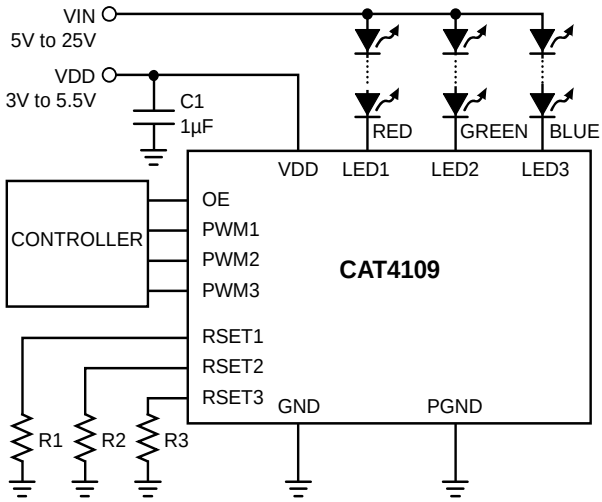
The device is available in a 16-lead SOIC package.

## PIN CONFIGURATION

**16-Lead SOIC (W)**
**Top View**




## TYPICAL APPLICATION CIRCUIT



## ABSOLUTE MAXIMUM RATINGS

| Parameter | Rating | Units |
|---|---|---|
| VDD Voltage | 6 | V |
| Input Voltage Range (OE, PWM1, PWM2, PWM3) | -0.3V to 6V | V |
| LED1, LED2, LED3 Voltage | 25 | V |
| DC Output Current on LED1 to LED3 | 200 | mA |
| Storage Temperature Range | -55 to +160 | °C |
| Junction Temperature Range | -40 to +150 | °C |
| Lead Soldering Temperature (10sec.) | 300 | °C |
| ESD Rating on All Pins: • Human Body Model<br>• Machine Model | 2000<br>200 | V |

## RECOMMENDED OPERATING CONDITIONS

| Parameter | Range | Units |
|---|---|---|
| VDD | 3.0 to 5.5 | V |
| Voltage applied to LED1 to LED3, outputs off | up to 25 | V |
| Voltage applied to LED1 to LED3, outputs on | up to 6* | V |
| Output Current on LED1 to LED3 | 2 to 175 | mA |
| Ambient Temperature Range | -40 to +85 | °C |

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

## ELECTRICAL OPERATING CHARACTERISTICS

### DC CHARACTERISTICS

Min and Max values are over recommended operating conditions unless specified otherwise.
Typical values are at VDD = 5.0V, $T_{AMB}$ = 25°C

| Symbol | Name | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $I_{DD1}$ | Supply Current Outputs Off | $V_{LED}$ = 5V, $R_{SET}$ = 24.9kΩ | | 2 | 5 | mA |
| $I_{DD2}$ | Supply Current Outputs Off | $V_{LED}$ = 5V, $R_{SET}$ = 5.23kΩ | | 4 | 10 | mA |
| $I_{DD3}$ | Supply Current Outputs On | $V_{LED}$ = 0.5V, $R_{SET}$ = 24.9kΩ | | 2 | 5 | mA |
| $I_{DD4}$ | Supply Current Outputs On | $V_{LED}$ = 0.5V, $R_{SET}$ = 5.23kΩ | | 4 | 10 | mA |
| $I_{SHDN}$ | Shutdown Current | $V_{OE}$ = 0V | | | 1 | µA |
| $I_{LKG}$ | LED Output Leakage | $V_{LED}$ = 5V, Outputs Off | -1 | | 1 | µA |
| $R_{OE}$ | OE pull-down resistance | | 140 | 190 | 250 | kΩ |
| $V_{OE\_IH}$<br>$V_{OE\_IL}$ | OE logic high input voltage<br>OE logic low input voltage | | <br>0.4 | | 1.2 | V |
| $V_{PWM\_IH}$<br>$V_{PWM\_IL}$ | PWMx logic high input voltage<br>PWMx logic low input voltage | | <br>0.3x $V_{DD}$ | | 0.7x $V_{DD}$ | V |
| $I_{IL}$ | Logic Input Leakage Current (PWMx) | $V_{PWMx}$ = $V_{DD}$ or GND | -5 | 0 | 5 | µA |
| $V_{RSETx}$ | RSETx Regulated Voltage | | 1.17 | 1.2 | 1.23 | V |
| $T_{SD}$ | Thermal Shutdown | | | 150 | | °C |
| $T_{HYS}$ | Thermal Hysteresis | | | 20 | | °C |
| $I_{LED}/I_{RSET}$ | RSET to LED Current Gain ratio | 100mA LED Current | | 400 | | |
| $V_{UVLO}$ | Undervoltage Lockout (UVLO) Threshold | | | 1.8 | | V |

## RECOMMENDED TIMING

Min and Max values are over recommended operating conditions unless specified otherwise.
Typical values are at VDD = 5.0V, $T_{AMB}$ = 25°C

| Symbol | Name | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $T_{PS}$ | Turn-On time, OE rising to $I_{LED}$ from Shutdown | $I_{LED}$ = 100mA | | 1.4 | | µs |
| $T_{P1}$ | Turn-On time, OE or PWMx rising to | $I_{LED}$ = 100mA | | 600 | | ns |
| $T_{P2}$ | Turn-Off time, OE or PWMx falling to | $I_{LED}$ = 100mA | | 300 | | ns |
| $T_R$ | LED rise time | $I_{LED}$ = 100mA | | 300 | | ns |
| $T_F$ | LED fall time | $I_{LED}$ = 100mA | | 300 | | ns |
| $T_{LO}$ | OE low time | | 1 | | | µs |
| $T_{HI}$ | OE high time | | 5 | | | µs |
| $T_{PWRDWN}$ | OE low time to shutdown delay | | | 4 | 8 | ms |

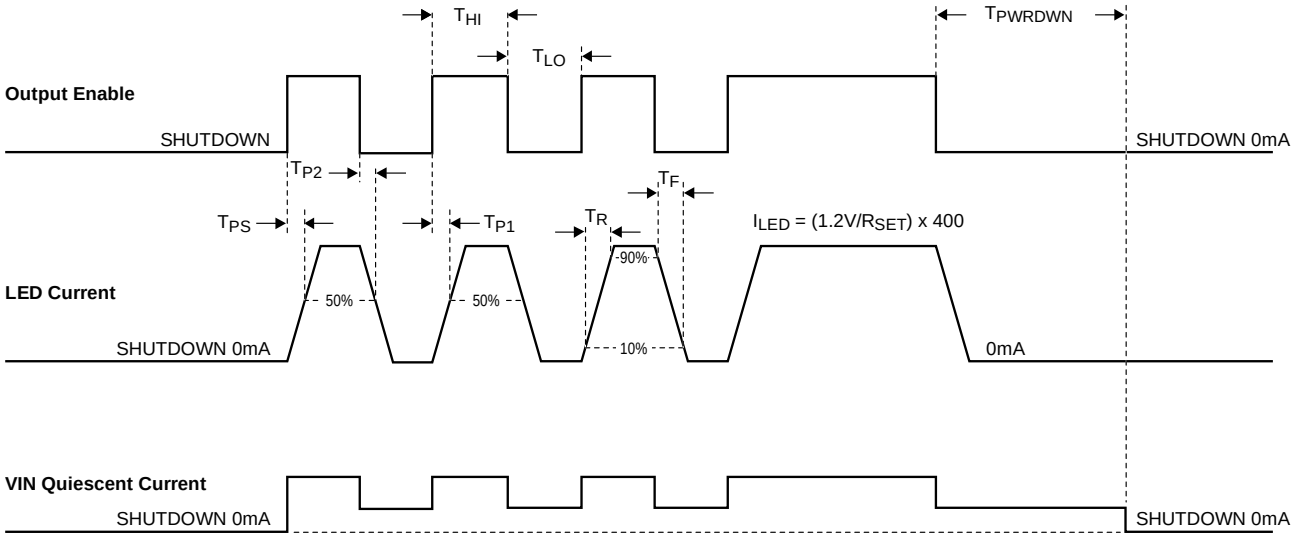



**Figure 1. CAT4109 OE Timing**

## OE OPERATION

The Output Enable (OE) pin has two primary functions. When the OE input goes from high to low, all three LED channels are turned off. If OE remains low for longer than $T_{PWRDWN}$, the device enters shutdown mode drawing "zero current" from the supply.

The OE input can be used to adjust the contrast of the RGB LED by applying an external PWM signal. The device has a very fast turn-on time (from OE rising to LED on) allowing "instant on" when dimming LEDs.

When applying PWM signals to the three PWMx inputs and using the OE pin for dimming, the OE PWM frequency should be much lower to preserve the color mixing.

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

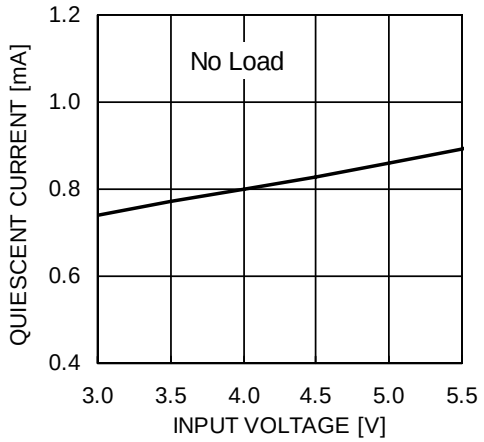
When performing a combination of low frequencies and small duty cycles, the device may enter shutdown mode. This has no effect on the dimming accuracy, because the turn-on time $T_{PS}$ is very short, in the range of 1µs.

To ensure that PWM pulses are recognized, pulse width low time $T_{LO}$ should be longer than 1µs. The driver enters a "zero current" shutdown mode after a 4ms delay (typical) when OE is held low.

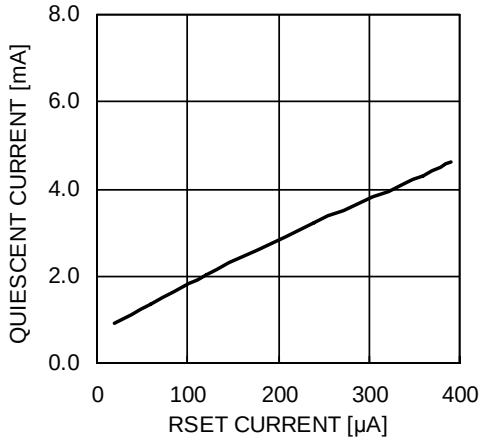
## TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN}$ = 5V, $V_{DD}$ = 5V, C1 = 1µF, $T_{AMB}$ = 25°C unless otherwise specified.

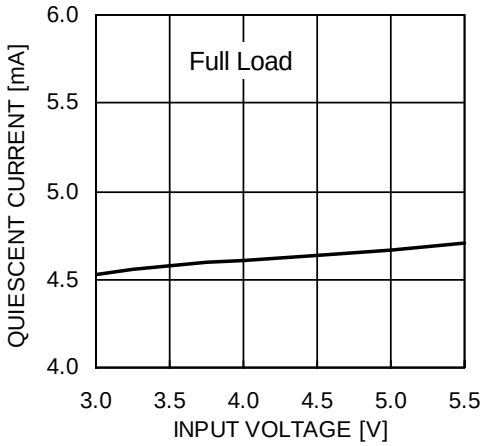
**Quiescent Current vs. Input Voltage ($I_{LED}$ = 0mA)**



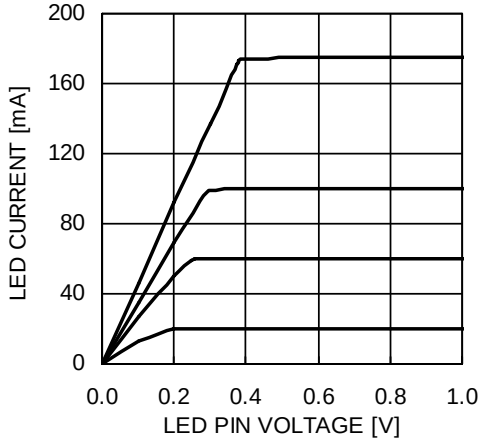

**Quiescent Current vs. RSET Current**



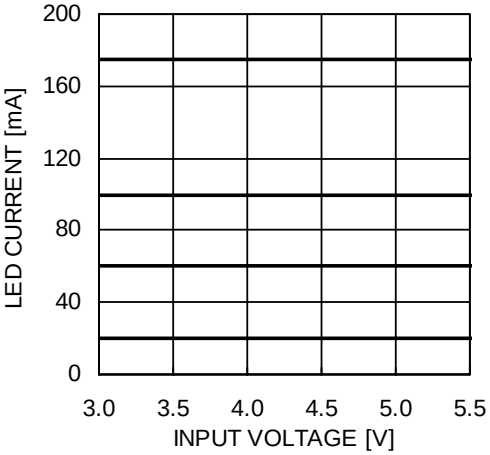

**Quiescent Current vs. Input Voltage ($I_{LED}$ = 175mA)**



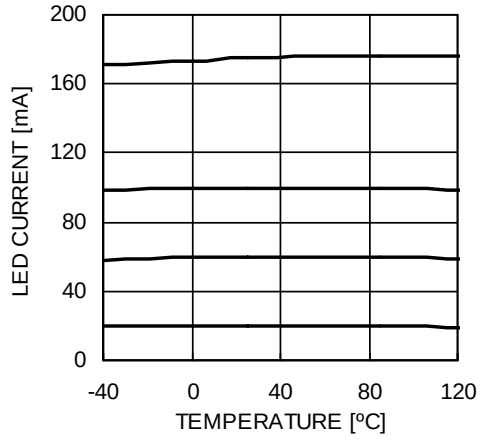

**LED Current vs. LED Pin Voltage**




**LED Current Change vs. Input Voltage**



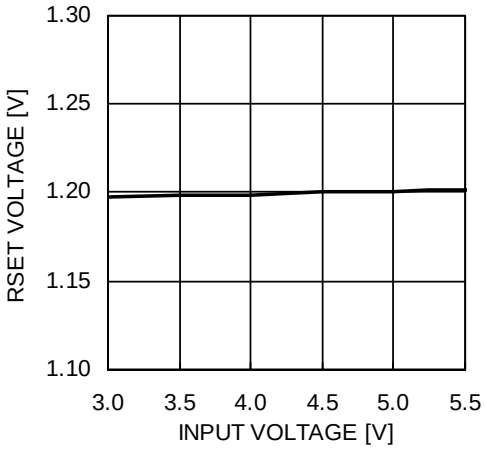

**LED Current Change vs. Temperature**



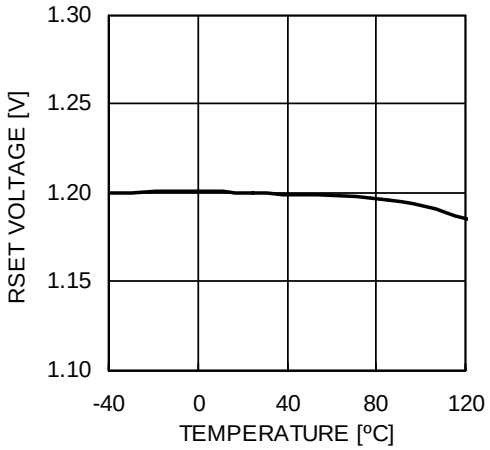
## TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN}$ = 5V, $V_{DD}$ = 5V, C1 = 1µF, $T_{AMB}$ = 25°C unless otherwise specified.

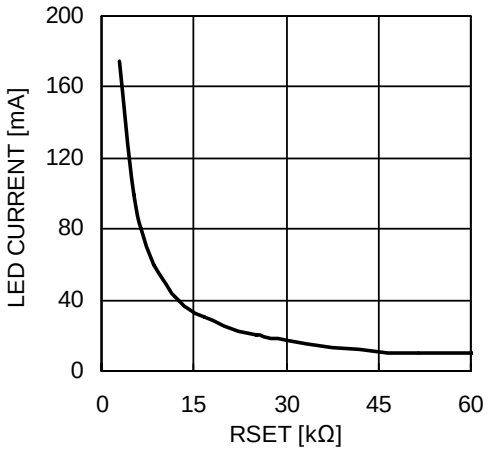
**RSET Pin Voltage vs. Input Voltage**



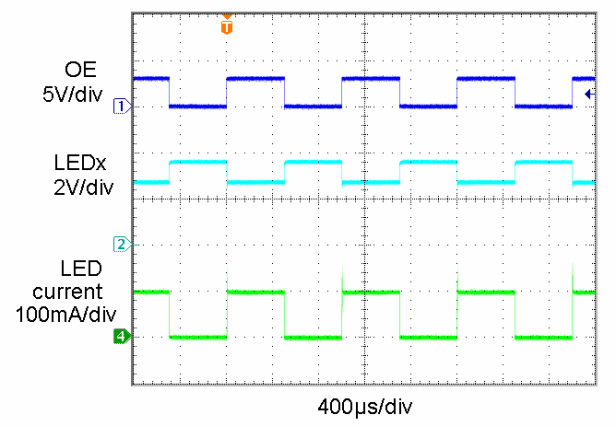

**RSET Pin Voltage vs. Temperature**



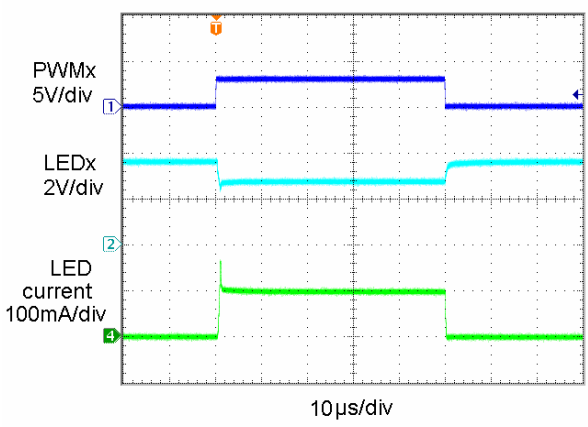

**LED Current vs. RSET Resistor**




**OE Transient Response at 1kHz**




**PWMx Transient Response**



## PIN DESCRIPTIONS

| Name | Pin Number | Function |
|---|---|---|
| PGND | 1 | Power Ground. |
| GND | 2 | Ground Reference. |
| PWM3 | 3 | PWM control input for LED3 |
| PWM2 | 4 | PWM control input for LED2 |
| PWM1 | 5 | PWM control input for LED1 |
| RSET3 | 6 | LED current set pin for LED3 |
| RSET2 | 7 | LED current set pin for LED2 |
| RSET1 | 8 | LED current set pin for LED1 |
| LED3 | 9 | LED channel 3 cathode terminal |
| LED2 | 10 | LED channel 2 cathode terminal |
| LED1 | 11 | LED channel 1 cathode terminal |
| NC | 12 | Not connected inside package |
| NC | 13 | Not connected inside package |
| NC | 14 | Not connected inside package |
| OE | 15 | Output Enable input pin |
| VDD | 16 | Device Supply pin |

## PIN FUNCTION

**PGND** is the power ground reference pin for the device. This pin must be connected to the GND pin and to the ground plane on the PCB.

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

**PWM1 to PWM3** are the control inputs respectively for LED1, LED2 and LED3 channels. When PWMx are low, the associated LED channels are turned off. When PWMx are high, the corresponding channels are turned on, assuming the OE input is also high. PWMx pins can not be left open and must be set to either to logic high or low.

**RSET1 to RSET3** are the LED current set inputs. The current pulled out of these pins will be mirrored in the corresponding LED channel with a gain of 400.

**LED1 to LED3** are the LED current sink inputs. These pins are connected to the bottom cathodes of the LED strings. The current sinks bias the LEDs with a current equal to 400 times the corresponding RSETx pin current. For the LED sink to operate correctly the voltage on the LED pin must be above 0.4V. Each LED channel can withstand voltages up to 25V.

**OE** is the output enable input. When high, all LED channels are enabled according to the state of their corresponding PWMx control inputs. When low, all LED channels are turned off. This pin can be used to turn all the LEDs off independently of the state of the PWMx inputs. If the OE stays low for a duration longer than $T_{PWRDWN}$, the device enters shutdown mode.

**VDD** is the positive supply pin voltage for the entire device. A small 1µF bypass ceramic capacitor is recommended between VDD pin and ground near the device.

## BLOCK DIAGRAM

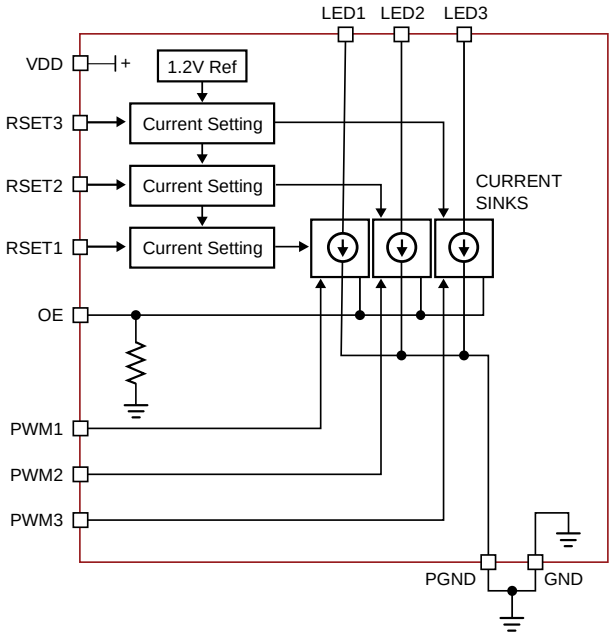



**Figure 2. CAT4109 Functional Block Diagram**

## BASIC OPERATION

The CAT4109 uses 3 independent current sinks to accurately regulate the current in each LED channel to 400 times the current sink from the corresponding RSET pin. Each of the resistors tied to the RSET1, RSET2, RSET3 pins set the current respectively in the LED1, LED2, and LED3 channels. Table 1 shows standard resistor values for RSET and the corresponding LED current.

**Table 1. RSET Resistor Settings**

| LED Current [mA] | RSET[kΩ] |
|---|---|
| 20 | 24.9 |
| 60 | 8.45 |
| 100 | 5.23 |
| 175 | 3.01 |

Tight current regulation for all channels is possible over a wide range of input and LED voltages due to independent current sensing circuitry on each channel. The LED channels have a low dropout of 0.4V or less for all current ranges and supply voltages. This helps improve heat dissipation and efficiency.

Upon power-up, an under-voltage lockout circuit sets all outputs to off. Once the VDD supply voltage is greater than the under-voltage lockout threshold, the device channel can be turned on. The on/off state of each channel LED1, LED2 and LED3 is independently controlled repectivelly by PWM1, PWM2, PWM3. When a PWMx is high, the associated LEDx channel is turned on.

## APPLICATION INFORMATION

### POWER DISSIPATION

The power dissipation ($P_D$) of the CAT4109 can be calculated as follows:

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

where $V_{LEDN}$ is the voltage at the LED pin, and $I_{LEDN}$ is the associated LED current. Combinations of high $V_{LED}$ voltage or high ambient temperature can cause the CAT4109 to enter thermal shutdown. In applications where $V_{LEDN}$ is high, a resistor can be inserted in series with the LED string to lower $P_D$.

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 74°C/W.

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

$$P_{Dmax} = \frac{(T_{Jmax} - T_{AMB})}{\theta_{JA}} = \frac{(150 - 60)}{74} = 1.2W$$

### RECOMMENDED LAYOUT

Bypass capacitor C1 should be placed as close to the IC as possible. RSET resistors should be directly connected to the GND pin of the device. For better thermal dissipation, multiple via can be used to connect the GND pad to a large ground plane. It is also recommended to use large pads and traces on the PCB wherever possible to spread out the heat. The LEDs for this layout are driven from a separate supply (VLED+), but they can also be driven from the same supply connected to VDD.

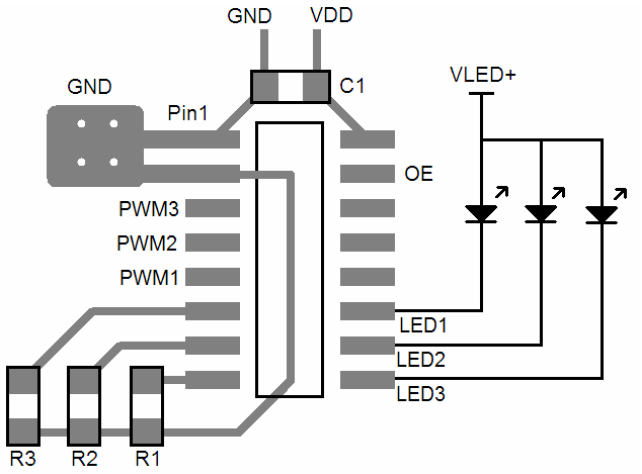
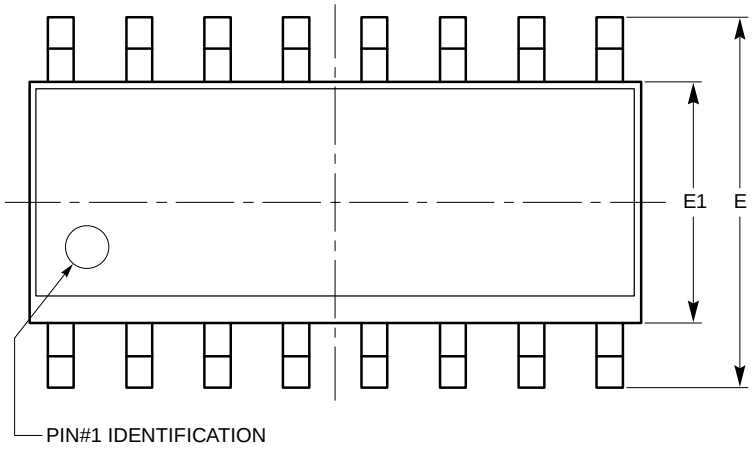



**Figure 3. Recommended Layout**

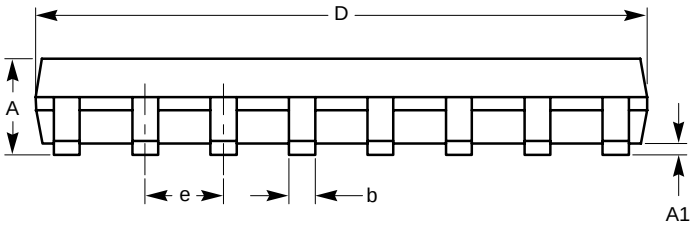
## PACKAGE OUTLINE DRAWING

**SOIC 16-Lead 150mils (V) [(1)(2)]**

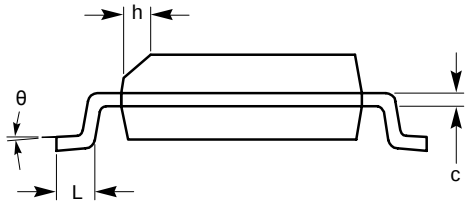



**TOP VIEW**

| 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 | 9.80 | 9.90 | 10.00 |
| E | 5.80 | 6.00 | 6.20 |
| E1 | 3.80 | 3.90 | 4.00 |
| e | | 1.27 BSC | |
| h | 0.25 | | 0.50 |
| L | 0.40 | | 1.27 |
| θ | 0º | | 8º |




**SIDE VIEW**




**END VIEW**

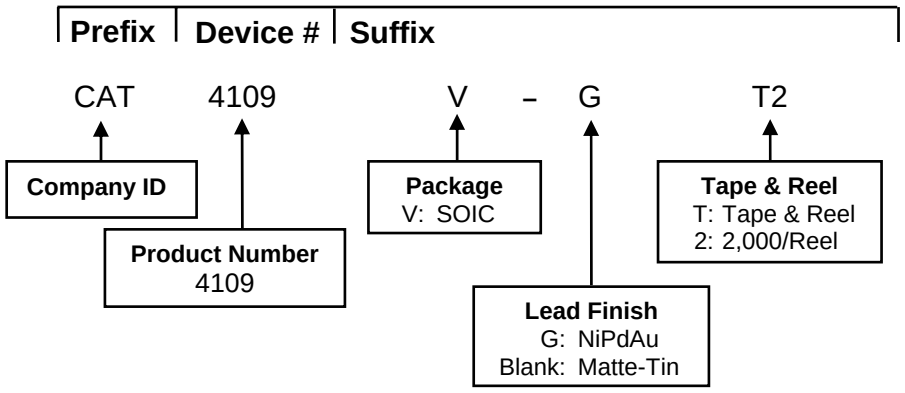
**For current Tape and Reel information, download the PDF file from: http://www.catsemi.com/documents/tapeandreel.pdf.**

**Notes:**

(1) All dimensions in millimeters. Angle in degrees.

(2) Compiles with JEDEC standard-012.

## EXAMPLE OF ORDERING INFORMATION




**Notes:**

(1) All packages are RoHS-compliant (Lead-free, Halogen-free).

(2) The standard plated finish is NiPdAu.

(3) The device used in the above example is a CAT4109V-GT2 (SOIC, NiPdAu, Tape & Reel, 2,000/Reel).

(4) For additional temperature options, please contact your nearest ON Semiconductor Sales office.

## REVISION HISTORY

| Date | Revision | Description |
|---|---|---|
| 7-Jan-09 | A | Initial Issue |



**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

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