TSZ151

Datasheet

Very high accuracy (7 µV) high bandwidth (1.6 MHz) zero-drift 5 V op amp

TSZ151
SC70-5

TSZ151
SOT23-5

Product status link	Channel	Automotive	Package
TSZ151ICT	1		SC70-5
TSZ151IYCT	1	•	SC70-5
TSZ151ILT	1		SOT23-5
TSZ151IYLT	1	•	SOT23-5

Related products	
TSZ121	Zero drift amplifier for more power savings (400 kHz, 31 µA)
TSZ181	Zero drift amplifier for higher bandwidth (3 MHz, 800 µA)

Features

- Very high accuracy and stability: offset voltage
  - 7 µV max. at 25 °C
  - 10 µV over full temperature range (-40 °C to 125 °C)
- Rail-to-rail input and output
- Low supply voltage: from 1.8 to 5.5 V
- Low power consumption: 210 µA at 5 V
- Gain bandwidth product: 1.6 MHz
- Extended temperature range: -40 to 125 °C
- AEC-Q100 qualified
- Benefits:
  - Higher accuracy without calibration
  - Accuracy is virtually unaffected by temperature change

Applications

- High accuracy signal conditioning
- Automotive current measurement and sensors signal conditioning

Description

The TSZ151 is a single operational amplifier featuring very low offset voltages with virtually zero-drift versus temperature changes.

The TSZ151 offers rail-to-rail input and output, an excellent speed/power consumption ratio, and 1.6 MHz gain bandwidth product, while consuming just 210 µA at 5 V.

The device also features an ultra-low input bias current. These features make the TSZ151 ideal for high-accuracy sensor interfaces.

1 Pin description

1.1 TSZ151 single operational amplifier (SC70-5)

Figure 1. Pin connection (top view)

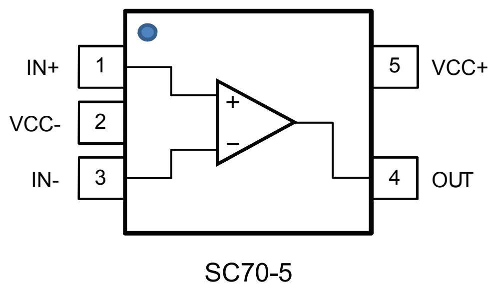


Table 1. Pin description

Pin n°	Pin name	Description
1	IN+	Non-inverting input channel
2	VCC-	Negative supply voltage
3	IN-	Inverting input channel
4	OUT	Output channel
5	VCC+	Positive supply voltage

1.2 TSZ151 single operational amplifier (SOT23-5)

Figure 2. Pin connection (top view)

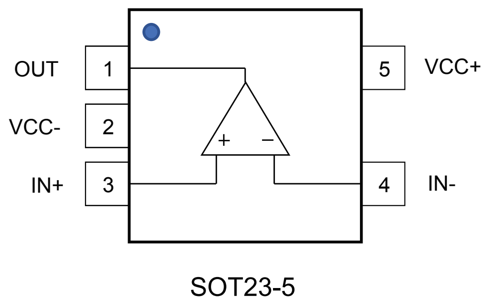


Table 2. Pin description

Pin n°	Pin name	Description
1	OUT	Output channel
2	VCC-	Negative supply voltage
3	IN+	Non-inverting input channel
4	IN-	Inverting input channel
5	VCC+	Positive supply voltage

2 Maximum ratings

Table 3. Absolute maximum ratings

Symbol	Parameter [1]		Value	Unit
V_{CC}	Supply voltage		6	V
V_{id}	Differential input voltage (V_{IN+} - V_{IN-})		$\pm V_{CC}$	
V_{in}	Input voltage [2]		(V_{CC-}) -0.2 to (V_{CC+}) +0.2	
I_{in}	Input current		±10	mA
T_{stg}	Storage temperature		-65 to +150	°C
T_j	Maximum junction temperature		150	
R_{th-ja}	Thermal resistance junction-to-ambient [3]	SC70-5	205	°C/W
		SOT23-5	250	
ESD	HBM: human body model (industrial grade) [4]		4000	V
	HBM: human body model (automotive grade) [5]		4000	
	CDM: charged device model		1000	

1. *All voltage values are with respect to the VCC- pin, unless otherwise specified.*
2. *The maximum input voltage value may be extended on the condition that the input current is limited to ±10 mA.*
3. *R_{th-ja} is a typical value, obtained with PCB according to JEDEC 2s2p without vias.*
4. *Human body model: HBM test according to the standard ESDA-JS-001-2017.*
5. *Human body model: HBM test according to the standard AEC-Q100-002.*

Table 4. Operating conditions

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	1.8 to 5.5	V
V_{icm}	Common-mode input voltage range	(V_{CC-}) -0.1 V to (V_{CC+}) +0.1	
T_{oper}	Operating free-air temperature range	-40 to 125	°C

3 Electrical characteristics

Table 5. Electrical characteristics at V_{CC} = 5 V, V_{icm} = V_{OUT} = V_{CC} / 2, T = 25 °C, C_L = 100 pF and R_L = 10 kΩ connected to V_{CC} / 2 (unless otherwise specified).

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
		DC performance				
V_{io}	Input offset voltage	T = 25 °C		1	±7	µV
		-40 °C ≤ T ≤ 125 °C			±10	
$\Delta V_{io}/\Delta T$	Input offset voltage temperature drift (1)	-40 °C ≤ T ≤ 125 °C	-15		35	nV/°C
I_{ib}	Input bias current	T = 25 °C		50	200	pA
		-40 °C ≤ T ≤ 125 °C			300	
I_{io}	Input offset current	T = 25 °C		100	400	pA
		-40 °C ≤ T ≤ 125 °C			600	
A_{VD}	Open loop gain	V_{CC-}+200 mV ≤ V_{OUT} ≤ V_{CC+}-200 mV, T = 25 °C	120	135		dB
		V_{CC-}+200 mV ≤ V_{OUT} ≤ V_{CC+}-200 mV, -40 °C ≤ T ≤ 125 °C	115			
CMR	Common-mode rejection ratio 20.log ($\Delta V_{io}/\Delta V_{icm}$)	V_{CC-} ≤ V_{icm} ≤ V_{CC+}, T = 25 °C	120	132		dB
		V_{CC-} ≤ V_{icm} ≤ V_{CC+}, -40 °C ≤ T ≤ 125 °C	115			
SVR	Supply-voltage rejection ratio 20.log($\Delta V_{io}/\Delta V_{CC}$)	1.8 V ≤ V_{CC} ≤ 5.5 V, T = 25 °C, V_{icm} = 0 V	120	140		dB
		1.8 V ≤ V_{CC} ≤ 5.5 V, -40 °C ≤ T ≤ 125 °C, V_{icm} = 0 V	120			
V_{OH}	High level output voltage drop (V_{OH} = V_{CC+} - V_{OUT})	T = 25 °C			30	mV
		-40 °C ≤ T ≤ 125 °C			70	
V_{OL}	Low level output voltage drop (V_{OL} = V_{OUT})	T = 25 °C			30	mV
		-40 °C ≤ T ≤ 125 °C			70	
I_{OUT}	I_{SINK}, OUT connected to V_{CC+}	T = 25 °C	20	30		mA
		-40 °C ≤ T ≤ 125 °C	15			
	I_{SOURCE}, OUT connected to V_{CC-}	T = 25 °C	20	30		
		-40 °C ≤ T ≤ 125 °C	15			
I_{CC}	Supply current (by operational amplifier)	T = 25 °C		210	300	µA
		-40 °C ≤ T ≤ 125 °C			300	
		AC performance				
GBP	Gain bandwidth product			1.6		MHz
SR	Slew rate (2)	A_V = 1 V/V, V_{in} = 0.3 V to V_{CC+} -0.3 V, measured from 10% to 90%		0.8		V/µs
Φm	Phase margin			60		degrees
en	Input voltage noise density	f = 1 kHz		27		nV/√Hz
en p-p	Input noise voltage	0.1 Hz ≤ f ≤ 10 Hz		0.5		μV_{pp}
t_{rec}	Overload recovery time	V_{in} from (V_{CC+} +100 mV) to (V_{CC+} -1 V) , V_{OUT} measured at (V_{CC+} -100 mV), A_V = +1		5		µs

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
t_{init}	Initialization time, V_{OUT} at 100 mV from final value	T = 25 °C		80		µs
EMIRR	EMI rejection rate = -20 log ($V_{RFpeak}/\Delta V_{io}$)	V_{RF} = 100 mVpp, f = 400 MHz		84		dB
		V_{RF} = 100 mVpp, f = 900 MHz		87		
		V_{RF} = 100 mVpp, f = 1800 MHz		90		
		V_{RF} = 100 mVpp, f = 2400 MHz		91		

Table 6. Electrical characteristics at V_{CC} = 3.3 V, V_{icm} = V_{OUT} = V_{CC} / 2, T = 25 °C, C_L = 100 pF and R_L = 10 kΩ connected to V_{CC} / 2 (unless otherwise specified).

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
		DC performance				
V_{io}	Input offset voltage	T = 25 °C		1	±7	µV
		-40 °C ≤ T ≤ 125 °C			±10	
$\Delta V_{io}/\Delta T$	Input offset voltage temperature drift [1]	-40 °C ≤ T ≤ 125 °C	-18		38	nV/°C
I_{ib}	Input bias current	T = 25 °C		50	200	pA
		-40 °C ≤ T ≤ 125 °C			300	
I_{io}	Input offset current	T = 25 °C		100	400	pA
		-40 °C ≤ T ≤ 125 °C			600	
A_{VD}	Open loop gain	V_{CC-}+200 mV ≤ V_{OUT} ≤ V_{CC+}-200 mV, T = 25 °C	116	131		dB
		V_{CC-}+200 mV ≤ V_{OUT} ≤ V_{CC+}-200 mV, -40 °C ≤ T ≤ 125 °C	111			
CMR	Common-mode rejection ratio 20.log ($\Delta V_{io}/\Delta V_{icm}$)	V_{CC-} ≤ V_{icm} ≤ V_{CC+}, T = 25 °C	116	128		dB
		V_{CC-} ≤ V_{icm} ≤ V_{CC+}, -40 °C ≤ T ≤ 125 °C	111			
V_{OH}	High level output voltage drop (V_{OH} = V_{CC+} - V_{OUT})	T = 25 °C			25	mV
		-40 °C ≤ T ≤ 125 °C			60	
V_{OL}	Low level output voltage drop (V_{OL} = V_{OUT})	T = 25 °C			25	mV
		-40 °C ≤ T ≤ 125 °C			60	
I_{OUT}	I_{SINK}, OUT connected to V_{CC+}	T = 25 °C	14	21		mA
		-40 °C ≤ T ≤ 125 °C	10			
	I_{SOURCE}, OUT connected to V_{CC-}	T = 25 °C	14	21		
		-40 °C ≤ T ≤ 125 °C	10			
I_{CC}	Supply current (by operational amplifier)	T = 25 °C		210	300	µA
		-40 °C ≤ T ≤ 125 °C			300	
		AC performance				
GBP	Gain bandwidth product			1.6		MHz
SR	Slew rate [2]	A_V = 1 V/V, V_{in} = 0.3 V to V_{CC+} -0.3 V, measured from 10% to 90%		0.8		V/µs
Φm	Phase margin			60		degrees
en	Input voltage noise density	f = 1 kHz		28		nV/√Hz
en p-p	Input noise voltage	0.1 Hz ≤ f ≤ 10 Hz		0.5		$µV_{pp}$
t_{rec}	Overload recovery time	V_{in} from (V_{CC+} +100 mV) to (V_{CC+} -1 V) , V_{OUT} measured at (V_{CC+} -100 mV), A_V = +1		3		µs
t_{init}	Initialization time, V_{OUT} at 100 mV from final value	T = 25 °C		70		µs
EMIRR	EMI rejection rate = -20 log ($V_{RFpeak}/\Delta V_{io}$)	V_{RF} = 100 mVpp, f = 400 MHz		84		dB
		V_{RF} = 100 mVpp, f = 900 MHz		87		
		V_{RF} = 100 mVpp, f = 1800 MHz		90		
		V_{RF} = 100 mVpp, f = 2400 MHz		91		

Table 7. Electrical characteristics at V_{CC} = 1.8 V, V_{icm} = V_{OUT} = V_{CC} / 2, T = 25 °C, C_L = 100 pF and R_L = 10 kΩ connected to V_{CC} / 2 (unless otherwise specified).

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
DC performance						
V_{io}	Input offset voltage	T = 25 °C		1	±7	µV
		-40 °C ≤ T ≤ 125 °C			±10	
$\Delta V_{io}/\Delta T$	Input offset voltage temperature drift (1)	-40 °C ≤ T ≤ 125 °C	-38		43	nV/°C
I_{ib}	Input bias current	T = 25 °C		50	200	pA
		-40 °C ≤ T ≤ 125 °C			300	
I_{io}	Input offset current	T = 25 °C		100	400	pA
		-40 °C ≤ T ≤ 125 °C			600	
A_{VD}	Open loop gain	V_{CC-}+200 mV ≤ V_{OUT} ≤ V_{CC+}-200 mV, T = 25 °C	110	125		dB
		V_{CC-}+200 mV ≤ V_{OUT} ≤ V_{CC+}-200 mV, -40 °C ≤ T ≤ 125 °C	105			
CMR	Common-mode rejection ratio 20.log ($\Delta V_{io}/\Delta V_{icm}$)	V_{CC-} ≤ V_{icm} ≤ V_{CC+}, T = 25 °C	110	122		dB
		V_{CC-} ≤ V_{icm} ≤ V_{CC+}, -40 °C ≤ T ≤ 125 °C	105			
V_{OH}	High level output voltage drop (V_{OH} = V_{CC+} - V_{OUT})	T = 25 °C			20	mV
		-40 °C ≤ T ≤ 125 °C			50	
V_{OL}	Low level output voltage drop (V_{OL} = V_{OUT})	T = 25 °C			20	mV
		-40 °C ≤ T ≤ 125 °C			50	
I_{OUT}	I_{SINK}, OUT connected to V_{CC+}	T = 25 °C	7	11		mA
		-40 °C ≤ T ≤ 125 °C	5			
	I_{SOURCE}, OUT connected to V_{CC-}	T = 25 °C	7	11		
		-40 °C ≤ T ≤ 125 °C	5			
I_{CC}	Supply current (by operational amplifier)	T = 25 °C		210	300	µA
		-40 °C ≤ T ≤ 125 °C			300	
AC performance						
GBP	Gain bandwidth product			1.6		MHz
SR	Slew rate (2)	A_V = 1 V/V, V_{in} = 0.3 V to V_{CC+} -0.3 V, measured from 10% to 90%		0.8		V/µs
Φm	Phase margin			60		degrees
en	Input voltage noise density	f = 1 kHz		33		nV/√Hz
en p-p	Input noise voltage	0.1 Hz ≤ f ≤ 10 Hz		0.57		μV_{pp}
t_{rec}	Overload recovery time	V_{in} from (V_{CC+} +100 mV) to (V_{CC+} -1 V) , V_{OUT} measured at (V_{CC+} -100 mV), A_V = +1		2		µs
t_{init}	Initialization time, V_{OUT} at 100 mV from final value	T = 25 °C		60		µs
EMIRR	EMI rejection rate = -20 log ($V_{RFpeak}/\Delta V_{io}$)	V_{RF} = 100 mVpp, f = 400 MHz		84		dB
		V_{RF} = 100 mVpp, f = 900 MHz		87		
		V_{RF} = 100 mVpp, f = 1800 MHz		90		
		V_{RF} = 100 mVpp, f = 2400 MHz		91		

1. *See section 4.2 Input offset voltage drift vs. temperature.*
2. *The slew rate value is the average of rising and falling values.*

4 Application information

4.1 Operating voltages

The TSZ151 device can operate from 1.8 to 5.5 V. The parameters are fully specified at 1.8 V, 3.3 V, and 5 V power supplies. However, the parameters are very stable over the full V_{CC} range and several characterization curves show the TSZ151 device characteristics over the full operating range. Additionally, the main specifications are guaranteed in an extended temperature range from -40 to 125 °C.

4.2 Input offset voltage drift vs. temperature

The maximum input voltage drift variation vs. temperature is defined as the offset variation related to the offset value measured at 25 °C. The operational amplifier is one of the main circuits of the signal conditioning chain, and the amplifier input offset (V_{io}) is a major contributor to the chain accuracy. The signal chain accuracy at 25 °C can be compensated during production at application level. The maximum input voltage drift vs. temperature enables the system designer to anticipate the effect of temperature variations. The maximum input voltage drift vs. temperature is computed using equation 1.

$$\frac{\Delta V_{io}}{\Delta T} = \left(\frac{V_{io\_T} - V_{io\_25°C}}{T - 25°C}\right)_{T = -40\,°C \ \ and \ \ T = 125\,°C} \tag{1}$$

The datasheet minimum and maximum values are guaranteed by a measurement on a representative sample size ensuring a C_{pk} (process capability index) greater than 1.3.

4.3 Maximum power dissipation

The usable output load current drive is limited by the maximum power dissipation allowed by the device package. The absolute maximum junction temperature for the TSZ151 is 150 °C. The junction temperature can be estimated as follows:

$$T_J = P_D \times \theta_{JA} + T_A \tag{2}$$

T_J is the die junction temperature.

P_D is the power dissipated in the package.

θ_{JA} is the junction to thermal resistance of the package.

T_A is the ambient temperature.

The power dissipated in the package P_D is the sum of the quiescent power dissipated and the power dissipated by the output stage transistor. It is calculated as follows:

$P_D = (V_{CC} \times I_{CC}) + (V_{CC+} - V_{OUT}) \times I_{OUT}$ when the op amp is sourcing the current.

$P_D = (V_{CC} \times I_{CC}) + (V_{OUT} - V_{CC-}) \times I_{OUT}$ when the op amp is sinking the current.

Do not exceed the 150 °C maximum junction temperature for the device. Exceeding the junction temperature limit can cause degradation in the parametric performance or even destroy the device.

4.4 PCB layout recommendations

Particular attention must be paid to the layout of the PCB tracks connected to the amplifier, load, and power supply. The power and ground traces are critical as they must provide adequate energy and grounding for all circuits. The best practice is to use short and wide PCB traces to minimize voltage drops and parasitic inductance. In addition, to minimize parasitic impedance over the entire surface, use a multi-via technique that connects the bottom and top layer ground planes together in many locations. The copper traces that connect the output pins to the load and supply pins should be as wide as possible to minimize trace resistance.

4.5 Decoupling capacitor

In order to ensure op amp full functionality, it is mandatory to place a decoupling capacitor of at least 22 nF as close as possible to the op amp supply pin. A good decoupling helps to reduce an electromagnetic interference impact.

4.6 Macromodel

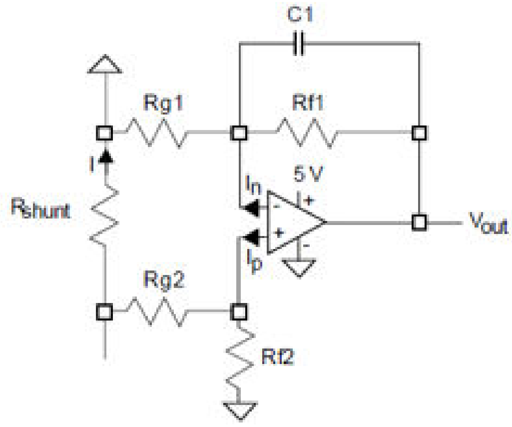
Accurate macromodels of the TSZ151 device are available on the STMicroelectronics website at: www.st.com. These models are a trade-off between the accuracy and complexity (that is, time simulation) of the TSZ151 operational amplifier. They emulate the nominal performance of a typical device within the specified operating conditions mentioned in the datasheet. They also help to validate a design approach and to select the right operational amplifier, but they do not replace on-board measurements.

5 Typical applications

5.1 Low-side current sensing

Power management mechanisms are found in most electronic systems. Current sensing is useful for protecting applications. The low-side current sensing method consists of placing a sense resistor between the load and the circuit ground. The resulting voltage drop is amplified using the TSZ151.

Figure 3. Low-side current sensing schematic



V_{out} can be expressed as follows:

$$V_{out} = R_{shunt} \cdot I\left(1 - \frac{Rg2}{Rg2 + rf2}\right) \cdot \left(1 + \frac{Rf1}{Rf2}\right) + I_p \cdot \frac{Rg2 \cdot Rf2}{Rg2 + Rf2} \cdot \left(1 + \frac{Rf1}{Rg1}\right) - I_n \cdot Rf1 - V_{io} \cdot \left(1 + \frac{Rf1}{rg1}\right) \quad (3)$$

Assuming that Rf2 = Rf1 = Rf and Rg2 = Rg1 = Rg, equation 4 can be simplified as follows:

$$V_{out} = R_{shunt} \cdot I \cdot \frac{Rf}{Rg} - V_{io} \cdot \left(1 + \frac{Rf}{Rg}\right) + Rf \cdot I_{io} \quad (4)$$

The main advantage of using the TSZ151 for a low-side current sensing relies on its low V_{io}, compared to general purpose operational amplifiers. For the same current and targeted accuracy, the shunt resistor can be chosen with a lower value, resulting in lower power dissipation, lower drop in the ground path, and lower cost. Particular attention must be paid to the precision of Rg1 and Rf1, to maximize the accuracy of the measurement.

Note that the open loop gain of TSZ151 is defined close to the rail. It enables measurements over a wide range of currents.

6 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

6.1 SC70-5 (or SOT323-5) package information

Figure 4. **SC70-5 (or SOT323-5) package outline**

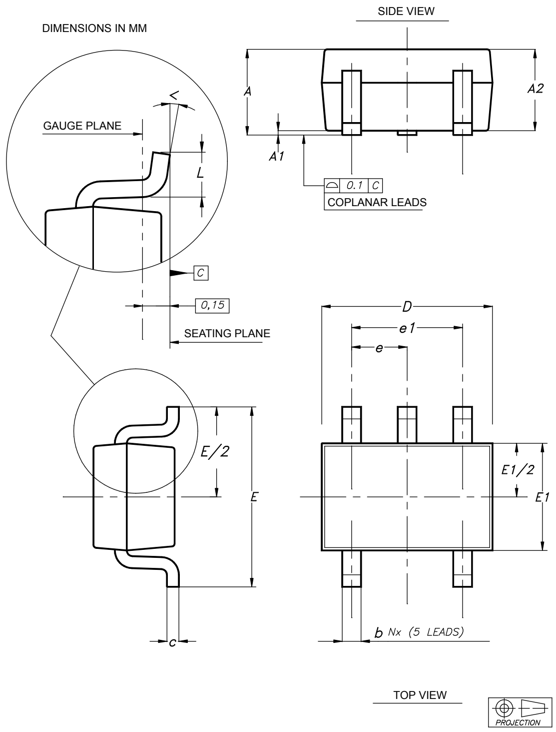


Table 8. **SC70-5 (or SOT323-5) package mechanical data**

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.80		1.10	0.032		0.043
A1			0.10			0.004
A2	0.80	0.90	1.00	0.032	0.035	0.039
b	0.15		0.30	0.006		0.012
c	0.10		0.22	0.004		0.009
D	1.80	2.00	2.20	0.071	0.079	0.087
E	1.80	2.10	2.40	0.071	0.083	0.094
E1	1.15	1.25	1.35	0.045	0.049	0.053
e		0.65			0.025	
e1		1.30			0.051	
L	0.26	0.36	0.46	0.010	0.014	0.018
<	0°		8°	0°		8°

6.2 SOT23-5 package information

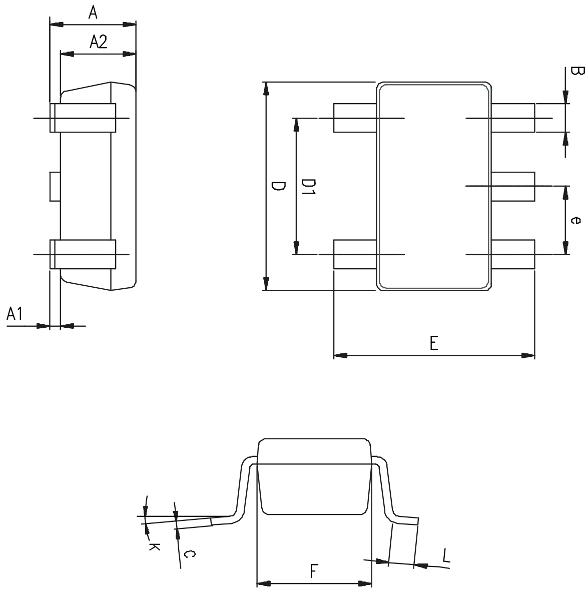


Figure 5. SOT23-5 package outline

Table 9. SOT23-5 mechanical data

Symbol	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.90	1.20	1.45	0.035	0.047	0.057
A1			0.15			0.006
A2	0.90	1.05	1.30	0.035	0.041	0.051
B	0.35	0.40	0.50	0.014	0.016	0.020
C	0.09	0.15	0.20	0.004	0.006	0.008
D	2.80	2.90	3.00	0.110	0.114	0.118
D1		1.90			0.075	
e		0.95			0.037	
E	2.60	2.80	3.00	0.102	0.110	0.118
F	1.50	1.60	1.75	0.059	0.063	0.069
L	0.10	0.35	0.60	0.004	0.014	0.024
K	0°		10°	0°		10°

7 Ordering information

Table 10. Order codes

Order code	Temperature range	Package	Marking
TSZ151ICT	-40 °C to 125 °C	SC70-5	K4K
TSZ151ILT		SOT23-5	K234
TSZ151IYCT	-40 °C to 125 °C automotive grade (1)	SC70-5	K4L
TSZ151IYLT		SOT23-5	K235

1. *Qualification and characterization according to AEC Q100 and Q003 or the equivalent, advanced screening according to AEC Q001 & Q002 or the equivalent. For qualification status details, check the "Maturity Status" link on the first page ("Quality & Reliability" tab on www.st.com).*

Revision history

Table 11. **Document revision history**

Date	Revision	Changes
13-Oct-2023	1	Initial release.

Contents