SA89550 Series

Precision Micropower Shunt Voltage Reference

General Description

The SA89550 is a high precision, micro power, low temperature drift shunt voltage reference.

The utilization of package level trim technology enables the achievement of better than ±0.1% initial accuracy at 25°C. The device does not require an output capacitor to be stable but tolerates capacitive loads. The SA89550 supports wide operating current range from I_{RMIN} to 15mA.

The SA89550 is available in a SOT-23 package and capable of operating within a temperature range of -40 to 125°C. All versions of the SA89550 is AEC-Q100 Grade 1 qualified.

Features

- Fixed Reverse Breakdown Voltage of 2.048V, 2.5V, 3.0V, 3.3V, 4.096V and 5V.
- Output Voltage Tolerance ±0.1% (Maximum)
- Low output noise (10Hz to 10kHz) 38μVrms (Typical)
- No output Capacitor Required
- Tolerates Capacitive Loads
- Wide Operating Current Range 15mA
- Industrial Temperature Range −40°C to 125°C
- Low Temperature Coefficient ±43 ppm/°C(max)
- Small Package: SOT-23
- AEC-Q100 Grade 1 qualified

Applications

- Power Line Monitoring
- Portable, Battery-Powered Equipment
- Data Acquisition Systems
- Instrumentation
- Process Control
- Energy Management
- Product Testing
- Automotive
- Precision Audio Components

Typical Application

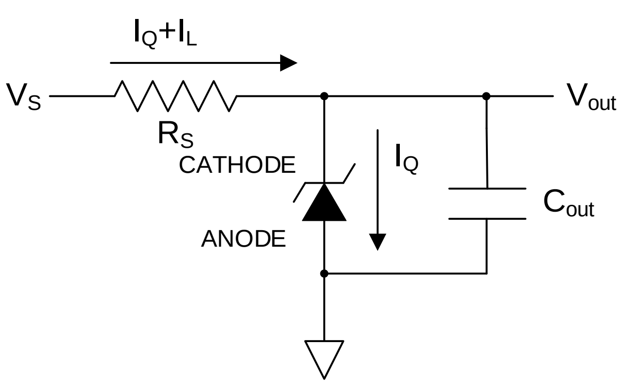


Figure 1. Typical Application

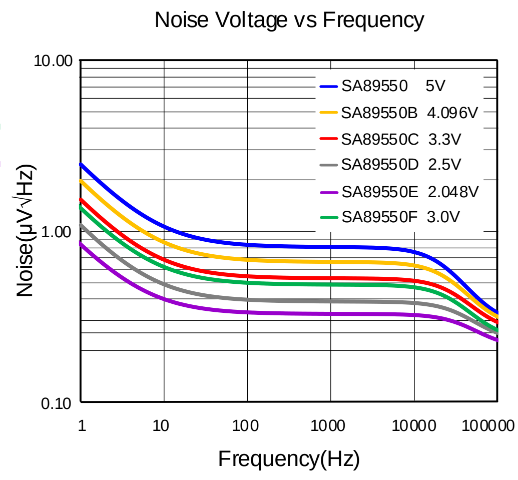


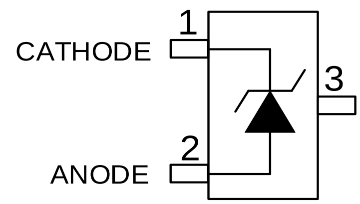
Figure 2. Noise Voltage vs Frequency

Ordering Information

Ordering Part Number	Package Type	Top Mark	Output Voltage
SA89550AOT	SOT-23	**4hxyz**	**5V**
SA89550BAOT	SOT-23	**6dxyz**	**4.096V**
SA89550CAOT	SOT-23	**6exyz**	**3.3V**
SA89550DAOT	SOT-23	**6fxyz**	**2.5V**
SA89550EAOT	SOT-23	**6gxyz**	**2.048V**
SA89550FAOT	SOT-23	**8fxyz**	**3.0V**

x = year code, y = week code, z = lot number code

Pinout (Top View)



(SOT-23)

Pin Description

Pin No.	Pin Name	Pin Description
1	CATHODE	Positive pin of the reference.
2	ANODE	Negative pin of the reference, normally connected to ground.
3	NC	This pin must be left floating or connected to pin 2.

Block Diagram

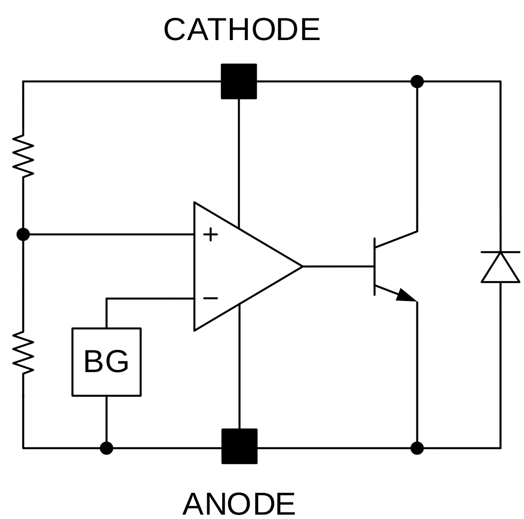


Figure 3. Block Diagram

Absolute Maximum Ratings

Parameter (	Min	Max	Unit
Input Current into CATHODE	-10	20	mA
NC	-0.3	0.3	V
Junction Temperature, Operating	-40	150	°C
Storage Temperature	-65	150	
ESD: HBM (Human Body Model)	± 2000		V
ESD: CDM (Charged Device Model)	± 1000		

Thermal Information

Parameter (Note 2)	Value	Unit
θ_{JA} Junction-to-ambient Thermal Resistance	309.5	°C/W
θ_{JC} Junction-to-case (top) Thermal Resistance	122	
θ_{JB} Junction-to-board Thermal Resistance	60	
ψ_{JT} Junction-to-top Characterization Parameter	7	
P_D Power Dissipation T_A = 25°C	280	mW

Recommended Operating Conditions

Parameter (Note 3)	Min	Max	Unit
Input Current into CATHODE	I_{RMIN}	15	mA
Ambient Temperature	-40	125	°C

Electrical Characteristics 5V

I_R = 150 μA, T_A=−40°C to 125°C, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Reverse Breakdown Voltage	V_R	T_A = 25°C	4.995	5.000	5.005	V
Reverse Breakdown Voltage Tolerance			-25		25	mV
Minimum Operating Current	I_{RMIN}	T_A = 25°C		88	100	μA
				115	125	
Average Reverse Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta T$	I_R = 15 mA		±15	±48	ppm/°C
		I_R = 1 mA		±6	±41	
				±6	±41	
Reverse Breakdown Voltage Changes with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \le I_R \le$ 1 mA, T_A = 25°C, excluding die temperature change effect	-0.6	0.2	0.8	mV
		$I_{RMIN} \le I_R \le$ 1 mA, excluding die temperature change effect	-0.7	0.6	1.6	
		1mA ≤ I_R ≤ 15mA, T_A = 25°C, excluding die temperature change effect	-3.5	-1	2.5	
		1mA ≤ I_R ≤ 15mA, excluding die temperature change effect	-6	4	11	
Reverse Dynamic Impedance	Z_R	I_R = 1mA, f = 120Hz, I_{AC} = 0.1 I_R		0.5		Ω
Wideband Noise	e_N	10 Hz ≤ f ≤ 10 kHz		80		μV_{rms}
Reverse Breakdown Voltage Long Term Stability	ΔV_R	t = 1000hrs		90		ppm
Thermal Hysteresis	V_{HYST}	Full temperature cycle, from 25°C to -40°C, then rise to 125°C and finally back to 25°C		0.5		mV

Electrical Characteristics 4.096V

I_R = 150 μA, T_A=−40°C to 125°C, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Reverse Breakdown Voltage	V_R	T_A = 25°C	4.092	4.096	4.100	V
Reverse Breakdown Voltage Tolerance			-20.5		20.5	mV
Minimum Operating Current	I_{RMIN}	T_A = 25°C		85	97	μA
				111	128	
Average Reverse Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta T$	I_R = 15 mA		±7	±36	ppm/°C
		I_R = 1 mA		±5	±35	
				±5	±33	
Reverse Breakdown Voltage Changes with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \le I_R \le$ 1 mA, T_A = 25°C, excluding die temperature change effect	-0.3	0.2	0.7	mV
		$I_{RMIN} \le I_R \le$ 1 mA, excluding die temperature change effect	-0.3	0.5	1.2	
		1mA ≤ I_R ≤ 15mA, T_A = 25°C, excluding die temperature change effect	-3.5	1	5.5	
		1mA ≤ I_R ≤ 15mA, excluding die temperature change effect	-4	3.3	10	
Reverse Dynamic Impedance	Z_R	I_R = 1mA, f = 120Hz, I_{AC} = 0.1 I_R		0.5		Ω
Wideband Noise	e_N	10 Hz ≤ f ≤ 10 kHz		65		μV_{rms}
Reverse Breakdown Voltage Long Term Stability	ΔV_R	t = 1000hrs		85		ppm
Thermal Hysteresis	V_{HYST}	Full temperature cycle, from 25°C to -40°C, then rise to 125°C and finally back to 25°C		0.41		mV

Electrical Characteristics 3.3V

I_R = 150 μA, T_A=−40°C to 125°C, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Reverse Breakdown Voltage	V_R	T_A = 25°C	3.2967	3.3	3.3033	V
Reverse Breakdown Voltage Tolerance			-16.5		16.5	mV
Minimum Operating Current	I_{RMIN}	T_A = 25°C		83	94	μA
				109	126	
Average Reverse Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta T$	I_R = 15 mA		±7	±39	ppm/°C
		I_R = 1 mA		±5	±39	
				±5	±37	
Reverse Breakdown Voltage Changes with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \le I_R \le$ 1 mA, T_A = 25°C, excluding die temperature change effect	-0.25	0.2	0.7	mV
		$I_{RMIN} \le I_R \le$ 1 mA, excluding die temperature change effect	-0.5	0.5	1.4	
		1mA ≤ I_R ≤ 15mA, T_A = 25°C, excluding die temperature change effect	-0.3	2.2	4	
		1mA ≤ I_R ≤ 15mA, excluding die temperature change effect	-1.6	4.6	11.7	
Reverse Dynamic Impedance	Z_R	I_R = 1mA, f = 120Hz, I_{AC} = 0.1 I_R		0.4		Ω
Wideband Noise	e_N	10 Hz ≤ f ≤ 10 kHz		51		μV_{rms}
Reverse Breakdown Voltage Long Term Stability	ΔV_R	t = 1000hrs		70		ppm
Thermal Hysteresis	V_{HYST}	Full temperature cycle, from 25°C to -40°C, then rise to 125°C and finally back to 25°C		0.33		mV

Electrical Characteristics 2.5V

I_R = 150 μA, T_A=−40°C to 125°C, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Reverse Breakdown Voltage	V_R	T_A = 25°C	2.4975	2.500	2.5025	V
Reverse Breakdown Voltage Tolerance			-12.5		12.5	mV
Minimum Operating Current	I_{RMIN}	T_A = 25°C		80	88	μA
				106	115	
Average Reverse Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta T$	I_R = 15 mA		±12	±43	ppm/°C
		I_R = 1 mA		±16	±43	
				±17	±43	
Reverse Breakdown Voltage Changes with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \le I_R \le$ 1 mA, T_A = 25°C, excluding die temperature change effect	-0.4	0.24	0.7	mV
		$I_{RMIN} \le I_R \le$ 1 mA, excluding die temperature change effect	-0.4	0.5	1.2	
		1mA ≤ I_R ≤ 15mA, T_A = 25°C, excluding die temperature change effect	-0.5	2.2	4.4	
		1mA ≤ I_R ≤ 15mA, excluding die temperature change effect	-0.8	4.6	9	
Reverse Dynamic Impedance	Z_R	I_R = 1mA, f = 120Hz, I_{AC} = 0.1 I_R		0.3		Ω
Wideband Noise	e_N	10 Hz ≤ f ≤ 10 kHz		38		μV_{rms}
Reverse Breakdown Voltage Long Term Stability	ΔV_R	t = 1000hrs		110		ppm
Thermal Hysteresis	V_{HYST}	Full temperature cycle, from 25°C to -40°C, then rise to 125°C and finally back to 25°C		0.25		mV

Electrical Characteristics 2.048V

I_R = 150 μA, T_A=−40°C to 125°C, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Reverse Breakdown Voltage	V_R	T_A = 25°C	2.046	2.048	2.050	V
Reverse Breakdown Voltage Tolerance			-10.25		10.25	mV
Minimum Operating Current	I_{RMIN}	T_A = 25°C		78	88	μA
				104	115	
Average Reverse Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta T$	I_R = 15 mA		±9	±45	ppm/°C
		I_R = 1 mA		±5	±41	
				±5	±38	
Reverse Breakdown Voltage Changes with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \le I_R \le$ 1 mA, T_A = 25°C, excluding die temperature change effect	-0.3	0.2	0.8	mV
		$I_{RMIN} \le I_R \le$ 1 mA, excluding die temperature change effect	-0.7	0.45	1	
		1mA ≤ I_R ≤ 15mA, T_A = 25°C, excluding die temperature change effect	-0.3	2.4	5.5	
		1mA ≤ I_R ≤ 15mA, excluding die temperature change effect	-0.5	4.5	10.5	
Reverse Dynamic Impedance	Z_R	I_R = 1mA, f = 120Hz, I_{AC} = 0.1 I_R		0.3		Ω
Wideband Noise	e_N	10 Hz ≤ f ≤ 10 kHz		33		μV_{rms}
Reverse Breakdown Voltage Long Term Stability	ΔV_R	t = 1000hrs		135		ppm
Thermal Hysteresis	V_{HYST}	Full temperature cycle, from 25°C to -40°C, then rise to 125°C and finally back to 25°C		0.2		mV

Electrical Characteristics 3.0V

I_R = 150 μA, T_A=−40°C to 125°C, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Reverse Breakdown Voltage	V_R	T_A = 25°C	2.997	3	3.003	V
Reverse Breakdown Voltage Tolerance			-15		15	mV
Minimum Operating Current	I_{RMIN}	T_A = 25°C		82	92	μA
				108	123	
Average Reverse Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta T$	I_R = 15 mA		±7	±45	ppm/°C
		I_R = 1 mA		±6	±39	
				±6	±39	
Reverse Breakdown Voltage Changes with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \le I_R \le$ 1 mA, T_A = 25°C, excluding die temperature change effect	-0.2	0.2	0.7	mV
		$I_{RMIN} \le I_R \le$ 1 mA, excluding die temperature change effect	-1	0.5	1.3	
		1mA ≤ I_R ≤ 15mA, T_A = 25°C, excluding die temperature change effect	-0.3	1.6	4.6	
		1mA ≤ I_R ≤ 15mA, excluding die temperature change effect	-1.4	4.6	10.5	
Reverse Dynamic Impedance	Z_R	I_R = 1mA, f = 120Hz, I_{AC} = 0.1 I_R		0.4		Ω
Wideband Noise	e_N	10 Hz ≤ f ≤ 10 kHz		48		μV_{rms}
Reverse Breakdown Voltage Long Term Stability	ΔV_R	t = 1000hrs		70		ppm
Thermal Hysteresis	V_{HYST}	Full temperature cycle, from 25°C to -40°C, then rise to 125°C and finally back to 25°C		0.3		mV

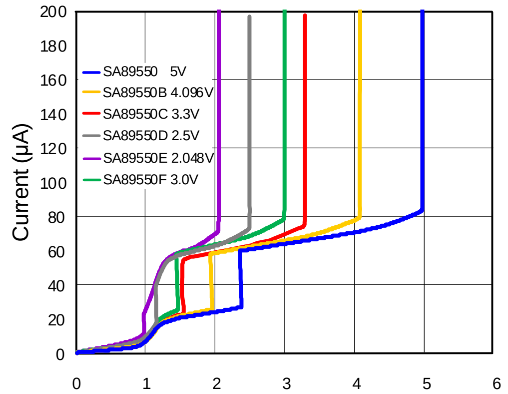
Note 1: Stresses beyond the “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2: θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective single layer thermal conductivity test board of JESD51-3.

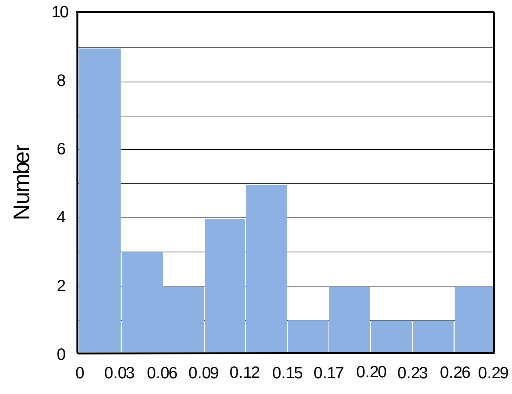
Note 3: The device is not guaranteed to function outside its operating conditions.

Typical Performance Characteristics

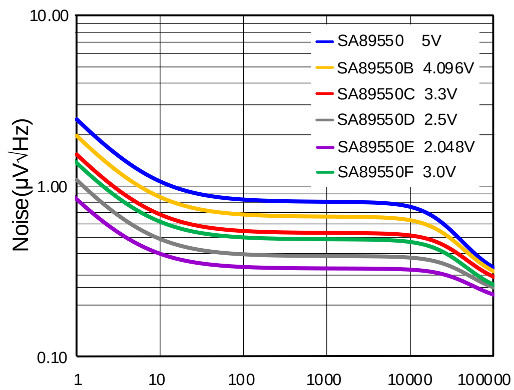
Reverse Characteristics



Thermal Hysteresis

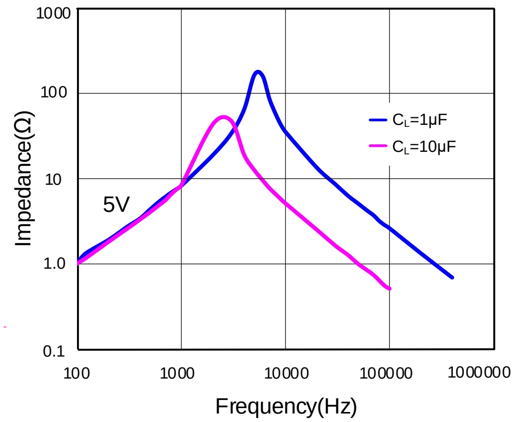


Noise Voltage vs Frequency

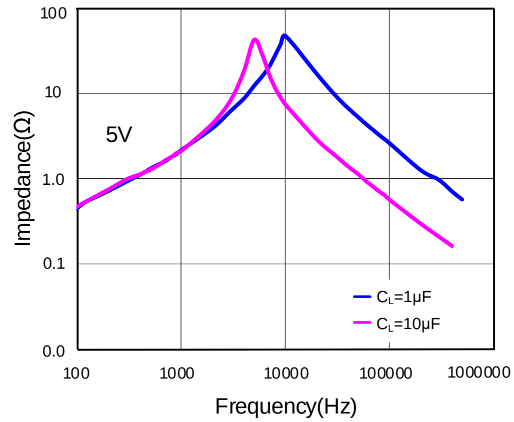


SA89550 5V

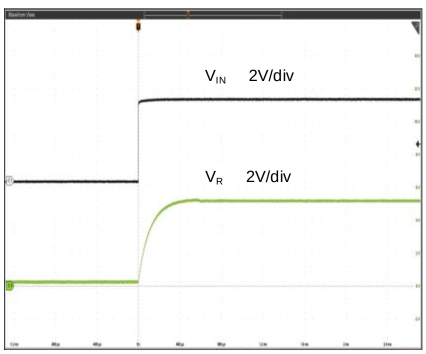
Output Impedance vs Frequency
(I_R=250μA, I_{AC}=0.1I_R)



Output Impedance vs Frequency
(I_R=1mA, I_{AC}=0.1I_R)

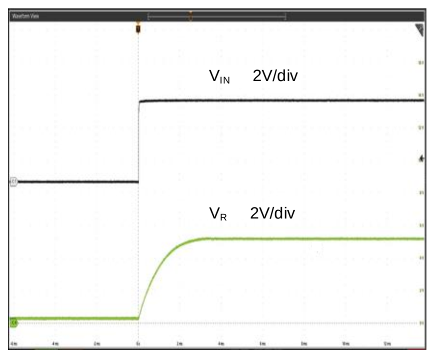


Input Voltage Step Response-5V
(C_L=1μF, I_R=1mA)



Time (400μs/div)

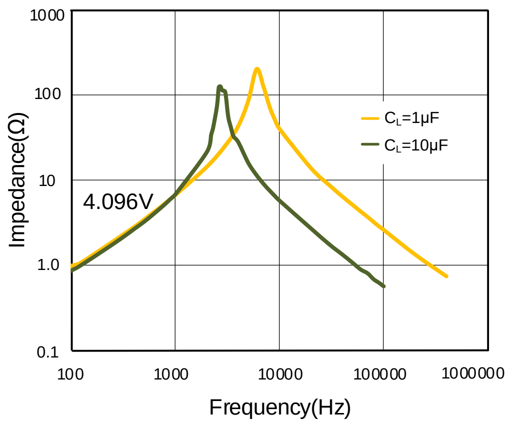
Input Voltage Step Response-5V
(C_L=10μF, I_R=1mA)



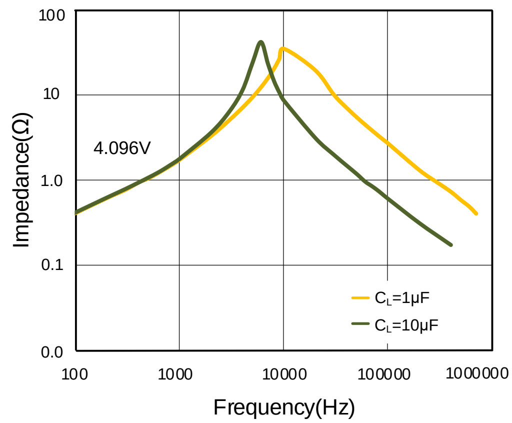
Time (2ms/div)

SA89550B 4.096V

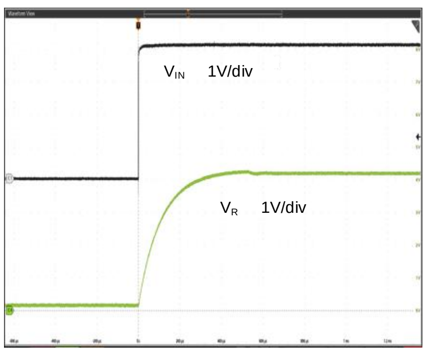
Output Impedance vs Frequency
(I_R=250μA, I_{AC}=0.1I_R)



Output Impedance vs Frequency
(I_R=1mA, I_{AC}=0.1I_R)

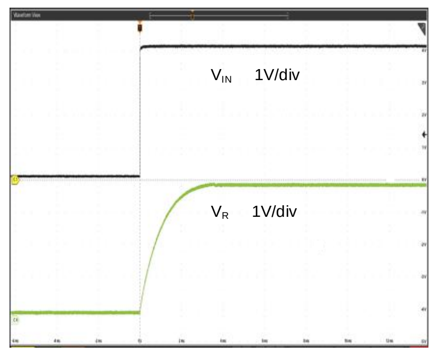


Input Voltage Step Response-4.096V
(C_L=1μF, I_R=1mA)



Time (200μs/div)

Input Voltage Step Response-4.096V
(C_L=10μF, I_R=1mA)

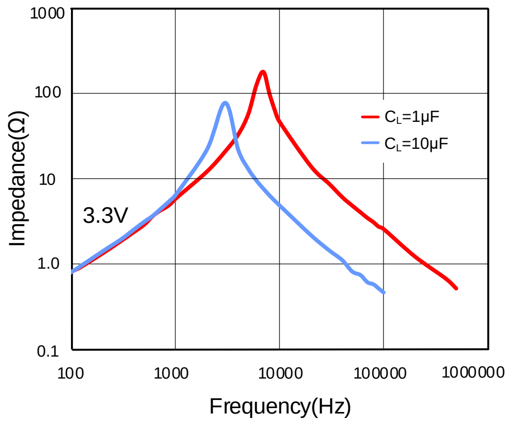


Time (2ms/div)

SA89550C 3.3V

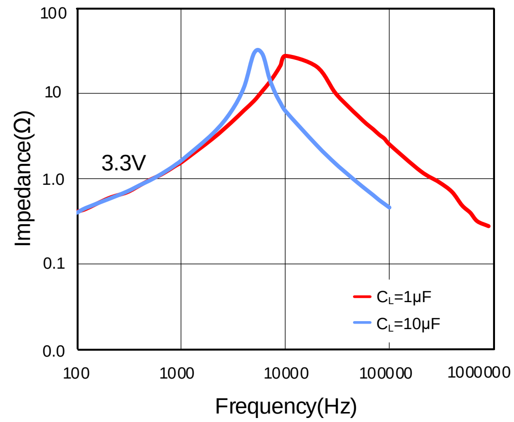
Output Impedance vs Frequency

(I_R=250μA, I_{AC}=0.1I_R)



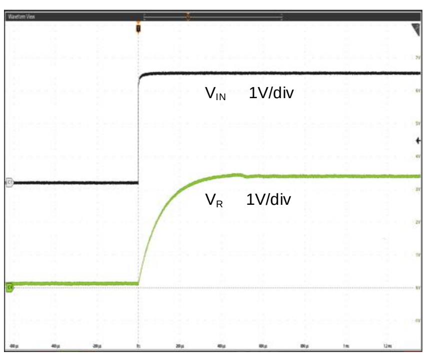
Output Impedance vs Frequency

(I_R=1mA, I_{AC}=0.1I_R)



Input Voltage Step Response-3.3V

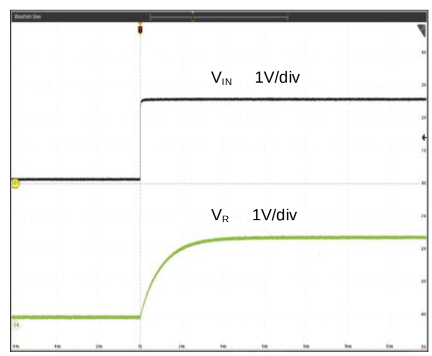
(C_L=1μF, I_R=1mA)



Time (200μs/div)

Input Voltage Step Response-3.3V

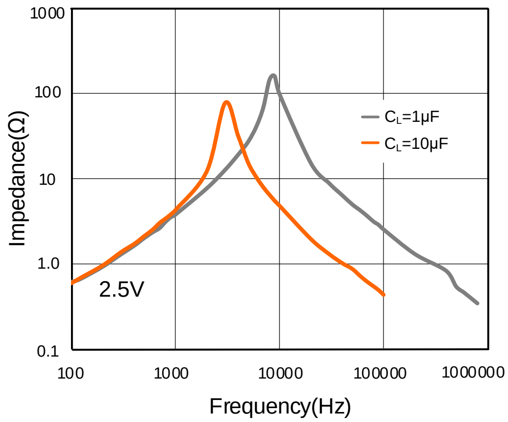
(C_L=10μF, I_R=1mA)



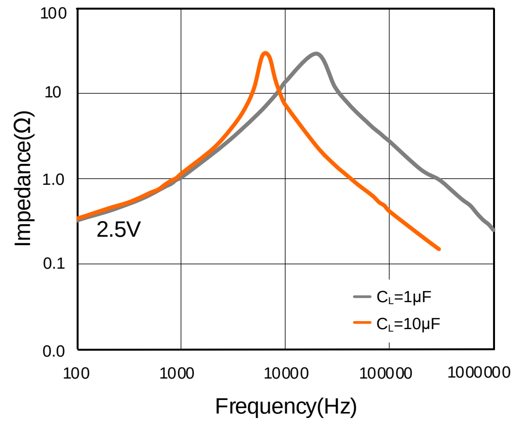
Time (2ms/div)

SA89550D 2.5V

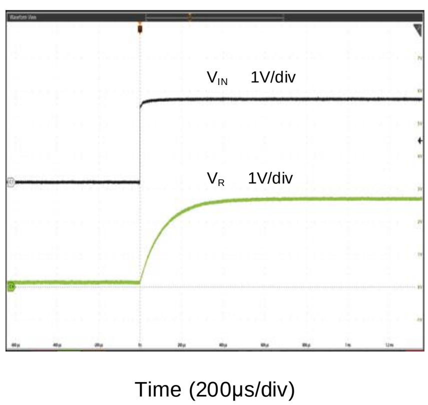
Output Impedance vs Frequency
(I_R=250μA, I_{AC}=0.1I_R)



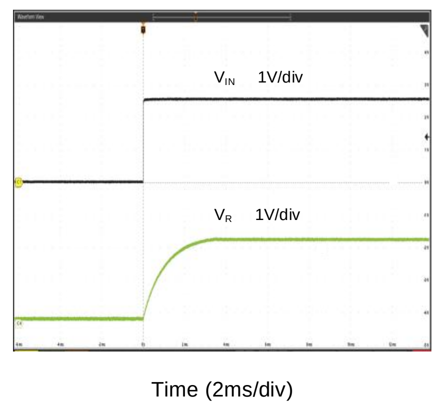
Output Impedance vs Frequency
(I_R=1mA, I_{AC}=0.1I_R)



Input Voltage Step Response-2.5V
(C_L=1μF, I_R=1mA)

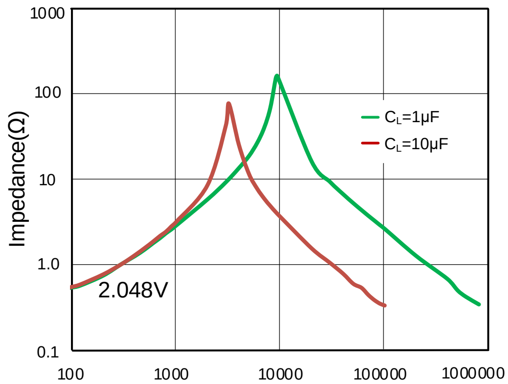


Input Voltage Step Response-2.5V
(C_L=10μF, I_R=1mA)

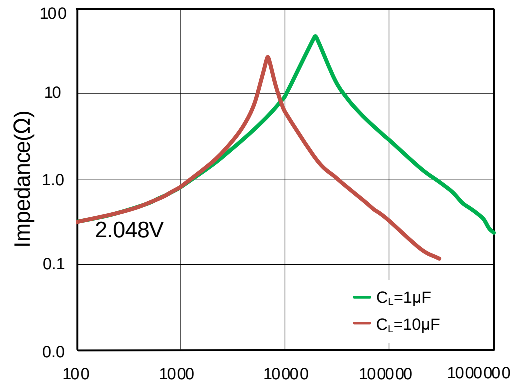


SA89550E 2.048V

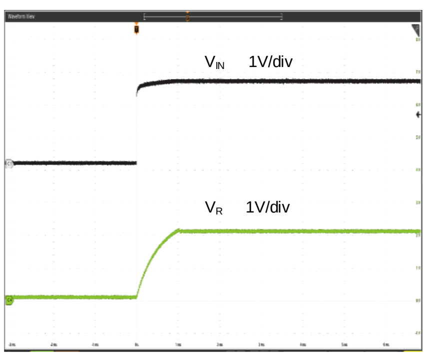
Output Impedance vs Frequency
(I_R=250μA, I_{AC}=0.1I_R)



Output Impedance vs Frequency
(I_R=1mA, I_{AC}=0.1I_R)

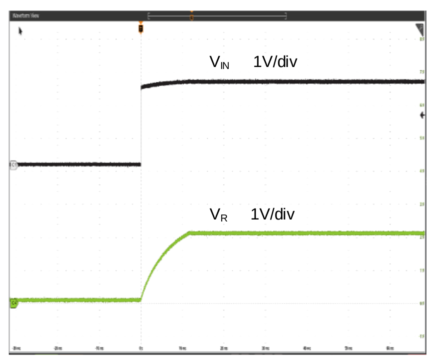


Input Voltage Step Response-2.048V
(C_L=1μF, I_R=1mA)



Time (1ms/div)

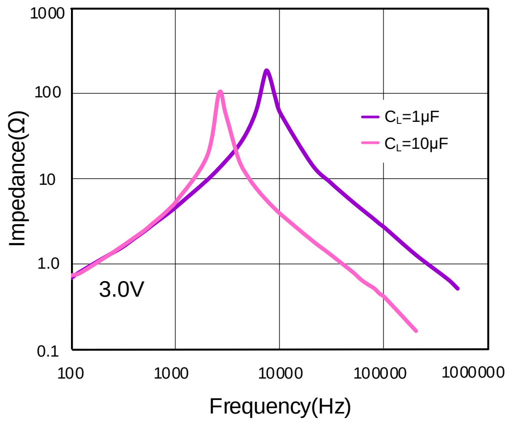
Input Voltage Step Response-2.048V
(C_L=10μF, I_R=1mA)



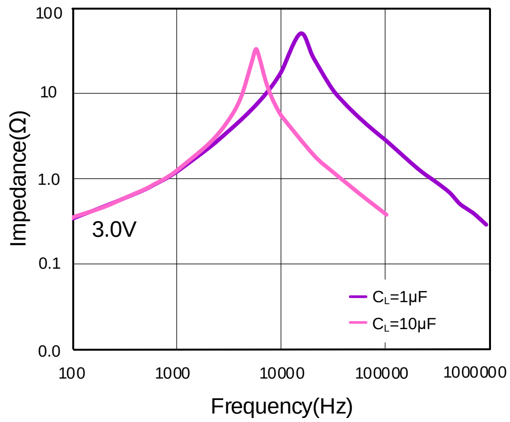
Time (10ms/div)

SA89550F 3.0V

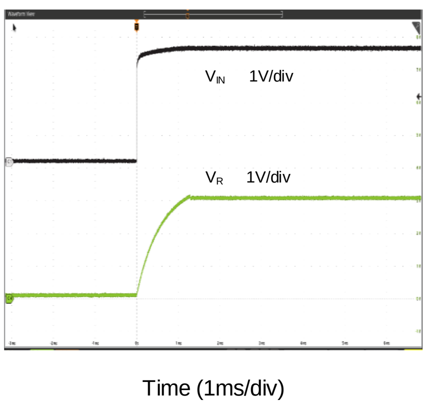
Output Impedance vs Frequency
(I_R=250µA, I_{AC}=0.1I_R)



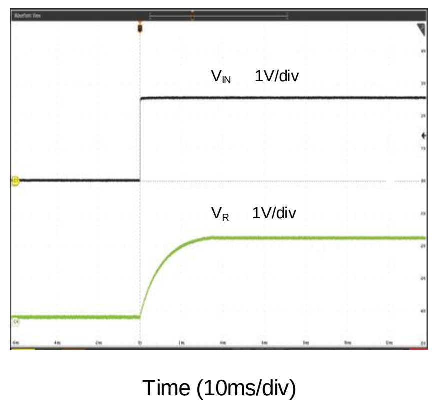
Output Impedance vs Frequency
(I_R=1mA, I_{AC}=0.1I_R)



Input Voltage Step Response-3.0V
(C_L=1µF, I_R=1mA)



Input Voltage Step Response-3.0V
(C_L=10µF, I_R=1mA)



Functional Description

The SA89550 is a high precision, micro power, low temperature drift shunt voltage reference which is available in SOT-23 package. All versions of the SA89550 is AEC-Q100 Grade 1 qualified.

The utilization of package level trim technology enables the achievement of better than ±0.1% initial accuracy at 25°C. The device does not require an output capacitor to be stable but tolerates capacitive loads.

In order to enhance the design flexibility, the devices can provide different options of fixed reverse breakdown voltages, including 2.5V, 3.3V, 4.096V, and 5V. All versions of the SA89550 provide a maximum current capability of 15mA. It is recommended to either leave the NC pin unconnected or connect it to the ANODE pin.

Minimum Operation Current

As a shunt reference, the SA89550 requires a minimum operation current that flows into CATHODE to keep the output voltage stable. The value of the minimum operation current varies with the fixed output voltage and the environment temperature. See Electrical Characteristics Table for more details.
It is recommended to provide enough margin for the operating current when selecting components and account for the input voltage changes, resistor tolerance and load current range for the target application. See Application Information Section for more details.

Output Capacitance

The SA89550 does not require an output capacitor to be stable but tolerates capacitive loads. The output capacitor improves the performance at higher frequencies. See Output Impedance versus Frequency waveform for more details.

Application Information

As Figure 4 typical application diagram shows, a series resistor (R_S) is needed to limit the total input current. The total input current is divided into two parts: the load current (I_L) and the SA89550 bias operation current (I_Q). The value of R_S is determined by the supply voltage (V_S), I_L, I_Q, and the reverse breakdown voltage of the SA89550 (V_R). The formula for calculating R_S is shown below:

$$R_S = \frac{V_S - V_R}{I_L + I_Q}$$

Since the load current and supply voltage may vary, it is important for R_S to have a low enough value to ensure that the SA89550 will receive at least the minimum required current (I_{RMIN}), even when operating with the lowest supply voltage and highest load current. The formula for calculating maximum R_S is shown below:

$$R_{SMAX} < \frac{V_{SMIN} - V_{RMAX}}{I_{LMAX} + I_{QMAX}}$$

Conversely, when the supply voltage is at its maximum value and the load current is at its minimum, the R_S should have a large enough value to limit the current flowing through the SA89550 to a value below its maximum operating current of 15mA. The formula for calculating minimum R_S is as follows:

$$R_{SMIN} > \frac{V_{SMAX} - V_{RMIN}}{I_{LMIN} + I_{QMIN}}$$

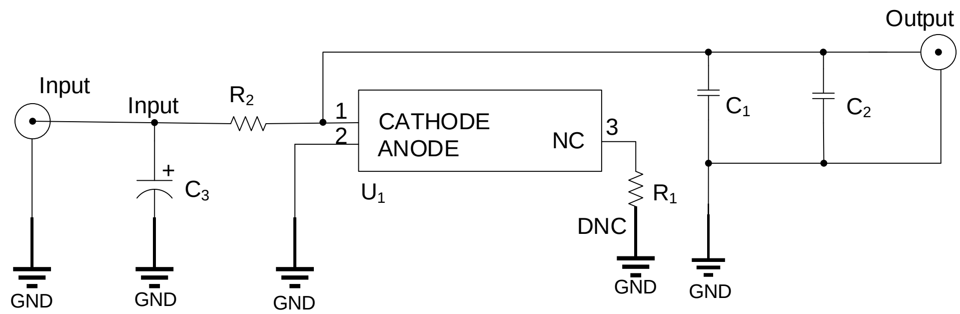
It is recommended to leave enough margin for I_Q when calculating R_S. For example, choose I_{QMAX} as 10mA and I_{QMIN} as 3mA. In this case, the SA89550 will operate correctly with the bias currents in the range of 3mA to 10mA, independent of how the supply voltage V_S and load current I_L change.

Ensure the power dissipation of resistor is below its nominal value. The formula for calculating the power dissipation of the resistor RS is shown below:

$$P_S = (V_S - V_R) * (I_L + I_Q)$$

Once the nominal value of resistor R_S is determined, it is recommended to check the accuracy and temperature drift coefficient of the resistor, which influence the actual value of resistor.

Application Schematic



BOM List

Designator	Description	Part Number	Manufacturer
U_1	Shunt voltage reference	SA89550	Silergy
C_1	0805, 10uF/25V		
C_2	DNC		
C_3	0805, 1uF/25V		
Input, Output	SMB Straight Connector		
R_1	DNC		
R_2	0603, 510Ω		

Layout Design

Noise on the power supply input to the R_S has a discernible impact on the output noise performance. To mitigate this effect, using a 0.1µF or higher ceramic bypass capacitor can improve the noise performance.

Place R_S as close to the CATHODE as possible. If input and output capacitors are used, the capacitors should be placed as close to the SA89550 as possible, as shown in figure 4.

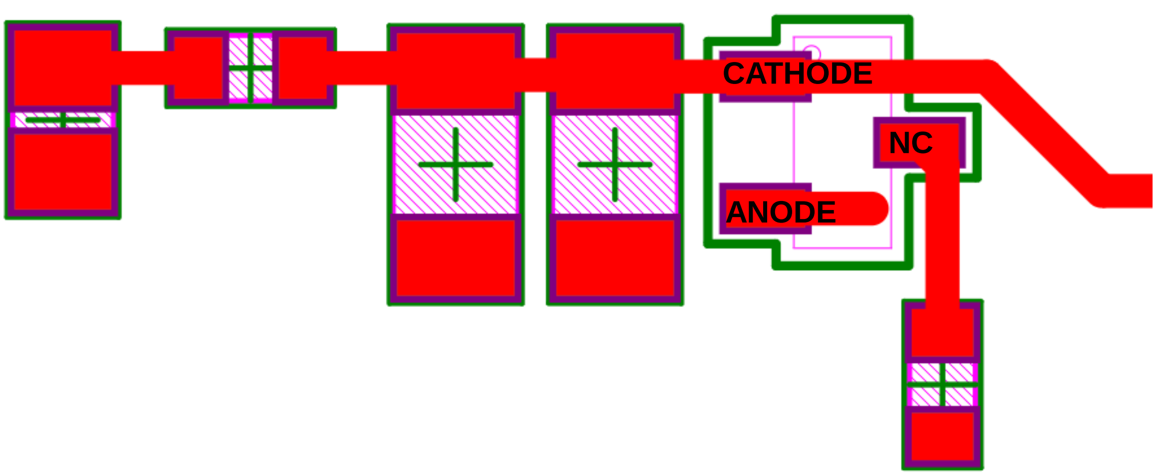
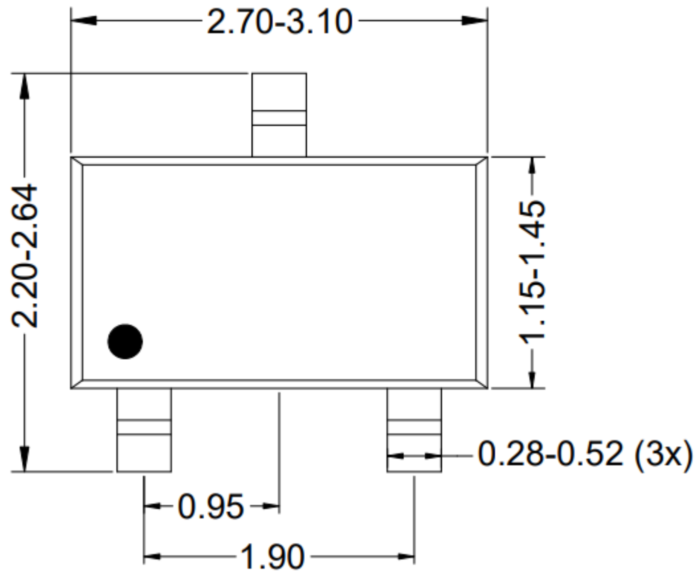
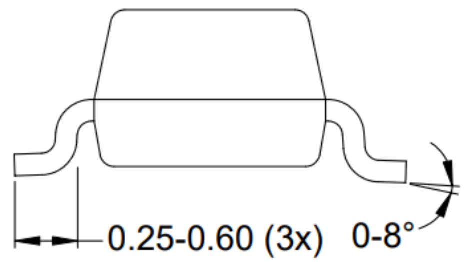


Figure 5. Layout Recommendation

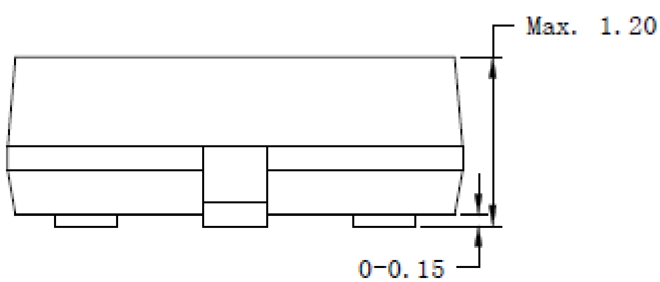
SOT-23 Package Outline Drawing



Top view



Side view A



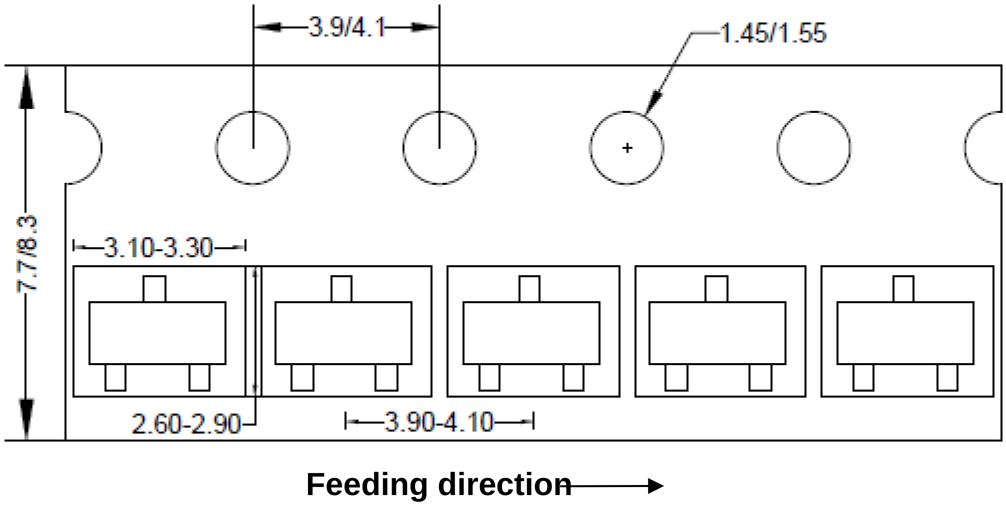
Side view B

Notes: **All dimension in millimeter and exclude mold flash & metal burr.**

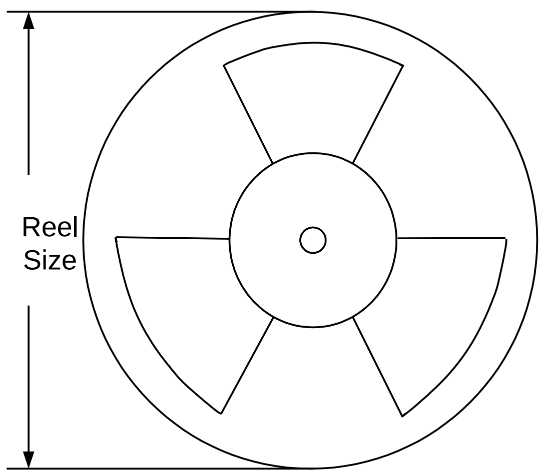
Taping & Reel Specification

1. Taping Orientation

SOT-23



2. Carrier Tape & Reel Specification for Packages



Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer length(mm)	Leader length (mm)	Qty per reel
SOT-23	8	4	7"	400	400	3000

3. Others: NA

Revision History

The revision history provided is for informational purposes only and is believed to be accurate; however, it is not warrantied. Please make sure that you have the latest revision.

Date	Revision	Change
Aug. 3, 2023	Revision 1.0	Initial Release

IMPORTANT NOTICE

1. **Right to make changes.** Silergy and its subsidiaries (hereafter Silergy) reserve the right to change any information published in this document, including but not limited to circuitry, specification and/or product design, manufacturing or descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products are sold subject to Silergy's standard terms and conditions of sale.

2. **Applications.** Application examples that are described herein for any of these products are for illustrative purposes only. Silergy makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification. Buyers are responsible for the design and operation of their applications and products using Silergy products. Silergy or its subsidiaries assume no liability for any application assistance or designs of customer products. It is customer's sole responsibility to determine whether the Silergy product is suitable and fit for the customer's applications and products planned. To minimize the risks associated with customer's products and applications, customer should provide adequate design and operating safeguards. Customer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Silergy assumes no liability related to any default, damage, costs or problem in the customer's applications or products, or the application or use by customer's third-party buyers. Customer will fully indemnify Silergy, its subsidiaries, and their representatives against any damages arising out of the use of any Silergy components in safety-critical applications. It is also buyers' sole responsibility to warrant and guarantee that any intellectual property rights of a third party are not infringed upon when integrating Silergy products into any application. Silergy assumes no responsibility for any said applications or for any use of any circuitry other than circuitry entirely embodied in a Silergy product.

3. **Limited warranty and liability.** Information furnished by Silergy in this document is believed to be accurate and reliable. However, Silergy makes no representation or warranty, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. In no event shall Silergy be liable for any indirect, incidental, punitive, special or consequential damages, including but not limited to lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges, whether or not such damages are based on tort or negligence, warranty, breach of contract or any other legal theory. Notwithstanding any damages that customer might incur for any reason whatsoever, Silergy' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Standard Terms and Conditions of Sale of Silergy.

4. **Suitability for use.** Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of Silergy components in its applications, notwithstanding any applications-related information or support that may be provided by Silergy. Silergy products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of a Silergy product can reasonably be expected to result in personal injury, death or severe property or environmental damage. Silergy assumes no liability for inclusion and/or use of Silergy products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

5. **Terms and conditions of commercial sale**. Silergy products are sold subject to the standard terms and conditions of commercial sale, as published at https:// www.silergy.com, unless otherwise agreed in a valid written individual agreement specifically agreed to in writing by an authorized officer of Silergy. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. Silergy hereby expressly objects to and denies the application of any customer's general terms and conditions with regard to the purchase of Silergy products by the customer.

6. **No offer to sell or license**. Nothing in this document may be interpreted or construed as an offer to sell products that is open for acceptance or the grant, conveyance or implication of any license under any copyrights, patents or other industrial or intellectual property rights. Silergy makes no representation or warranty that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right. Information published by Silergy regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from Silergy under the patents or other intellectual property of Silergy.

For more information, please visit: www.silergy.com