Bi-directional, Zero-Drift Current Sense Amplifiers

1 Features

- Wide common-mode range: −0.3V to 30V
- Maximum ±150μV Offset voltage (GD30IN199-IA1) at V_{CM}=0V
- Accuracy
  - Maximum ±1% Gain Error
  - Maximum 1μV/°C Offset Drift
  - Maximum 10ppm/°C Gain Drift
- Choice of Gains:
  - GD30IN199-IA1: 50V/V
  - GD30IN199-IA2: 100V/V
  - GD30IN199-IA3: 200V/V
- Quiescent Current: Maximum 250μA
- Package: SC70-6L

2 Applications

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

3 Description

The GD30IN199 series of bidirectional zero-drift current sense amplifier can sense drops across shunts at common-mode voltages from −0.3V to 30V, independent of the supply voltage. Unidirectional operation allows the GD30IN199 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 GD30IN199 series operates from a single +2.7V to +30V power supply, drawing a maximum of 100μA of supply current. The device is specified from –40°C to +105°C, and offered in SC70-6L packages.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
GD30IN199	SC70-5L	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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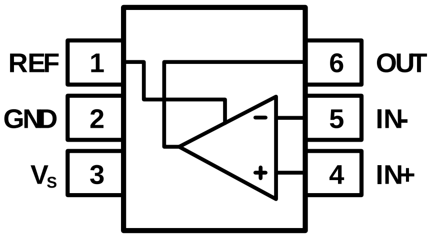
4 Device Overview

4.1 Pinout and Pin Assignment

SC70-6L
Top View



4.2 Pin Description

PINS		PIN TYPE[1]	FUNCTION
NAME	NUMBER		
REF	1	I	Reference voltage.
GND	2	G	Negative power supply.
V_S	3	P	Positive power supply. Typically, the voltage is from +2.7V to +30V. A bypass capacitor of 0.1µF as close to the part as possible should be used between power supply pin and ground pin.
IN+	4	I	Non-inverting input of the amplifier.
IN-	5	I	Inverting input of the amplifier.
OUT	6	O	Amplifier output. The voltage range extends to within millivolt of each supply rail.

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

5 Parameter Information

5.1 Absolute Maximum Ratings

Exceeding the operating temperature range(unless otherwise noted)[1]

SYMBOL	PARAMETER	MIN	MAX	UNIT
Vs to GND	Supply voltage		30	V
$V_{IN+} - V_{IN-}$	Analog input(IN+, IN-), Differential	−30	30	V
V_{CM}	Analog input(IN+, IN-), Common-Mode	GND-0.3	30	V
V_{REF}	REF input voltage	GND-0.3	V_S + 0.3	V
V_{OUT}	Output voltage	GND-0.3	V_S + 0.3	V
I_{IO}	Input current into all pins		5	mA
T_J	Operating junction temperature		150	°C
T_{stg}	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_S can cause excessive heating and eventual destruction.

5.2 Recommended Operation Conditions

SYMBOL[1,2]	PARAMETER	MIN	TYP	MAX	UNIT
V_S	Input supply voltage range	3		30	V
V_{CM}	Common-mode voltage range	−0.3		30	V
T_A	Operating temperature range	−40		125	°C

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

5.3 Electrical Sensitivity

SYMBOL	CONDITIONS	VALUE	UNIT
$V_{ESD(HBM)}$	Human-body model (HBM), ANSI/ESDA/JEDEC JS-001-2017[1]	±3000	V
$V_{ESD(CDM)}$	Charge-device model (CDM), ANSI/ESDA/JEDEC JS-002-2022[2]	±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[1]	CONDITIONS	PACKAGE	VALUE	UNIT
Θ_{JA}	Natural convection, 2S2P PCB	SC70-6L	250	°C/W

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°C, unless otherwise noted.
Boldface limits apply over the specified temperature range, T_A = −40°C to +105°C.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS						
V_{OS}	Input offset voltage	V_{SENSE} = 0mV		±25	±150	μV
dV_{OS}/dT	Input offset voltage drift[1]	T_A = −40°C to 105°C		0.4	1	μV/°C
I_B	Input bias current	V_{SENSE} = 0mV		28		μA
I_{OS}	Input offset current	V_{SENSE} = 0mV		±0.4		μA
V_{CM}	Common-mode voltage range		−0.3		30	V
CMRR	Common-mode rejection ratio	VIN+ = 0V to 26V, V_{SENSE} = 0mV	90	105		dB
OUTPUT CHARACTERISTICS						
G	Gain	GD30IN199-IA1		50		V/V
		GD30IN199-IA2		100		
		GD30IN199-IA3		200		
E_G	Gain error	V_{SENSE} = −5mV to 5mV		±0.1	±1	%
E_GTC	Gain error drift	T_A = −40°C to 105°C		3	10	ppm/°C
	Nonlinearity	V_{SENSE} = −5mV to 5mV		±0.01		%
C_L	Maximum capacitive load	No sustained oscillation		1		nF
V_{OH}	Swing to V_S rail	RL = 10KΩ to GND		V_S − 30		mV
V_{OL}	Swing to GND			V_{GND} + 2		
NOISE						
e_n	Input voltage noise density	Reference to input		30		nV/√Hz
FREQUENCY RESPONSE						
GBW	Gain-bandwidth product	GD30IN199-IA1, C_{LOAD} = 10pF		120		KHz
		GD30IN199-IA2, C_{LOAD} = 10pF		50		
SR	Slew rate			1.5		V/μs
POWER SUPPLY						
I_Q	Quiescent current	V_{SENSE} = 0mV		180	250	μA
		V_{SENSE} = 0mV, T_A = −40 to +105°C			290	
V_S	Operation power supply		3		30	V
PSR	Input vs power supply	V_S = 2.5V to 18V, V_{IN+} = 18V, V_{SENSE} = 0mV		±4	±20	μV/V

1. Guaranteed by design and engineering sample characterization.

5.6 Typical Characteristics

T_A = +25°C, V_S = +5.0V, V_{IN+} = 12V, and V_{REF} = V_S /2, unless otherwise noted.

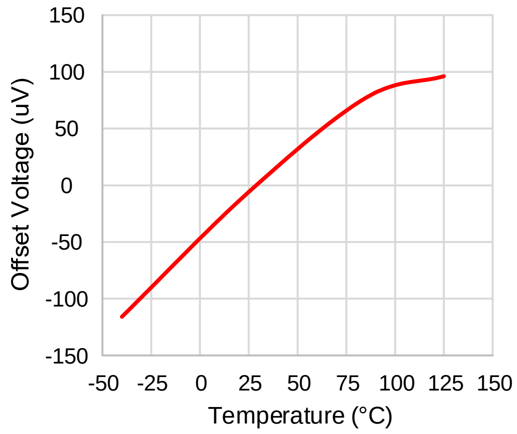


Figure 1. Offset Voltage vs. Temperature

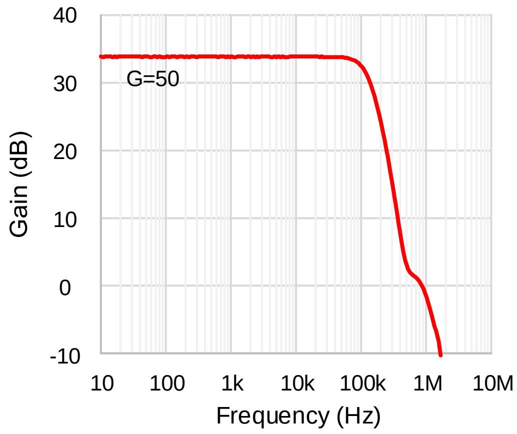


Figure 2. Gain vs. Frequency

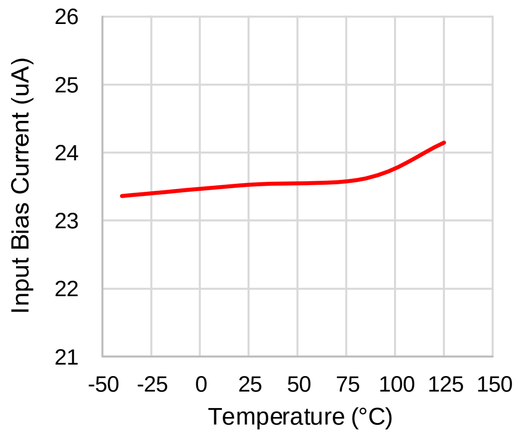


Figure 3. Input Bias Current vs. Temperature

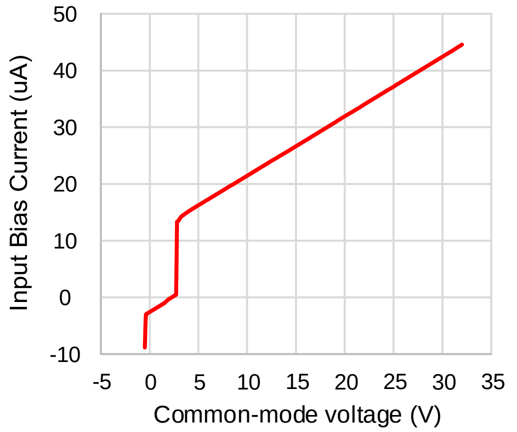


Figure 4. Input Bias Current vs. Common-mode voltage

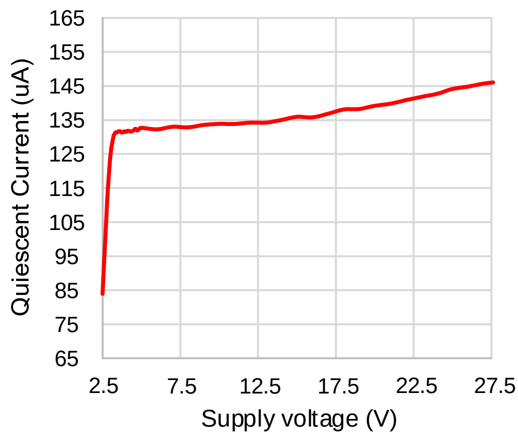


Figure 5. Quiescent Current vs. Supply Voltage

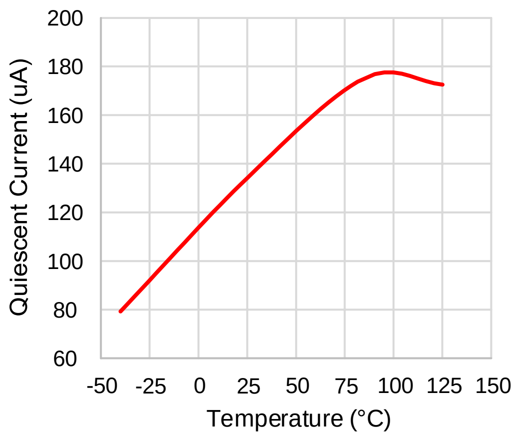


Figure 6. Quiescent Current vs. Temperature

Typical Characteristics(continued)

T_A = +25°C, V_S = +5.0V, V_{IN+} = 12V, and V_{REF} = V_S /2, unless otherwise noted.

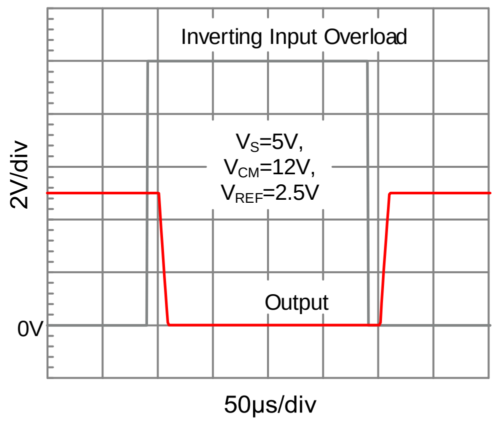


Figure 7. Inverting Differential Input Overload

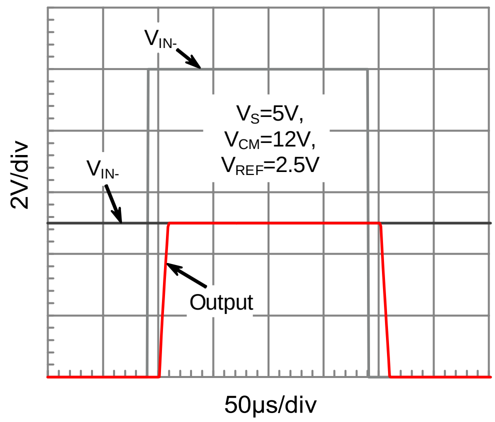


Figure 8. Noninverting Differential Input Overload

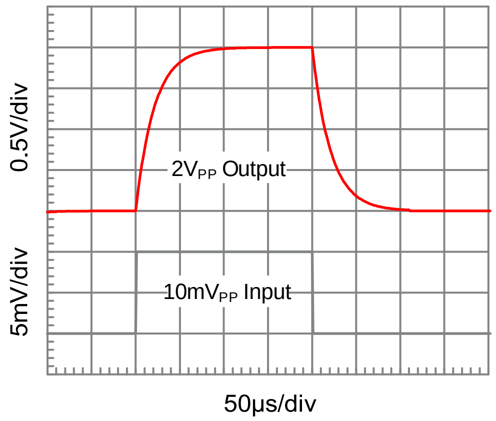


Figure 9. Step Response (10mV$_{PP}$ Input Step)

6 Application Information

6.1 Typical Application

Figure 10 shows the basic connections for the GD30IN199. 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.

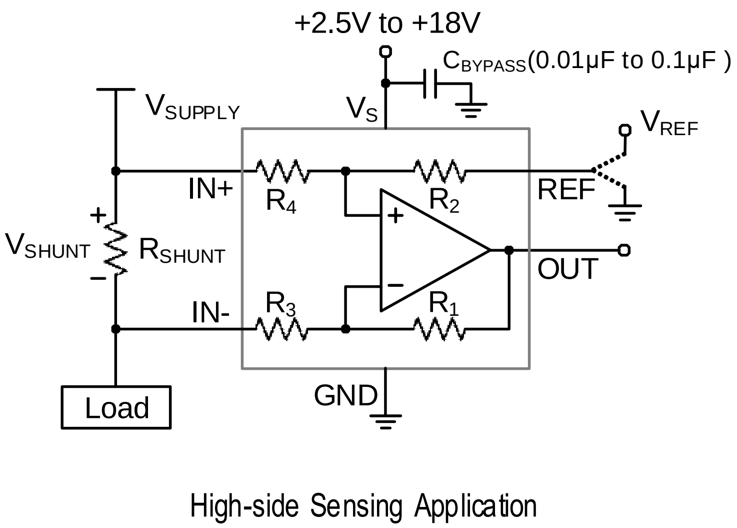


Figure 10. Application Schematic

6.2 Power Supply

The input circuitry of the GD30IN199 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 GD30IN199 can withstand the full –0.3V to +30V 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 GD30IN199 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 GD30IN199 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 GD30IN199 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 GD30IN199 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 ±30% tolerance of the internal resistances. Figure 11 shows a filter placed at the input pins.

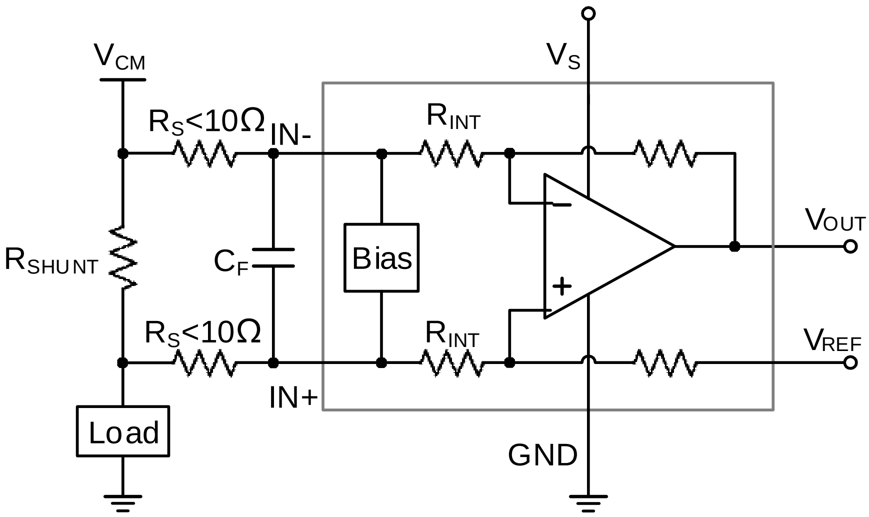


Figure 11. Filter at Input Pins

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 11 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, RINT as shown in Figure 11. 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:
RINT is the internal input resistor (R3 and R4, 10kΩ), and RS 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):

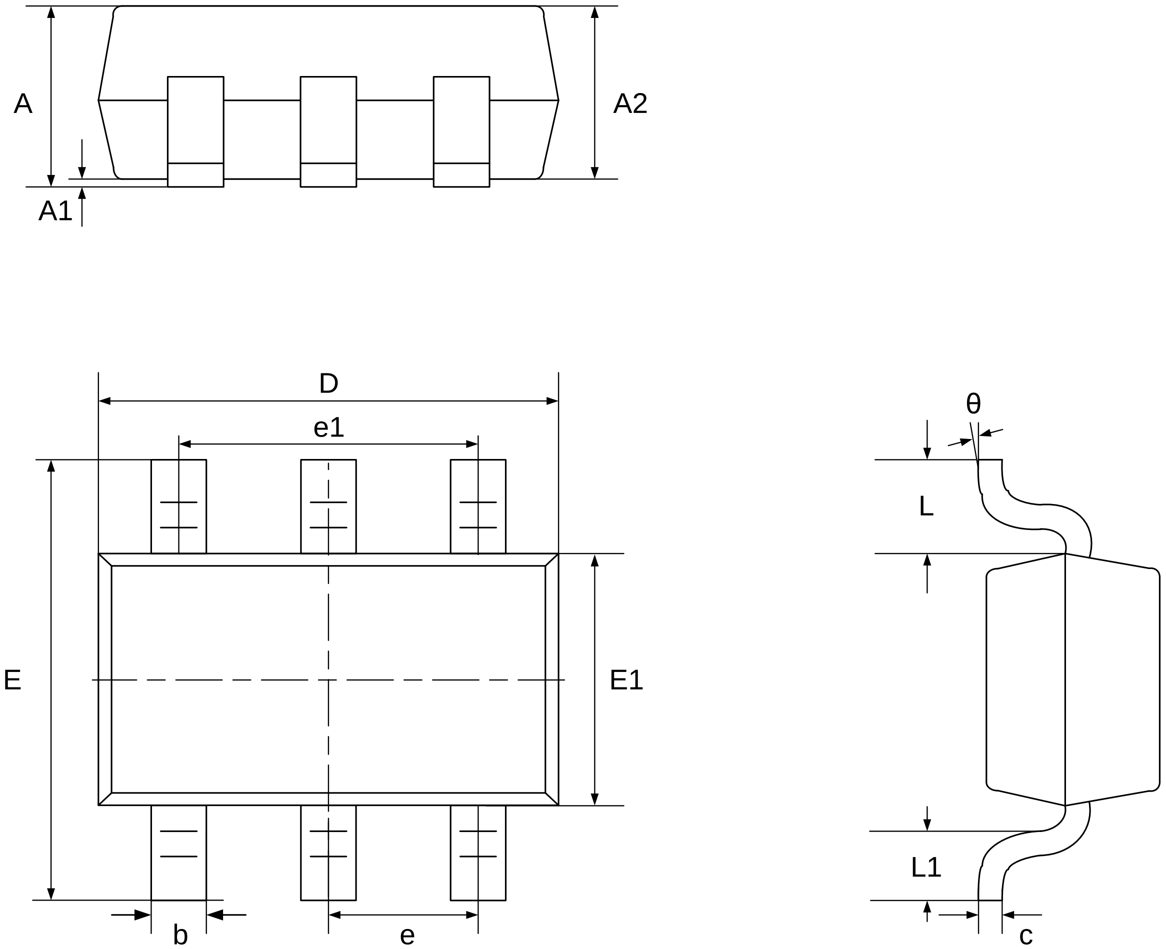
$$\text{Gain Error}(\%) = 100 - (100 \times \text{Gain Error Factor}) \quad (2)$$

For GD30IN199, a series resistance of 10Ω 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 10Ω series resistors.

7 Package Information

7.1 Outline Dimensions

SC70-6L Package Outline



NOTES:

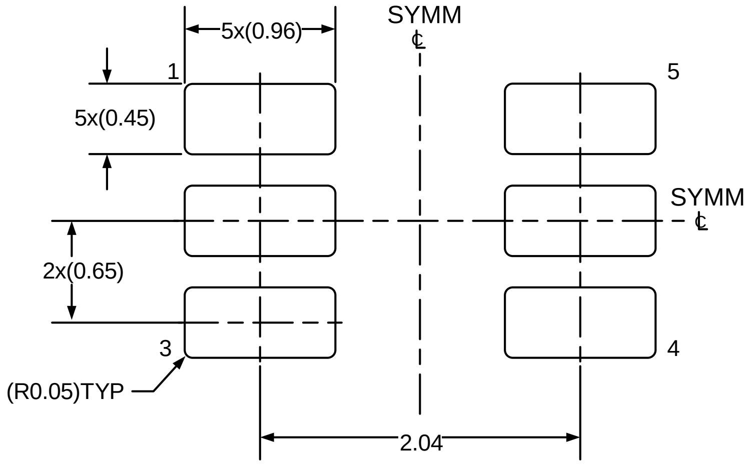
1. All dimensions are in millimeters.
2. Package dimensions does not include mold flash, protrusions, or gate burrs.
3. Refer to the Table 1 *SC70-6L dimensions(mm)*.

Table 1. SC70-6L dimensions(mm)

SYMBOL	MIN	NOM	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-IA1	SC70-6L	Green	Tape & Reel	3000	−40°C to +125°C
GD30IN199GSDTR-IA2	SC70-6L	Green	Tape & Reel	3000	−40°C to +125°C
GD30IN199GSDTR-IA3	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	2024

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