8 nV/ √ Hz Noise, RRO, Precision Instrumentation Amplifier

Features

- Gain set with one external resistor (Gain range 1 to 10,000)
- High CMRR: 105 dB min (G = 1, Grade B)
  95 dB min (G = 1, -40 °C to +125 °C, Grade B)
- Low Input Offset Voltage: 25 μV max (Grade B)
- Low Input Offset Drift: 0.3 μV/°C
- Low Input Bias Current: 5 pA
- Low Noise: 8 nV/$\sqrt{\text{Hz}}$
- 2 μV$_{P-P}$ input noise (0.1 Hz to 10 Hz, G = 1)
- Bandwidth: 625 kHz (G = 10)
- Supply Current: 3.3 mA
- Supply Voltage: ±2.4 V to ±18 V
- Specified Temperature Range: -40 °C to +125 °C

Applications

- Precision data acquisition
- Instrumentation
- Sensor signal conditioning
- Industrial control
- Communication systems
- Smart grid

ZJA3600 Product Family

Part Number	Gain Setting	
	G =1 + 49.4 kΩ/R$_G$	**G =1 + 50 kΩ/ R$_G$**
Classic Pinout	ZJA3600	ZJA3618
	ZJA3610 (G ≥ 10)	ZJA3608 (G ≥ 10)
Optimized Pinout	**ZJA3601**	**ZJA3619**
	ZJA3611 (G ≥ 10)	ZJA3609 (G ≥ 10)

General Description

The ZJA3601/ZJA3619 is a precision, low-noise instrumentation amplifier that can be used to set the gain range from 1 to 10,000 with a single external resistor.

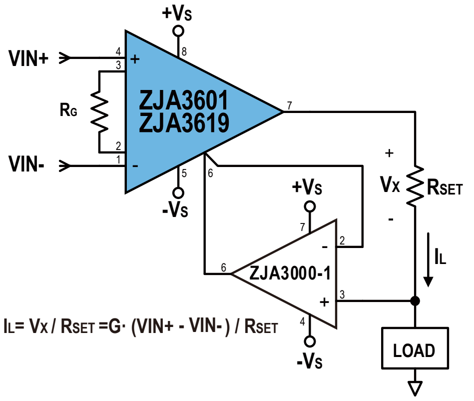
The ZJA3601/ZJA3619 is based on classic three-op-amp structure to provide high common-mode rejection ratio (CMRR) over 120 dB at a gain of 10. This allows it to accurately amplify useful signals in the presence of large external interference, which is a common situation in precision data acquisition, bridge sensor interface, thermocouples, and medical signal acquisition (such as ECG, EEG, etc.). The ZJA3601/ZJA3619 also guarantees a CMRR of over 95 dB (G = 1, Grade B) over a temperature range of -40 °C to +125 °C, providing a solid foundation for applications requiring guaranteed performance over a wide temperature range. This is an outstanding feature of the ZJA3601/ZJA3619.

The ZJA3601/ZJA3619 has both excellent DC and AC performances. Its input offset voltage is better than 25 μV (Grade B), its drift is typically 0.3 μV/°C, and its input bias current is around 5 pA. This simplifies system calibration costs. The noise is 8 nV/$\sqrt{\text{Hz}}$ at 1 kHz, and the 0.1 Hz to 10 Hz noise is 2 μV$_{P-P}$ (G = 1), making it very suitable for the first stage of precision circuits. The ZJA3601/ZJA3619 is a rail-to-rail output instrumentation amplifier, which can maximize the use of the ADC input range. The bandwidth is 625 kHz at a gain of 10, the slew rate is 2 V/μs, and the 0.01% settling time is 6.5 μs. This makes it suitable for precision multi-channel switching data acquisition systems.

The ZJA3601/ZJA3619 uses an optimized pinout (the gain-setting resistor is connected to pins 2 and 3), which can extend the frequency range of the CMRR, thus improving system performance.

The ZJA3601/ZJA3619 perform is specified over a wide temperature range of -40 °C to +125 °C. Its supply voltage is from ±2.4 V to ±18 V. The ZJA3601/ZJA3619 is available in 8-lead SOIC and MSOP packages.

Application Examples



Typical Performance Characteristics

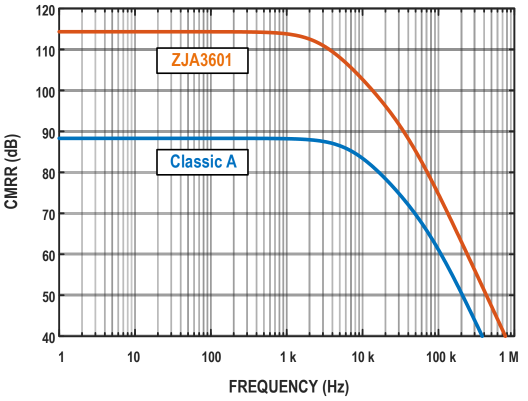


Table of contents

Version (Release B)[1]

Revision History

May 2024 - Release B

Added ZJA3619

Changes to "Specifications"

September 2023 - Release A

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Pin Configurations and Function Descriptions

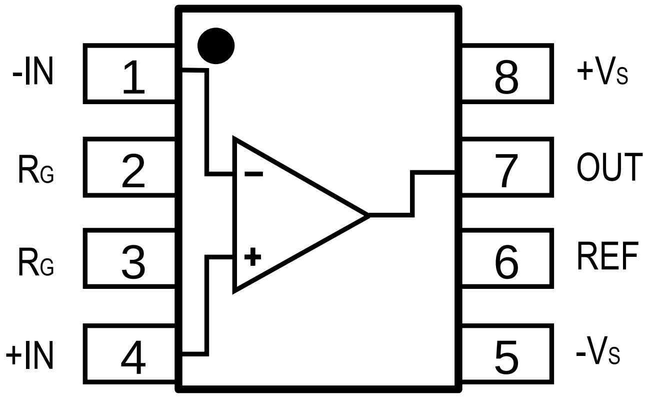

Figure 1. ZJA3601/ZJA3619 Pin Configuration (8-lead SOIC and MSOP)

Mnemonic	Pin No.	I/O[1]	Description
-IN	1	AI	Inverting input
R_G	2	AI	Gain setting pin. Place a gain resistor between pin 2 and pin 3
R_G	3	AI	Gain setting pin. Place a gain resistor between pin 2 and pin 3
+IN	4	AI	Non-inverting input
$-V_S$	5	P	Negative power supply
REF	6	AI	Reference input. This pin must be driven by a low impedance source
OUT	7	AO	Output
$+V_S$	8	P	Positive power supply

---

[1] AI: Analog Input; P: Power; AO: Analog Output.

Absolute Maximum Ratings [1]

Parameter	Rating
Supply Voltage	±20 V
Input Voltage	±Vs
Input Current [2]	±10 mA
Differential Input Voltage (G = 1 to10)	$(+V_S) - (-V_S)$
Output Short-Circuit Duration to GND [3]	Continuous
Operating Temperature Range	-40 °C to 125 °C
Storage Temperature Range	-65 °C to 150 °C
Maximum Reflow Temperature [4]	150 °C
Lead Temperature, Soldering (10 sec)	260 °C
Electrostatic Discharge (ESD) [5]	
Human Body Model (HBM) [6]	3 kV
Charged Device Model (CDM) [7]	2 kV

Thermal Resistance [8]

Package Type	θ_{JA}	θ_{JC}	Unit
SOIC-8	158	43	°C/W
MSOP-8	190	44	°C/W

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[1] These ratings apply at 25 °C, unless otherwise noted. Note that stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

[2] There are clamping diodes between the input pins and the power pins, and also between each other. When the input signal exceeds the supply rail by 0.3 V, the input current is limited to 10 mA.

[3] Limited by Over Temperature Protection (OTP).

[4] IPC/JEDEC J-STD-020 Compliant

[5] Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

[6] ANSI/ESDA/JEDEC JS-001 Compliant

[7] ANSI/ESDA/JEDEC JS-002 Complaint

[8] θ_{JA} addresses the conditions for soldering devices onto circuit boards to achieve surface mount packaging.

Specifications

The ● denotes the specification which apply over the specified temperature range, otherwise specifications are at V_S = ±15 V, V_{REF} = 0 V, G = 1, R_L= 2 kΩ, T_A = 25 °C.

Parameter	Symbol	Conditions		Min	Typ	Max	Unit
GAIN		ZJA3601: G = 1 + (49.4 kΩ/R_G) ZJA3619: G =1 + (50 kΩ/ R_G)					
Range Of Gain				1		10,000	V/V
Gain Error	GE	V_{OUT} = ±10 V					
G = 1		B Grade			0.0001	0.001	%
			●			0.003	%
		A Grade				0.01	%
G = 10		B Grade			0.01	0.10	%
			●			0.25	%
		A Grade				0.15	%
G = 100		B Grade			0.01	0.10	%
			●			0.25	%
		A Grade				0.15	%
G = 1,000		B Grade			0.01	0.10	%
			●			0.25	%
		A Grade				0.15	%
Gain Nonlinearity		V_{OUT} = -10 V to +10 V					
G = 1 to 10		R_L = 10 kΩ			0.5	5	ppm
G = 100		R_L = 10 kΩ				10	ppm
G = 1000		R_L = 10 kΩ				20	ppm
G = 1 to 100		R_L = 2 kΩ				20	ppm
Gain vs temperature							
G = 1		B Grade	●		0.1	0.5	ppm/°C
		A Grade	●		0.3	1	ppm/°C
G > 1[1]			●	-50	10	50	ppm/°C
OFFSET VOLTAGE							
Input Offset Voltage	V_{OSI}	B Grade			5	25	µV
			●			85	µV
		A Grade				50	µV
			●			110	µV
Average TC	TCV_{OSI}		●			0.6	µV/°C

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[1] The values specified for G > 1 do not include the effects of the external gain-setting resistor, R_G.

Parameter	Symbol	Conditions		Min	Typ	Max	Unit
Output Offset Voltage	V_{OSO}	B Grade			30	150	µV
			●			200	µV
		A Grade				300	µV
			●			500	µV
Average TC	TCV_{OSO}	B Grade	●			2.0	µV/°C
		A Grade	●			5.0	µV/°C
POWER SUPPLY REJECTION RATIO	PSRR	Vs = ±2.4 V to ±18 V					
G = 1		B Grade		110	130		dB
		A Grade		100	120		dB
G = 10		B Grade		130	140		dB
		A Grade		120	130		dB
G = 100		B Grade		130	140		dB
		A Grade		120	130		dB
G = 1,000		B Grade		140	150		dB
		A Grade		130	140		dB
INPUT BIAS CURRENT							
Input Bias Current	I_B				5	25	pA
Average TC	TCI_B		●		1		pA/°C
Input Offset Current	I_{OS}				2	20	pA
Average TC	TCI_{OS}		●		1		pA/°C
INPUT CHARACTERISTICS							
Input Impedance	R_{IN}/C_{IN}	Differential Mode			100/2		GΩ/pF
		Common Mode			100/2		GΩ/pF
Input Operating Voltage Range[1]	IVR	V_S = ±2.4 V to ±15 V		$-V_S+0.2$		$+V_S-1.1$	V
Common-ode Rejection Ratio	CMRR	DC to 60 Hz, V_{CM} = -10 V to +10 V					
G = 1		B Grade		105	120		dB
			●	94			dB
		A Grade		95			dB
G = 10		B Grade		120	140		dB
		A Grade		115			dB
G = 100		B Grade		140	150		dB
		A Grade		135			dB
G=1,000		B Grade		140	150		dB
		A Grade		140			dB

---

[1] One input is connected to ground.

Parameter	Symbol	Conditions		Min	Typ	Max	Unit
OUTPUT CHARACTERISTICS							
Output Swing		Vs = ±2.4 V to ±15 V, R_L = 2 kΩ		-Vs+0.3		+Vs-0.3	V
Short-Circuit Current	I_{SC}	source			90		mA
		sink			50		mA
DYNAMIC PERFORMANCE							
Small Signal Bandwidth, -3 dB		G = 1			3200		kHz
		G = 10			625		kHz
		G = 100			70		kHz
		G = 1000			9		kHz
Slew Rate	SR			0.75	2		V/μs
Settling Time (to 0.01 %)	t_S	G = 1 to 10, 0 to 10 V step			6.5		μs
		G = 100, 0 to 10 V step			23		μs
		G = 1,000, 0 to 10 V step			213		μs
NOISE PERFORMANCE		Referred-To-Input (RTI)= $\sqrt{e_{ni}^2 + b(e_{no}/G)^2}$					
Voltage Noise		f = 1 kHz					
Input Voltage Noise	e_{ni}				8		$nV/\sqrt{Hz}$
Output Voltage Noise	e_{no}				75		$nV/\sqrt{Hz}$
RTI		f = 0.1 Hz to 10 Hz					
G = 1					2		μV_{P-P}
G = 10					0.9		μV_{P-P}
G = 100 to 1000					0.9		μV_{P-P}
Input Current Noise		f = 1 kHz			0.8		$fA/\sqrt{Hz}$
		0.1 Hz to 10 Hz			6		pA_{P-P}
REFERENCE INPUT		VIN+, VIN-, V_{REF} = 0					
R_{IN}					10		kΩ
I_{IN}					0.003	0.03	μA
Voltage Range				$-V_S+0.2$		$+V_S-1.1$	V
Reference Gain to Output					1±0.0001		V/V
POWER SUPPLY							
Operating Range				±2.4		±18	V
Quiescent Current	I_{SY}				3.3	3.8	mA
			●			3.8	mA
TEMPERATURE RANGE		Specified Temperature Range		-40		125	°C

Typical Performance Characteristics

Unless otherwise stated, $T_A = 25\ °C$, $V_S = \pm 15\ V$, $R_L = 2\ k\Omega$.

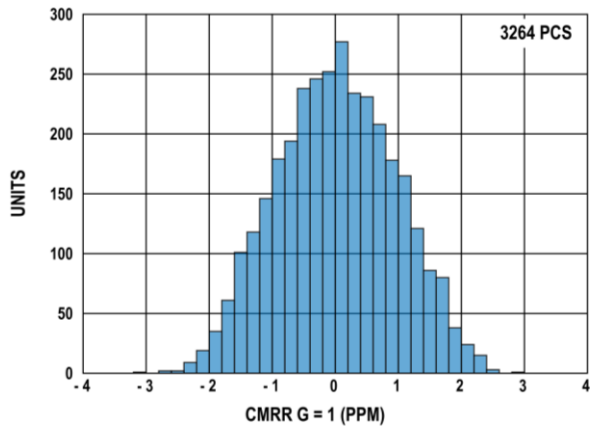

Figure 2. Typical Distribution of CMRR (G = 1)

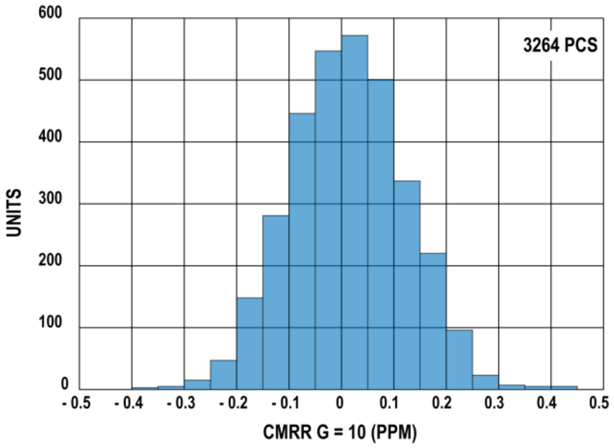

Figure 3. Typical Distribution of CMRR (G = 10)

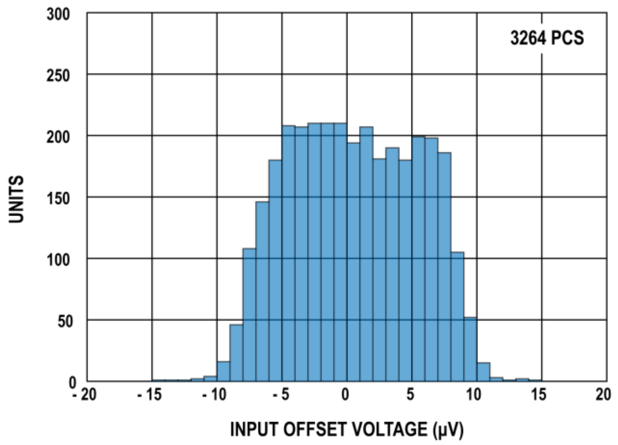

Figure 4. Typical Distribution of Input Offset Voltage V_{OSI}

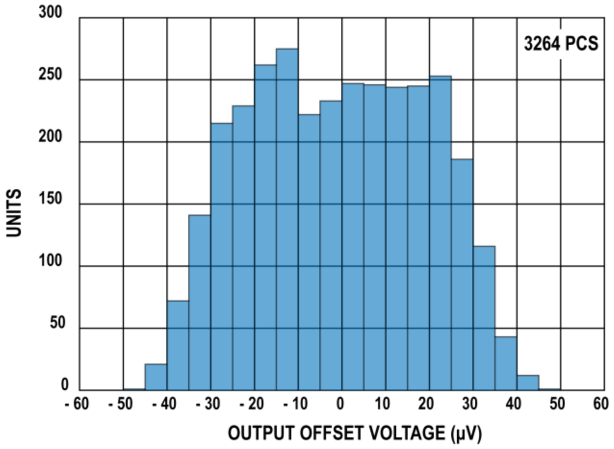

Figure 5. Typical Distribution of Output Offset Voltage V_{OSO}

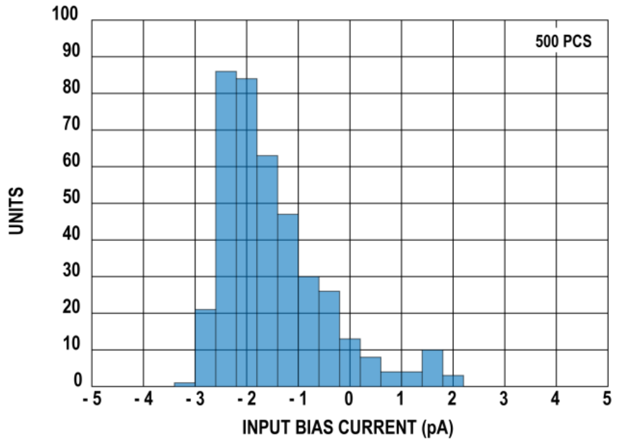

Figure 6. Typical Distribution of Input Bias Current I_{BIAS}

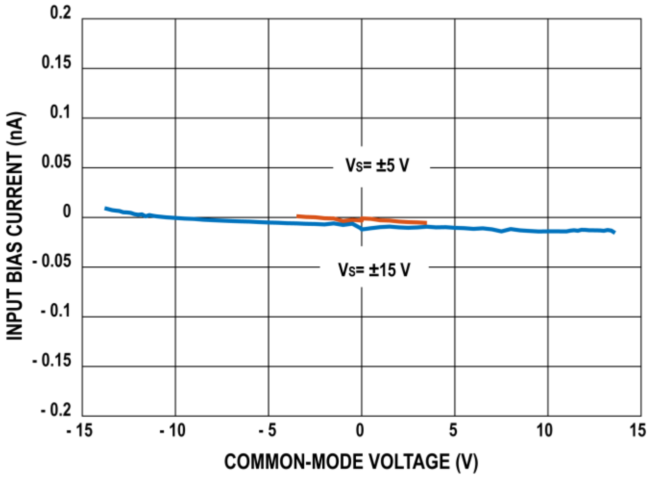

Figure 7. Input Bias Current vs. Common-Mode Voltage

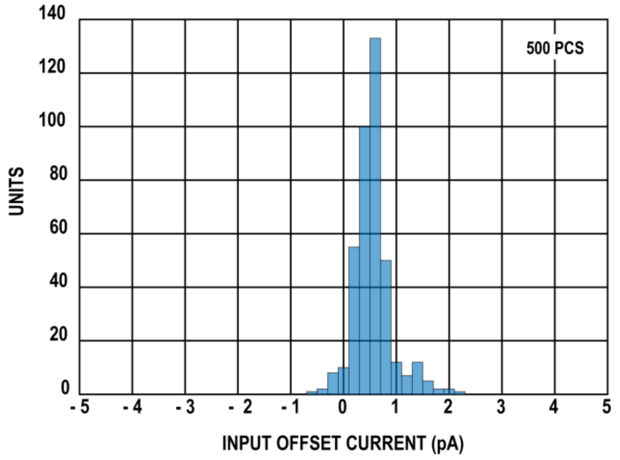

Figure 8. Typical Distribution of Input Offset Current

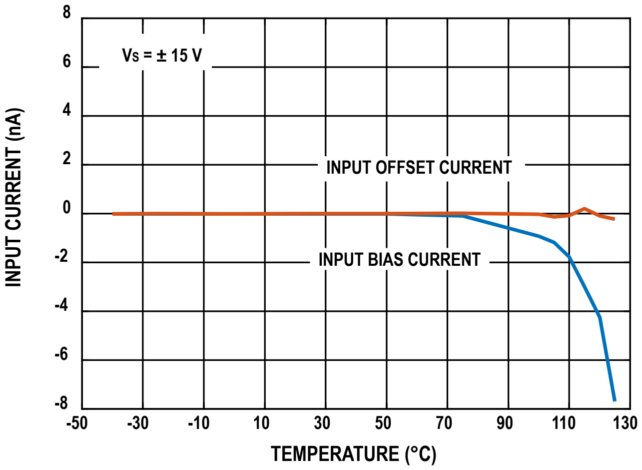

Figure 9. Input Bias Current & Offset Current vs. Temperature

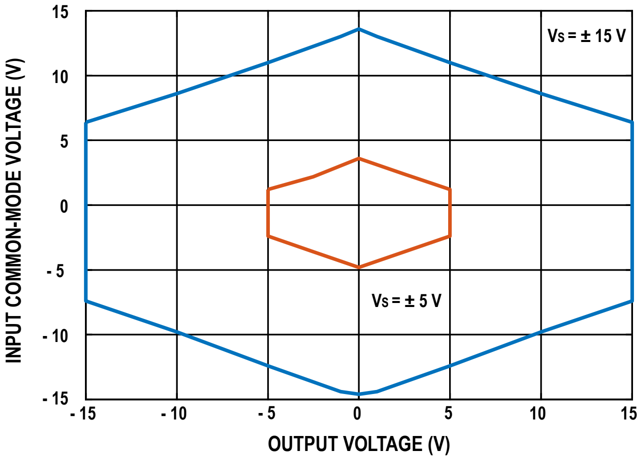

Figure 10. Input Common-Mode Voltage vs. Output Voltage (G = 1)

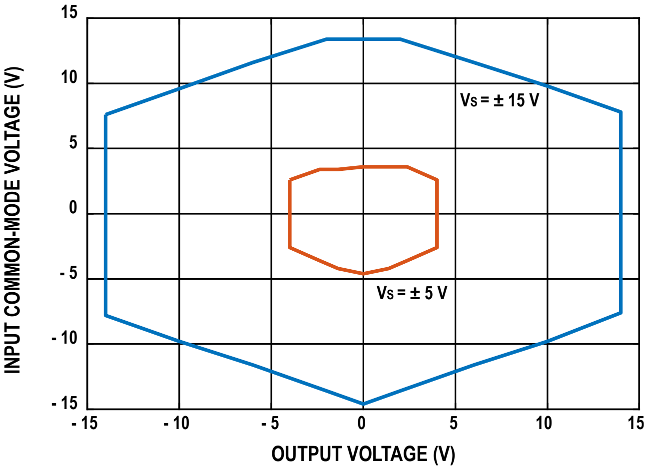

Figure 11. Input Common-Mode Voltage vs. Output Voltage (G = 100)

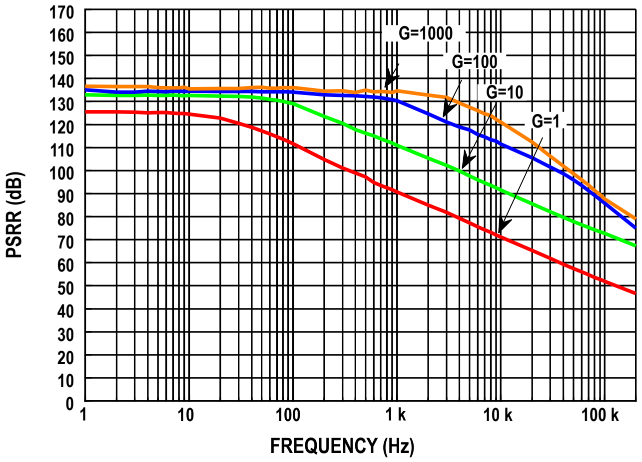

Figure 12. Positive Power Supply Rejection Ratio (PSRR) vs. Frequency, RTI (G = 1 to 1000)

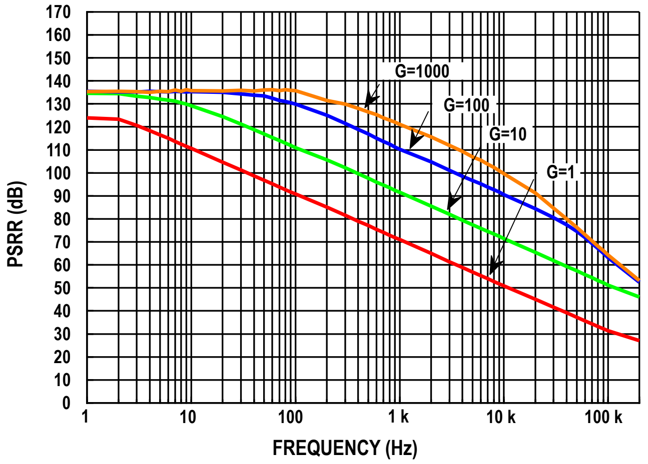

Figure 13. Negative Power Supply Rejection Ratio (PSRR) vs. Frequency, RTI (G = 1 to 1000)

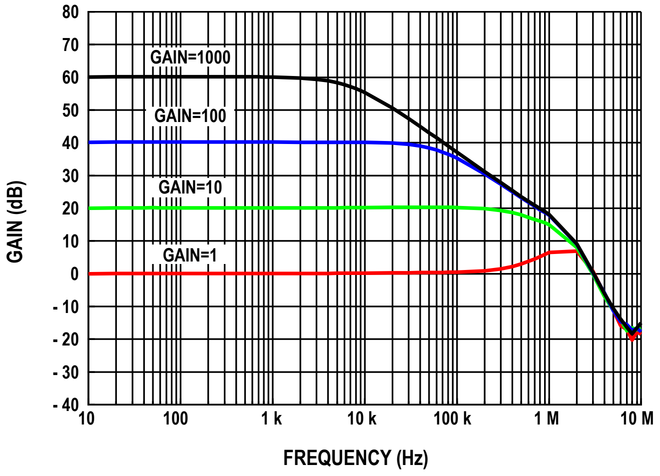

Figure 14. Gain vs. Frequency

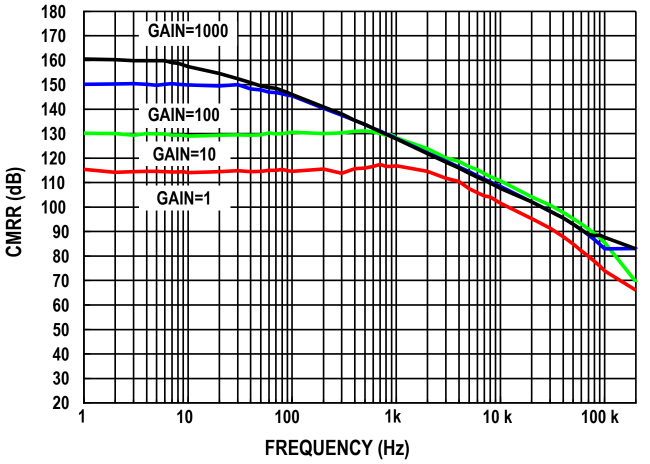

Figure 15. Common Mode Rejection Ratio (CMRR) vs. Frequency (RTI)

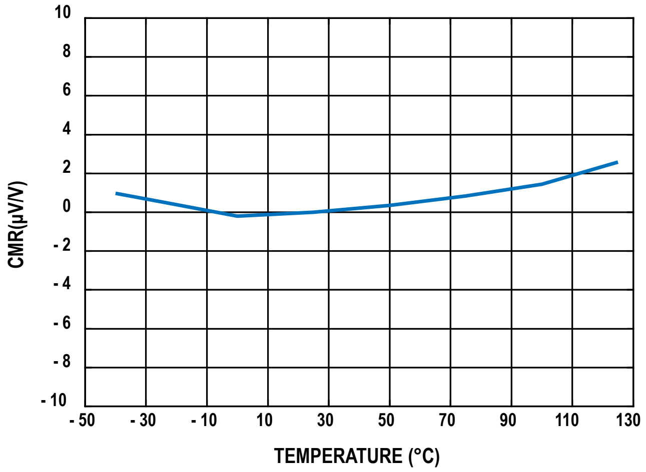

Figure 16. Common Mode Rejection Ratio (CMRR) vs. Temperature

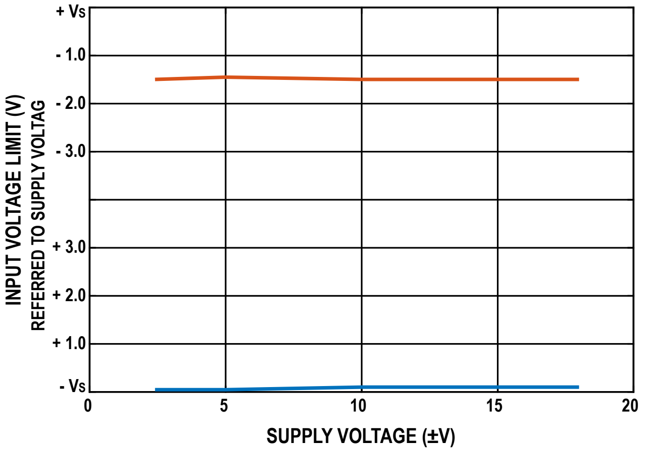

Figure 17. Input Voltage Limit vs. Supply Voltage (G = 1)

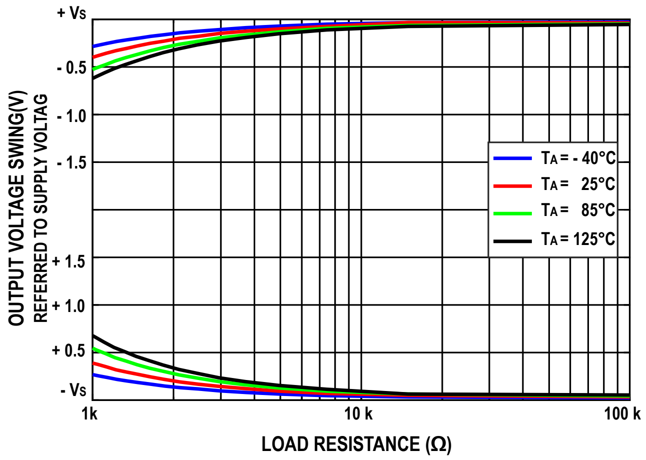

Figure 18. Output Voltage Swing vs. Load Resistance

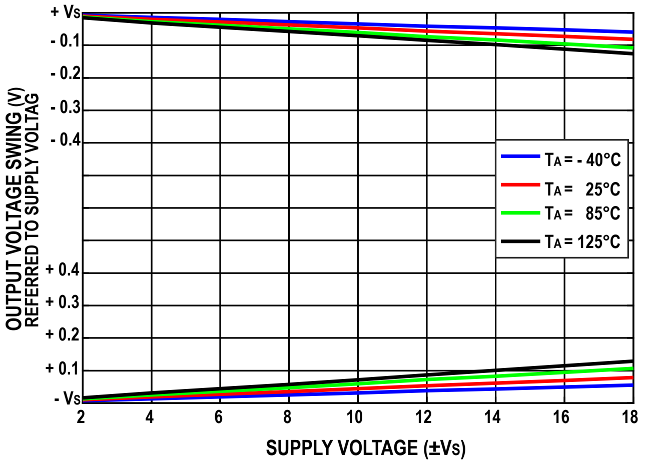

Figure 19. Output Voltage Swing vs. Supply Voltage (G = 1, R_L = 10 kΩ)

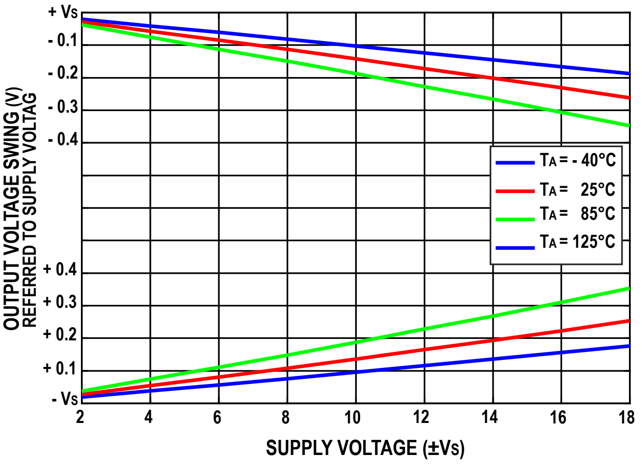

Figure 20. Output Voltage Swing vs. Supply Voltage (G = 1, R_L = 2 kΩ)

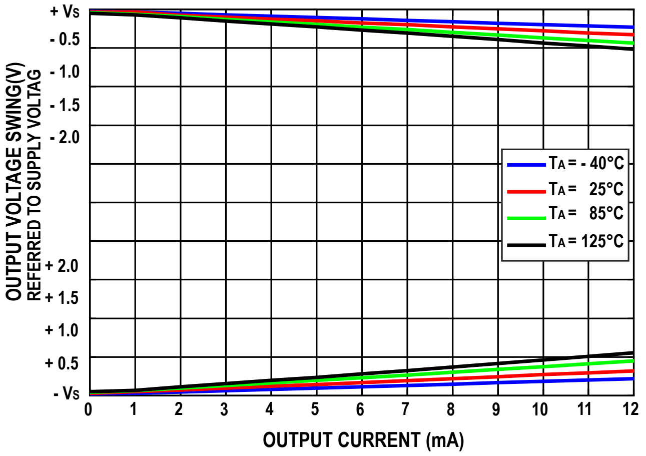

Figure 21. Output Voltage Swing vs. Output Current (G = 1)

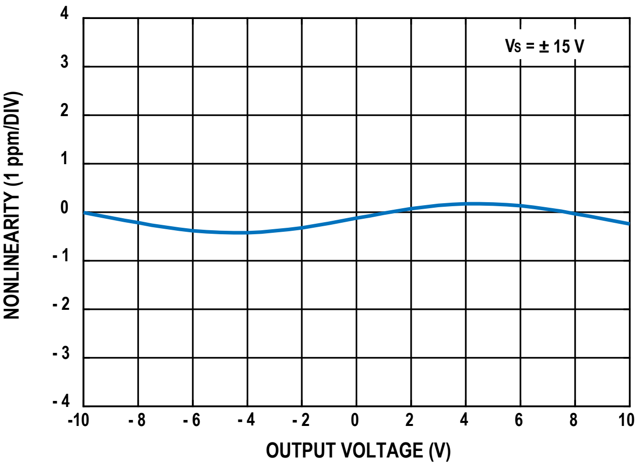

Figure 22. Gain Nonlinearity (G = 1, R_L = 10 kΩ)

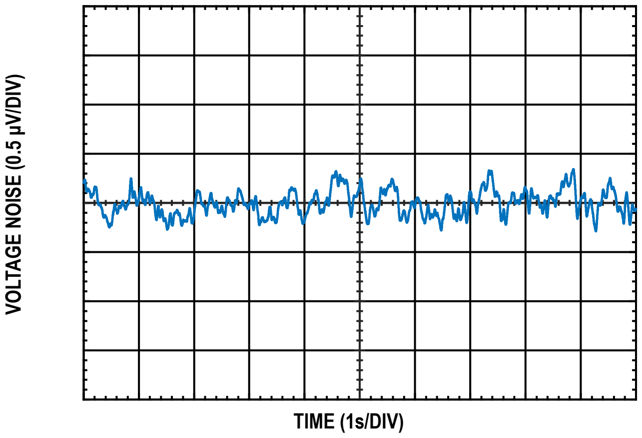

Figure 23. 0.1 Hz to 10 Hz RTI Voltage Noise (G = 100)

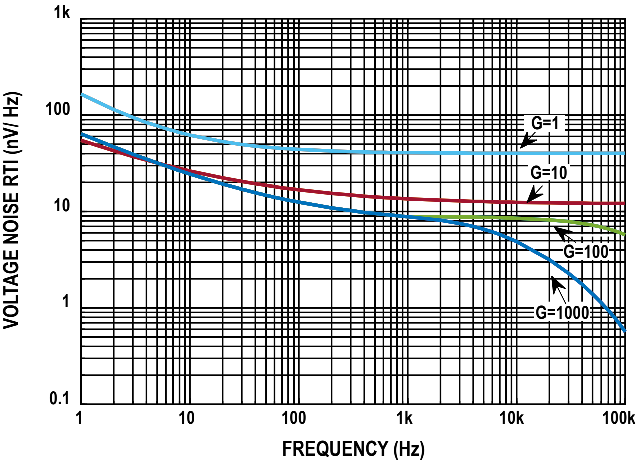

Figure 24. RTI Voltage Noise Spectral Density vs. Frequency (G = 1 to 1000)

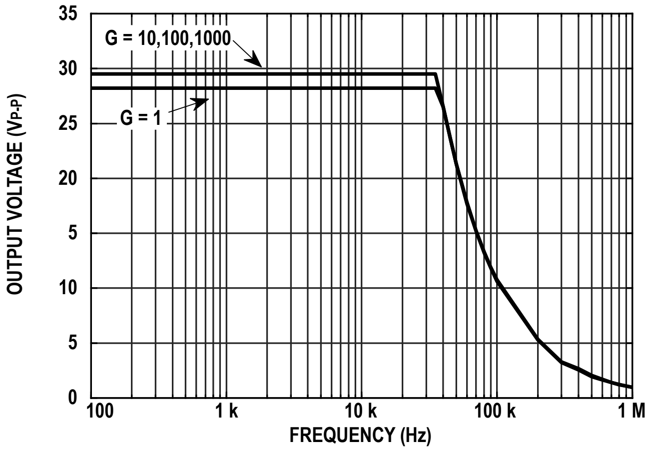

Figure 25. Large Signal Frequency Response

Figure 26. Small Signal Pulse Response
(G = 1, R_L = 2 kΩ, C_L = 100 pF)

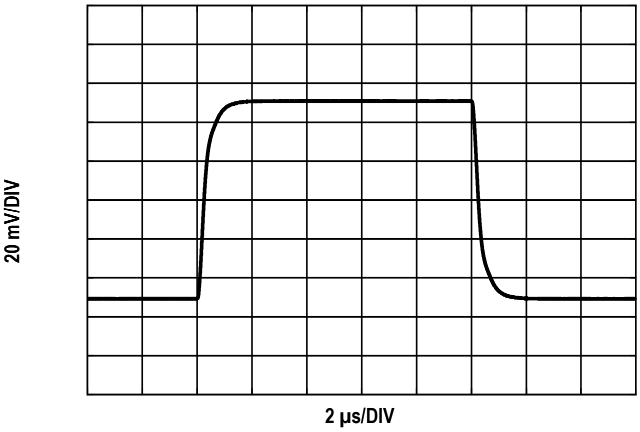

Figure 27. Small Signal Pulse Response
(G = 10, R_L = 2 kΩ, C_L = 100 pF)

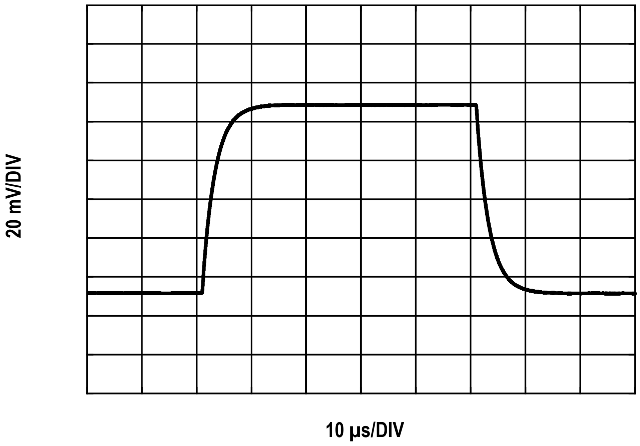

Figure 28. Small Signal Pulse Response
(G = 100, R_L = 2 kΩ, C_L = 100 pF)

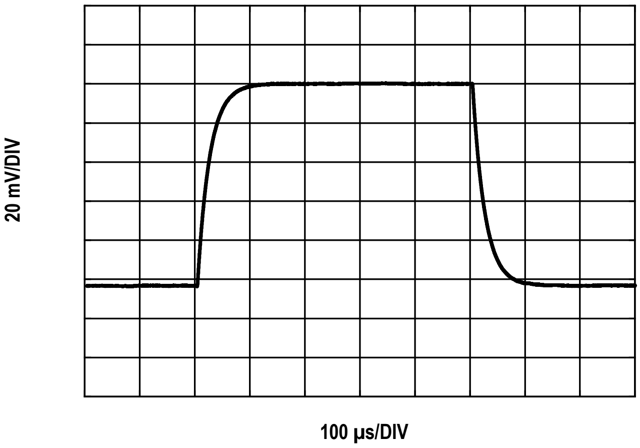

Figure 29. Small Signal Pulse Response
(G = 1000, R_L = 2 kΩ, C_L = 100 pF)

Theory of Operation

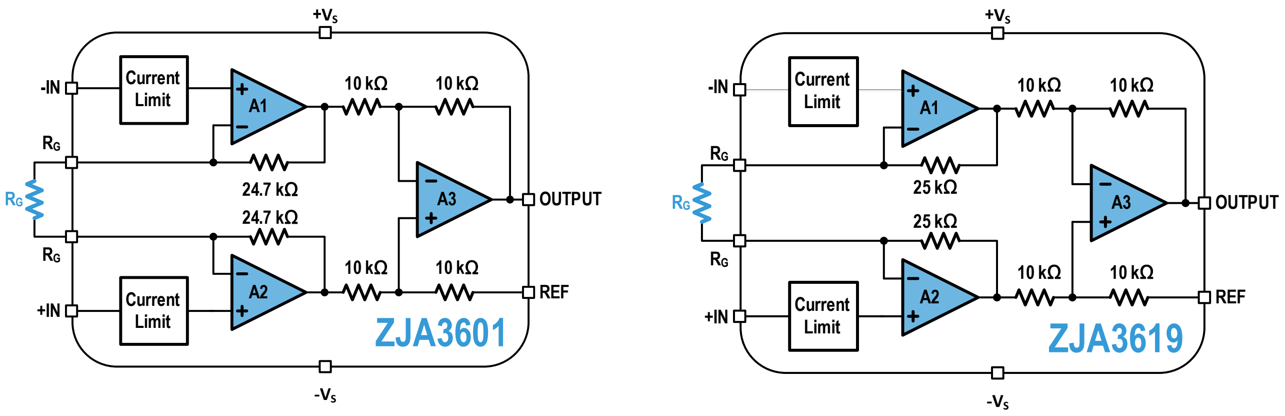

Figure 30. ZJA3601/ZJA3619 Simplified Schematic

The ZJA3601/ZJA3619 is a monolithic instrumentation amplifier based on the classic 3-op amp topology. The input stage consists of amplifiers A1 and A2, two trimmed 24.7 kΩ or 25 kΩ resistors are integrated. They are used along with an external resistor R_G, to set the gain. The amplified differential and common-mode signals are applied to a difference amplifier that rejects the common-mode voltage but amplifies the differential voltage. The difference amplifier employs innovations that result in low output offset voltage as well as low output offset voltage drift. The proprietary ZHIJINGTRIM® is used to trim these resistors and amplifiers, achieving a highly accurate instrumentation amplifier with gain error less than 0.1 % and CMRR exceeding 105 dB (G = 1, Grade B).

The ZJA3601/ZJA3619 offers extremely high input impedance, low I_B (below 25 pA at room temperature and symmetrical for +IN and -IN), low I_B drift, low I_{OS} (lower than 1 nA from -40 °C to 125 °C), low input bias current noise, and extremely low voltage noise of $8\ \text{nV}/\sqrt{\text{Hz}}$.

The gain equation of the ZJA3601 is

$$G = 1+\frac{49.4\ \text{k}\Omega}{R_G}$$

The gain equation of the ZJA3619 is

$$G = 1+\frac{50\ \text{k}\Omega}{R_G}$$

Users can easily and accurately set the gain using a single standard resistor.

The gain-bandwidth product of the ZJA3601/ZJA3619 increases with gain, resulting in a system that does not suffer from the expected bandwidth loss of voltage feedback architectures at higher gains. To maintain high accuracy at low input levels, the ZJA3601/ZJA3619 has been carefully designed and laid out to meet the most demanding application requirements.

A unique pinout enables the ZJA3601/ZJA3619 to meet a CMRR specification of 100 dB at 10 kHz (G=1) and 130 dB at 1 kHz (G=1000). The balanced pinout, shown in Figure 1, reduces the parasitics that had, in the past, adversely affected CMRR performance. This feature expands the application range of the ZJA3601/ZJA3619, making it suitable for emerging applications such as renewable energy testing. In addition, the new pinout simplifies board layout because associated traces are grouped together. For example, the gain setting resistor pins are adjacent to the inputs, and the reference pin REF is next to the output V_{OUT}.

Gain Selection

Placing a resistor across the R_G terminals set the gain of ZJA3601, which can be calculated by referring to Table 1 or by using the gain equation.

$$R_G = \frac{49.4\ \text{k}\Omega}{G - 1}$$

1 % Standard Table Value of R_G (Ω)	Calculated Gain	0.1 % Standard Table Value of R_G (Ω)	Calculated Gain
49.9 k	1.990	49.3 k	2.002
12.4 k	4.984	12.4 k	4.984
5.49 k	9.998	5.49 k	9.998
2.61 k	19.93	2.61 k	19.93
1.00 k	50.40	1.01 k	49.91
499	100.0	499	100.0
249	199.4	249	199.4
100	495.0	98.8	501.0
49.9	991.0	49.3	1003

Table 1. Commonly-Used Gains and Resistor Values

The ZJA3601 defaults to G = 1 when no gain resistor is used. Gain accuracy is determined by the absolute tolerance of R_G. The TC of the external gain resistor increases the gain drift of the instrumentation amplifier. Gain error and gain drift are kept to a minimum when the gain resistor is not used. Integrated instrumentation amplifiers, owing to their precise pre-trimming, generally boast superior gain accuracy and temperature stability compared to discrete solutions.

Unlike the traditional high-gain amplifiers with built-in precision resistors having a negative TC, the ZJA3601's embedded resistors feature a positive TC (10 ppm/°C), aligning with most external resistors. This enables achieving unparalleled system temperature coefficients, crucial for precision applications requiring gain above 1 over a wide temperature range.

Placing a resistor across the R_G terminals set the gain of ZJA3619, which can be calculated by referring to Table 2 or by using the gain equation.

$$R_G = \frac{50\ \text{k}\Omega}{G - 1}$$

1 % Standard Table Value of R_G (Ω)	Calculated Gain	0.1 % Standard Table Value of R_G (Ω)	Calculated Gain
49.9 k	2.002	49.9 k	2.002
12.4 k	5.032	12.4 k	5.032
5.62 k	9.897	5.56 k	9.993
2.61 k	20.16	2.64 k	19.94
1.02 k	50.02	1.02 k	50.02
511	98.85	505	100.0
249	201.8	252	199.4
100	501.0	100	501.0
49.9	1003	49.9	1003

Table 2. Commonly-Used Gains and Resistor Values

The ZJA3619 defaults to G=1 when no gain resistor is used. Gain accuracy is determined by the absolute tolerance of R_G. The TC of the external gain resistor increases the gain drift of the instrumentation amplifier. Gain error and gain drift are kept to a minimum when the gain resistor is not used. Integrated instrumentation amplifiers, owing to their precise pre-trimming, generally boast superior gain accuracy and temperature stability compared to discrete solutions.

Unlike the traditional high-gain amplifiers with built-in precision resistors having a negative TC, the ZJA3619's embedded resistors feature a positive TC (10 ppm/°C), aligning with most external resistors. This enables achieving unparalleled system temperature coefficients, crucial for precision applications requiring gain above 1 over a wide temperature range.

Common Mode Rejection

One benefit of the high CMRR over frequency of the ZJA3601/ZJA3619 is that it has greater immunity to disturbances, such as line noise and its associated harmonics, than do typical instrumentation amplifiers. Typically, these amplifiers have CMRR fall-off at 200 Hz; common-mode filters are often used to compensate for this shortcoming. The ZJA3601/ZJA3619 is able to reject CMRR over a greater frequency range, reducing the need for filtering. The circuit simplification reduces area and cost while maintaining performance.

A well implemented layout helps to maintain the high CMRR over frequency of the ZJA3601/ZJA3619. Input source impedance and capacitance should be closely matched. In addition, source resistance and capacitance should be placed as close to the inputs as permissible.

Offset Voltage

The offset voltage of the ZJA3601/ZJA3619 is attributed to two sources, input offset voltage V_{OSI} and output offset voltage V_{OSO}. The V_{OSO} is divided by G when referred to the input. In practice, the V_{OSI} dominates at high gains, and the V_{OSO} dominates at low gains. V_{OSI} includes the offset voltage generated by input amplifiers A1 and A2; V_{OSO} is the offset voltage of amplifier A3. The total V_{OS} for a given gain is calculated as

$$\text{Total Error RTI } (V_{OS,RTI}) = V_{OSI} + \frac{V_{OSO}}{G}$$

$$\text{Total Error RTO } (V_{OS,RTO}) = G * V_{OSI} + V_{OSO}$$

ZJA3601/ZJA3619's low offset voltages eliminate the need for system-level calibration, reducing costs and improving efficiency.

Input Bias Current Return Path

Instrumentation amplifiers typically interface with high-impedance signal sources. The ZJA3601/ZJA3619 boasts an exceptional input bias current of under 25 pA at room temperature, a performance previously only found in expensive JFET amplifiers. Furthermore, it delivers this unmatched current level alongside significantly improved accuracy. When the source, such as a thermocouple, cannot provide a return current path, one should be created, as shown in Figure 31 and Figure 32.

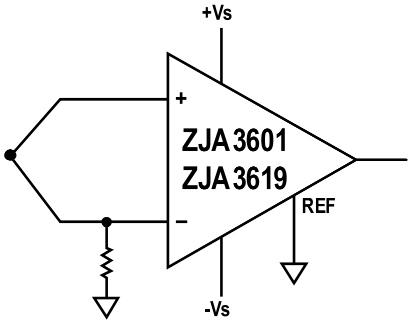

Figure 31. ZJA3601/ZJA3619 Interfaces with Thermocouple

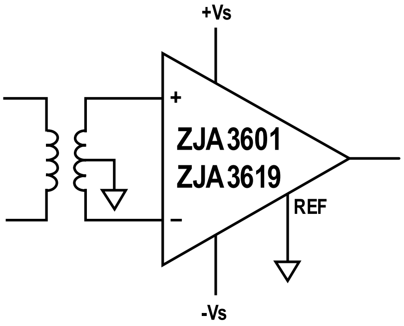

Figure 32. ZJA3601/ZJA3619 Interfaces with Transformer

When using ZJA3601/ZJA3619 for AC coupling, it is important to provide a return path to the input AC coupling capacitors. Otherwise, the input offset voltage will accumulate due to parasitic leakage and input currents, potentially causing the output to lock to a fixed voltage near the power rail. Figure 33 shows the correct connection for AC coupling, which utilizes a high-pass filter with a cutoff frequency determined by RC. And due to the differential inputs, the matching of R and C is crucial.

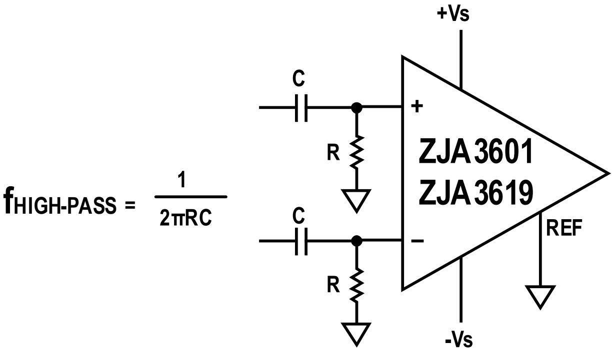

Figure 33. ZJA3601/ZJA3619 in AC Coupling Connection

Input Protection

The ZJA3601/ZJA3619 features a 3 kV ESD rating in the Human Body Model (HBM). As shown in Figure 30, each input of the ZJA3601/ZJA3619 has a current-limit circuit, protecting both the device itself and the system.

For applications where the ZJA3601/ZJA3619 encounters extreme overload voltages, as in cardiac defibrillators, external series resistors, and low leakage diode clamps, such as BAV199Ls, FJH1100s, or SP720s should be used.

Reference Terminal

The reference terminal REF defines the zero-output voltage and is especially useful when the load does not share a precise ground with the rest of the system. It can interface with pseudo-differential input ADCs easily, for example, ZJC2002 (pseudo-differential unipolar) and ZJC2003 (pseudo-differential bipolar).

As shown in Figure 30, the REF pin is directly connected to one end of the internally trimmed 10 kΩ resistor, and the output of the instrumentation amplifier is referenced to the voltage on the REF pin. When ZJA3601/ZJA3619 interfaces with ADC ZJC2002, which requires the output of the front-end circuit to be referenced to half of its supply voltage ($V_{DD}/2$). In this case, an external $V_{DD}/2$ source can be connected to the REF pin of ZJA3601/ZJA3619, which is very convenient.

Parasitic resistance should be kept to a minimum for optimum CMRR. To achieve the best performance, the REF pin should maintain a low source impedance, as parasitic resistance can adversely affect CMRR and gain accuracy. If the REF pin is not connected to a clean and low-impedance system ground, a precision op amp buffer (such as ZJA3000) between the REF pin and the signal source is recommended to achieve the best performance.

Power Supply Regulation and Bypassing

A stable dc voltage should be used to power the instrumentation amplifier. Noise on the supply pins can adversely affect performance. Bypass capacitors should be used to decouple the amplifier.

A low ESR 0.1 μF capacitor should be placed close to each supply pin. High-quality surface-mount ceramic capacitors (such as X5R or X7R) are recommended. As shown in Figure 34, a 10 μF tantalum capacitor can be used, and in most cases, it can be shared by other precision integrated circuits. Refer to the Layout Example section for specific layout examples.

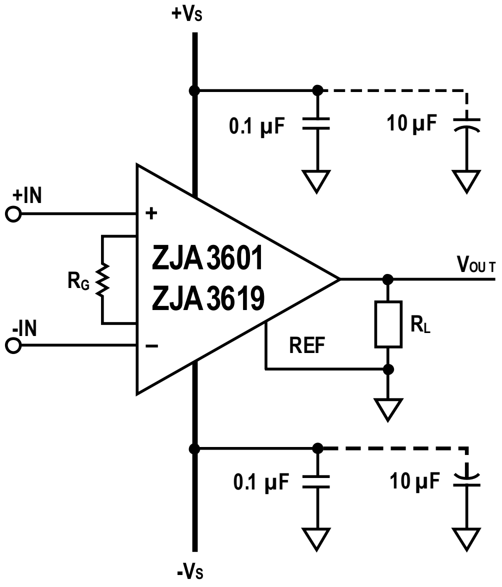

Figure 34. Supply Decoupling, REF, and Output Referred to Local Ground

Although the ZJA3601/ZJA3619 is a very reliable chip with certain protection functions, it is generally recommended to power on the ZJA3601/ZJA3619 before applying the input signals.

Grounding

Star grounding is recommended for the ZJA3601/ZJA3619 circuit, as shown in Figure 34. Maintain low impedance for the REF pin because the output voltage of the ZJA3601/ZJA3619 is developed with respect to the potential on the REF. Place the decoupling capacitors as close to the power pins as possible to minimize the loop area.

In a multilayer PCB, use a large area ground plane if possible. Place analog signals on the layer above the ground plane.

In mixed-signal environments, low level analog signals need to be isolated from the noisy digital environment. Modern precision SAR ADCs have separate analog and digital ground, and they are all connected to the analog ground. When used with this type of ADC, the ZJA3601/ZJA3619 uses the analog ground as the reference.

The ZJA3601/ZJA3619 has a low bias current. To reduce leakage current, it is recommended to remove the ground plane below the signal traces of the two inputs. Refer to the Layout Examples section for specific examples.

Over Temperature Protection

Due to its high operating voltage (up to 36 V) and short-circuit current (source 90 mA and sink 50 mA), the ZJA3601/ZJA3619 can dissipate up to 2 W of power during use. As thermal resistance for various package formats typically exceeds 100 °C/W, self-heating and the risk of permanent damage from high temperatures are concerns in real-world applications. To address this, the ZJA3601/ZJA3619 incorporates an automatic over-temperature protection (OTP) function. When the chip temperature reaches 150 °C, OTP triggers, putting the chip into shutdown mode. Both input and output terminals enter a high-impedance state, significantly reducing power consumption and facilitating temperature drop. Once the chip cools down to 130 °C, OTP disengages, and the chip resumes normal operation.

ZJA3601/ZJA3619 Comparison to Zero-drift Instrumentation Amplifiers

ZJA3601/ZJA3619 is a continuous-signal processing instrumentation amplifier, unlike chopping/auto-zero-based zero-drift amplifiers reliant on non-continuous switch-based technology. These amplifiers contain a sampling capacitor at the input, causing the input bias current to exhibit periodic glitches invisible in datasheets due to averaging. Eliminating these glitches requires an output filter, significantly limiting their usable bandwidth and often restricting them to DC and near-DC signals. Adding a filter also adds complexity to system design. Additionally, tolerance of their internal sampling capacitors leads to variations in glitch amplitude across different ICs. More critically, their linearity (THD & THD+N) is often not great. While they may boast better low-frequency noise, this comes at the cost of transferring noise to the switching frequency, resulting in a noisy spectrum with large spike components. Consequently, their overall noise performance is often inferior to high-performance continuous sampling amplifiers like the ZJA3601/ZJA3619.

Furthermore, the usable bandwidth of zero-drift amplifiers is typically only 1/10 or 1/100 of what their datasheets suggest, severely limiting their usability. Their settling time and overload recovery time are also often much longer, making them unsuitable for multi-channel switching or applications with dynamic performance requirements.

Applications and Implementation

Bridge Circuit Interface

Bridge circuits are widely used in various sensing systems. Figure 35 shows how the ZJA3601/ZJA3619 interfaces with a bridge circuit, enabling its integration into a data acquisition system (DAS). Bridge circuits have different designs depending on the parameters being measured (excitation voltage Vexc, resistance Rb, and sensitivity, etc.), resulting in different electrical characteristics. The excitation voltage and resistance have the greatest impact on the interface circuit. As a general-purpose differential-to-single-ended input device, the instrumentation amplifier is very suitable for the interface of bridge circuit sensors. The excitation voltage determines the input common-mode voltage of the instrumentation amplifier as Vexc/2. It is necessary to pay attention to the supply voltage of the instrumentation amplifier to ensure that Vexc/2 is within the allowable input range. The wide supply voltage of ZJA3601/ZJA3619 provides flexibility in use, and its excellent common-mode rejection ratio (CMRR) and guaranteed temperature characteristics (ZJA3601/ZJA3619's CMRR is guaranteed in the -40 °C to 125 °C range) ensure the accuracy of the circuit over the entire temperature range, simplifying system design. The resistance Rb has a significant impact on the instrumentation amplifier, and it is generally required that the instrumentation amplifier has high input impedance and low voltage noise. If Rb is higher than 100 kΩ, users need to carefully check the bias current and current noise of the instrumentation amplifier. The ZJA3601/ZJA3619’s bias current is within 25 pA and current noise is $0.8\ \text{pA}/\sqrt{\text{Hz}}$ at room temperature, making it ideal to interface with high-output impedance bridge circuits and ensuring system SNR (signal-to-noise ratio) and resolution.

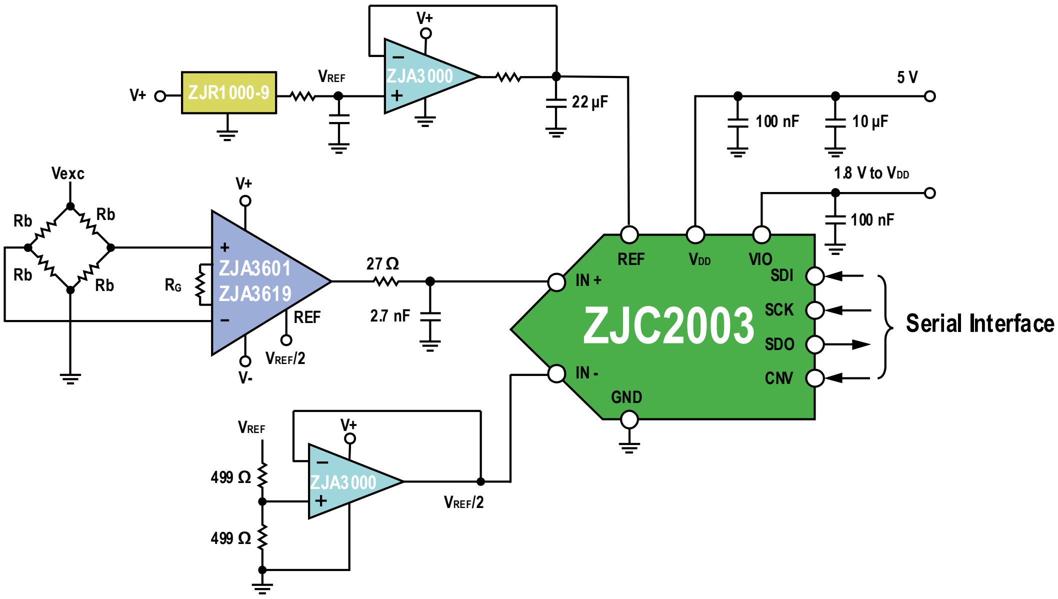

Figure 35. ZJA3601/ZJA3619 Interfaces with Bridge Circuit

Building Precision Current Source with ZJA3601/ZJA3619

Figure 36 illustrates the construction of a precision current source using a single ZJA3601/ZJA3619 instrumentation amplifier, one ZJA3000-1 precision operational amplifier, and two resistors. This design offers flexibility with a supply voltage range of ±2.4 V to ±18 V. The ZJA3601/ZJA3619's characteristics simplify setting the circuit's current output. The actual current output is equal to the set value minus the input bias current of the ZJA3000, which is within 25 pA at room temperature, making it often negligible.

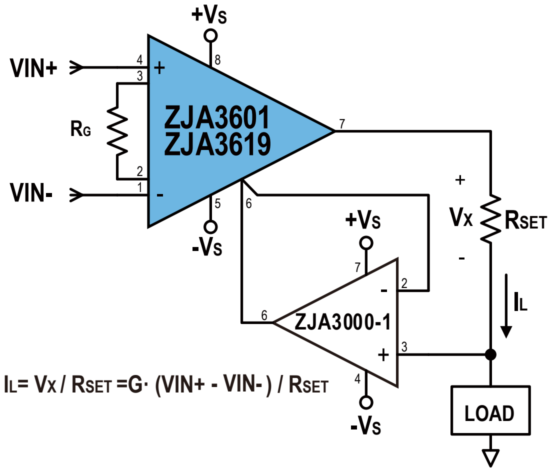

Figure 36. Building Precision Current Source with ZJA3601/ZJA3619

Precision Current Sensing

The ZJA3601/ZJA3619 is often used for precision current sensing due to its high accuracy, wide bandwidth, low input bias current, and ease of use. As shown in Figure 37, the shunt resistor Rs is typically low, possibly a few Ohms, or even in the mΩ range. The ZJA3601/ZJA3619's high input impedance and input bias current of 25 pA or less allow it to detect currents as low as 1 nA; its low-frequency noise of 0.9 μV_{P-P} allows it to detect µV-level signals. The ZJA3601/ZJA3619 has a wide input range, allowing it to accurately measure input signals with a large dynamic range from µV to several volts. In general, current changes rapidly, so the ZJA3601/ZJA3619's wide bandwidth is very suitable. This is particularly beneficial in applications like motor control or battery monitoring, where current can fluctuate rapidly. On the other hand, the voltage Vm can be a high voltage varying at a certain frequency. In this case, the ZJA3601/ZJA3619's high CMRR is critical for accuracy. The ZJA3601/ZJA3619's CMRR performance with frequency is very good, with a several-fold improvement over traditional pin-out instrumentation amplifiers. This meets the new current sensing requirements of many emerging industries. For example, with the adoption of renewable energies, the frequency of current and voltage has increased. To maintain the same detection accuracy, the CMRR of the instrumentation amplifier must also be increased with frequency. The characteristics of the ZJA3601/ZJA3619 meet this new requirement, enabling systems to meet requirements without modifying hardware, which greatly accelerates the product iteration speed.

For applications that require long-term operation and large environmental temperature changes, the ZJA3601/ZJA3619's long-term stability and temperature drift characteristics are very valuable, making the design simpler and more reliable.

In some applications, the signal dynamic range is too big, and the accuracy or linearity of the instrumentation amplifier must be sacrificed by changing R_G to meet the needs of measuring the entire dynamic range. In this case, using digital potentiometers (digi-POTs) is not a good solution, because their temperature characteristics are often not very good. Engineers may consider the series and parallel connection of precision resistors, utilizing relays with good temperature characteristics to switch between ranges. Attention should be paid to wiring in such configurations.

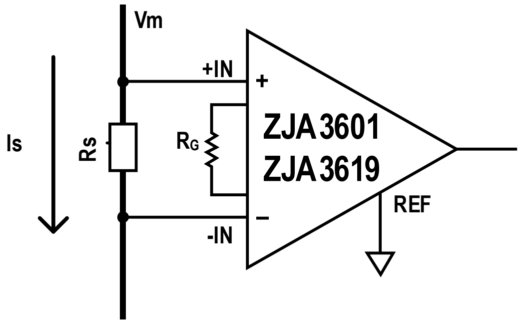

Figure 37. Using ZJA3601/ZJA3619 for Precision Current Sensing

In precision current sensing, if a zero-drift instrumentation amplifier is used, the offset voltage caused by bias current glitch and high-frequency noise will limit the minimum detectable current, thereby limiting the detection accuracy. The available bandwidth of a zero-drift instrumentation amplifier is typically 1/10 to 1/100 of its data sheet bandwidth, which limits the available bandwidth of the current to be measured. This can often make it difficult to keep up with fast-changing currents, resulting in missed information or limiting the bandwidth of closed-loop systems. The longer settling time and lower slew rate of zero-drift instrumentation amplifiers will reduce the system's response speed. The poor linearity of zero-drift instrumentation amplifiers can make the design of control systems difficult or even impossible.

The ZJA3601/ZJA3619 is a good choice for precision current sensing applications. It offers a combination of high accuracy, wide bandwidth, low input bias current, and ease of use that is not available in other instrumentation amplifiers.

Layout Guidelines

For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and op amp itself. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1-μF ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds paying attention to the flow of the ground current.
- In order to reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible in order to minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.
- Cleaning the PCB following board assembly is recommended for best performance.
- Any precision integrated circuit may experience performance shifts due to moisture ingress into the plastic package. Following any aqueous PCB cleaning process, baking the PCB assembly is recommended to remove moisture introduced into the device packaging during the cleaning process. A low temperature, post cleaning bake at 85 °C for 30 minutes is sufficient for most circumstances.

Layout Example

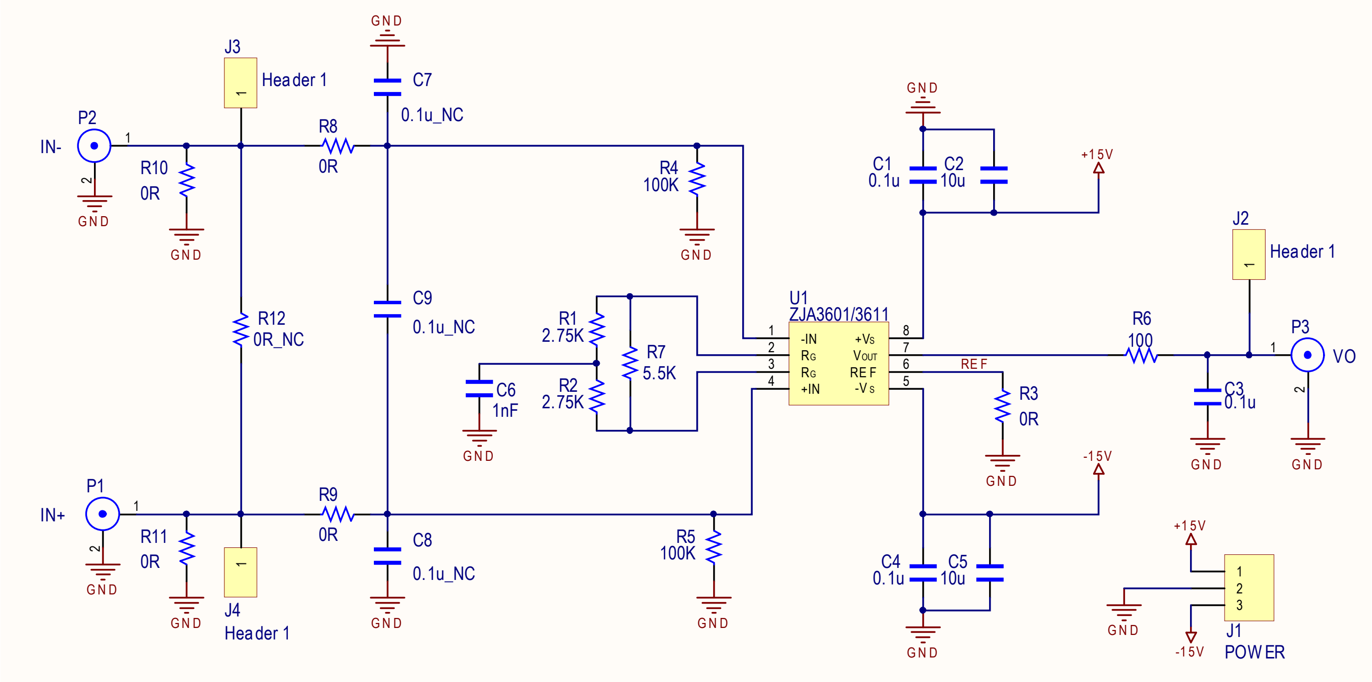

Figure 38. ZJA3601/ZJA3619/ZJA3611 Evaluation Board Schematic

When evaluating the ZJA3601/ZJA3619, only R7 is required for gain setting. Other passive components R10, R12, C7, C9, R4, R11, R9, C8, and R5 do not require population. However, if necessary, suitable values of R8, C7, C9, R9, and C8 can be populated to form a common-mode rejection filter.

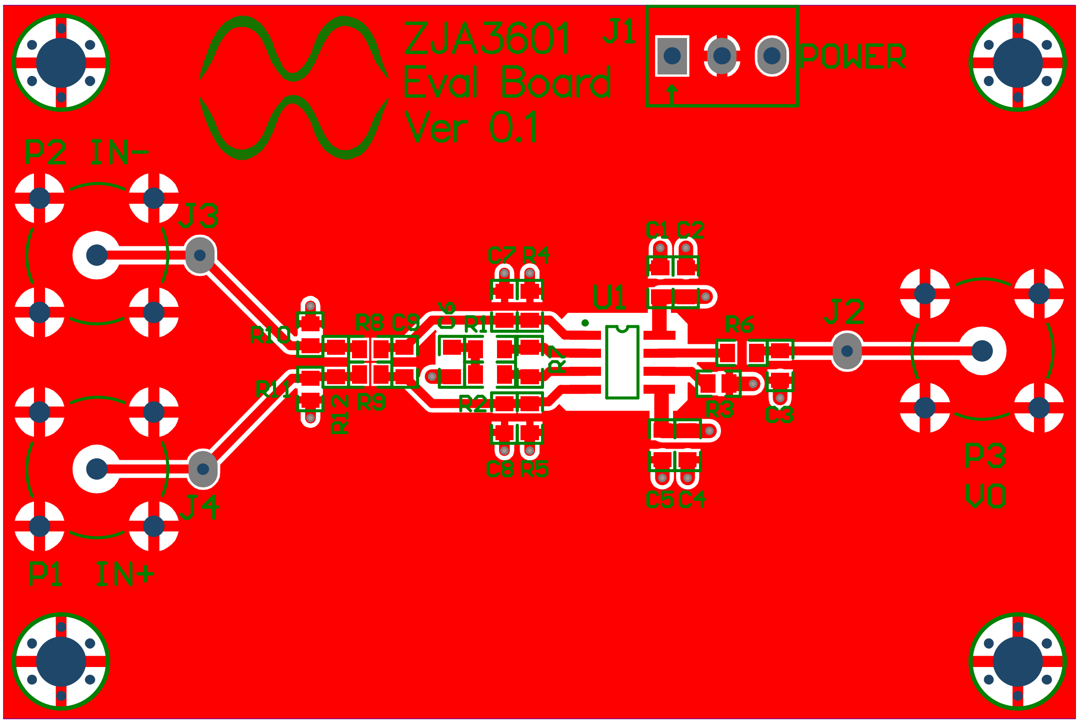

Figure 39. Layout of ZJA3601/ZJA3619/ZJA3611 Evaluation Board (Top Layer)

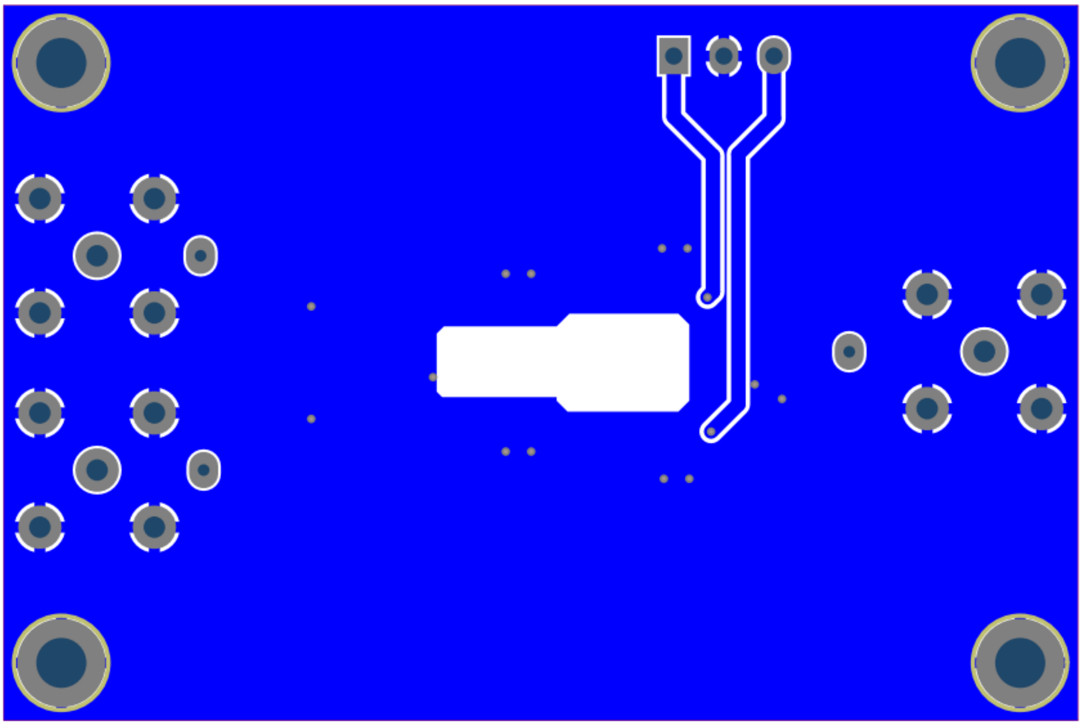

Figure 40. Layout of ZJA3601/ZJA3619/ZJA3611 Evaluation Board (Bottom Layer)

Outline Dimensions

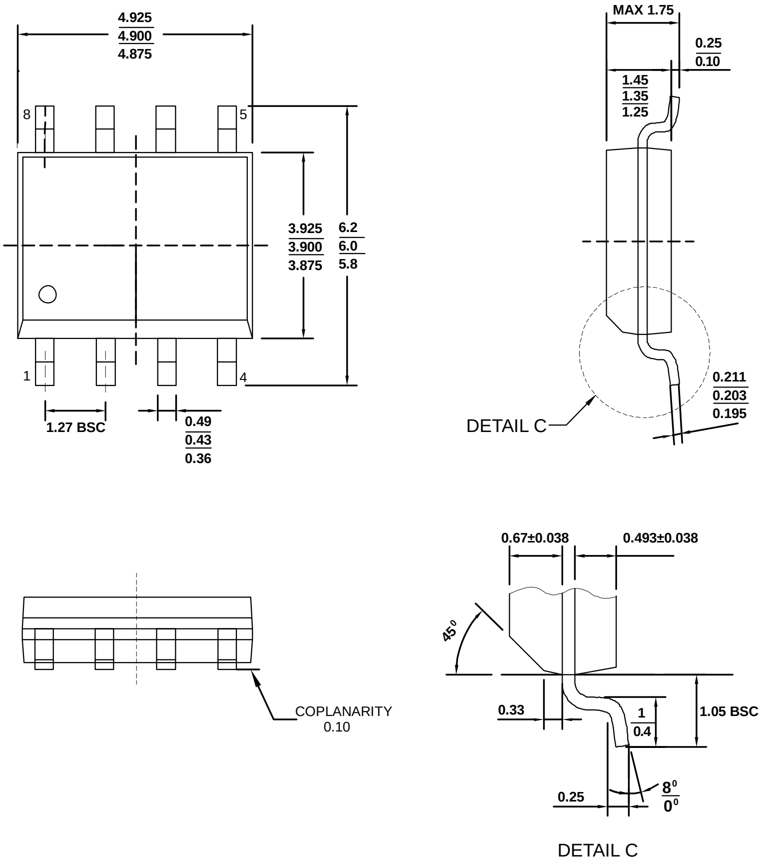

Figure 41. 8-Lead SOIC Package Dimensions shown in millimeters

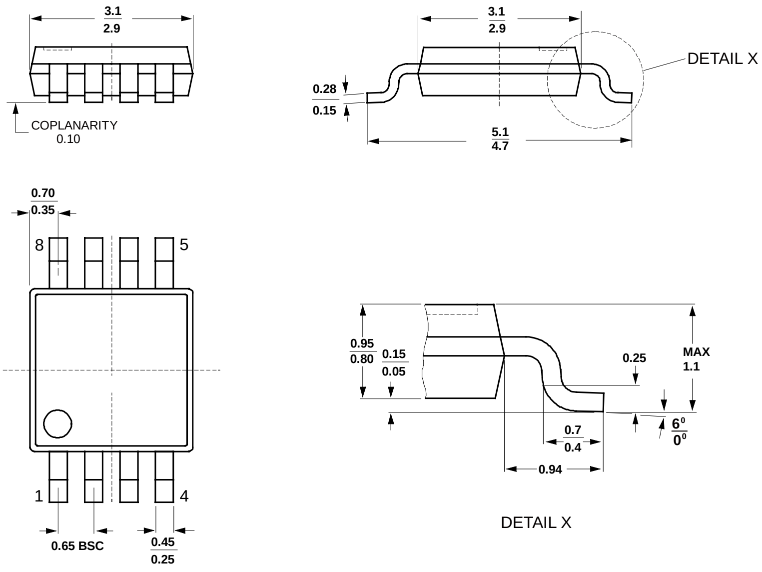

Figure 42. 8-Lead MSOP Package Dimensions shown in millimeters

Ordering Guide

Model	Package	Orderable Device	Temperature Range (°C)	External Package
ZJA3601	SOIC-8	ZJA3601BSABT	-40 to 125	Tube
	SOIC-8	ZJA3601BSABR	-40 to 125	13” reel
	SOIC-8	ZJA3601ASABT	-40 to 125	Tube
	SOIC-8	ZJA3601ASABR	-40 to 125	13” reel
	MSOP-8	ZJA3601BUABT	-40 to 125	Tube
	MSOP-8	ZJA3601BUABR	-40 to 125	13” reel
	MSOP-8	ZJA3601AUABT	-40 to 125	Tube
	MSOP-8	ZJA3601AUABR	-40 to 125	13” reel
ZJA3619	SOIC-8	ZJA3619BSABT	-40 to 125	Tube
	SOIC-8	ZJA3619BSABR	-40 to 125	13” reel
	SOIC-8	ZJA3619ASABT	-40 to 125	Tube
	SOIC-8	ZJA3619ASABR	-40 to 125	13” reel
	MSOP-8	ZJA3619BUABT	-40 to 125	Tube
	MSOP-8	ZJA3619BUABR	-40 to 125	13” reel
	MSOP-8	ZJA3619AUABT	-40 to 125	Tube
	MSOP-8	ZJA3619AUABR	-40 to 125	13” reel

Orderable Device Explanation

ZJXXXXX X X X X X Q1

Q1: Automotive Grade
External Package: T = tube; R = reel
Temperature range: A = -40 °C to 125 °C Automotive Grade 1; B = -40 °C to 125 °C; E = -40 °C to 85 °C
Number of Pins: T = 6; A = 8; B = 10; D = 14; E = 16; P = 20
Package type: S = SOIC; U = MSOP, TSSOP, SOT; T = DFN, QFN
Grade: B grade is better than A grade
Base: R = Voltage reference; A = Amplifier; C = Data Converter; G = Switches and Multiplexers; M = Others

Related Parts

Part Number	Description	Comments
ADC		
ZJC2020	20-bit 350 kSPS SAR ADC	Fully differential input, SINAD 101.4 dB, THD -118 dB
ZJC2000/2010	18-bit 400 kSPS/200 kSPS SAR ADC	Fully differential input, SINAD 99.3 dB, THD -113 dB
ZJC2001/2011	16-bit 500 kSPS/250 kSPS SAR ADC	Fully differential input, SINAD 95.3 dB, THD -113 dB
ZJC2002/2012 ZJC2003/2013	16-bit 500 kSPS/250 kSPS SAR ADC	Pseudo-differential unipolar input, SINAD 91.7 dB, THD -105 dB Pseudo-differential bipolar input, SINAD 91.7 dB, THD -105 dB
ZJC2004/2014 ZJC2005/2015	18-bit 400 kSPS/200 kSPS SAR ADC	Pseudo-differential unipolar input, SINAD 94.2 dB, THD -105 dB Pseudo-differential bipolar input, SINAD 94.2 dB, THD -105 dB
ZJC2007/2017 ZJC2008/2018	14-bit 600 kSPS/300 kSPS SAR ADC	Pseudo-differential unipolar input, SINAD 85 dB, THD -105 dB Pseudo-differential bipolar input, SINAD 85 dB, THD -105 dB
ZJC2100/1-18 ZJC2100/1-16	18-bit 400 kSPS/200 kSPS 4-ch differential SAR ADC, SINAD 99.3 dB, THD -113 dB 16-bit 500 kSPS/250 kSPS 4-ch differential SAR ADC, SINAD 95.3 dB, THD -113 dB	
ZJC2102/3-18 ZJC2102/3-16 ZJC2102/3-14	18-bit 400 kSPS/200 kSPS 8-ch pseudo-differential SAR ADC, SINAD 94.2 dB, THD -105 dB 16-bit 500 kSPS/250 kSPS 8-ch pseudo-differential SAR ADC, SINAD 91.7 dB, THD -105 dB 14-bit 600 kSPS/300 kSPS 8-ch pseudo-differential SAR ADC, SINAD 85 dB, THD -105 dB	
ZJC2104/5-18 ZJC2104/5-16	18-bit 400 kSPS/200 kSPS 4-ch pseudo-differential SAR ADC, SINAD 94.2 dB, THD -105 dB 16-bit 500 kSPS/250 kSPS 4-ch pseudo-differential SAR ADC, SINAD 91.7 dB, THD -105 dB	
DAC		
ZJC2541-18/16/14 ZJC2543-18/16/14	18/16/14-bit 1 MSPS single channel DAC with unipolar output	Power on reset to 0 V (ZJC2541) or $V_{REF}/2$ (ZJC2543), 1 nV-S glitch, SOIC-8, MSOP-10/8, DFN-10 packages
ZJC2542-18/16/14 ZJC2544-18/16/14	18/16/14-bit 1 MSPS single channel DAC with bipolar output	Power on reset to 0 V (ZJC2542) or $V_{REF}/2$ (ZJC2544), 1 nV-S glitch, SOIC-14/TSSOP-16/QFN-16 packages
Amplifier		
ZJA3000-1/2/4	Single/Dual/Quad 36 V low bias current precision Op Amps	3 MHz GBW, 35 µV max Vos, 0.5 µV/°C max Vos drift, 25 pA max Ibias, 1 mA/Amplifier, input to V-, RRO, 4.5 V to 36 V
ZJA3001-1/2/4	Single/Dual/Quad 36 V low bias current precision Op Amps	3 MHz GBW, 35 µV max Vos, 0.5 µV/°C max Vos drift, 25 pA max Ibias, 1 mA/Amplifier, RRO, 4.5 V to 36 V
ZJA3512-2/4	Dual/Quad 36 V 7 MHz precision JFET Op Amps	7 MHz GBW, 35 V/µS SR, 50 µV max Vos, 1 µV/°C max Vos drift, 2 mA/Amplifier, RRO, 9 V to 36 V
ZJA3600/1	36 V ultra-high precision in-amp	CMRR 105 dB min (G = 1), 25 pA max Ibias, 25 µV max Vosi, gain error 1 ppm max (G = 1), 3.3 mA Iq, ±2.4 V to ±18 V, -40 °C to 125 °C specified
ZJA3622/8	36 V low-cost precision in-amp	CMRR 93 dB min (G = 10), 0.5 nA max Ibias, 125 µV max Vosi, 625 kHz BW (G = 10), 3.3 mA Iq, ±2.4 V to ±18 V
ZJA3611, ZJA3609	36 V ultra-high precision wider bandwidth precision in-amp (min gain of 10)	CMRR 120 dB min (G = 10), 25 pA max Ibias, 25 µV max Vosi, 1.2 MHz BW (G = 10), 3.3 mA Iq, ±2.4 V to ±18 V, -40 °C to 125 °C specified
ZJA3676/7	Low power, G = 1 Single/Dual 36 V difference amplifier	Input protection to ±65 V, CMRR 104 dB min, Vos 100 µV max, gain error 15 ppm max, 500 kHz BW, 330 µA/channel, 2.7 V to 36 V
ZJA3100	15 V precision fully differential amplifier	145 MHz GBW, 447 V/µS SR, 16-bit settling time 50 nS, 25 µV max Vos, 4.6 mA Iq, 3 V to 15 V, SOIC/MS-8, QFN-16
Voltage Reference		
ZJR1004	40 V supply precision voltage reference	V_{OUT} = 2.048/2.5/3/3.3/4.096/5/10 V, 5 ppm/°C max drift -40 °C to 125 °C
ZJR1000	15 V supply precision voltage reference	V_{OUT} = 1.25/2.048/2.5/3/4.096/5 V, 5 ppm/°C max drift -40 °C to 125 °C
ZJR1001/2 ZJR1003	5.5 V low power voltage reference (ZJR1001 with noise filter option)	V_{OUT} = 2.5/3/4.096/5 V, 5 ppm/°C max drift -40 °C to 125 °C, ±0.05% initial error, 130 µA, ZJR1001/2 in SOT23-6, ZJR1003 in SOIC/MS-8
Switches and Multiplexers		
ZJG4438/4439	36 V fault protection 8:1/dual 4:1 multiplexer	Protection to ± 50 V power on & off, latch-up immune, Ron 270 Ω,14.8 pC charge injection, t_{ON} 166 nS, 10 V to 36 V