LT181 Series
Low- and High-Side Voltage Output,Bidirectional Current Sense Amplifiers

General Description

The LT181 series of current sense amplifiers (also called current shunt monitors) are designed for cost-optimized applications, that sense voltage drops across current-sense resistors at common-mode voltages from −0.2 V to +26 V, independent of the supply voltage. The LT181 series integrate a matched resistor gain network in four fixed-gain device options: 20 V/V, 50 V/V, 100 V/V, or 200 V/V. This matched gain resistor network minimizes gain error and reduces the temperature drift.

The LT181 series operate from a single +2.7-V to +5.5-V power supply, drawing a maximum of 110µA of supply current. The device is specified from -40℃ to +125℃, and offered in SOT23-6L packages.

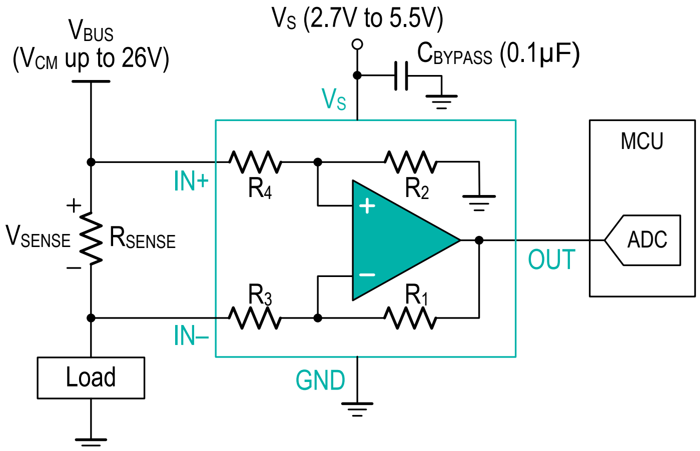
Features and Benefits

- Wide common-mode range: −0.2 V to 26 V
- Offset voltage
  - ±150 µV Maximum at V_{CM} = 0 V
  - ±500 µV Maximum at V_{CM} = 12 V
- Accuracy
  - Maximum ±1% Gain Error
  - Maximum 1 µV/℃ Offset Drift
- Gains Options:
  - 20V/V (LT181A1)
  - 50V/V (LT181A2)
  - 100V/V (LT181A3)
  - 200V/V (LT181A4)
- Output slew rate: 0.7 V/µs
- Quiescent Current: Maximum 110µA
- Package: SOT23-6L

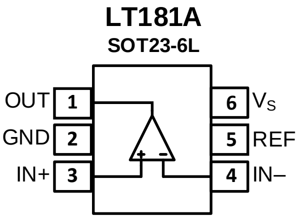
Applications

- Motor Control
- Battery Monitor, BMS
- Power Management
- Lighting Control
- Over-Current Detection
- Solar Inverters

Block Diagram and Pin Configuration (Top View)



High-side Sensing Application



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Pin Description

Symbol	Description
IN−	Current-sense amplifier negative input. For high-side applications, connect to load side of sense resistor. For low-side applications, connect to ground side of sense resistor.
IN+	Current-sense amplifier positive input. For high-side applications, connect to bus-voltage (V_{BUS}) side of sense resistor. For low-side applications, connect to load side of sense resistor.
OUT	Output voltage. The voltage range extends to within millivolt of each supply rail.
REF	Reference voltage
V_S	Positive power supply. Typically, the voltage is from 2.7 V to 5.5 V. A bypass capacitor of 0.1µF as close to the part as possible should be used between power supply pin and ground pin.
GND	Negative power supply.

Ordering Information

Orderable Type Number	Gain (V/V)	Package Name	Package Quantity	Eco Class[1]	Marking Code
LT181A1XT6/R6	20	SOT23-6L	3 000	Green (RoHS & no Sb/Br)	8R1
LT181A2XT6/R6	50	SOT23-6L	3 000	Green (RoHS & no Sb/Br)	8R2
LT181A3XT6/R6	100	SOT23-6L	3 000	Green (RoHS & no Sb/Br)	8R3
LT181A4XT6/R6	200	SOT23-6L	3 000	Green (RoHS & no Sb/Br)	8R4

(1) Eco Class - The planned eco-friendly classification: Pb-Free (RoHS) or Green (RoHS & Halogen Free).
(2) Please contact to your Linearin representative for the latest availability information and product content details.

Limiting Value

In accordance with the Absolute Maximum Rating System (IEC 60134).

Parameter	Absolute Maximum Rating
Supply Voltage, V_S to GND	+10 V
Analog Inputs (IN+, IN−), Differential ($V_{IN+} - V_{IN-}$)	−26 V to +26 V
Analog Inputs (IN+, IN−), Common-Mode	(GND − 0.3V) to +26 V
Input Current Into All Pins	5 mA
Output	(GND − 0.3V) to (V_S + 0.3V)
Maximum output current, I_{OUT}	8 mA
Storage Temperature Range, T_{stg}	−65 ℃ to +150 ℃
Junction Temperature, T_J	150 ℃
Lead Temperature Range (Soldering 10 sec)	260 ℃

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ESD Rating

Parameter	Item	Value	Unit
Electrostatic Discharge Voltage	Human body model (HBM), per MIL-STD-883J / Method 3015.9	±4 000	V
	Charged device model (CDM), per ESDA/JEDEC JS-002-2014	±2 000	
	Machine model (MM), per JESD22-A115C	±400	

(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.

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Electrical Characteristics

T_A = +25℃, V_S = +5.0V, V_{IN+} = 12V, and V_{SENSE} = V_{IN+} − V_{IN-}, unless otherwise noted.
Boldface limits apply over the specified temperature range, T_A = −40 to +125 ℃.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
INPUT CHARACTERISTICS						
V_{OS}	Offset voltage	Referred-to-input		±100	±500	µV
		Referred-to-input, V_{IN+} = 0 V		±20	±100	
V_{OS} TC	Offset voltage drift	**Referred-to-input, over Temperature**		**0.2**	**1**	µV/℃
I_B	Input bias current	V_{SENSE} = 0 mV, V_{IN+} = 0 V		0.1		µA
		V_{SENSE} = 0 mV		80		
I_{OS}	Input offset current	V_{SENSE} = 0 mV		±0.05		µA
V_{CM}	Common-mode input voltage range	Referred-to-input	−0.2		26	V
CMRR	Common-mode rejection ratio	V_{IN+} = 0 V to +26 V, V_{SENSE} = 10 mV, T_A = −40 to +125℃	84	100		dB
OUTPUT CHARACTERISTICS						
G	Gain	LT181A1		20		V/V
		LT181A2		50		
		LT181A3		100		
		LT181A4		200		
E_G	Gain error	V_{OUT} = 0.5V to V_S−0.5 V		±0.1	±1	%
E_G TC	Gain error drift	**over Temperature**		**1.5**	**20**	ppm/℃
	Nonlinearity Error	V_{OUT} = 0.5V to V_S−0.5 V		±0.01		%
C_L	Maximum Capacitive Load	No sustained oscillation		1		nF
V_{OH}	Swing to V_S rail	R_L = 10kΩ to GND, T_A = −40 to +125℃	V_S−65	V_S−25		mV
V_{OL}	Swing to GND			V_{GND}+25	V_{GND}+65	
DYNAMIC PERFORMANCE						
BW	Bandwidth	LT181A1 , C_L = 10pF		200		kHz
		LT181A2 , C_L = 10pF		80		
		LT181A3 , C_L = 10pF		30		
		LT181A4 , C_L = 10pF		14		
SR	Slew rate			0.7		V/µs
NOISE PERFORMANCE						
e_n	Voltage noise density	Referred-to-input		30		nV/√Hz
POWER SUPPLY						
V_S	Operating supply voltage		+2.7		+5.5	V
PSRR	Power supply rejection ratio	Referred-to-input, V_S = +2.7V to +5.5V, V_{SENSE} = 10 mV		±8	±40	µV/V
I_Q	Quiescent current	V_{SENSE} = 10 mV		80	110	µA
		over Temperature			**130**	
THERMAL CHARACTERISTICS						
T_A	Operating temperature		-40		+125	℃
$θ_{JA}$	Package Thermal Resistance	SOT23-6L		190		℃/W

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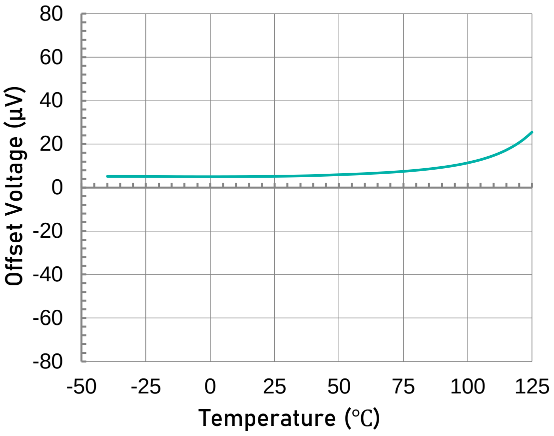
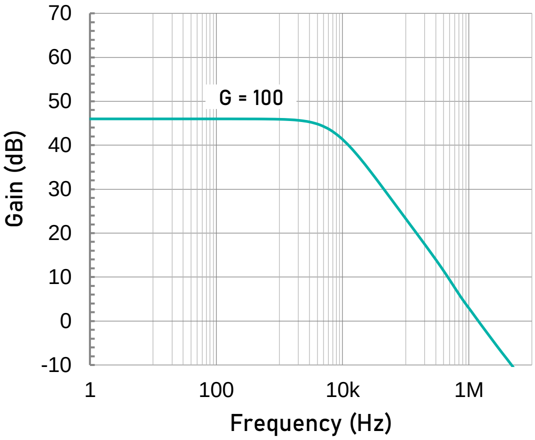
Typical Performance Characteristics

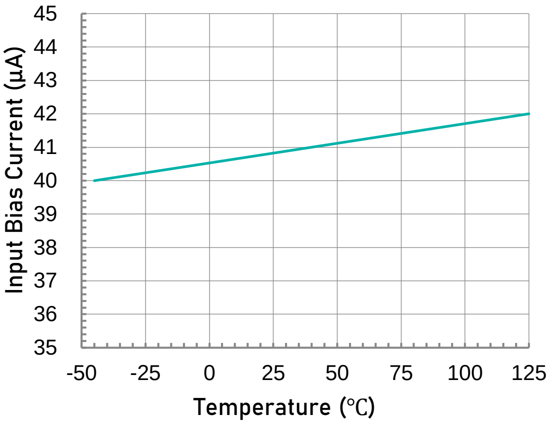
At T_A=+25℃, V_S=+5.0V, and V_{IN+} = 12V, unless otherwise noted.



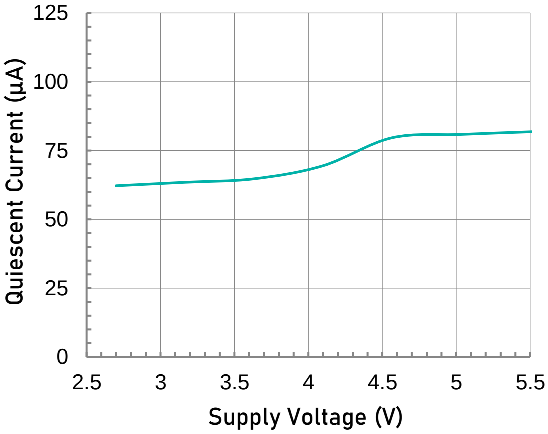
Offset Voltage vs. Temperature



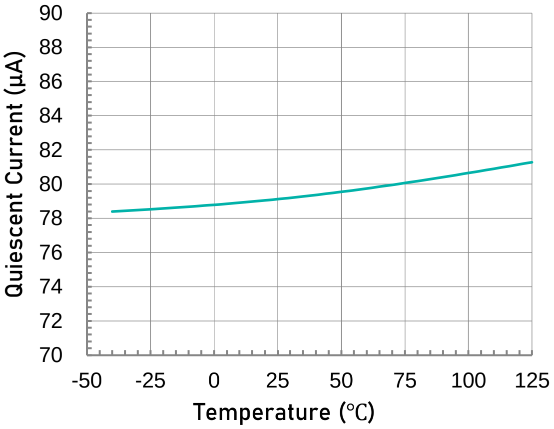
Gain vs. Frequency



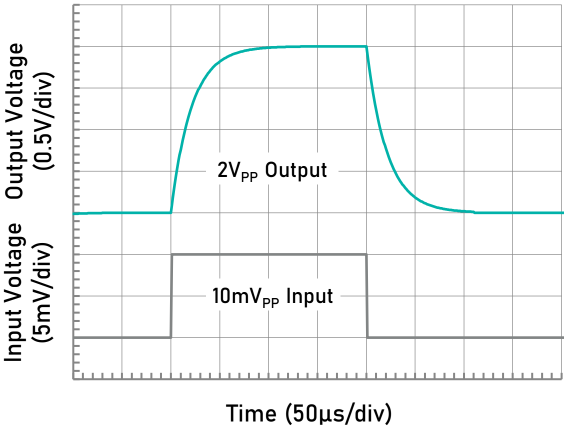
Input Bias Current vs. Temperature



Quiescent Current vs. Supply Voltage



Quiescent Current vs. Temperature



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

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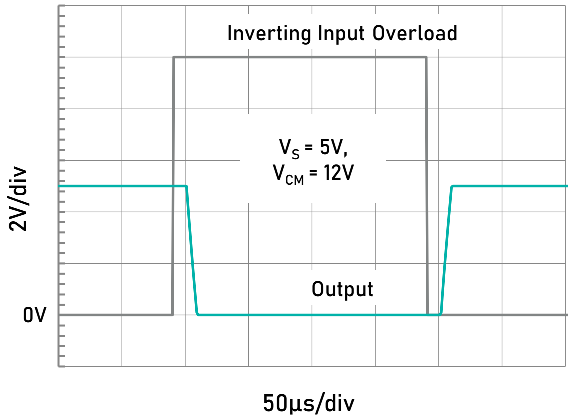
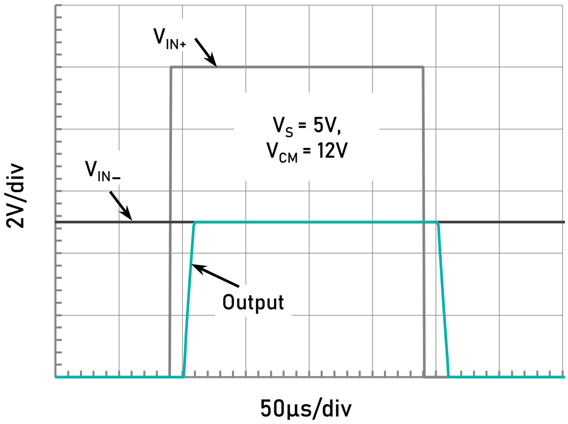
Typical Performance Characteristics (continued)

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



Inverting Differential Input Overload



Noninverting Differential Input Overload

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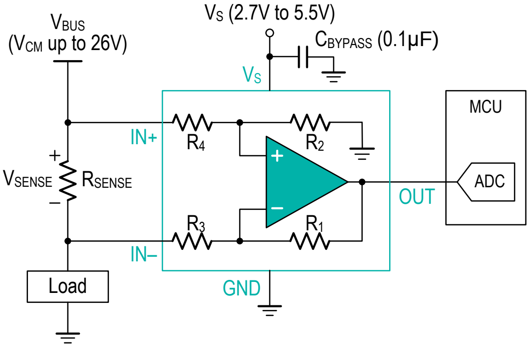
Application Notes

BASIC CONNECTIONS

Figure 1 shows the basic connections for the LT181 series. 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.



High-side Sensing Application

Figure 1. Typical Application

POWER SUPPLY

The input circuitry of the LT181 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 from 2.7V to 5.5V. However, the output voltage range of the OUT terminal is limited by the voltages on the power-supply pin. Note also that the LT181 can withstand the full –0.2V to +26V range in the input pins, regardless of whether the device has power applied or not.

PRECISE LOW-SIDE CURRENT SENSING

When used in low-side current sensing applications, the offset voltage of the LT181 series is within ±150µV. The low offset performance of the LT181 has several benefits. First, the low offset allows the device to be used in applications that must measure current over a wide dynamic range. In this case, the low offset improves the accuracy when the sensed currents are on the low end of the measurement range. Another advantage of low offset is the ability to sense lower voltage drop across the sense resistor accurately, thus allowing a lower-value shunt resistor. Lower-value shunt resistors reduce power loss in the current sense circuit, and help improve the power efficiency of the end application.

The gain error of the LT181 series is specified to be within 1% of the actual value. As the sensed voltage becomes much larger than the offset voltage, this voltage becomes the dominant source of error in the current sense measurement.

INPUT DIFFERENTIAL OVERLOAD

If the differential input voltage ($V_{IN+} - V_{IN-}$) times gain exceeds the voltage swing specification, the LT181 series drive the output as close as possible to the positive supply, and does not provide accurate measurement of the differential input voltage. If this input overload occurs during normal circuit operation, then reduce the value of the shunt resistor or use a lower-gain version with the chosen sense resistor to avoid this mode of operation. If a differential overload occurs in a fault event, then the output of the LT181 series return to the expected value approximately 20µs after the fault condition is removed.

When the LT181 output is driven to either the supply rail or ground, increasing the differential input voltage does not damage the device as long as the absolute maximum ratings are not violated. Following these guidelines, the LT181 output maintains polarity, and does not suffer from phase reversal.

BIDIRECTIONAL OPERATION

Bidirectional operation allows the LT181 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.

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 2 shows a filter placed at the inputs pins.

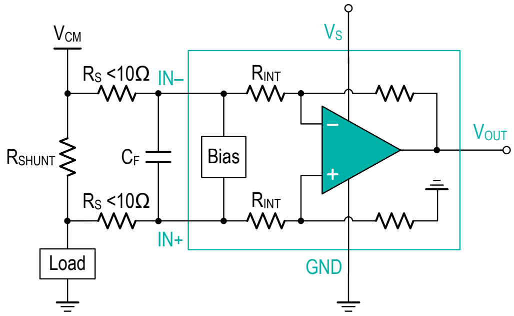


Figure 2. Filter at Input Pins

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 2 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

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Application Notes (continued)

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 2. 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:

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

where:

R_{INT} is the internal input resistor (R3 and R4, 10kΩ), 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:

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

For LT181, 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.

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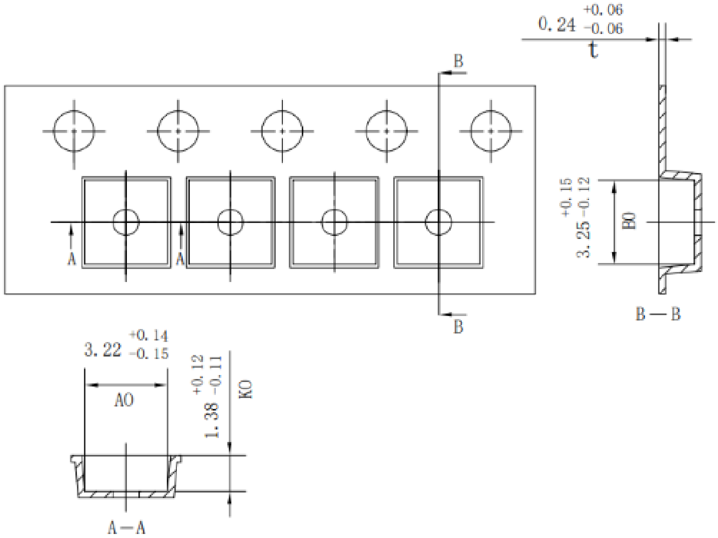
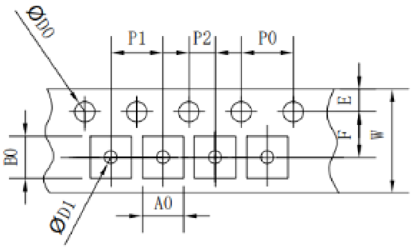
Tape and Reel Information





* All dimensions are nominal

Device	Package Type	Pins	SPQ	W (mm)	E (mm)	F (mm)	D0 (mm)	D1 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	t (mm)
LT181A1XT6/R6	SOT23	6	3 000	8.0	1.75	3.5	Φ1.5	Φ1.1	4.0	4.0	2.0	3.22	3.25	1.38	0.24
LT181A2XT6/R6	SOT23	6	3 000	8.0	1.75	3.5	Φ1.5	Φ1.1	4.0	4.0	2.0	3.22	3.25	1.38	0.24
LT181A3XT6/R6	SOT23	6	3 000	8.0	1.75	3.5	Φ1.5	Φ1.1	4.0	4.0	2.0	3.22	3.25	1.38	0.24
LT181A4XT6/R6	SOT23	6	3 000	8.0	1.75	3.5	Φ1.5	Φ1.1	4.0	4.0	2.0	3.22	3.25	1.38	0.24

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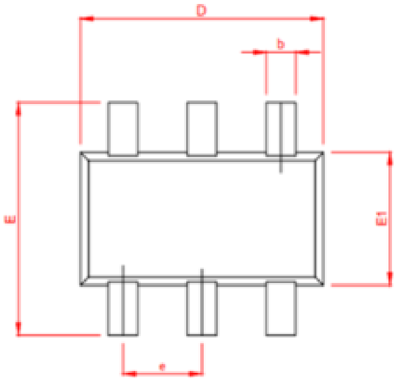
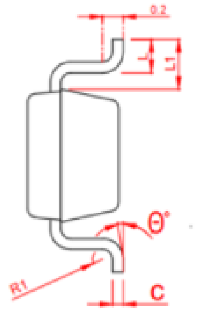
Package Outlines

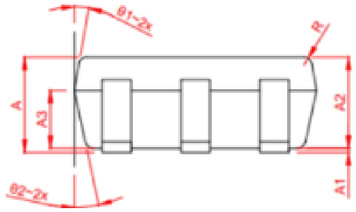
DIMENSIONS, SOT23-6L



TOP VIEW



SIDE VIEW



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	1.10	1.15	1.25
★ A1	0.02	0.06	0.10
★ A2	1.05	1.10	1.15
A3	0.60	0.65	0.70
★ b	0.32	0.35	0.48
★ c	0.152REF		
★ D	2.87	2.92	2.97
★ E	2.60	2.80	3.00
★ E1	1.55	1.60	1.65
★ e	0.95BSC		
★ L	0.35	0.45	0.55
L1	0.60 REF		
R	0.10 REF		
R1	0.12 REF		
★ θ	0°	3°	6°
θ1	7°BSC		
θ2	10°BSC		

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For additional product information, or full datasheet, please contact with the Linearin's Sales Department or Representatives.

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