



## Description

The TLV9004IDR(quad) is general purpose, low offset, high frequency response and low power operational amplifiers. With an excellent bandwidth of 1MHz, a slew rate of 1V/us, and a quiescent current of 28 uA per amplifier at 5V, the TLV9004IDR can be designed into a wide range of applications.

The TLV9004IDR op-amp is designed to provide optimal performance in low voltage and low power systems. The input common voltage range includes ground, and the maximum input offset voltage is 3mV. This part provides rail-to-rail output swing into heavy loads.

The TLV9004IDR operational amplifier is specified at the full temperature range of -55°C to +125°C under single or dual power supplies of 1.5V to 5.5V.

## Features

- Input Offset Voltage: 1mV(Typical)
- Low Supply Current: 28uA( $V_s=5V$ )
- Supply Range: 1.5V to 5.5V
- Gain Bandwidth: 1MHz( $V_s=5V$ )
- Slew rate: 1V/us( $V_s=5V$ )
- Rail-to-Rail Input and Output
- Low Cost

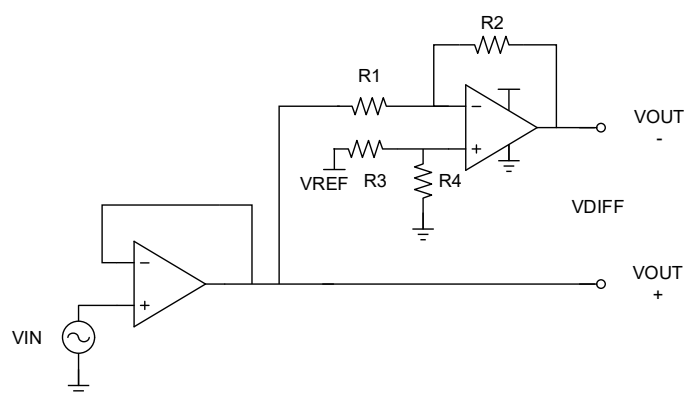
## Applications

- Battery and Power Supply Control
- Audio Outputs
- Smoke/Gas/Environment Sensors
- Portable Equipment and Mobile

### Devices

- Sensor Interfaces
- Active Filters
- Medical Equipment

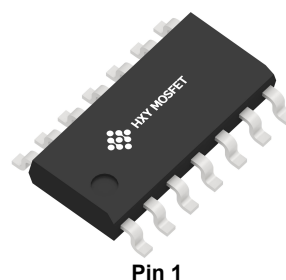
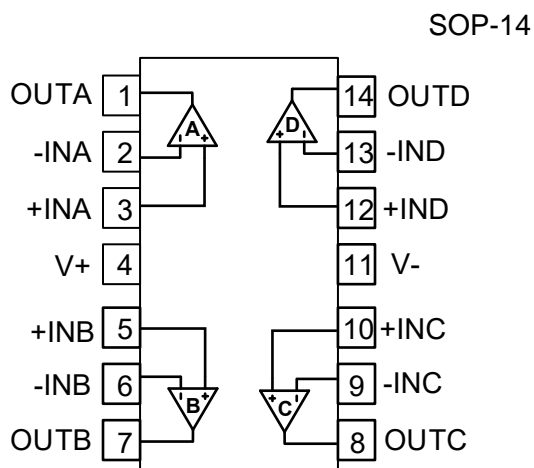
## Typical Application





## Pin Configuration and Functions (Top View)

### Pin Description



### TLV9004IDR

Pin		I/O	Description
Name	Number		
+INA	3	I	Noninverting input, channel A
+INB	5	I	Noninverting input, channel B
+INC	10	I	Noninverting input, channel C
+IND	12	I	Noninverting input, channel D
-INA	2	I	Inverting input, channel A
-INB	6	I	Inverting input, channel B
-INC	9	I	Inverting input, channel C
-IND	13	I	Inverting input, channel D
OUTA	1	O	Output, channel A
OUTB	7	O	Output, channel B
OUTC	8	O	Output, channel C
OUTD	14	O	Output, channel D
V-	4	-	Negative (lowest) power supply
V+	11	-	Positive (highest) power supply



### Absolute Maximum Ratings<sup>(1)</sup>

		Min	Max	Unit
Voltage	Supply Voltage		6	V
	Signal Input Terminals Voltage <sup>(2)</sup>	(V-) - 0.5	(V+) + 0.5	V
	Signal Input Terminals Voltage <sup>(3)</sup>	(V-) - 0.5	(V+) + 0.5	V
Current	Signal Input Terminals Current <sup>(2)</sup>	-10	10	mA
	Signal output Terminals Current <sup>(3)</sup>	-200	200	mA
	Output Short-Circuit <sup>(4)</sup>	Continuous		
$\theta_{JA}$	Operating Temperature Range	-55	125	°C
	Storage Temperature Range	-65	150	°C
	Junction Temperature	-40	150	°C

(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 0.5V beyond the supply rails should be current limited to 10mA or less.

(3) Output terminals are diode-clamped to the power-supply rails. Output signals that can swing more than 0.5V beyond the supply rails should be current-limited to  $\pm 200$ mA or less.

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

### ESD Ratings

			Value	Unit
$V_{(ESD)}$	Electrostatic discharge	Human-Body Model (HBM)	$\pm 2000$	V
		Charged-Device Model (CDM)	$\pm 500$	V
		Machine Model	100	V

### Recommended Operating Conditions

		Min	Max	Unit
Supply voltage, $V_S = (V+) - (V-)$	Single-supply	1.5	5.5	V
	Dual-supply	$\pm 0.75$	$\pm 2.75$	V



### Electrical Characteristics ( $V_S = +5V$ )

At  $T_A = 25^\circ C$ ,  $V_{CM}=V_{OUT}= V_S /2$ , unless otherwise noted.

Parameter		Conditions	Min	Typ	Max	Unit
Offset Voltage						
$V_{OS}$	Input Offset Voltage		-3	$\pm 1$	3	mV
$dV_{OS}/dT$	Input Offset Voltage Average Drift	$T_A = -55^\circ C$ to $125^\circ C$		1.8		$\mu V/^\circ C$
Input Current						
$I_B$	Input Bias Current			5		pA
$I_{OS}$	Input Offset Current			1		pA
Noise						
$V_N$	Input Voltage Noise	$f=0.1Hz$ to $10Hz$		20		$\mu V_{PP}$
$e_n$	Input Voltage Noise Density	$f=1kHz$		65		$nV/\sqrt{Hz}$
Input Voltage						
$V_{CM}$	Common-Mode Voltage Range		$V_S-0.1$		$V_S+0.1$	V
CMRR	Common-Mode Rejection Ratio	$V_{CM}=0.1V$ to $4V$	70	80		dB
Frequency Response						
GBW	Gain-Bandwidth Product			1		MHz
SR	Slew Rate	$G = +1$ , $V_{IN}=2V$ Step		1		V/us
$t_s$	Settling Time to 0.1%	$G = +1$ , $V_{IN}=2V$ Step		2.5		us
Output						
$A_V$	Open-Loop Voltage Gain	$V_{OUT}=0.1V$ to $4.9V$ $R_L=100k\Omega$	80	100		dB
$V_{OUT-SWING}$	Output Swing from Rail	$R_L=100k\Omega$			5	mV
$I_{SC}$	Output Short-Circuit Current	Source current		45		mA
		Sink current		70		mA
$C_L^{(1)}$	Capacitive Load Drive	$G = +1$ , $V_{IN}=0.2V$ Step			1000	pF



Power Supply						
PSRR	Power-Supply Rejection Ratio	$V_S=1.5V$ to $5.5V$	80	90		dB
$V_S$	Operating Voltage Range		1.5		5.5	V
$I_Q$	Quiescent Current/Amplifier	$I_O=0A$		28	40	$\mu A$

(1) Capacitive load drive means that above a given maximum value, the output waveform will oscillate under the step response.



## Typical Characteristics

At  $T_A = 25^\circ\text{C}$ ,  $V_S = +5\text{V}$ ,  $G=+1$ ,  $V_{IN}=V_{OUT}= V_S / 2$ , unless otherwise noted.

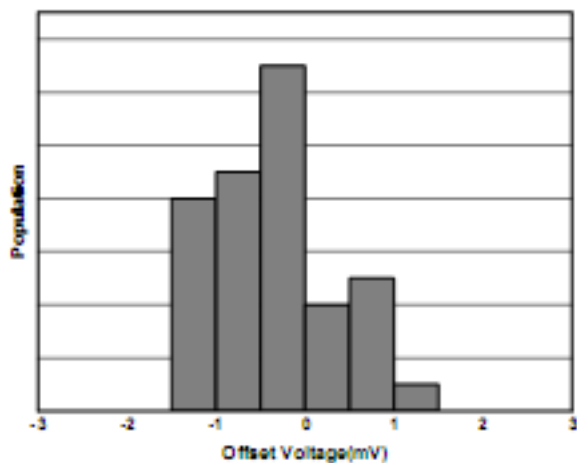


Figure 2. Offset Voltage Production Distribution

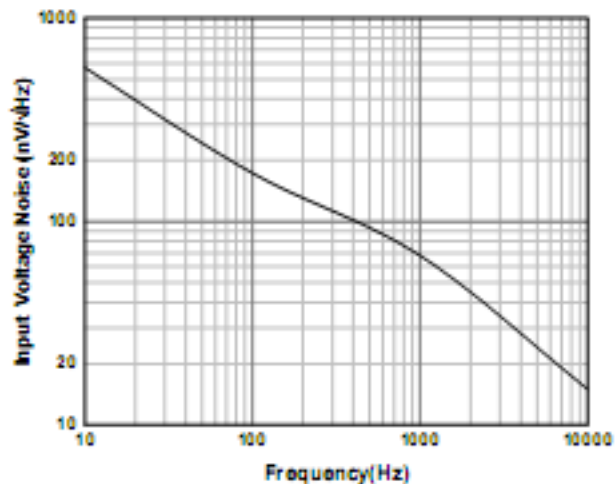


Figure 3. Input Voltage Noise Spectral Density

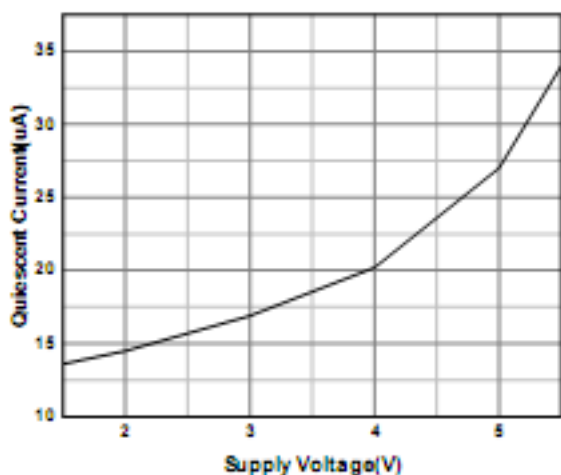


Figure 4. Quiescent Current vs Supply Voltage

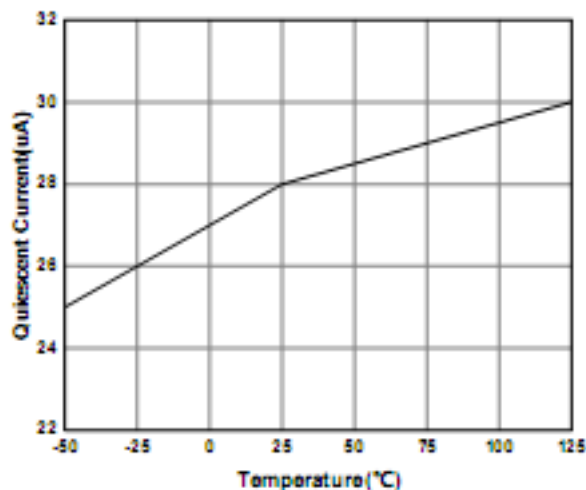


Figure 5. Quiescent Current vs Temperature

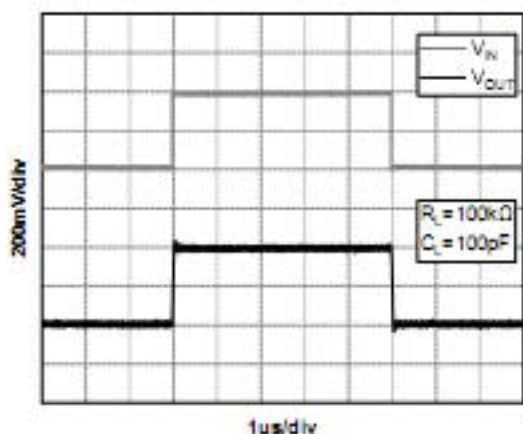


Figure 6. Small-Signal Step Response( $V_S=5\text{V}$ )



Figure 7. Large-Signal Step Response( $V_S=5\text{V}$ )

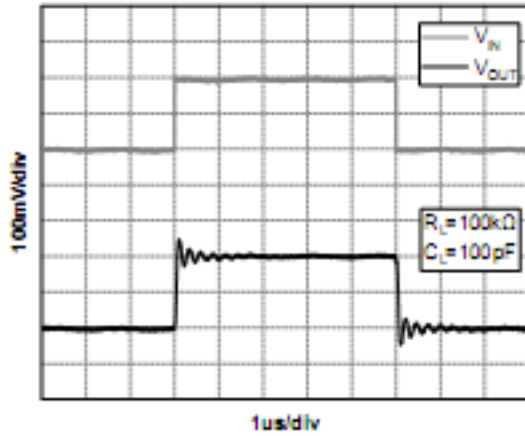


Figure 8. Small-Signal Step Response( $V_S=1.5V$ )

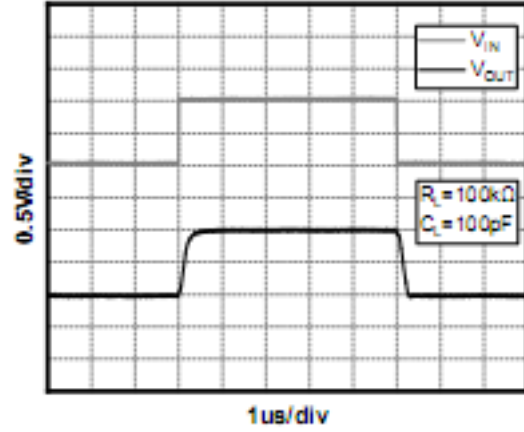


Figure 9. Large-Signal Step Response( $V_S=1.5V$ )

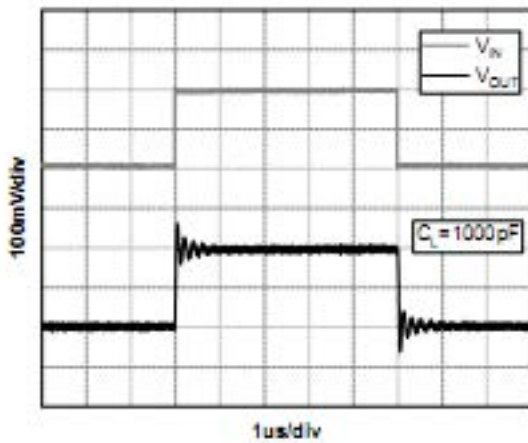


Figure 10. Capacitive Load Drive( $C_L=1000pF$ )

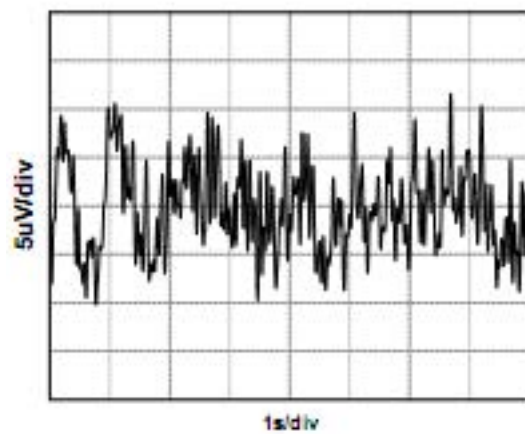


Figure 11. 0.1Hz to 10Hz Noise



## Detailed Description

### Overview

The TLV9004IDR device is a low power, unity-gain stable, rail-to-rail operational amplifier that operate in a single-supply voltage range of 1.5V to 5.5V ( $\pm 0.75\text{V}$  to  $\pm 2.75\text{V}$ ). A high supply voltage of 6V (absolute maximum) can permanently damage the amplifier. Rail-to-rail input and output wobbles significantly increase the dynamic range, especially in low-supply applications. Good layout practices require that a 0.1 $\mu\text{F}$  capacitor be used where it is tightly threaded through the power supply pin.

### Phase Reversal Protection

The TLV9004IDR device have internal phase-reversal protection. Many op amps exhibit phase reversal when the input is driven beyond the linear common-mode range. This condition is most often encountered in noninverting circuits when the input is driven beyond the specified common-mode voltage range, causing the output to reverse into the opposite rail. The input of the TLV9004IDR prevents phase reversal with excessive commonmode voltage. Instead, the appropriate rail limits the output voltage.

## Typical Applications

### 1 Voltage Follower

As shown in Figure 12, the voltage gain is 1. With this circuit, the output voltage  $V_{\text{OUT}}$  is configured to be equal to the input voltage  $V_{\text{IN}}$ . Due to the high input impedance and low output impedance, the circuit can also stabilize the output voltage, the output voltage expression is

$$V_{\text{OUT}} = V_{\text{IN}}$$

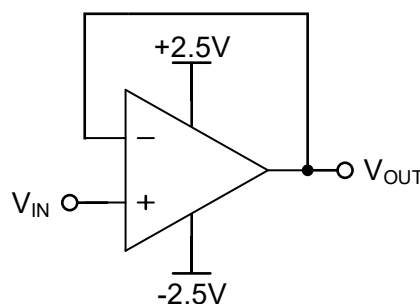


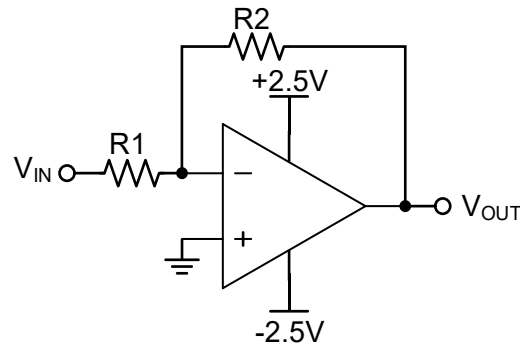
Figure 12. Voltage Follower

### 2 Inverting Proportional Amplifier

As shown in Figure 13, for a reverse-phase proportional amplifier, the input voltage  $V_{\text{IN}}$  is amplified by a voltage gain that depends on the ratio of  $R_1$  to  $R_2$ . The output voltage  $V_{\text{OUT}}$  is inversely with the input voltage  $V_{\text{IN}}$ . The input impedance of the circuit is equal to  $R_1$ , and the output voltage expression is

$$V_{\text{OUT}} = -\frac{R_2}{R_1} V_{\text{IN}}$$



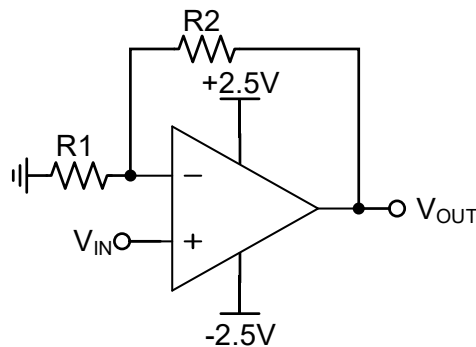


**Figure 13. Inverting Proportional Amplifier**

### 3 Noninverting Proportional Amplifier

As shown in Figure 14, for a noninverting amplifier, the input voltage  $V_{IN}$  is amplified by a voltage gain that depends on the ratio of  $R1$  to  $R2$ . The output voltage  $V_{OUT}$  is in phase with the input voltage  $V_{IN}$ . In fact, this circuit has a high input impedance because its input side is the same as the input side of the operational amplifier. The output voltage expression is

$$V_{OUT} = \left(1 + \frac{R2}{R1}\right) V_{IN}$$



**Figure 14. Noninverting Proportional Amplifier**

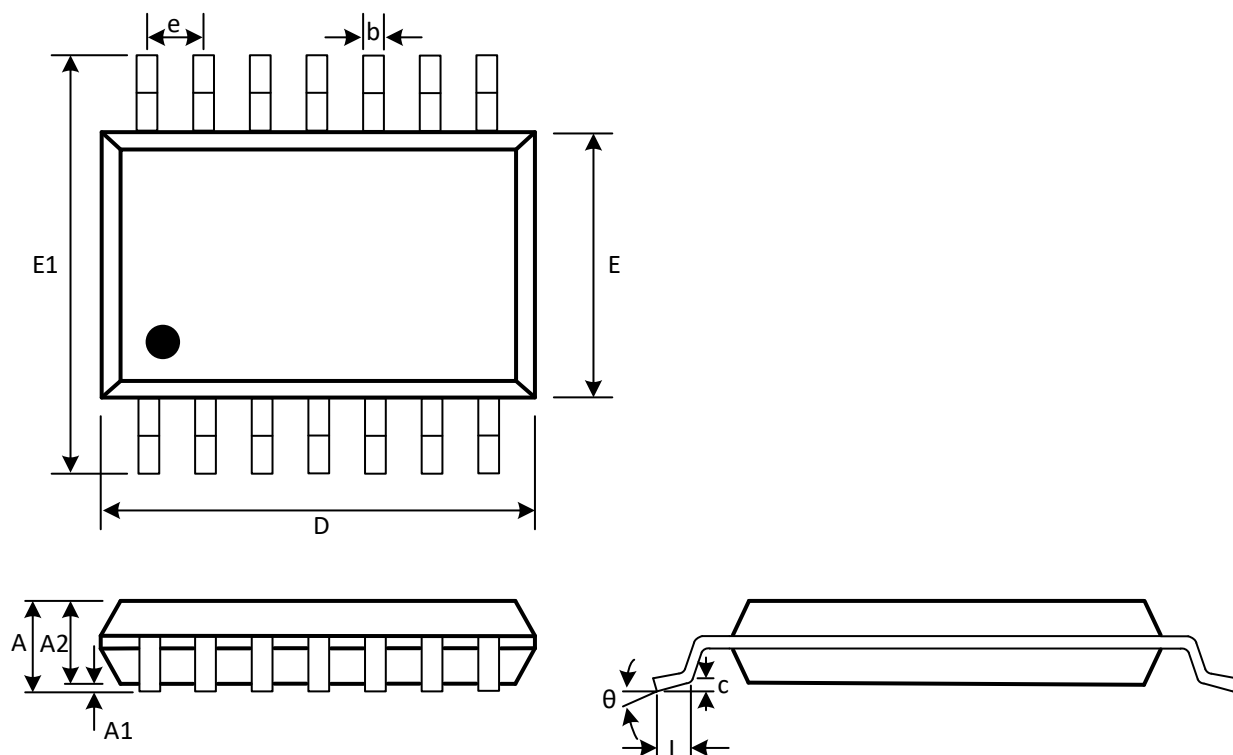
### Layout Guidelines

Attention to good layout practices is always recommended. Keep traces short. When possible, use a PCB ground plane with surface-mount components placed as close to the device pins as possible. Place a 0.1uF 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 EMI susceptibility.



## Package Outline Dimensions SOP-14



(Unit: mm)

Symbol	Min	Max
A	1.350	1.750
A1	0.100	0.250
A2	1.350	1.550
b	0.310	0.510
c	0.100	0.250
D	8.450	8.850
e	1.270(BSC)	
E	5.800	6.200
E1	3.800	4.000
L	0.400	1.270
$\theta$	0°	8°



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