–6V to 40V, Common-Mode, Ultra-Precise Current Sense Amplifier

Rev B, July 2025

1. FEATURES

- Compliant with AEC-Q100
  - Temperature Grade 1: –40°C to 125°C operating ambient temperature
- Excellent CMRR: 150dB DC CMRR (typ)
- Wide common-mode range: –6V to 40V
- Accuracy:
  - Gain:
    - Gain error: 0.3% (max)
    - Gain drift: 9ppm/°C (typ)
  - Offset:
    - Offset voltage: ±50μV (max)
    - Offset drift: 1μV/°C (max)
- Available gains:
  - CSA601LQ: 20V/V
  - CSA601MQ: 50V/V
  - CSA601NQ: 100V/V
- Quiescent current: 1.4mA (typ)

2. APPLICATIONS

- Motor controls
- Solenoid and valve controls
- Actuator controls
- Telecom equipment
- BMS system

3. DESCRIPTION

The CSA601Q device is a voltage-output, current-sense amplifier that can sense drops across shunt resistors over a wide common-mode voltage range from –6V to 40V. The negative common-mode voltage allows the device to operate below ground.

The device operates from a single 2.7V to 5.5V supply with a typical supply current of 1.4mA and a typical bandwidth of 550kHz. Three fixed gains are available: 20V/V, 50V/V, and 100V/V.

All versions are specified over the extended operating temperature range (–40°C to +125°C), and are offered in SOT23-5 package. See Table 1 for the order information.

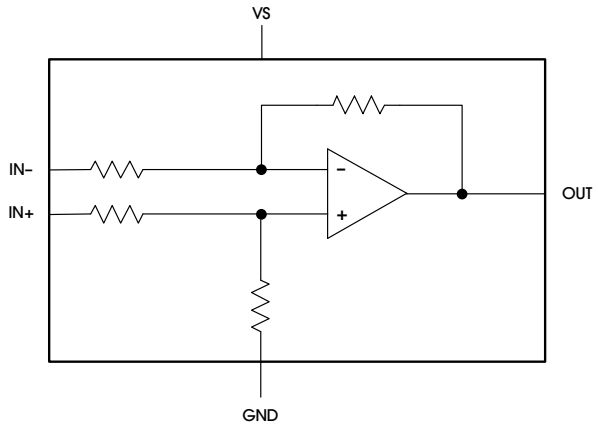


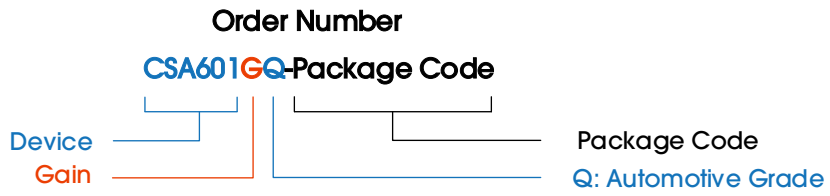
Table 1 lists the order information.

Table 1. Order Information

ORDER NUMBER[1]	PART NUMBER	MARK	CH (#)	PACKAGE	V_{CC} (V)	I_Q TYP (mA)	GBW (kHz)	GAIN (TYP) (V/V)	OPERATING TEMP (°C)	RATING	MSL	PACKAGE OPTION
CSA601LQCSOT235[2]	CSA601LQ	C601LQ/XXXXXX[3]	1	SOT23-5	–6-40	1.4	550	20	–40-125	Auto	1	T/R-3000
CSA601MQCSOT235[2]	CSA601MQ	C601MQ/XXXXXX[3]	1	SOT23-5	–6-40	1.4	550	50	–40-125	Auto	1	T/R-3000
CSA601NQCSOT235[2]	CSA601NQ	C601NQ/XXXXXX[3]	1	SOT23-5	–6-40	1.4	550	100	–40-125	Auto	1	T/R-3000

Devices can be ordered via the following two ways:
1. Place orders directly on our website (www.analogysemi.com), or;
2. Contact our sales team by mailing to sales@analogysemi.com.

Note 1:



Note 2: Available in the Future.
Note 3: "XXXXXX": For internal use.

4. PIN CONFIGURATION AND FUNCTIONS

Figure 1 illustrates the pin configuration.

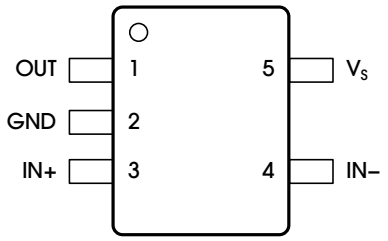


Figure 1. Pin Configuration

Table 2 lists the pin functions.

Table 2. Pin Functions

POSITION	NAME	TYPE	DESCRIPTION
1	OUT	Analog output	Output voltage
2	GND	Analog	Ground
3	IN+	Analog input	Connect to power supply side of shunt resistor.
4	IN–	Analog input	Connect to load side of shunt resistor.
5	V_S	—	Power supply, 2.7V to 5.5V

5. SPECIFICATIONS

5.1 ABSOLUTE MAXIMUM RATINGS

Table 3 lists the absolute maximum ratings of the CSA601Q.

Table 3. Absolute Maximum Ratings

PARAMETER	DESCRIPTION		MIN	MAX	UNITS
Voltage	Supply			6	V
	Analog inputs, V_{IN+}, V_{IN-} (2)	Differential (V_{IN+}) – (V_{IN-}), 1s maximum duration due to package thermal dissipation	–40	40	V
		Common-mode	–6	40	
	Output		GND – 0.3	V_S + 0.3	V
Temperature	Operating free-air, T_A		–40	125	°C
	Junction, T_J			150	°C
	Storage, T_{stg}		–65	150	°C

Note 1: Stresses beyond those listed under Table 3 may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Table 5. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

Note 2: V_{IN+} and V_{IN-} are the voltages at the IN+ and IN– pins, respectively.

5.2 ESD RATINGS

Table 4 lists the ESD ratings of the CSA601Q.

Table 4. ESD Ratings

PARAMETER	SYMBOL	DESCRIPTION	VALUE	UNITS
Electrostatic Discharge	$V_{(ESD)}$	Human-body model (HBM), per AEC-Q100	±6000	V
		Charged-device model (CDM), per AEC-Q100	±2000	

5.3 RECOMMENDED OPERATING CONDITIONS

Table 5 lists the recommended operating conditions for the CSA601Q.

Table 5. Recommended Operating Conditions

PARAMETER	SYMBOL	MIN	NOM	MAX	UNITS
Common-Mode Input Voltage	V_{CM}	–6	12	40	V
Operating Supply Voltage	V_S	2.7	5	5.5	V
Operating Free-Air Temperature	T_A	–40	25	125	°C

5.4 THERMAL INFORMATION

Table 6 lists the thermal information for the CSA601Q.

Table 6. Thermal Information

PARAMETER	SYMBOL	SOT23-5	UNITS
Junction-to-Ambient Thermal Resistance	$R_{\theta JA}$	168	°C/W
Junction-to-Board Thermal Resistance	$R_{\theta JB}$	39	°C/W
Junction-to-Top Characterization Parameter	ψ_{JT}	10	°C/W
Junction-to-Board Characterization Parameter	ψ_{JB}	36	°C/W
Junction-to-Case (Top) Thermal Resistance	$R_{\theta JC(top)}$	103	°C/W

5.5 ELECTRICAL CHARACTERISTICS

Table 7 lists the electrical characteristics of the CSA601Q. T_A = 25°C, V_S = 5V, V_{SENSE} = V_{IN+} – V_{IN-}=1mV, V_{CM} = 12V, unless otherwise noted.

Table 7. Electrical Characteristics

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
INPUT						
Common-Mode Input Range	V_{CM}	V_{IN+} = –6V to 40V, T_A = –40°C to 125°C	–6		40	V
Common-Mode Rejection Ratio	CMRR	V_{IN+} = –6V to 40V, T_A = –40°C to 125°C	135	150		dB
Offset Voltage, Input-Referred	V_{OS}	V_{SENSE} = 0mV		±7	±50	µV
Offset Voltage Drift	dV_{OS}/dT	V_{SENSE} = 0mV, T_A = –40°C to 125°C		±350	±1000	nV/°C
Power-Supply Rejection Ratio	PSRR	V_S = 2.7V to 5.5V, T_A = –40°C to 125°C		±1	±7.3	µV/V
Input Bias Current	I_B	I_{B+}, I_{B-}, V_{SENSE} = 0mV		±30		nA
OUTPUT						
Gain	G	CSA601LQ		20		V/V
		CSA601MQ		50		
		CSA601NQ		100		
Gain Error		GND + 50mV ≤ V_{OUT} ≤ V_S – 200mV		±0.05	±0.3	%
		T_A = –40°C to 125°C		±9	±30	ppm/°C
Maximum Capacitive Load		No sustained oscillation		2		nF
VOLTAGE OUTPUT						
Swing to V_S Power-Supply Rail		R_L = 10kΩ to GND, T_A = –40°C to 125°C	V_S – 0.015	V_S – 0.005		V
Swing to GND		R_L = 10kΩ to GND, V_{SENSE} = 0mV, T_A = –40°C to 125°C		V_{GND} + 10	V_{GND} + 15	mV
FREQUENCY RESPONSE						
Bandwidth	BW	All gains, –3dB bandwidth		550		kHz
Slew Rate	SR			1.5		V/µs
NOISE (INPUT REFERRED)						
Voltage Noise Density				89		nV/√Hz
POWER SUPPLY						
Operating Voltage Range	V_S	T_A = –40°C to 125°C	2.7		5.5	V
Quiescent Current	I_Q			1.4	1.8	mA
		T_A = –40°C to 125°C			2	
TEMPERATURE RANGE						
Specified Range			–40		125	°C

6. TYPICAL CHARACTERISTICS

T_A = 25°C, V_S = 5V, V_{CM} = 12V, unless otherwise noted.

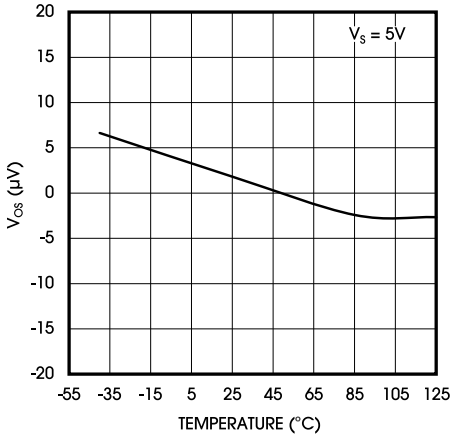


Figure 2. Offset Voltage vs. Temperature

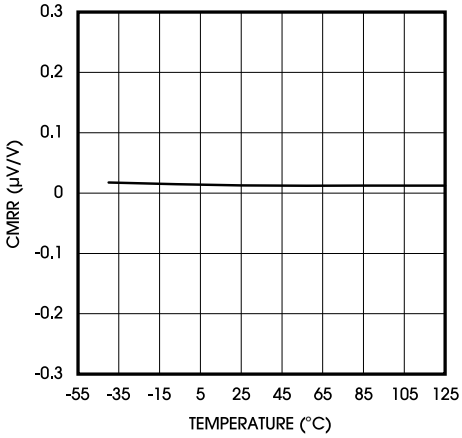


Figure 3. Common-Mode Rejection Ratio vs. Temperature

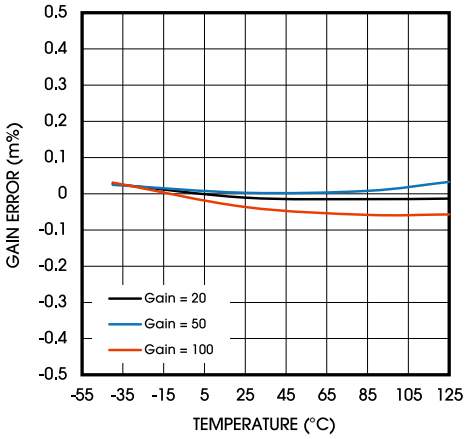


Figure 4. Gain Error vs. Temperature

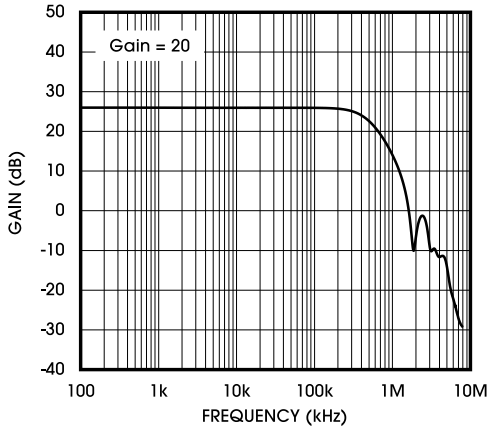


Figure 5. Gain vs. Frequency

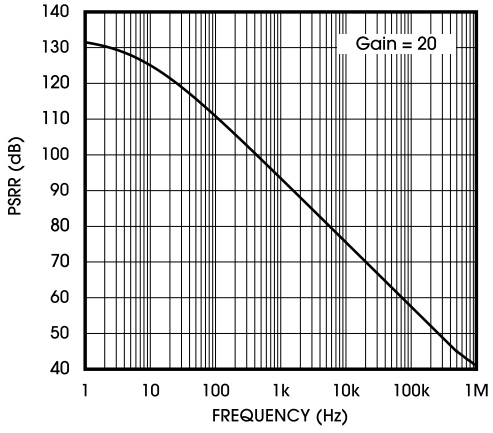


Figure 6. Power-Supply Rejection Ratio vs. Frequency

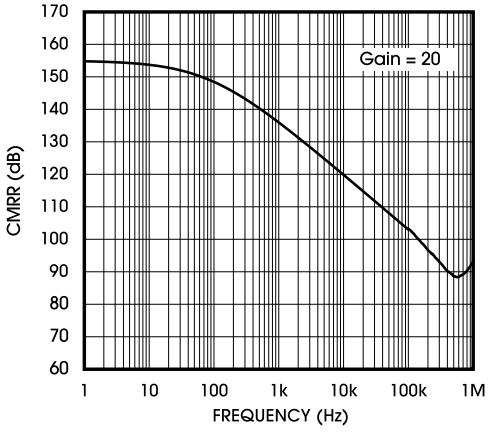


Figure 7. Common-Mode Rejection Ratio vs. Frequency

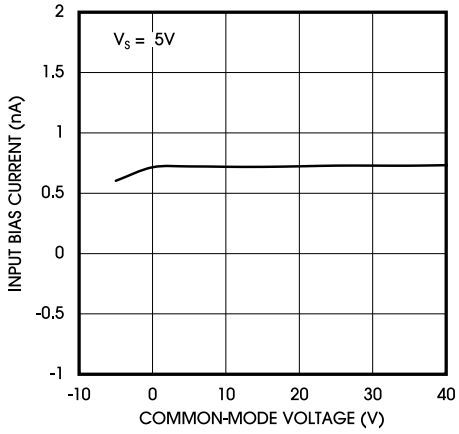


Figure 8. Input Bias Current vs. Common-Mode Voltage

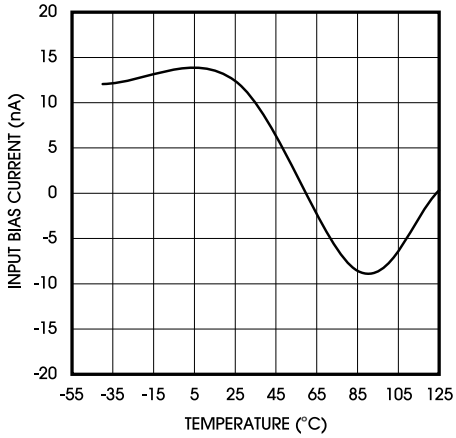


Figure 9. Input Bias Current vs. Temperature

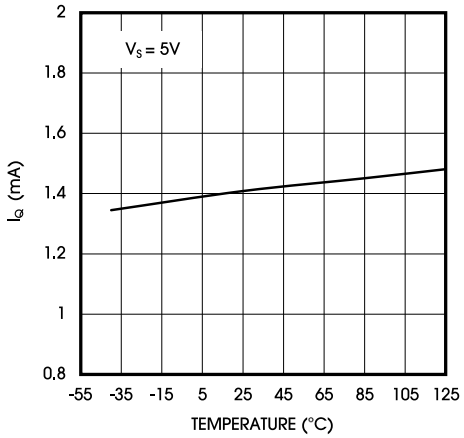


Figure 10. Quiescent Current vs. Temperature

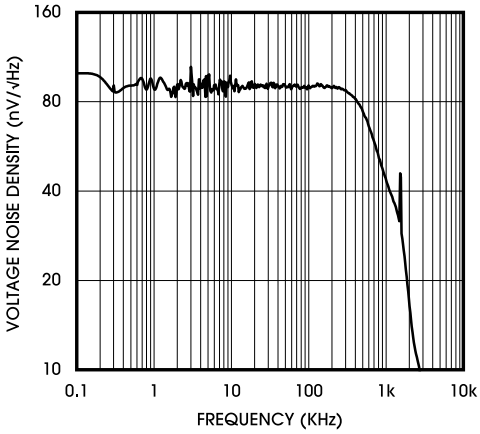


Figure 11. Input-Referred Voltage Noise vs. Frequency

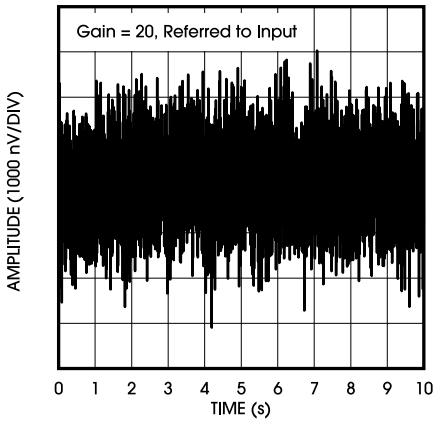


Figure 12. 0.1Hz to 10Hz Voltage Noise

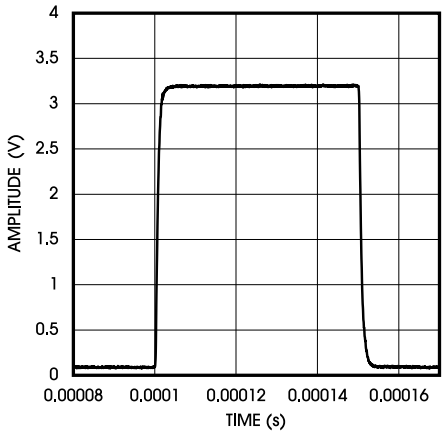


Figure 13. Step Response

7. DETAILED DESCRIPTION

7.1 OVERVIEW

The CSA601Q is a current-sense amplifier that offers a wide common-mode range, precision, zero-drift topology, and excellent common-mode rejection ratio (CMRR). The bandwidth is up to 550kHz and multiple gain versions are available: 20V/V, 50V/V and 100V/V, allowing for the optimization of the desired full-scale output voltage based on the target current range expected in the application.

7.2 FUNCTIONAL BLOCK DIAGRAM

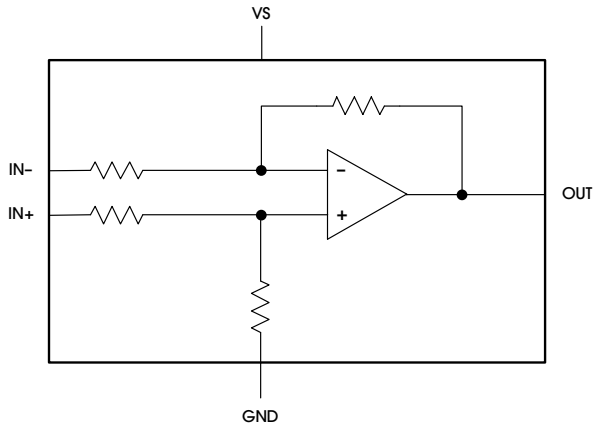


Figure 14. Functional Block Diagram

7.3 FEATURE DESCRIPTION

7.3.1 INPUT SIGNAL

The CSA601Q bandwidth is defined by the –3dB bandwidth of the current-sense amplifier inside the device: 550kHz (typ.); see the ELECTRICAL CHARACTERISTICS table. The device bandwidth provides fast throughput and fast response required for the rapid detection and processing of overcurrent events. Without the higher bandwidth, protection circuitry may not have adequate response time and damage may occur to the monitored application or circuit.

8. APPLICATION AND IMPLEMENTATION

NOTE

The information provided in this section is not part of the Company's component specification. Hence, Company does not warrant its completeness or accuracy. Customers are responsible for determining suitability of components and system functionality for their applications. Validation and testing should be performed prior to design implementation.

8.1 TYPICAL APPLICATIONS

The CSA601Q offers advantages for multiple applications including the following:

- High common-mode range and excellent CMRR enables direct inline sensing
- Ultra-low offset and drift eliminates the necessity of calibration
- Wide supply range enables a direct interface with most microprocessors

8.1.1 INLINE MOTOR CURRENT-SENSE APPLICATION

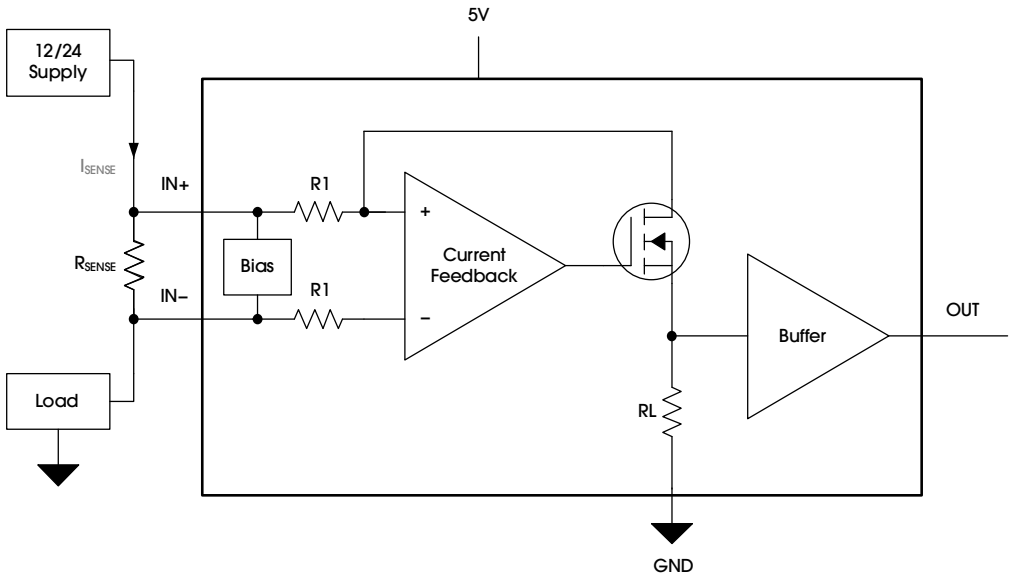


Figure 15. Typical Application

8.2 KELVIN CONNECTION FROM THE CURRENT-SENSE RESISTOR

To provide accurate current measurements, verify the routing between the current-sense resistor and the amplifier uses a Kelvin connection.

9. POWER SUPPLY RECOMMENDATIONS

The CSA601Q series makes accurate measurements beyond the connected power-supply voltage (V_S) because the inputs (IN+ and IN–) operate anywhere between –6V and 40V independent of V_S. For example, the V_S power supply equals 5V and the common-mode voltage of the measured shunt can be as high as 40V.

Although the common-mode voltage of the input can be beyond the supply voltage, the output voltage range of the CSA601Q series is constrained to the supply voltage.

Place the power-supply bypass capacitor as close as possible to the supply and ground pins. The bypass capacitor is recommended to be 0.1µF. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

10. LAYOUT

Poor routing of the current-sensing resistor can result in additional resistance between the input pins of the amplifier. Any additional high-current carrying impedance can cause significant measurement errors because the current resistor has a very-low-ohmic value. Use a Kelvin or 4-wire connection to connect to the device input pins. This connection technique ensures that only the current-sensing resistor impedance is detected between the input pins.

11. PACKAGE INFORMATION

The CSA601Q is available in the SOT23-5 package. Figure 16 shows the package view.

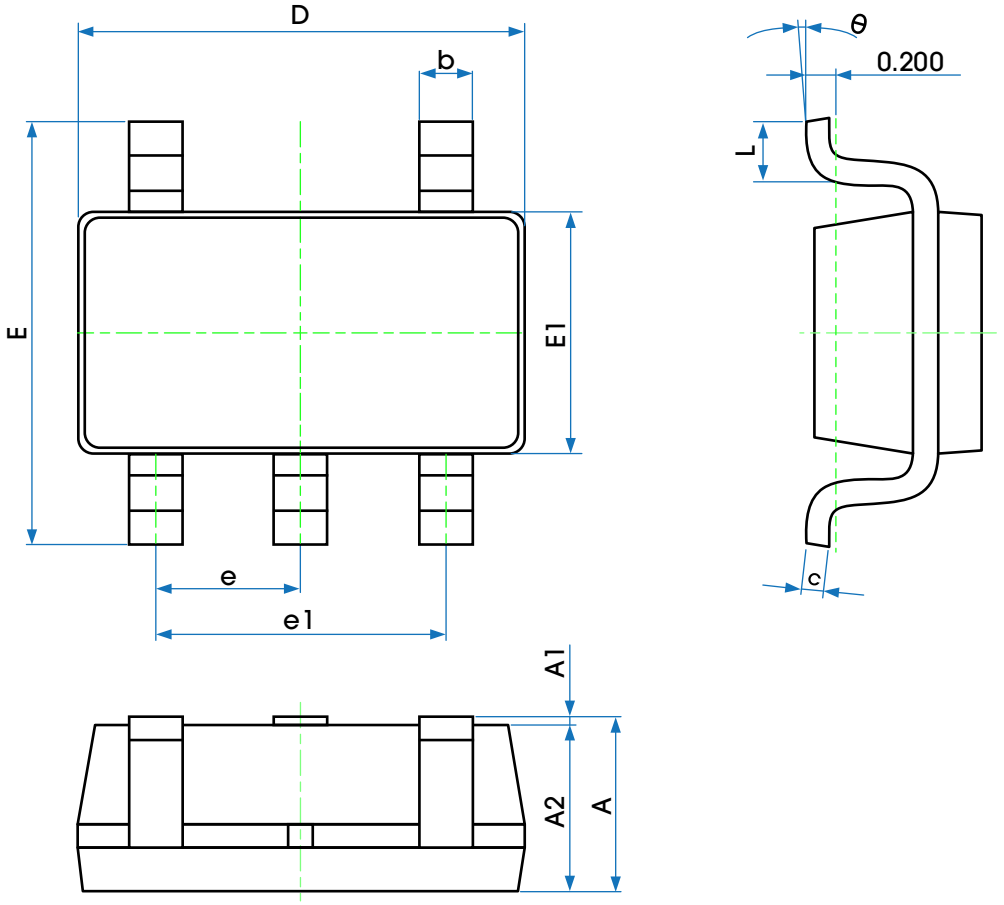


Figure 16. Package View

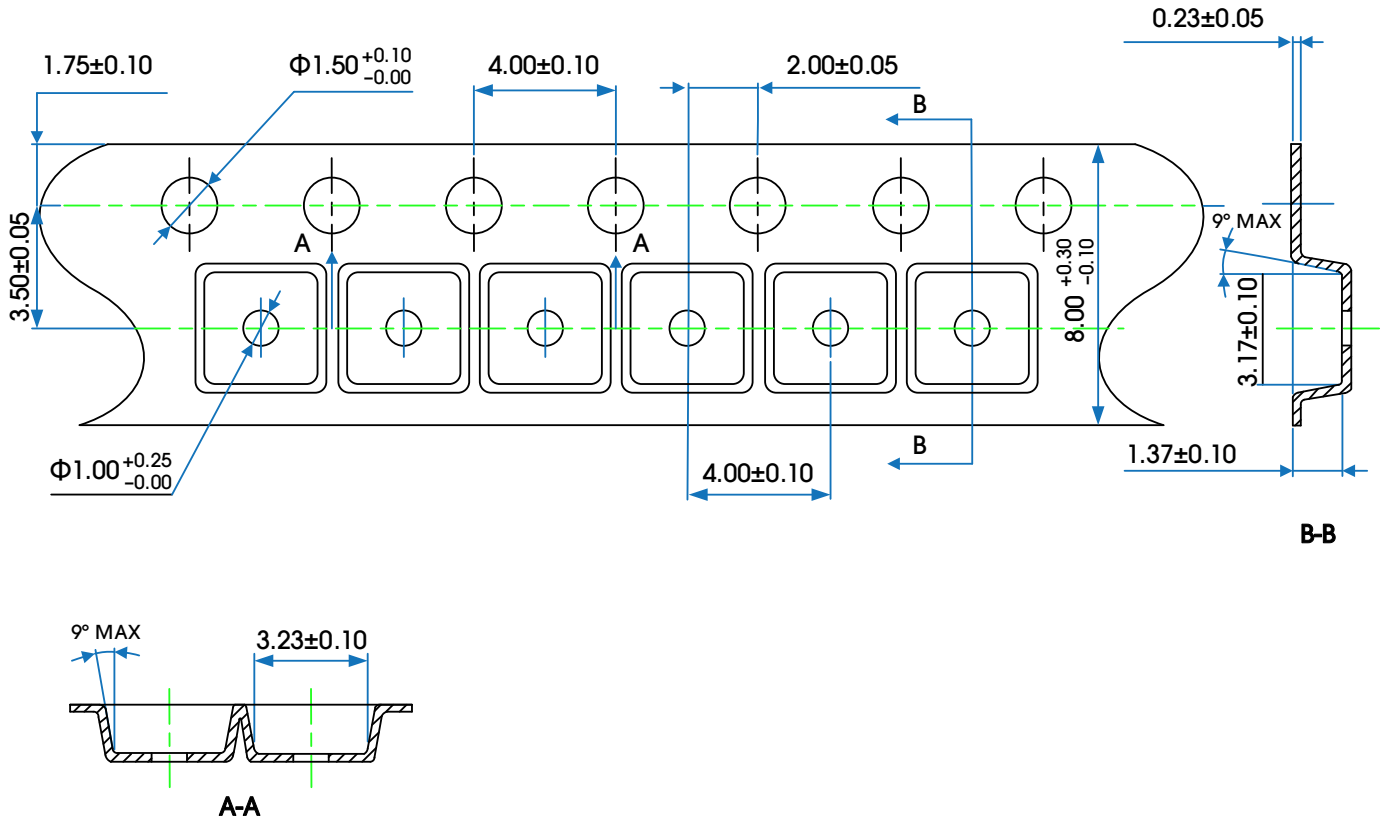
Table 8 provides detailed information about the dimensions.

Table 8. Dimensions

SYMBOL	DIMENSIONS IN MILLIMETERS		DIMENSIONS IN INCHES	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	2.650	2.950	0.104	0.116
E1	1.500	1.700	0.059	0.067
e	0.950 (BSC)		0.037 (BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
L1	0.600REF		0.024REF	
θ	0°	8°	0°	8°

12. TAPE AND REEL INFORMATION

Figure 17 illustrates the carrier tape.



Notes:
1. Cover tape width: 5.50 ± 0.10.
2. Cumulative tolerance of 10 sprocket hole pitch: ±0.20 (max).
3. Camber: not to exceed 2mm in 250mm.
4. Mold#: SOT23-5.
5. All dimensions: mm.
6. Direction of view:

Figure 17. Carrier Tape Drawing

Table 9 provides information about tape and reel.

Table 9. Tape and Reel Information

PACKAGE TYPE	REEL	QTY/REEL	REEL/ INNER BOX	INNER BOX/ CARTON	QTY/CARTON	INNER BOX SIZE (mm)	CARTON SIZE (mm)
SOT23-5	7''	3000	1	10	30000	259*234*20	255*235*275

Figure 18 shows the product loading orientation—pin 1 is assigned on the lower left corner.

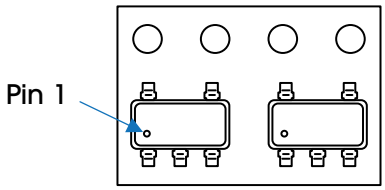


Figure 18. Product Loading Orientation

REVISION HISTORY

REVISION	DATE	DESCRIPTION
Rev A	15 April 2025	Rev A release.
Rev B	07 July 2025	Updated Table 9.