

# General Purpose 1.2MHz, RRIO, 1.8V CMOS Amplifiers

## 1 Features

- Wide common-mode range: -0.3V to 26V
- Maximum 180 $\mu$ V Offset voltage (GD30IN199G--IL1/-IL2) Enable Shunt Drops of 10mV Full-scale
- Accuracy
  - Maximum  $\pm 0.5\%$  Gain Error
  - Maximum 0.5 $\mu$ V/ $^{\circ}$ C Offset Drift
  - Maximum 10ppm/ $^{\circ}$ C Gain Drift
- Choice of Gains:
  - GD30IN199G-IL1: 50V/V
  - GD30IN199G-IL2: 100V/V
- Quiescent Current: Maximum 100 $\mu$ A
- Package: SC70-6L, TQFN-10L

## 2 Applications

- Power Management
- Battery Chargers
- Electrical Cigarette
- Smart Phones and Tablets
- Notebook Computers
- Telecom Equipments
- Welding Equipments

## 3 Description

The GD30IN199G series of bidirectional zero-drift current sense amplifier can sense drops across shunts at common-mode voltages from -0.3V to 26V, independent of the supply voltage. Unidirectional operation allows the GD30IN199G series to measure currents through a resistive shunt in one direction, while bidirectional operation allows the device to measure currents through a resistive shunt in two directions. The low offset of the zero-drift architecture enables current sensing with maximum drops across the shunt as low as 10mV full-scale.

The GD30IN199G series operates from a single +2.5V to +18V power supply, drawing a maximum of 100 $\mu$ A of supply current. The device is specified from -40 $^{\circ}$ C to +105 $^{\circ}$ C, and offered in SC70-6L and TQFN-10L packages.

Device Information<sup>1</sup>

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|-------------|---------|-----------------|
| GD30IN199G  | SC70-6L | 2.10mm x 1.25mm |

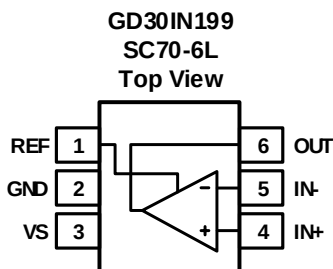
1. For all available packages, see the [Package Information](#) and [Ordering Information](#) at the end of data sheet.

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## 4 Device Overview

### 4.1 Pinout and Pin Assignment



### 4.2 Pin Description

| NAME | PIN TYPE <sup>1</sup> | FUNCTION                                                                                                                                                                                                         |
|------|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| IN-  | I                     | Inverting input of the amplifier.                                                                                                                                                                                |
| IN+  | I                     | Non-inverting input of the amplifier.                                                                                                                                                                            |
| REF  | P                     | Reference voltage.                                                                                                                                                                                               |
| VS   | P                     | Positive power supply. Positive power supply. Typically, the voltage is from +2.5V to +18V. A bypass capacitor of 0.1μF as close to the part as possible should be used between power supply pin and ground pin. |
| GND  | P                     | Negative power supply.                                                                                                                                                                                           |
| OUT  | O                     | Amplifier output. The voltage range extends to within millivolt of each supply rail.                                                                                                                             |

1. I = Input, O = Output, P = Power.

## 5 Parameter Information

### 5.1 Absolute Maximum Ratings

Exceeding the operating temperature range(unless otherwise noted)<sup>1</sup>

| SYMBOL                              | PARAMETER                                 | MIN       | MAX                   | UNIT |
|-------------------------------------|-------------------------------------------|-----------|-----------------------|------|
| V <sub>S+</sub> to GND              | Supply voltage                            |           | 20                    | V    |
| V <sub>IN+</sub> – V <sub>IN-</sub> | Analog input(IN+, IN-), Differential      | -26       | 26                    | V    |
| V <sub>CM</sub>                     | Analog input(IN+, IN-), Common-Mode       | GND – 0.3 | 26                    | V    |
| V <sub>REF</sub>                    | REF input voltage                         | GND – 0.3 | V <sub>S+</sub> + 0.3 | V    |
| V <sub>OUT</sub>                    | Output voltage                            | GND – 0.3 | V <sub>S+</sub> + 0.3 | V    |
| I <sub>IN</sub>                     | Input current into all pins               |           | 5                     | mA   |
| T <sub>J</sub>                      | Operating junction temperature            |           | 150                   | °C   |
| T <sub>stg</sub>                    | Storage temperature                       | -65       | 150                   | °C   |
|                                     | Lead Temperature Range (Soldering 10 sec) |           | 260                   | °C   |

1. The maximum ratings are the limits to which the device can be subjected without permanently damaging the device. Note that the device is not guaranteed to operate properly at the maximum ratings. Exposure to the absolute maximum rating conditions for extended periods may affect device reliability.
2. Differential voltages are at IN+, with respect to IN-.
3. Short circuits from outputs to V<sub>S</sub> can cause excessive heating and eventual destruction.

### 5.2 Recommended Operation Conditions

| SYMBOL <sup>1,2</sup> | PARAMETER                   | MIN  | TYP | MAX | UNIT |
|-----------------------|-----------------------------|------|-----|-----|------|
| V <sub>S</sub>        | Input supply voltage range  | 2.5  |     | 18  | V    |
| V <sub>CM</sub>       | Common-mode voltage range   | -0.3 |     | 26  | V    |
| T <sub>A</sub>        | Operating temperature range | -40  |     | 105 | °C   |

1. The device is not guaranteed to function outside of its operating conditions.

### 5.3 Electrical Sensitivity

| SYMBOL                | CONDITIONS                                                          | VALUE | UNIT |
|-----------------------|---------------------------------------------------------------------|-------|------|
| V <sub>ESD(HBM)</sub> | Human-body model (HBM), ANSI/ESDA/JEDEC JS-001-2017 <sup>1</sup>    | ±4000 | V    |
| V <sub>ESD(CDM)</sub> | Charge-device model (CDM), ANSI/ESDA/JEDEC JS-002-2022 <sup>2</sup> | ±2000 | V    |

1. JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
2. JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 5.4 Thermal Resistance

| SYMBOL <sup>1</sup> | CONDITIONS                   | PACKAGE | VALUE | UNIT |
|---------------------|------------------------------|---------|-------|------|
| Θ <sub>JA</sub>     | Natural convection, 2S2P PCB | SC70-6L | 250   | °C/W |
|                     |                              | QFN-10L | 80    |      |

1. Thermal characteristics are based on simulation, and meet JEDEC document JESD51-7.

## 5.5 Electrical Characteristics

$V_S = 5.0V$ ,  $V_{IN+} = 12V$ ,  $V_{SENSE} = V_{IN+} - V_{IN-}$ , and  $V_{REF} = V_S/2$ ,  $T_A = +25^\circ C$ , unless otherwise noted.

Boldface limits apply over the specified temperature range,  $T_A = -40^\circ C$  to  $+105^\circ C$ .

| SYMBOL                 | PARAMETER                               | CONDITIONS                                                                     | MIN                  | TYP                  | MAX                   | UNIT   |
|------------------------|-----------------------------------------|--------------------------------------------------------------------------------|----------------------|----------------------|-----------------------|--------|
| INPUT CHARACTERISTICS  |                                         |                                                                                |                      |                      |                       |        |
| V <sub>OS</sub>        | Input offset voltage                    | V <sub>SENSE</sub> = 0mV, GD30IN199G-IL1                                       | −250                 | +50                  | +300                  | μV     |
|                        |                                         | V <sub>SENSE</sub> = 0mV, GD30IN199G-IL2                                       |                      | ±50                  | ±180                  |        |
| dV <sub>OS</sub> /dT   | Input offset voltage drift <sup>1</sup> | T <sub>A</sub> = −40°C to 105°C                                                |                      | 0.1                  | 0.5                   | μV/°C  |
| I <sub>B</sub>         | Input bias current                      | V <sub>SENSE</sub> = 0mV                                                       |                      | 25                   |                       | μA     |
| I <sub>OS</sub>        | Input offset current                    | V <sub>SENSE</sub> = 0mV                                                       |                      | 0.02                 |                       | μA     |
| V <sub>CM</sub>        | Common-mode voltage range               |                                                                                | −0.3                 |                      | 26                    | V      |
| CMRR                   | Common-mode rejection ratio             | V <sub>IN+</sub> = 0V to 24V, V <sub>SENSE</sub> = 0mV, GD30IN199G-IL1         | 91                   | 105                  |                       | dB     |
|                        |                                         | V <sub>IN+</sub> = 0V to 26V, V <sub>SENSE</sub> = 0mV, GD30IN199G-IL2         | 96                   | 110                  |                       |        |
| OUTPUT CHARACTERISTICS |                                         |                                                                                |                      |                      |                       |        |
| G                      | Gain                                    | GD30IN199G-IL1                                                                 |                      | 50                   |                       | V/V    |
|                        |                                         | GD30IN199G-IL2                                                                 |                      | 100                  |                       |        |
| E <sub>G</sub>         | Gain error                              | V <sub>SENSE</sub> = −5mV to 5mV                                               |                      | ±0.03                | ±0.5                  | %      |
| E <sub>GTC</sub>       | Gain error drift                        | T <sub>A</sub> = −40°C to 105°C                                                |                      | 3                    | 10                    | ppm/°C |
|                        | Nonlinearity                            | V <sub>SENSE</sub> = −5mV to 5mV                                               |                      | ±0.01                |                       | %      |
| C <sub>L</sub>         | Maximum capacitive load                 | No sustained oscillation                                                       |                      | 1                    |                       | nF     |
| V <sub>OH</sub>        | Swing to V <sub>S</sub> rail            | R <sub>L</sub> = 10KΩ to GND                                                   | V <sub>S</sub> − 200 | V <sub>S</sub> − 5   |                       | mV     |
| V <sub>OL</sub>        | Swing to GND                            |                                                                                |                      | V <sub>GND</sub> + 5 | V <sub>GND</sub> + 50 | mV     |
| NOISE                  |                                         |                                                                                |                      |                      |                       |        |
| e <sub>n</sub>         | Input voltage noise density             | Reference to input                                                             |                      | 25                   |                       | nV/√Hz |
| FREQUENCY RESPONSE     |                                         |                                                                                |                      |                      |                       |        |
| GBW                    | Gain-bandwidth product                  | GD30IN199G-IL1, C <sub>LOAD</sub> = 10pF                                       |                      | 80                   |                       | KHz    |
|                        |                                         | GD30IN199G-IL2, C <sub>LOAD</sub> = 10pF                                       |                      | 30                   |                       |        |
| SR                     | Slew rate                               |                                                                                |                      | 0.65                 |                       | V/μs   |
| POWER SUPPLY           |                                         |                                                                                |                      |                      |                       |        |
| I <sub>Q</sub>         | Quiescent current                       | V <sub>SENSE</sub> = 0mV                                                       |                      | 70                   | 100                   | μA     |
|                        |                                         | V <sub>SENSE</sub> = 0mV, T <sub>A</sub> = −40 to +105°C                       |                      |                      | 115                   |        |
| V <sub>S</sub>         | Operation power supply                  |                                                                                | 2.5                  |                      | 18                    | V      |
| PSR                    | Input vs power supply                   | V <sub>S</sub> = 2.5V to 18V, V <sub>IN+</sub> = 18V, V <sub>SENSE</sub> = 0mV |                      | ±0.1                 |                       | μV/V   |

1. Guaranteed by design and engineering sample characterization.

## 5.6 Typical Characteristics

$T_A = +25^{\circ}\text{C}$ ,  $V_S = +5.0\text{V}$ ,  $V_{IN+} = 12\text{V}$ , and  $V_{REF} = V_S / 2$ , unless otherwise noted.

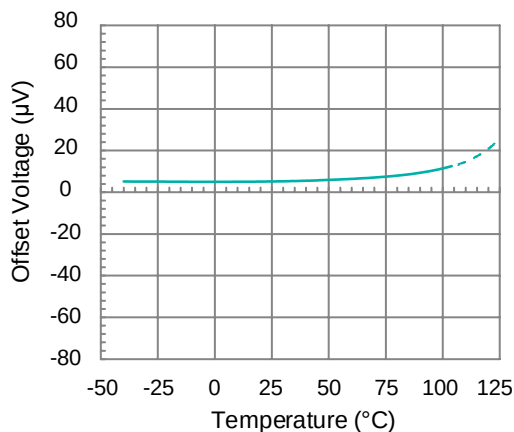


Figure 1. Offset Voltage vs. Temperature

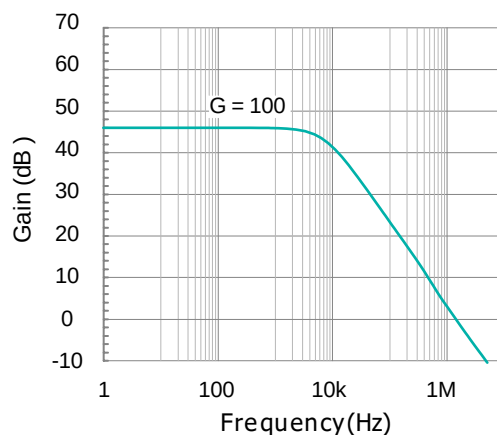


Figure 2. Gain vs. Frequency

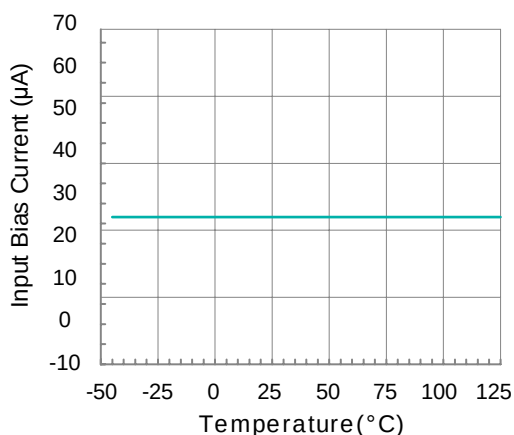


Figure 3. Input Bias Current vs. Temperature

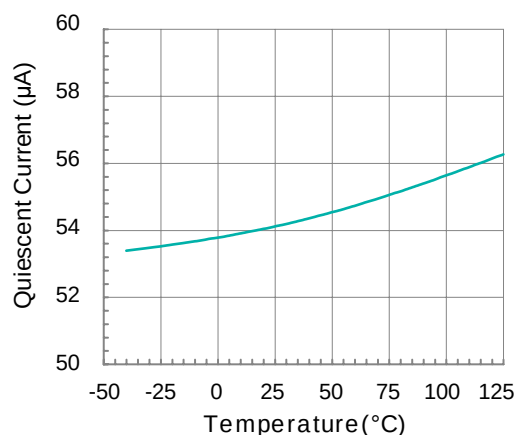


Figure 4. Quiescent Current vs. Temperature

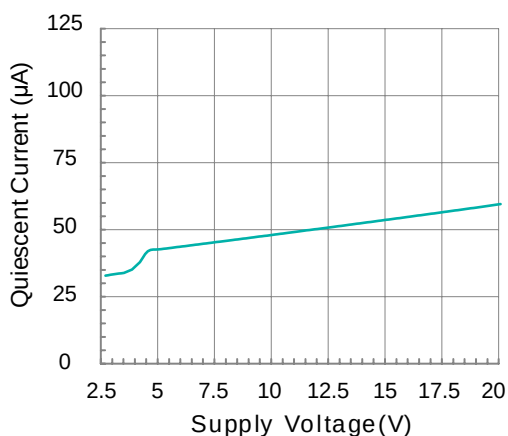


Figure 5. Quiescent Current vs. Supply Voltage

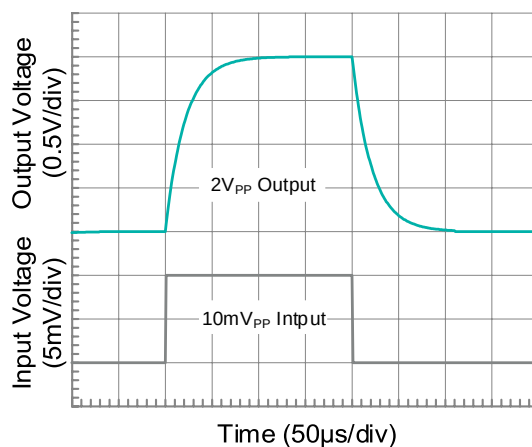


Figure 6. Step Response (10mV<sub>PP</sub> Input Step)

## Typical Characteristics(continued)

$T_A = +25^{\circ}\text{C}$ ,  $V_S = +5.0\text{V}$ ,  $V_{IN+} = 12\text{V}$ , and  $V_{REF} = V_S / 2$ , unless otherwise noted.

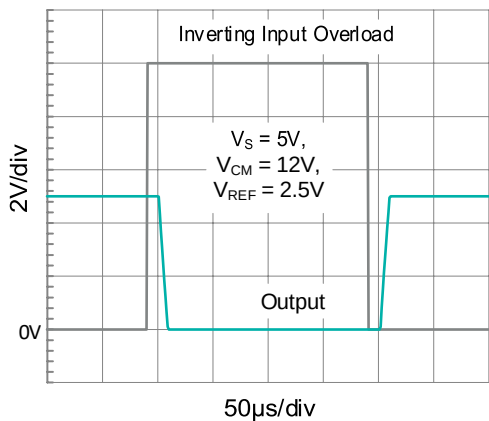


Figure 7. Inverting Differential Input Overload

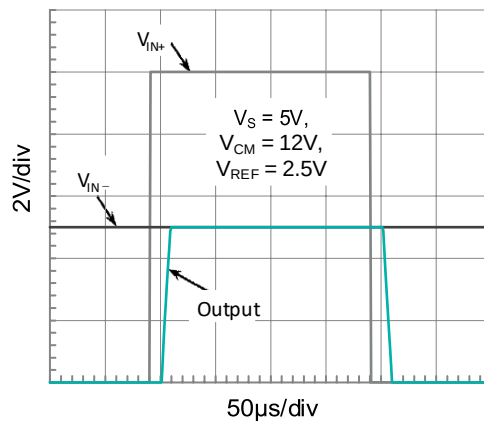


Figure 8. Noninverting Differential Input Overload

## 6 Application Information

### 6.1 Typical Application

Figure 9 shows the basic connections for the GD30IN199G. The input pins, IN+ and IN–, should be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance.

Power-supply bypass capacitors are required for stability. Applications with noisy or high-impedance power supplies may require additional decoupling capacitors to reject power-supply noise. Connect bypass capacitors close to the device pins.

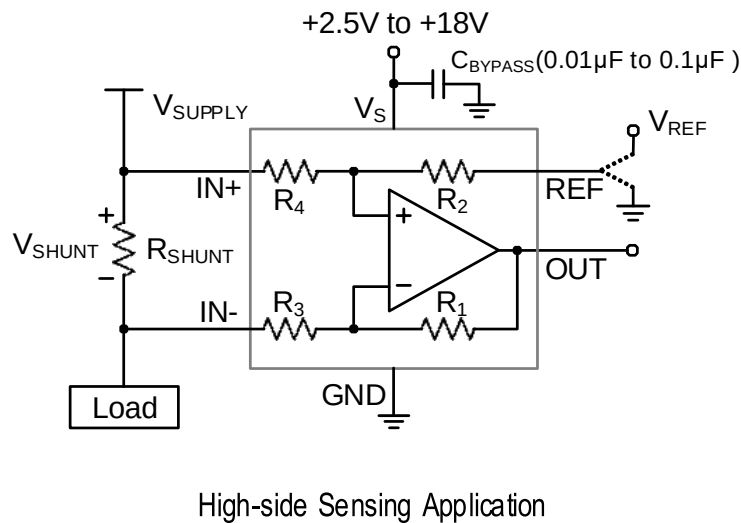


Figure 9. Application Schematic

### 6.2 Power Supply

The input circuitry of the GD30IN199G can accurately measure beyond its power-supply voltage,  $V_S$ . For example, the  $V_S$  power supply can be 5V, whereas the load power-supply voltage can be as high as +18V. However, the output voltage range of the OUT terminal is limited by the voltages on the power-supply pin. Note also that the GD30IN199G can withstand the full  $-0.3V$  to  $+26V$  range in the input pins, regardless of whether the device has power applied or not.

### 6.3 Selecting $R_s$

The zero-drift offset performance of the GD30IN199G offers several benefits. Most often, the primary advantage of the low offset characteristic enables lower full-scale drops across the shunt. For example, non-zero-drift current sense amplifiers typically require a full-scale range of 100mV.

The GD30IN199G of current sense amplifier gives equivalent accuracy at a full-scale range on the order of 10mV. This accuracy reduces shunt dissipation by an order of magnitude with many additional benefits.

Alternatively, there are applications that must measure current over a wide dynamic range that can take advantage of the low offset on the low end of the measurement. Most often, these applications can use the lower gain of 100 to accommodate larger shunt drops on the upper end of the scale.



## 6.4 Unidirectional Operation

Unidirectional operation allows the GD30IN199G to measure currents through a resistive shunt in one direction. The most frequent case of unidirectional operation sets the output at ground by connecting the REF pin to ground. In unidirectional applications where the highest possible accuracy is desirable at very low inputs, bias the REF pin to a convenient value above 50mV to get the device output swing into the linear range for zero inputs.

A less frequent case of unipolar output biasing is to bias the output by connecting the REF pin to the supply; in this case, the quiescent output for zero input is at quiescent supply. This configuration would only respond to negative currents (inverted voltage polarity at the device input).

## 6.5 Bidirectional Operation

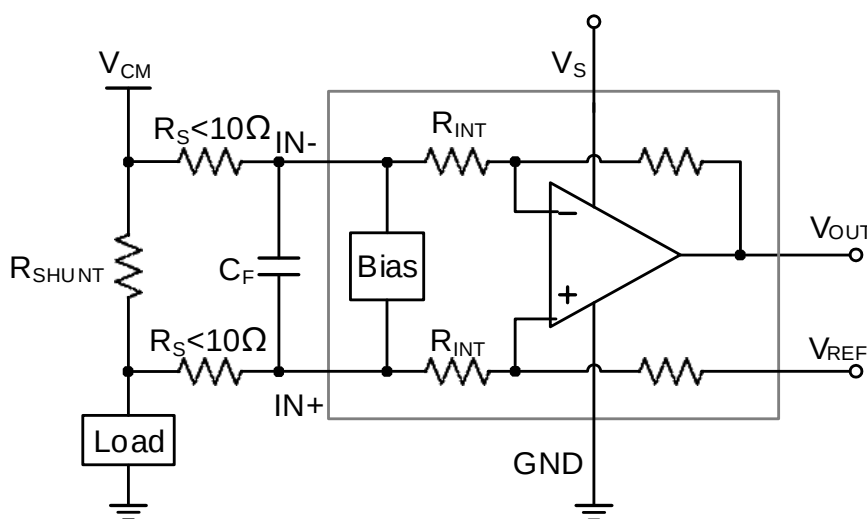
Bidirectional operation allows the GD30IN199G to measure currents through a resistive shunt in two directions. In this case, the output can be set anywhere within the limits of what the reference inputs allow (that is, between 0V to V+). Typically, it is set at half-scale for equal range in both directions. In some cases, however, it is set at a voltage

other than half-scale when the bidirectional current is nonsymmetrical.

The quiescent output voltage is set by applying voltage to the reference input. Under zero differential input conditions the output assumes the same voltage that is applied to the reference input.

## 6.6 Input Filtering

An obvious and straightforward filtering location is at the device output. However, this location negates the advantage of the low output impedance of the internal buffer. The only other filtering option is at the device input pins. This location, though, does require consideration of the  $\pm 30\%$  tolerance of the internal resistances. [Figure 10](#) shows a filter placed at the input pins.



**Figure 10. Filter at Input Pins**

The addition of external series resistance, however, creates an additional error in the measurement so the value of these series resistors should be kept to 10Ω or less if possible to reduce impact to accuracy. The internal bias network shown in [Figure 10](#) present at the input pins creates a mismatch in input bias currents when a differential

voltage is applied between the input pins. If additional external series filter resistors are added to the circuit, the mismatch in bias currents results in a mismatch of voltage drops across the filter resistors. This mismatch creates a differential error voltage that subtracts from the voltage developed at the shunt resistor. This error results in a voltage at the device input pins that is different than the voltage developed across the shunt resistor. Without the additional series resistance, the mismatch in input bias currents has little effect on device operation. The amount of error these external filter resistor add to the measurement can be calculated using [Equation \(2\)](#) where the gain error factor is calculated using [Equation\(1\)](#).

The amount of variance in the differential voltage present at the device input relative to the voltage developed at the shunt resistor is based both on the external series resistance value as well as the internal input resistors,  $R_{INT}$  as shown in [Figure 10](#). The reduction of the shunt voltage reaching the device input pins appears as a gain error when comparing the output voltage relative to the voltage across the shunt resistor. A factor can be calculated to determine the amount of gain error that is introduced by the addition of external series resistance. The equation used to calculate the expected deviation from the shunt voltage to what is seen at the device input pins is given in [Equation\(1\)](#):

$$\text{Gain Error Factor} = \frac{1250 \times R_{INT}}{1250 \times R_S + 1250 \times R_{INT} + R_S \times R_{INT}} \quad (1)$$

where:

$R_{INT}$  is the internal input resistor ( $R_3$  and  $R_4$ , 10k $\Omega$ ), and  $R_S$  is the external series resistance.

The gain error that can be expected from the addition of the external series resistors can then be calculated based on [Equation\(2\)](#):

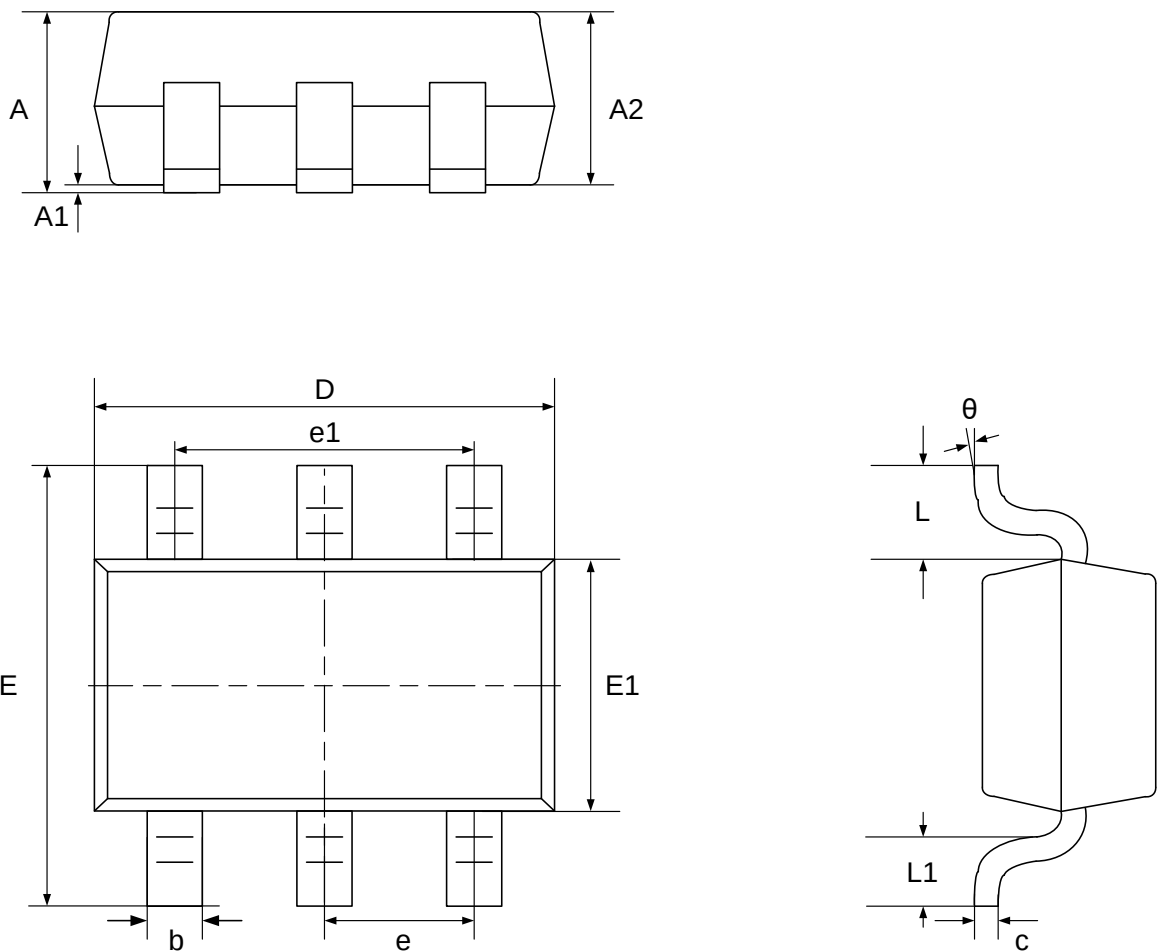
$$\text{Gain Error (\%)} = 100 - (100 \times \text{Gain Error Factor}) \quad (2)$$

For GD30IN199G, a series resistance of 10 $\Omega$  results in a gain error factor of 0.991. The corresponding gain error is then calculated using [Equation\(2\)](#), resulting in a gain error of approximately 0.89% solely because of the external 10 $\Omega$  series resistors.

## 7 Package Information

### 7.1 Outline Dimensions

#### SC70-6L Package Outline



#### NOTES:

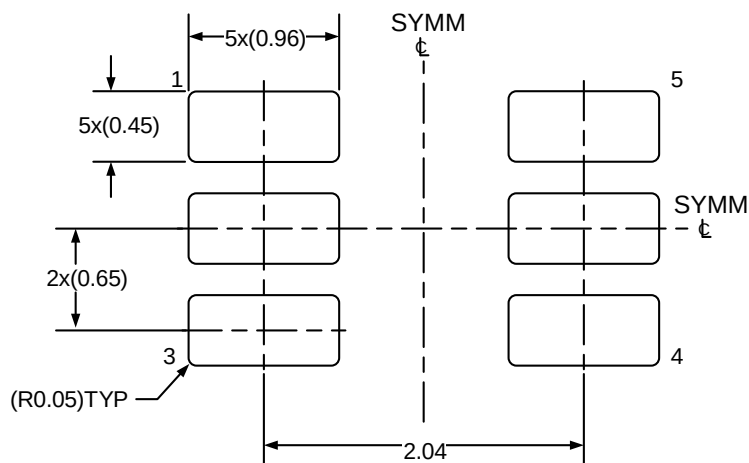
1. All dimensions are in millimeters.
2. Package dimensions does not include mold flash, protrusions, or gate burrs.
3. Refer to the [Table 1 SC70-6L dimensions\(mm\)](#).

Table 1. SC70-6L dimensions(mm)

| SYMBOL | MIN      | TYP | MAX  |
|--------|----------|-----|------|
| A      | 0.80     |     | 1.10 |
| A1     | 0.00     |     | 0.10 |
| A2     | 0.80     |     | 1.00 |
| b      | 0.15     |     | 0.30 |
| C      | 0.10     |     | 0.25 |
| D      | 1.85     |     | 2.20 |
| E      | 1.15     |     | 1.35 |
| E1     | 1.80     |     | 2.40 |
| e      | 0.65 BSC |     |      |
| e1     | 1.20     |     | 1.40 |
| L      | 0.42 REF |     |      |
| L1     | 0.10     |     | 0.45 |
| θ      | 0°       |     | 8°   |

## 7.2 Recommended Land Pattern

### SC70-6L Land Pattern Example



#### NOTES: (continued)

1. Refer to the IPC-7351 can also help you complete the designs.
2. Exposed metal shown.
3. Drawing is 20X scale.

## 8 Ordering Information

| Ordering Code      | Package Type | ECO Plan | Packing Type | MOQ  | OP Temp(°C)     |
|--------------------|--------------|----------|--------------|------|-----------------|
| GD30IN199GSDTR-IL1 | SC70-6L      | Green    | Tape & Reel  | 3000 | -40°C to +125°C |
| GD30IN199GSDTR-IL2 | SC70-6L      | Green    | Tape & Reel  | 3000 | -40°C to +125°C |

## 9 Revision History

| REVISION NUMBER | DESCRIPTION                        | DATE             |
|-----------------|------------------------------------|------------------|
| 1.0             | Initial release and device details | November 2, 2024 |

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