

# Micro-Power, Zero-Drift, Rail-to-Rail Out Instrumentation Amplifier

## 1 FEATURES

- **Fixed Gains: 1,2,4,5,10,20,50,100**
- **Low Offset Voltage:  $4+50/G \mu\text{V}$  (TYP)**
- **High CMRR: 110dB (TYP)**
- **Low Input Bias Current: 100pA (TYP)**
- **Supply Range: 2.3 V to 5.5 V**
- **Input Voltage: (V-) +0.1 V to (V+) - 0.1 V**
- **Low Quiescent Current: 165 $\mu\text{A}$**
- **Operating Temperature: -40°C to +125°C**
- **Micro SIZE PACKAGES: MSOP8**

## 2 APPLICATIONS

- **Bridge Amplifiers**
- **ECG Amplifiers**
- **Pressure Sensors**
- **Medical Instrumentation**
- **Portable Instrumentation**
- **Weigh Scales**
- **Thermocouple Amplifiers**
- **RTD Sensor Amplifiers**
- **Data Acquisition**

## 3 DESCRIPTIONS

The RS633 device is a low-power, precision instrumentation amplifier offering excellent accuracy. The versatile 3-operational amplifier design, small size, and low power make it ideal for a wide range of portable applications.

Provides multiple fixed gain configurations.

The RS633 device provides very low offset voltage ( $4+50/G \mu\text{V}$ ), and high common-mode rejection (110 dB). It operates with power supplies as low as 2.3V ( $\pm 1.15\text{V}$ ) and quiescent current is only 165 $\mu\text{A}$ , making it ideal for battery operated systems. Using autocalibration techniques to ensure excellent precision over the extended industrial temperature range.

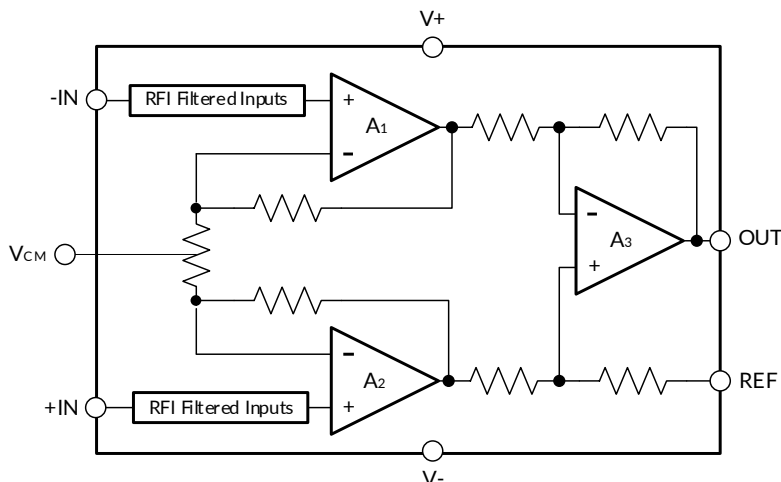
The RS633 device is available in the MSOP8 package. It operates over an ambient temperature range of -40°C to +125°C.

**Device Information<sup>(1)</sup>**

PART NUMBER	PACKAGE	BODY SIZE (NOM)
RS633	MSOP8	3.00mm×3.00mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

## Simplified Schematic



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## 4 Revision History

Note: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Version</b>	<b>Change Date</b>	<b>Change Item</b>
A.0	2023/05/26	Preliminary version completed
A.1	2024/02/02	Initial version completed
A.1.1	2024/02/29	Modify packaging naming

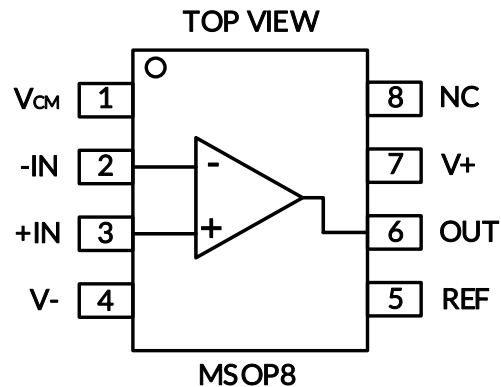
**5 PACKAGE/ORDERING INFORMATION (1)**

PRODUCT	ORDERING NUMBER	Gain	TEMPERATURE RANGE	PACKAGE LEAD	PACKAGE MARKING (2)	MSL (3)	PACKAGE OPTION
RS633	RS633AHXM	1	-40°C ~125°C	MSOP8	RS633A	MSL1	Tape and Reel,4000
	RS633BHXM	2	-40°C ~125°C	MSOP8	RS633B	MSL1	Tape and Reel,4000
	RS633CHXM	4	-40°C ~125°C	MSOP8	RS633C	MSL1	Tape and Reel,4000
	RS633DHXM	5	-40°C ~125°C	MSOP8	RS633D	MSL1	Tape and Reel,4000
	RS633EHXM	10	-40°C ~125°C	MSOP8	RS633E	MSL1	Tape and Reel,4000
	RS633FHXM	20	-40°C ~125°C	MSOP8	RS633F	MSL1	Tape and Reel,4000
	RS633GHXM	50	-40°C ~125°C	MSOP8	RS633G	MSL1	Tape and Reel,4000
	RS633HHXM	100	-40°C ~125°C	MSOP8	RS633H	MSL1	Tape and Reel,4000

**NOTE:**

- (1) This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the right-hand navigation.
- (2) There may be additional marking, which relates to the lot trace code information (data code and vendor code), the logo or the environmental category on the device.
- (3) MSL, The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications.

## 6 Pin Configuration and Functions (Top View)



### Pin Description

NAME	PIN		I/O <sup>(1)</sup>	DESCRIPTION
	RS633			
	MSOP8			
V <sub>CM</sub>	1	-	Input common voltage	
-IN	2	I	Inverting input	
+IN	3	I	Noninverting input	
V-	4	-	Negative (lowest) power supply	
REF	5	I	Reference input. This pin must be driven by low impedance or connected to ground.	
OUT	6	O	Output	
V+	7	-	Positive (highest) power supply	
NC <sup>(2)</sup>	8	-	No internal connection (can be left floating)	

(1) I = Input, O = Output.

(2) There is no internal connection. Typically, GND is the recommended connection to a heat spreading plane.

## 7 SPECIFICATIONS

### 7.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

		MIN	MAX	UNIT
Voltage	Supply Voltage		7	V
	Analog input voltage <sup>(2)</sup>	(V-)-0.3	(V+)+0.3	
Current	Output short-circuit <sup>(3)</sup>	Continuous		
$\theta_{JA}$	Package thermal impedance <sup>(4)</sup>	MSOP8	170	°C/W
Temperature	Operating range, $T_A$	-40	150	°C
	Junction, $T_J$ <sup>(5)</sup>	-40	150	
	Storage, $T_{stg}$	-65	150	

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

(2) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.3V beyond the supply rails should be current-limited to 10mA or less.

(3) Short-circuit to ground, one amplifier per package.

(4) The package thermal impedance is calculated in accordance with JESD-51.

(5) The maximum power dissipation is a function of  $T_{J(MAX)}$ ,  $R_{\theta JA}$ , and  $T_A$ . The maximum allowable power dissipation at any ambient temperature is  $P_D = (T_{J(MAX)} - T_A) / R_{\theta JA}$ . All numbers apply for packages soldered directly onto a PCB.

### 7.2 ESD Ratings

The following ESD information is provided for handling of ESD-sensitive devices in an ESD protected area only.

		VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM)	±4000
		Charged-device model (CDM)	±1000
		Machine Model (MM)	±200



#### ESD SENSITIVITY CAUTION

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 7.3 Recommended Operating Conditions

Over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
Supply voltage	Single-supply	2.3		5.5	V
	Dual-supply	±1.15		±2.75	
Specified temperature		-40		125	°C

## 7.4 ELECTRICAL CHARACTERISTICS

(For  $V_S = 2.3\text{ V}$  to  $5.5\text{ V}$  at  $T_A = 25^\circ\text{C}$ ,  $V_{REF} = V_S/2$ ,  $R_L = 10\text{ k}\Omega$ , and  $G = 10$ , FULL <sup>(11)</sup> =  $-40^\circ\text{C} \sim +125^\circ\text{C}$ , unless otherwise noted.) <sup>(1)</sup>

SYMBOL	PARAMETER	CONDITIONS	TEMP	MIN <sup>(2)</sup>	TYP <sup>(3)</sup>	MAX <sup>(2)</sup>	UNIT
<b>INPUT<sup>(4)</sup></b>							
$V_{OSI}$	Offset Voltage, RTI <sup>(5)</sup>		25°C		4+50/G	15+150/G	μV
$V_{OSI\ TC}$	RTI vs Temperature		FULL		±1.5		μV/°C
PSR	RTI vs Power Supply	$2.3\text{ V} \leq V_S \leq 5.5\text{ V}$	25°C		1+5/G	5+25/G	μV/V
$V_{CM}$	Common-Mode Voltage Range	$V_O = V_S/2$	25°C	(V-)+0.1		(V+)-0.1	V
CMR	Common-Mode Rejection	$V_{CM} = (V-)+0.1\text{V to } (V+)-0.1\text{V}$	25°C	95	110		dB
<b>INPUT BIAS CURRENT</b>							
$I_B$	Input Bias Current <sup>(6)(7)</sup>		25°C		±100		pA
$I_{OS}$	Input Offset Current <sup>(6)</sup>		25°C		±50		pA
<b>INPUT VOLTAGE NOISE</b>							
$e_{NI}$	Input Voltage Noise	$G = 100, R_S = 0\Omega, f = 0.1\text{Hz to } 10\text{Hz}$	25°C		3		μV <sub>PP</sub>
		$G = 10, R_S = 0\Omega, f = 0.1\text{ Hz to } 10\text{ Hz}$	25°C		4		μV <sub>PP</sub>
<b>GAIN</b>							
G	Gain	RS633A	25°C		1		V/V
		RS633B			2		
		RS633C			4		
		RS633D			5		
		RS633E			10		
		RS633F			20		
		RS633G			50		
		RS633H			100		
	Gain Error	$V_S = 5.5\text{ V}, (V-)+100\text{ mV} \leq V_O \leq (V+)-100\text{ mV}$	25°C		±0.15	1	%
	Gain vs Temperature		FULL		±15		ppm/°C
	Gain Nonlinearity	$V_S = 5.5\text{ V}, (V-)+100\text{ mV} \leq V_O \leq (V+)-100\text{ mV}, R_L = 10\text{ k}\Omega$	25°C		35		ppm
<b>OUTPUT</b>							
	Output Voltage Swing from Rail	$V_S = 5.5\text{ V}, R_L = 10\text{ k}\Omega$	25°C		10	25	mV
	Capacitive Load Drive		25°C		100		pF
$I_{SC}$	Short-Circuit Current <sup>(8)(9)</sup>	Source	25°C	18	25		mA
		Sink	25°C	13	20		mA
<b>FREQUENCY RESPONSE</b>							
$f_{-3dB}$	Bandwidth, -3dB	G=1	25°C		150		kHz
		G=10	25°C		35		kHz
		G=100	25°C		3.5		kHz
SR	Slew Rate <sup>(10)</sup>	$V_S = 5\text{ V}, V_O = 4\text{ V step}, G = 1$	25°C		0.24		V/μs
		$V_S = 5\text{ V}, V_O = 4\text{ V step}, G = 10$	25°C		0.21		V/μs
		$V_S = 5\text{ V}, V_O = 4\text{ V step}, G = 100$	25°C		0.02		V/μs
$t_s$	Settling Time to 0.01%	$V_{STEP} = 4\text{ V}, G = 1$	25°C		30		μs
		$V_{STEP} = 4\text{ V}, G = 10$	25°C		50		μs

		$V_{STEP} = 4\text{ V}, G = 100$	25°C		300		μs
	Overload Recovery	50% overdrive	25°C		50		μs
<b>REFERENCE INPUT</b>							
	$R_{IN}$		25°C		300		kΩ
	Voltage Range		25°C	V-		V+	V
<b>POWER SUPPLY</b>							
$V_S$	Voltage Range	Single voltage range	25°C	2.3		5.5	V
		Dual voltage range	25°C	±1.15		±2.75	V
$I_Q$	Quiescent Current	$V_{IN} = V_S / 2$	25°C		165	240	μA
			FULL			280	μA
<b>TEMPERATURE RANGE</b>							
	Specified Temperature Range			-40		125	°C
	Operating Temperature Range			-40		150	°C

**NOTE:**

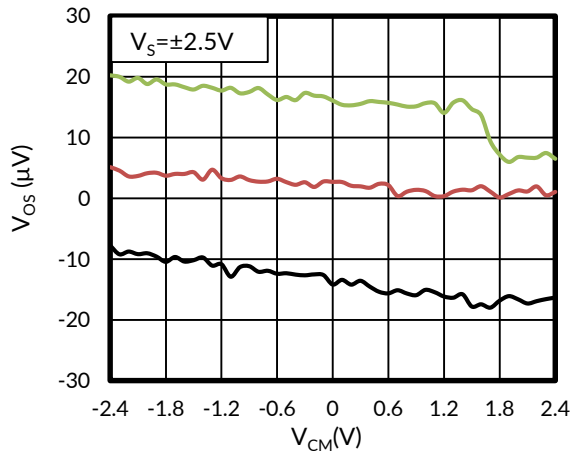
- (1) Electrical table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device.
- (2) Limits are 100% production tested at 25°C. Limits over the operating temperature range are ensured through correlations using statistical quality control (SQC) method.
- (3) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.
- (4) Total  $V_{OS}$ , referred-to-input =  $(V_{OSI}) + (V_{OSO} / G)$ .
- (5) RTI = Referred-to-input.
- (6) This parameter is ensured by design and/or characterization and is not tested in production.
- (7) Positive current corresponds to current flowing into the device.
- (8) The maximum power dissipation is a function of  $T_{J(MAX)}$ ,  $R_{\theta JA}$ , and  $T_A$ . The maximum allowable power dissipation at any ambient temperature is  $P_D = (T_{J(MAX)} - T_A) / R_{\theta JA}$ . All numbers apply for packages soldered directly onto a PCB.
- (9) Short circuit test is a momentary test.
- (10) Number specified is the slower of positive and negative slew rates.
- (11) Specified by characterization only.



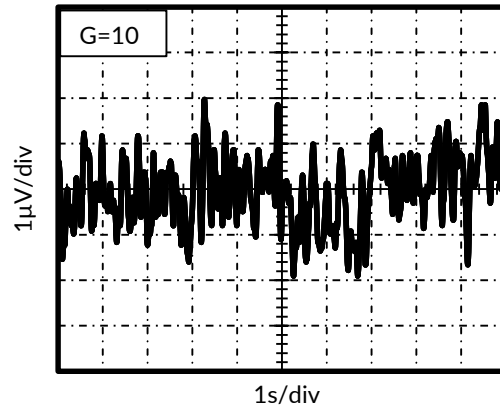
## 7.5 TYPICAL CHARACTERISTICS

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

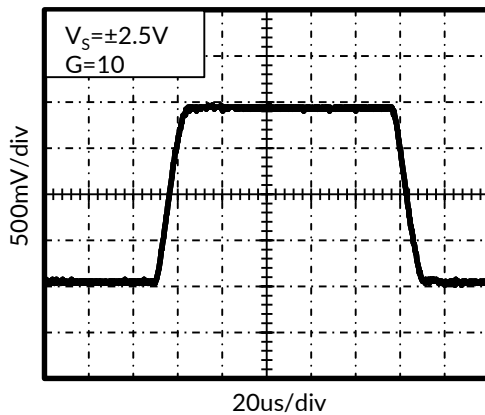
At  $T_A = +25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $R_L = 10\text{k}\Omega$ ,  $V_{REF} = V_S/2$ , and  $G = 10$ , unless otherwise noted.



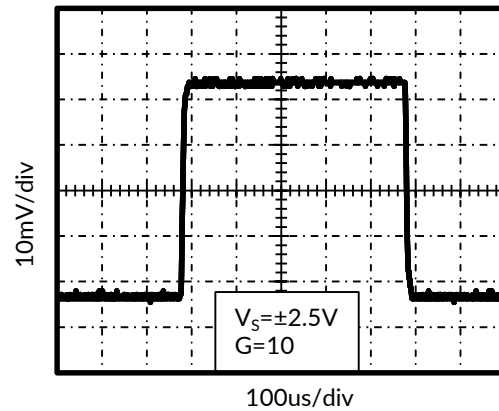
**Figure 1. Offset Voltage vs Common-Mode Voltage**



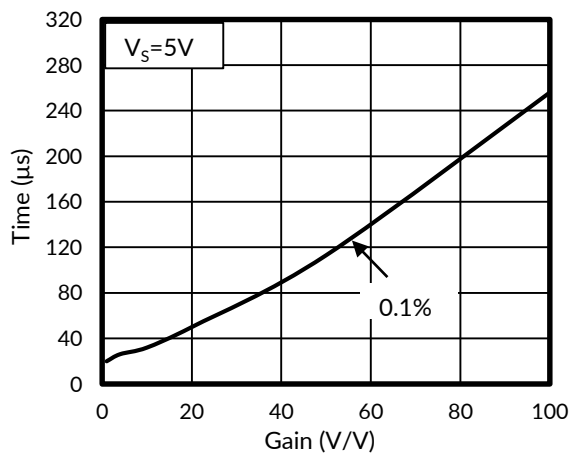
**Figure 2. 0.1Hz to 10Hz Input Voltage Noise**



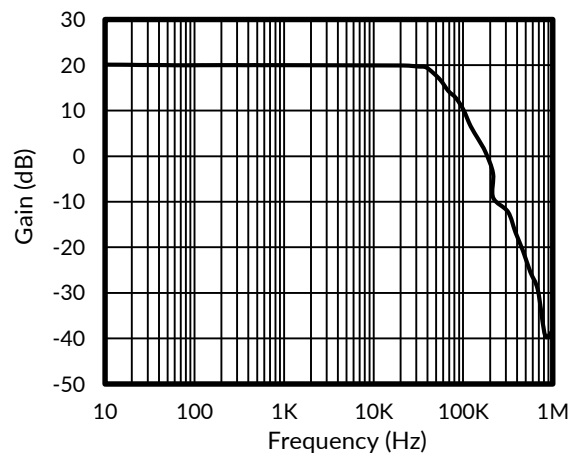
**Figure 3. Large-Signal Step Response**



**Figure 4. Small-Signal Step Response**



**Figure 5. Settling Time vs Gain**

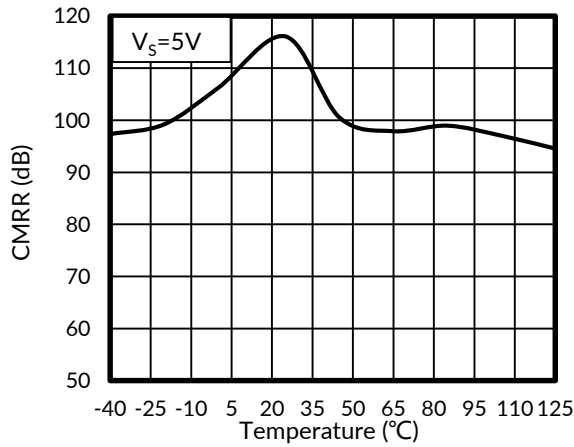


**Figure 6. Gain vs Frequency**

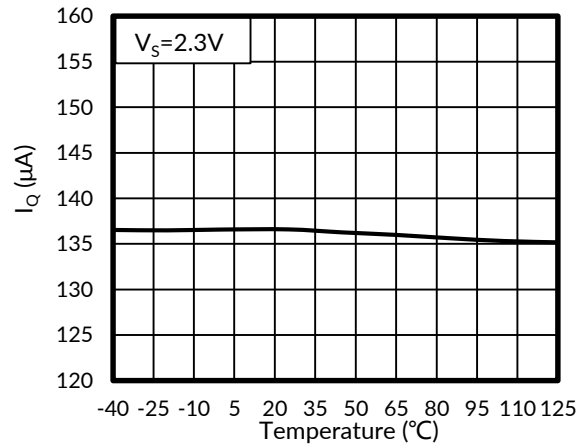
## TYPICAL CHARACTERISTICS

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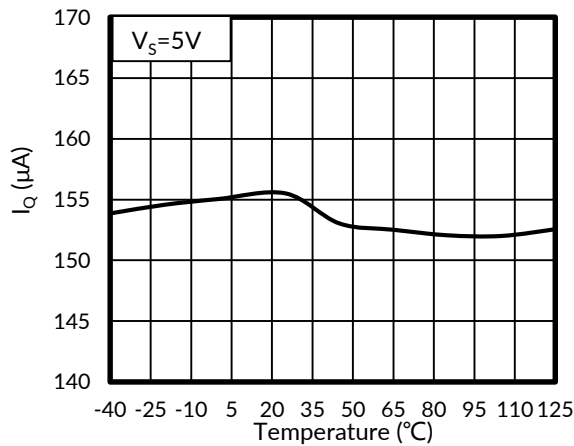
At  $T_A = +25^\circ\text{C}$ ,  $V_S=5\text{V}$ ,  $R_L = 10\text{k}\Omega$ ,  $V_{\text{REF}}= V_S/2$ , and  $G=10$ , unless otherwise noted.



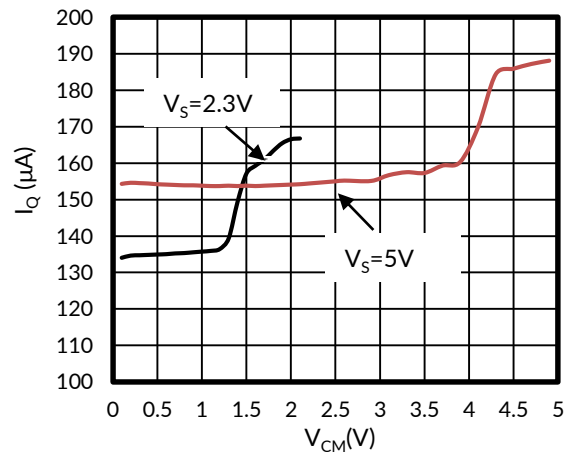
**Figure 7. Common-Mode Rejection Ratio vs Temperature**



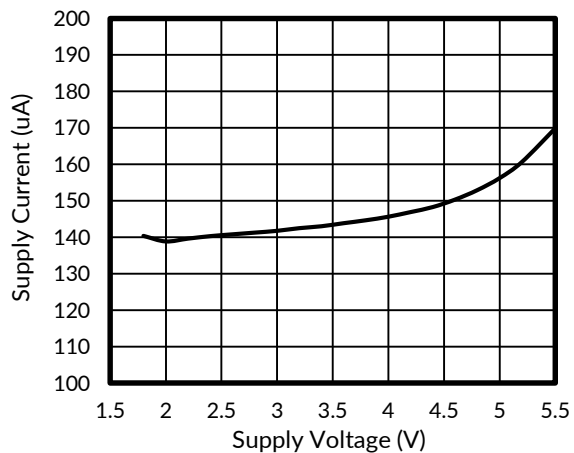
**Figure 8. Quiescent current vs Temperature**



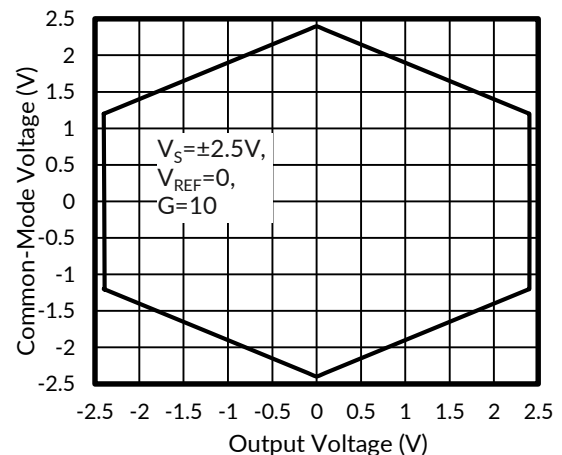
**Figure 9. Quiescent current vs Temperature**



**Figure 10. Quiescent current vs Common-Mode Voltage**



**Figure 11. Supply Current vs Supply Voltage**



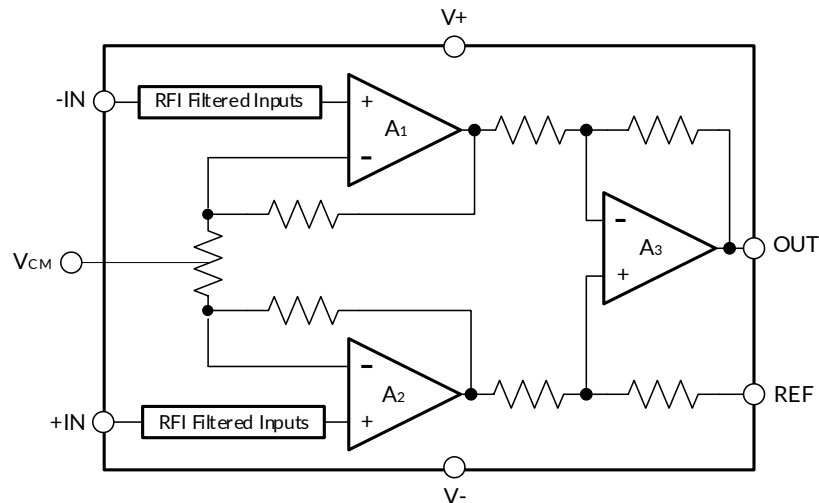
**Figure 12. Typical Common-Mode Range vs Output Voltage**

## 8 Detailed Description

### 8.1 Overview

The RS633 is a monolithic instrumentation amplifier (INA) based on the precision zero-drift operational amplifier core. The RS633 also integrates trimmed resistors to ensure excellent common-mode rejection and low gain error. The combination of the zero-drift amplifier core and the precision resistors allows this device to achieve outstanding DC precision and makes the RS633 ideal for many 3.3V and 5V industrial applications.

### 8.2 Functional Block Diagram



### 8.3 Feature Description

The RS633 is a low-power, zero-drift instrumentation amplifier offering excellent accuracy. The versatile three operational-amplifier design and small size make the amplifiers ideal for a wide range of applications. Zero-drift chopper circuitry provides excellent DC specifications. The RS633 offers a variety of fixed gains between 1 and 100. The RS633 is trimmed for very high common-mode rejection (110dB at  $G = 10$ ). This device operates with power supplies as low as 2.3V, and quiescent current of 165uA, typically.

## 9 Application and Implementation

Information in the following applications sections is not part of the RUNIC component specification, and RUNIC does not warrant its accuracy or completeness. RUNIC's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

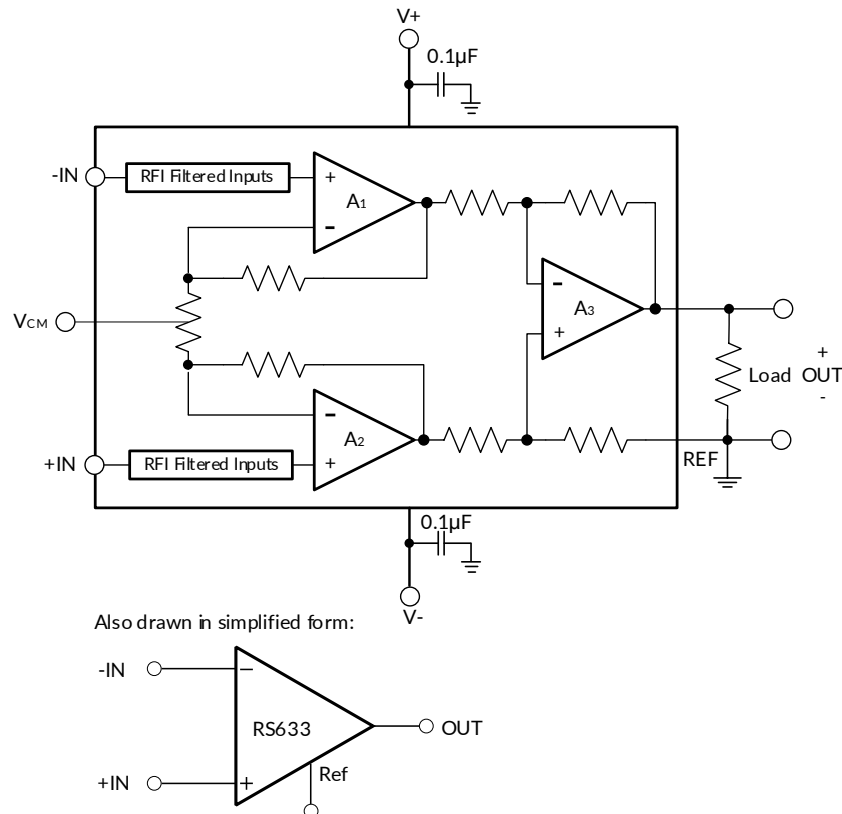
### 9.1 Application Information

The RS633 measures small differential voltage with high common-mode voltage developed between the noninverting and inverting input. The high input impedance makes the RS633 suitable for a wide range of applications. The ability to set the reference pin to adjust the functionality of the output signal offers additional flexibility that is practical for multiple configurations.

### 9.2 Typical Application

Figure 13 shows the basic connections required for operation of the RS633 device. Good layout practice mandates the use of bypass capacitors placed close to the device pins as shown.

The output of the RS633 device is referred to the output reference (REF) pin, which is normally grounded. This connection must be low-impedance to assure good common-mode rejection. Although 15Ω or less of stray resistance can be tolerated while maintaining specified CMRR, small stray resistances of tens of Ωs in series with the REF pin can cause noticeable degradation in CMRR.

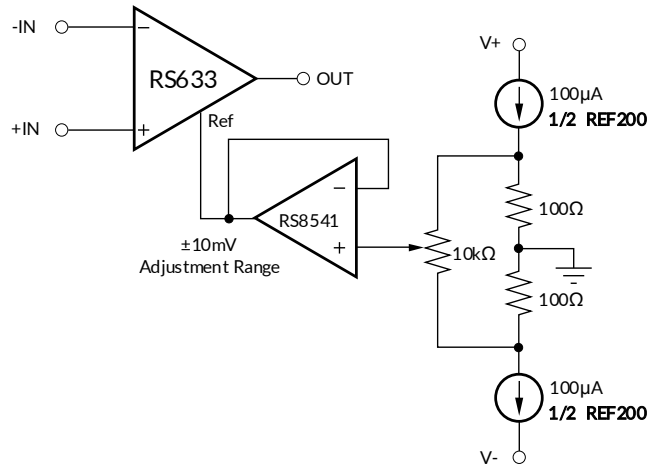


**Figure 13. Basic Connections**

## 9.3 Detailed Design Procedure

### 9.3.1 Offset Trimming

Most applications require no external offset adjustment; however, if necessary, adjustments can be made by applying a voltage to the REF pin. Figure 14 shows an optional circuit for trimming the output offset voltage. The voltage applied to REF pin is summed at the output. The operational amplifier buffer provides low impedance at the REF pin to preserve good common-mode rejection.



**Figure 14. Optional Trimming of Output Offset Voltage**

### 9.3.2 Noise Performance

Low frequency noise of the RS633 device is approximately  $4\mu\text{V}_{\text{PP}}$  measured from 0.1 Hz to 10 Hz, ( $G = 10$ ).

### 9.3.3 Internal Offset Correction

RS633 internal operational amplifiers use an auto-calibration technique with a time-continuous 350kHz operational amplifier in the signal path. The amplifier is zero-corrected ever  $10\mu\text{s}$  using a proprietary technique. Upon power up, the amplifier requires approximately  $100\mu\text{s}$  to achieve specified  $V_{\text{OS}}$  accuracy. This design has no aliasing or flicker noise.

### 9.3.4 Input Common-Mode Range

The linear input voltage range of the input circuitry of the RS633 is from approximately 0.1V below the positive supply voltage to 0.1V above the negative supply. As a differential input voltage causes the output voltage to increase, however, the linear input range is limited by the output voltage swing of amplifiers  $A_1$  and  $A_2$ . Thus, the linear common-mode input range is related to the output voltage of the complete amplifier. This behavior also depends on supply voltage.

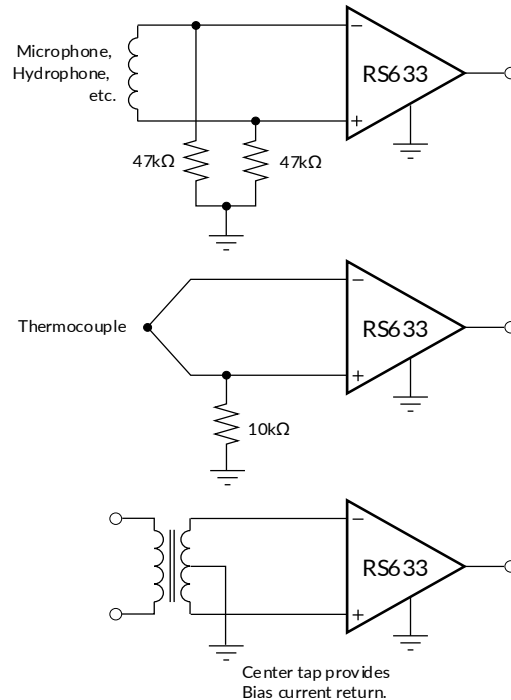
Input overload conditions can produce an output voltage that appears normal. For example, if an input overload condition drives both input amplifiers to the respective positive output swing limit, the difference voltage measured by the output amplifier is near zero. The output of the RS633 is near 0V even though both inputs are overloaded.

### 9.3.5 Input Bias Current Return Path

The input impedance of the RS633 device is extremely high—approximately  $100\text{G}\Omega$ . However, a path must be provided for the input bias current of both inputs. This input bias current is typically  $\pm 100\text{pA}$ . High input impedance means that this input bias current changes very little with varying input voltage.

Input circuitry must provide a path for this input bias current for proper operation. Figure 15 shows various provisions for an input bias current path. Without a bias current path, the inputs float to a potential that exceeds the common-mode range of the RS633 device, and the input amplifiers will saturate. If the differential source resistance is low, the bias current return path can be connected to one input (see the thermocouple example in Figure 15). With higher source impedance, using two equal resistors provides a balanced input with possible

advantages of lower input offset voltage as a result of bias current and better high-frequency common-mode rejection.



**Figure 15. Providing an Input Common-Mode Current Path**

### 9.3.6 Operating Voltage

The RS633 operates over a power-supply range of 2.3V to 5.5V ( $\pm 1.15V$  to  $\pm 2.75V$ ). Supply voltages higher than 7V (absolute maximum) can permanently damage the device.

### 9.3.7 Low Voltage Operation

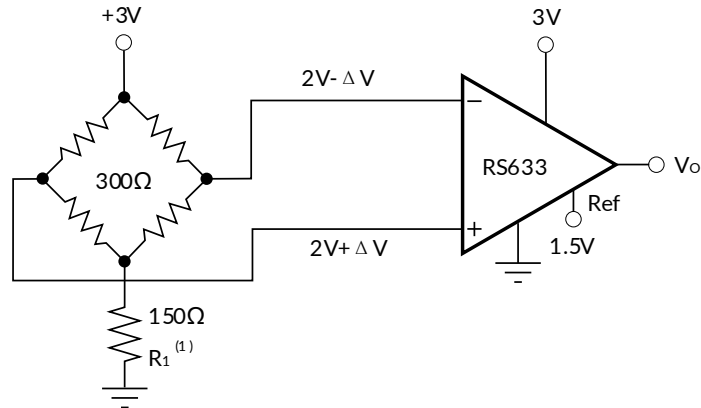
The RS633 device can be operated on power supplies as low as  $\pm 1.15V$ . Most parameters vary only slightly throughout this supply voltage range. Operation at very low supply voltage requires careful attention to assure that the input voltages remain within the linear range. Voltage swing requirements of internal nodes limit the input common-mode range with low power-supply voltage.

### 9.3.8 Single-Supply Operation

The RS633 device can be used on single power supplies of 2.3V to 5.5V. Figure 16 shows a basic single supply circuit. The output REF pin is connected to mid-supply. Zero differential input voltage demands an output voltage of mid-supply. Actual output voltage swing is limited to approximately 50mV more than ground, when the load is referred to ground as shown.

With single-supply operation, -IN and +IN must both be 0.1V more than ground for linear operation. For instance, the inverting input cannot be connected to ground to measure a voltage connected to the noninverting input.

To show the issues affecting low voltage operation, consider the circuit in Figure 16. It shows the RS633 device operating from a single 3V supply. A resistor in series with the low side of the bridge assures that the bridge output voltage is within the common-mode range of the amplifier inputs.



(1) R1 creates proper common-mode voltage, only for low-voltage operation—see Single-Supply Operation.

**Figure 16. Single-Supply Bridge Amplifier**

### 9.3.9 Input Protection

The input pins of the RS633 device are protected with internal diodes connected to the power-supply rails. These diodes clamp the applied signal to prevent it from damaging the input circuitry. If the input signal voltage can exceed the power supplies by more than 0.3V, the input signal current should be limited to less than 10mA to protect the internal clamp diodes. This current limiting can generally be done with a series input resistor. Some signal sources are inherently current-limited and do not require limiting resistors.

## 10 Power Supply Recommendations

The minimum power supply voltage for RS633 is 2.3V and the maximum power supply voltage is 5.5V. For optimum performance, 3.3V to 5V is recommended. Recommends adding a bypass capacitor at the input to compensate for the layout and power supply source impedance.

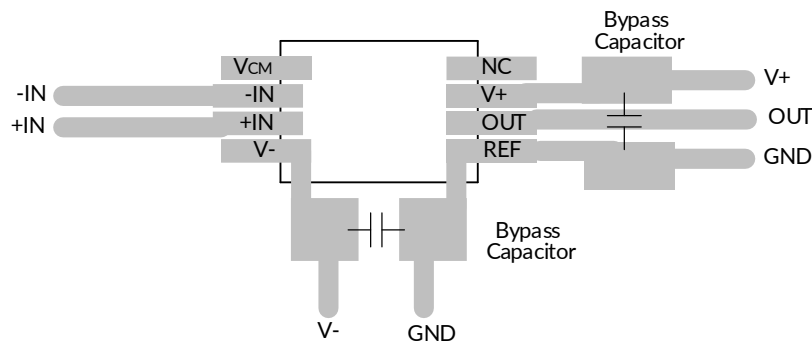
## 11 Layout

### 11.1 Layout Guidelines

Attention to good layout practices is always recommended. Keep traces short and, when possible, use a printed-circuit-board (PCB) ground plane with surface-mount components placed as close to the device pins as possible. Place a 0.1 $\mu$ F bypass capacitor closely across the supply pins. These guidelines should be applied throughout the analog circuit to improve performance and provide benefits such as reducing the electromagnetic interference (EMI) susceptibility.

Instrumentation amplifiers vary in the susceptibility to radio-frequency interference (RFI). RFI can generally be identified as a variation in offset voltage or DC signal levels with changes in the interfering RF signal. The RS633 device has been specifically designed to minimize susceptibility to RFI by incorporating passive RC filters with an 8MHz corner frequency at the -IN and +IN inputs. As a result, the RS633 device demonstrates remarkably low sensitivity compared to previous generation devices. Strong RF fields may continue to cause varying offset levels, however, and may require additional shielding.

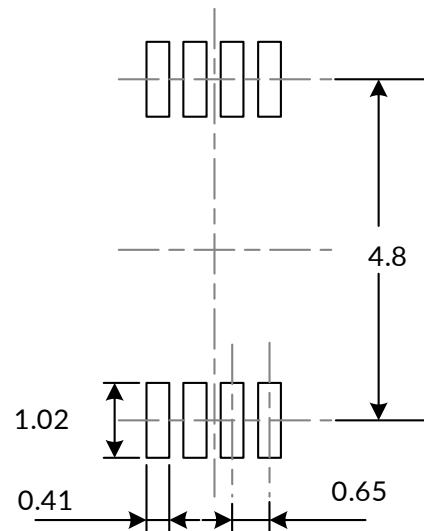
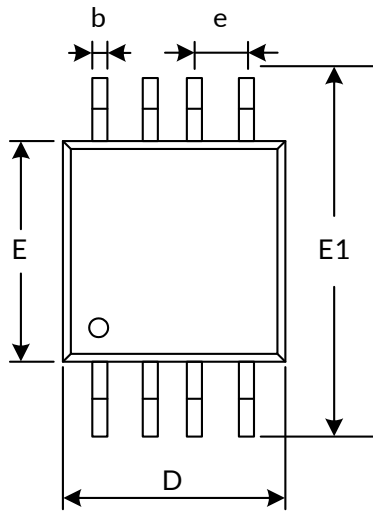
### 11.2 Layout Example



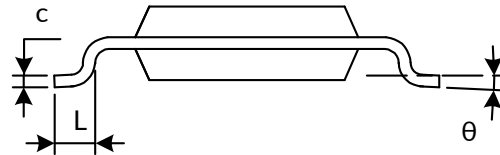
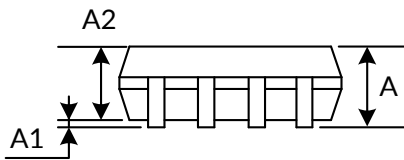
**Figure 17. RS633 Layout**



## 12 PACKAGE OUTLINE DIMENSIONS MSOP8<sup>(3)</sup>



RECOMMENDED LAND PATTERN (Unit: mm)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A <sup>(1)</sup>	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D <sup>(1)</sup>	2.900	3.100	0.114	0.122
e	0.650(BSC) <sup>(2)</sup>		0.026(BSC) <sup>(2)</sup>	
E <sup>(1)</sup>	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
$\theta$	0°	6°	0°	6°

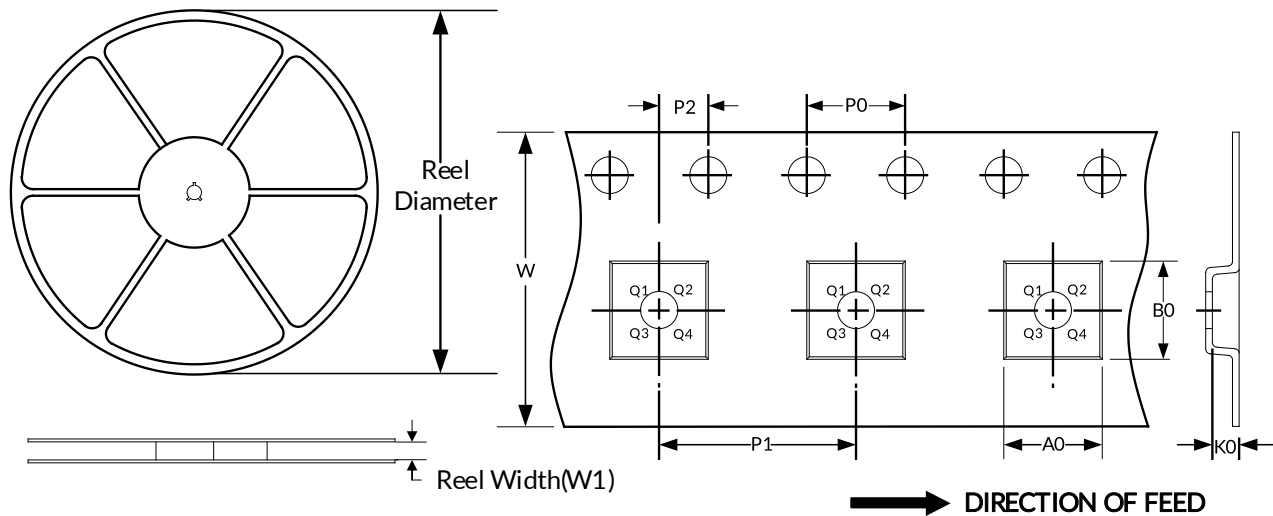
NOTE:

1. Plastic or metal protrusions of 0.15mm maximum per side are not included.
2. BSC (Basic Spacing between Centers), "Basic" spacing is nominal.
3. This drawing is subject to change without notice.

### 13 TAPE AND REEL INFORMATION

#### REEL DIMENSIONS

#### TAPE DIMENSION



NOTE: The picture is only for reference. Please make the object as the standard.

#### KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width(mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
MSOP8	13"	12.4	5.20	3.30	1.50	4.0	8.0	2.0	12.0	Q1

NOTE:

1. All dimensions are nominal.
2. Plastic or metal protrusions of 0.15mm maximum per side are not included.

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