

## LM358 Dual Operational Amplifiers

### 1 Features

- Wide Supply Ranges
  - Single Supply: 3 V to 32 V (26 V for LM2904)
  - Dual Supplies:  $\pm 1.5$  V to  $\pm 16$  V ( $\pm 13$  V for LM2904)
- Low Supply-Current Drain, Independent of Supply Voltage: 0.7 mA Typical
- Wide Unity Gain Bandwidth: 0.7 MHz
- Common-Mode Input Voltage Range Includes Ground, Allowing Direct Sensing Near Ground
- Low Input Bias and Offset Parameters
  - Input Offset Voltage: 3 mV Typical  
A Versions: 2 mV Typical
  - Input Offset Current: 2 nA Typical
  - Input Bias Current: 20 nA Typical  
A Versions: 15 nA Typical
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage: 32 V (26 V for LM2904)
- Open-Loop Differential Voltage Gain: 100 dB Typical
- Internal Frequency Compensation
- On Products Compliant to MIL-PRF-38535, All Parameters are Tested Unless Otherwise Noted. On All Other Products, Production Processing Does Not Necessarily Include Testing of All Parameters.

### 2 Applications

- Blu-ray Players and Home Theaters
- Chemical and Gas Sensors
- DVD Recorder and Players
- Digital Multimeter: Bench and Systems
- Digital Multimeter: Handhelds
- Field Transmitter: Temperature Sensors
- Motor Control: AC Induction, Brushed DC, Brushless DC, High-Voltage, Low-Voltage, Permanent Magnet, and Stepper Motor
- Oscilloscopes
- TV: LCD and Digital
- Temperature Sensors or Controllers Using Modbus
- Weigh Scales

### 3 Description

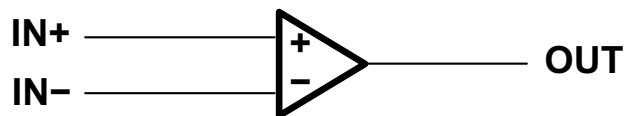
These devices consist of two independent, high-gain frequency-compensated operational amplifiers designed to operate from a single supply or split supply over a wide range of voltages.

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

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LMx58, LMx58x, LM2904, LM2904V	VSSOP (8)	3.00 mm x 3.00 mm
	SOIC (8)	4.90 mm x 3.90 mm
	SO (8)	5.20 mm x 5.30 mm
	TSSOP (8)	3.00 mm x 4.40 mm
	PDIP (8)	9.81 mm x 6.35 mm
LMx58, LMx58x, LM2904V	CDIP (8)	9.60 mm x 6.67 mm
	LCCC (20)	8.89 mm x 8.89 mm

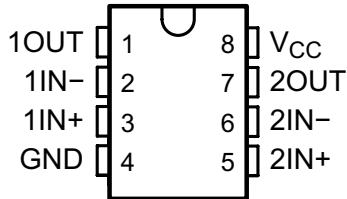
(1) For all available packages, see the orderable addendum at the end of the data sheet.

#### Symbol (Each Amplifier)

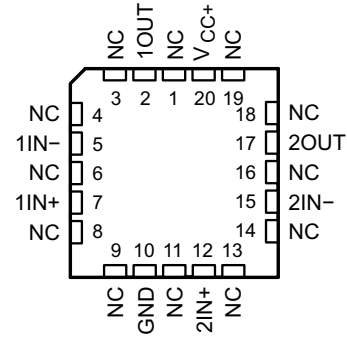


## 5 Pin Configuration and Functions

D, DGK, P, PS, PW and JG Package  
8-Pin SOIC, VSSOP, PDIP, SO, TSSOP and CDIP  
(Top View)



FK Package  
20-Pin LCCC  
(Top View)



NC - No internal connection

### Pin Functions

NAME	PIN		I/O	DESCRIPTION
	LCCC NO.	SOIC, SSOP, CDIP, PDIP, SO, TSSOP, CFP NO.		
1IN-	5	2	I	Negative input
1IN+	7	3	I	Positive input
1OUT	2	1	O	Output
2IN-	15	6	I	Negative input
2IN+	12	5	I	Positive input
2OUT	17	7	O	Output
GND	10	4	—	Ground
NC	1	—	—	Do not connect
	3			
	4			
	6			
	8			
	9			
	11			
	13			
	14			
	16			
18				
19				
V <sub>CC</sub>	—	8	—	Power supply
V <sub>CC+</sub>	20	—	—	Power supply

## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

		LMx58, LMx58x, LM2904V		LM2904		UNIT
		MIN	MAX	MIN	MAX	
$V_{CC}$	Supply voltage <sup>(2)</sup>	-0.3	±16 or 32	-0.3	±13 or 26	V
$V_{ID}$	Differential input voltage <sup>(3)</sup>	-32	32	-26	26	V
$V_I$	either input Input voltage	-0.3	32	-0.3	26	V
Duration of output short circuit (one amplifier) to ground at (or below) $T_A = 25^\circ\text{C}$ , $V_{CC} \leq 15\text{ V}$ <sup>(4)</sup>		Unlimited		Unlimited		s
$T_A$	Operating free air temperature	LM158, LM158A	-55	125		°C
		LM258, LM258A	-25	85		
		LM358, LM358A	0	70		
		LM2904	-40	125	-40	
$T_J$	Operating virtual junction temperature	150		150		°C
	Case temperature for 60 seconds	FK package	260			°C
	Lead temperature 1.6 mm (1/16 inch) from case for 60 seconds	JG package	300		300	°C
$T_{stg}$	Storage temperature	-65	150	-65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values (except differential voltages and  $V_{CC}$  specified for the measurement of  $I_{OS}$ ) are with respect to the network GND.
- (3) Differential voltages are at IN+, with respect to IN-.
- (4) Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.

### 6.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±500
		Charged-device model (CDM), per JEDEC specification JESD22-C101	±1000

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

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

		LMx58, LMx58x, LM2904V		LM2904		UNIT	
		MIN	MAX	MIN	MAX		
$V_{CC}$	Supply voltage	3	30	3	26	V	
$V_{CM}$	Common-mode voltage	0	$V_{CC} - 2$	0	$V_{CC} - 2$	V	
$T_A$	Operating free air temperature	LM158	-55	125		°C	
		LM2904	-40	125	-40		125
		LM358	0	70			
		LM258	-25	85			

## 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		LMx58, LMx58x, LM2904V, LM2904					LMx58, LMx58x, LM2904 V	LMx58, LMx58x, LM2904 V	UNIT
		D (SOIC)	DGK (VSSOP)	P (PDIP)	PS (SO)	PW (TSSOP)	FK (LCCC)	JG (CDIP)	
		8 PINS	8 PINS	8 PINS	8 PINS	8 PINS	20 PINS	8 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	97	172	85	95	149	—	—	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	72.2	—	—	—	—	5.61	14.5	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

## 6.5 Electrical Characteristics for LMx58

at specified free-air temperature, V<sub>CC</sub> = 5 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>(1)</sup>	T <sub>A</sub> <sup>(2)</sup>	LM158 LM258			LM358			UNIT
			MIN	TYP <sup>(3)</sup>	MAX	MIN	TYP <sup>(3)</sup>	MAX	
V <sub>IO</sub>	Input offset voltage	V <sub>CC</sub> = 5 V to MAX, V <sub>IC</sub> = V <sub>ICR(min)</sub> , V <sub>O</sub> = 1.4 V	25°C	3	5	3	7	mV	
			Full range		7		9		
αV <sub>IO</sub>	Average temperature coefficient of input offset voltage		Full range	7		7		μV/°C	
I <sub>IO</sub>	Input offset current	V <sub>O</sub> = 1.4 V	25°C	2	30	2	50	nA	
			Full range		100		150		
αI <sub>IO</sub>	Average temperature coefficient of input offset current		Full range	10		10		pA/°C	
I <sub>IB</sub>	Input bias current	V <sub>O</sub> = 1.4 V	25°C	-20	-150	-20	-250	nA	
			Full range		-300		-500		
V <sub>ICR</sub>	Common-mode input voltage range	V <sub>CC</sub> = 5 V to MAX	25°C	0 to V <sub>CC</sub> - 1.5		0 to V <sub>CC</sub> - 1.5		V	
			Full range	0 to V <sub>CC</sub> - 2		0 to V <sub>CC</sub> - 2			
V <sub>OH</sub>	High-level output voltage	R <sub>L</sub> ≥ 2 kΩ	25°C	V <sub>CC</sub> - 1.5			V <sub>CC</sub> - 1.5		V
		R <sub>L</sub> ≥ 10 kΩ	25°C						
		V <sub>CC</sub> = MAX	R <sub>L</sub> = 2 kΩ	Full range	26		26		
			R <sub>L</sub> ≥ 10 kΩ	Full range	27	28	27	28	
V <sub>OL</sub>	Low-level output voltage	R <sub>L</sub> ≤ 10 kΩ	Full range	5	20	5	20	mV	
A <sub>VD</sub>	Large-signal differential voltage amplification	V <sub>CC</sub> = 15 V V <sub>O</sub> = 1 V to 11 V, R <sub>L</sub> ≥ 2 kΩ	25°C	50	100	25	100	V/mV	
			Full range	25		15			
CMRR	Common-mode rejection ratio	V <sub>CC</sub> = 5 V to MAX, V <sub>IC</sub> = V <sub>ICR(min)</sub>	25°C	70	80	65	80	dB	
k <sub>SVR</sub>	Supply-voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> )	V <sub>CC</sub> = 5 V to MAX	25°C	65	100	65	100	dB	
V <sub>O1</sub> /V <sub>O2</sub>	Crosstalk attenuation	f = 1 kHz to 20 kHz	25°C	120			120		dB
I <sub>O</sub>	Output current	V <sub>CC</sub> = 15 V, V <sub>ID</sub> = 1 V, V <sub>O</sub> = 0	Source	25°C	-20	-30	-20	-30	mA
			Full range	-10		-10			
		Sink	25°C	10	20	10	20		
			Full range	5		5			
		V <sub>ID</sub> = -1 V, V <sub>O</sub> = 200 mV	25°C	12	30	12	30	μA	
I <sub>OS</sub>	Short-circuit output current	V <sub>CC</sub> at 5 V, GND at -5 V, V <sub>O</sub> = 0	25°C	±40	±60	±40	±60	mA	
I <sub>CC</sub>	Supply current (two amplifiers)	V <sub>O</sub> = 2.5 V, No load	Full range	0.7	1.2	0.7	1.2	mA	
		V <sub>CC</sub> = MAX, V <sub>O</sub> = 0.5 V <sub>CC</sub> , No load	Full range	1	2	1	2		

- (1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX V<sub>CC</sub> for testing purposes is 26 V for LM2902 and 30 V for the others.  
(2) Full range is -55°C to 125°C for LM158, -25°C to 85°C for LM258, and 0°C to 70°C for LM358, and -40°C to 125°C for LM2904.  
(3) All typical values are at T<sub>A</sub> = 25°C

## 6.6 Electrical Characteristics for LM2904

 at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>(1)</sup>		$T_A$ <sup>(2)</sup>	LM2904			UNIT
				MIN	TYP <sup>(3)</sup>	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V to MAX,}$ $V_{IC} = V_{ICR(min)},$ $V_O = 1.4\text{ V}$	Non-A-suffix devices	25°C	3	7	mV	
			Full range		10		
		A-suffix devices	25°C	1	2		
			Full range		4		
$\alpha V_{IO}$ Average temperature coefficient of input offset voltage			Full range	7		$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$ Input offset current	$V_O = 1.4\text{ V}$	Non-V device	25°C	2	50	nA	
			Full range		300		
		V-suffix device	25°C	2	50		
			Full range		150		
$\alpha I_{IO}$ Average temperature coefficient of input offset current			Full range	10		$\text{pA}/^\circ\text{C}$	
$I_{IB}$ Input bias current	$V_O = 1.4\text{ V}$		25°C	-20	-250	nA	
			Full range		-500		
$V_{ICR}$ Common-mode input voltage range	$V_{CC} = 5\text{ V to MAX}$		25°C	0 to $V_{CC} - 1.5$		V	
			Full range	0 to $V_{CC} - 2$			
$V_{OH}$ High-level output voltage	$R_L \geq 10\text{ k}\Omega$	$V_{CC} = \text{MAX, Non-V device}$	$R_L = 2\text{ k}\Omega$	Full range	22	V	
			$R_L \geq 10\text{ k}\Omega$	Full range	23		24
	$V_{CC} = \text{MAX, V-suffix device}$	$R_L = 2\text{ k}\Omega$	Full range	26			
		$R_L \geq 10\text{ k}\Omega$	Full range	27	28		
$V_{OL}$ Low-level output voltage	$R_L \leq 10\text{ k}\Omega$		Full range	5	20	mV	
$A_{VD}$ Large-signal differential voltage amplification	$V_{CC} = 15\text{ V,}$ $V_O = 1\text{ V to }11\text{ V,}$ $R_L \geq 2\text{ k}\Omega$		25°C	25	100	V/mV	
			Full range	15			
CMRR Common-mode rejection ratio	$V_{CC} = 5\text{ V to MAX,}$ $V_{IC} = V_{ICR(min)}$	Non-V device	25°C	50	80	dB	
		V-suffix device	25°C	65	80		
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC} / \Delta V_{IO}$ )	$V_{CC} = 5\text{ V to MAX}$		25°C	65	100	dB	
$V_{O1} / V_{O2}$ Crosstalk attenuation	$f = 1\text{ kHz to }20\text{ kHz}$		25°C		120	dB	
$I_O$ Output current	$V_{CC} = 15\text{ V,}$ $V_{ID} = 1\text{ V,}$ $V_O = 0$	Source	25°C	-20	-30	mA	
			Full range		-10		
	$V_{CC} = 15\text{ V,}$ $V_{ID} = -1\text{ V,}$ $V_O = 15\text{ V}$	Sink	25°C	10	20		
			Full range		5		
$V_{ID} = -1\text{ V, } V_O = 200\text{ mV}$	Non-V device	25°C		30	$\mu\text{A}$		
	V-suffix device	25°C		12		40	
$I_{OS}$ Short-circuit output current	$V_{CC}$ at 5 V, $V_O = 0$ , GND at -5 V		25°C	$\pm 40$	$\pm 60$	mA	
$I_{CC}$ Supply current (four amplifiers)	$V_O = 2.5\text{ V, No load}$		Full range	0.7	1.2	mA	
	$V_{CC} = \text{MAX, } V_O = 0.5 V_{CC}, \text{ No load}$		Full range	1	2		

- (1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX  $V_{CC}$  for testing purposes is 26 V for LM2902 and 32 V for LM2902V.
- (2) Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for LM158,  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for LM258,  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for LM358, and  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for LM2904.
- (3) All typical values are at  $T_A = 25^\circ\text{C}$ .

## 6.7 Electrical Characteristics for LM158A and LM258A

 at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>(1)</sup>	$T_A$ <sup>(1)</sup>	LM158A			LM258A			UNIT
			MIN	TYP <sup>(2)</sup>	MAX	MIN	TYP <sup>(2)</sup>	MAX	
$V_{IO}$ Input offset voltage	$V_{CC} = 5\text{ V to }30\text{ V,}$ $V_{IC} = V_{ICR(min)},$ $V_O = 1.4\text{ V}$	25°C			2		2	3	mV
		Full range			4			4	

- (1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX  $V_{CC}$  for testing purposes is 26 V for LM2904 and 30 V for others.
- (2) All typical values are at  $T_A = 25^\circ\text{C}$ .

**Electrical Characteristics for LM158A and LM258A (continued)**

 at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>(1)</sup>	$T_A$ <sup>(1)</sup>	LM158A			LM258A			UNIT		
			MIN	TYP <sup>(2)</sup>	MAX	MIN	TYP <sup>(2)</sup>	MAX			
$\alpha V_{IO}$	Average temperature coefficient of input offset voltage	Full range		7	15 <sup>(3)</sup>		7	15	$\mu\text{A}/^\circ\text{C}$		
$I_{IO}$	Input offset current	25°C		2	10		2	15	nA		
		Full range			30			30			
$\alpha I_{IO}$	Average temperature coefficient of input offset current	Full range		10	200		10	200	$\text{pA}/^\circ\text{C}$		
$I_{IB}$	Input bias current	25°C		-15	-50		-15	-80	nA		
		Full range			-100			-100			
$V_{ICR}$	Common-mode input voltage range	25°C		0 to $V_{CC} - 1.5$			0 to $V_{CC} - 1.5$		V		
		Full range		0 to $V_{CC} - 2$			0 to $V_{CC} - 2$				
$V_{OH}$	High-level output voltage	$R_L \geq 2\text{ k}\Omega$	25°C	$V_{CC} - 1.5$			$V_{CC} - 1.5$			V	
		$V_{CC} = 30\text{ V}$	$R_L = 2\text{ k}\Omega$	Full range	26			26			
			$R_L \geq 10\text{ k}\Omega$	Full range	27	28		27	28		
$V_{OL}$	Low-level output voltage	$R_L \leq 10\text{ k}\Omega$	Full range		5	20		5	20	mV	
$A_{VD}$	Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$ , $V_O = 1\text{ V to } 11\text{ V}$ , $R_L \geq 2\text{ k}\Omega$	25°C	50	100		50	100	V/mV		
			Full range	25			25				
CMRR	Common-mode rejection ratio	25°C	70	80		70	80	dB			
$k_{SVR}$	Supply-voltage rejection ratio ( $\Delta V_D / \Delta V_{IO}$ )	25°C	65	100		65	100	dB			
$V_{O1} / V_{O2}$	Crosstalk attenuation	$f = 1\text{ kHz to } 20\text{ kHz}$	25°C		120			120	dB		
$I_O$	Output current	$V_{CC} = 15\text{ V}$ , $V_{ID} = 1\text{ V}$ , $V_O = 0$	Source	25°C	-20	-30	-60	-20	-30	-60	mA
			Full range		-10			-10			
		Sink	25°C	10	20		10	20			
			Full range	5			5				
	$V_{ID} = -1\text{ V}$ , $V_O = 200\text{ mV}$	25°C	12	30		12	30	$\mu\text{A}$			
$I_{OS}$	Short-circuit output current	$V_{CC}$ at 5 V, GND at -5 V, $V_O = 0$	25°C	$\pm 40$	$\pm 60$		$\pm 40$	$\pm 60$	mA		
$I_{CC}$	Supply current (four amplifiers)	$V_O = 2.5\text{ V}$ , No load	Full range		0.7	1.2		0.7	1.2	mA	
		$V_{CC} = \text{MAX V}$ , $V_O = 0.5\text{ V}$ , No load	Full range		1	2		1	2		

(3) On products compliant to MIL-PRF-38535, this parameter is not production tested.

**6.8 Electrical Characteristics for LM358A**

 at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>(1)</sup>	$T_A$ <sup>(2)</sup>	LM358A			UNIT
			MIN	TYP <sup>(3)</sup>	MAX	
$V_{IO}$	$V_{CC} = 5\text{ V to } 30\text{ V}$ , $V_{IC} = V_{ICR(\text{min})}$ , $V_O = 1.4\text{ V}$	25°C		2	3	mV
		Full range			5	
$\alpha V_{IO}$	Average temperature coefficient of input offset voltage	Full range		7	20	$\mu\text{A}/^\circ\text{C}$
$I_{IO}$	Input offset current	25°C		2	30	nA
		Full range			75	
$\alpha I_{IO}$	Average temperature coefficient of input offset current	Full range		10	300	$\text{pA}/^\circ\text{C}$

 (1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX  $V_{CC}$  for testing purposes is 26 V for LM2904 and 30 V for others.

 (2) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX  $V_{CC}$  for testing purposes is 26 V for LM2904 and 30 V for others.

 (3) All typical values are at  $T_A = 25^\circ\text{C}$ .

**Electrical Characteristics for LM358A (continued)**

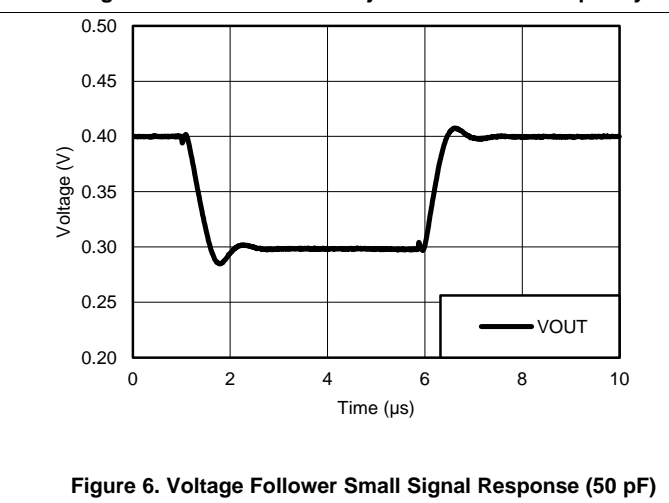
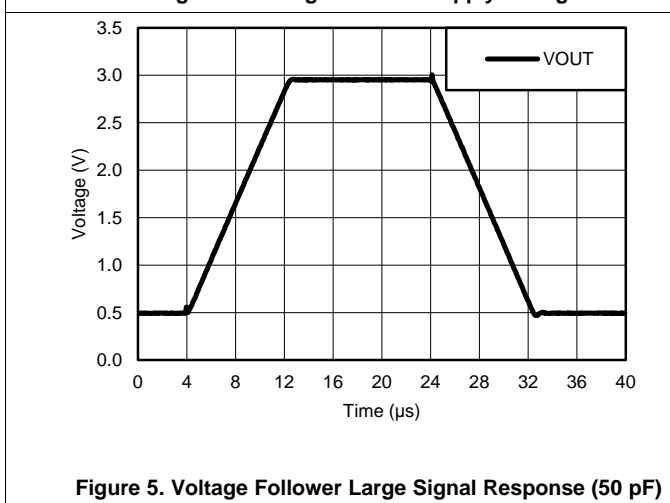
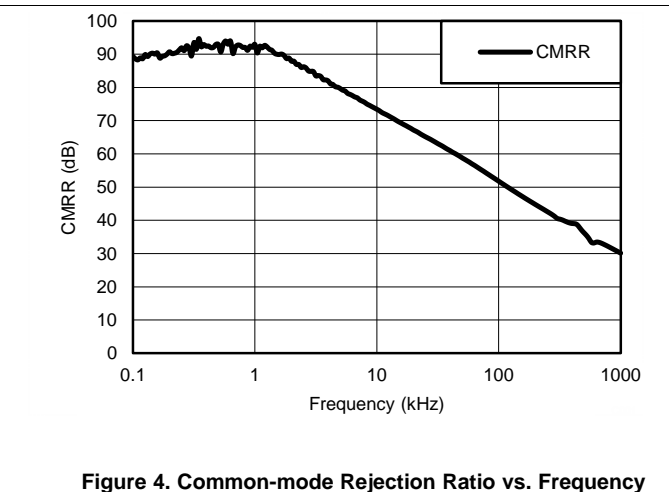
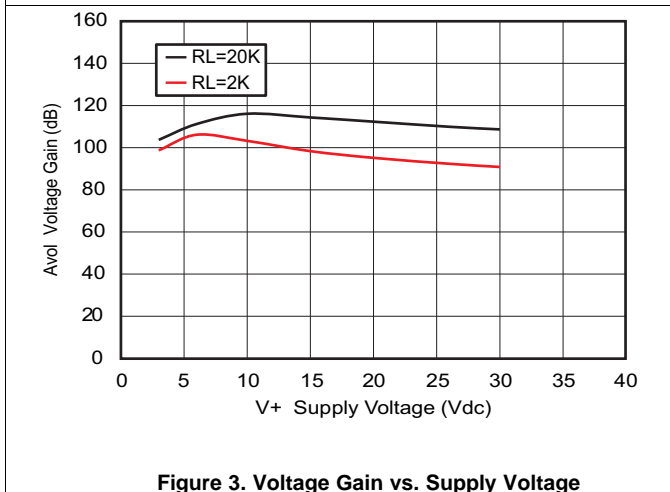
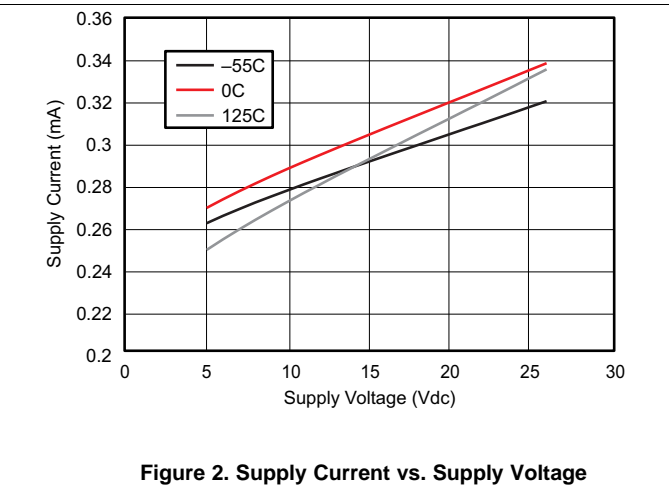
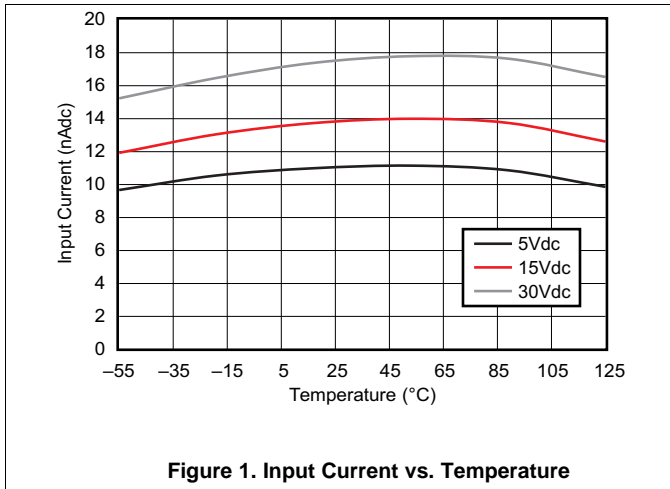
 at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS <sup>(1)</sup>	$T_A$ <sup>(2)</sup>	LM358A			UNIT		
			MIN	TYP <sup>(3)</sup>	MAX			
$I_{IB}$	Input bias current $V_O = 1.4\text{ V}$	25°C		-15	-100	nA		
		Full range			-200			
$V_{ICR}$	Common-mode input voltage range $V_{CC} = 30\text{ V}$	25°C	0 to $V_{CC} - 1.5$			V		
		Full range	0 to $V_{CC} - 2$					
$V_{OH}$	High-level output voltage $R_L \geq 2\text{ k}\Omega$ $V_{CC} = 30\text{ V}$	25°C	$V_{CC} - 1.5$			V		
		Full range	$R_L = 2\text{ k}\Omega$	26				
			$R_L \geq 10\text{ k}\Omega$	27	28			
$V_{OL}$	Low-level output voltage $R_L \leq 10\text{ k}\Omega$	Full range		5	20	mV		
$A_{VD}$	Large-signal differential voltage amplification $V_{CC} = 15\text{ V}$ , $V_O = 1\text{ V}$ to $11\text{ V}$ , $R_L \geq 2\text{ k}\Omega$	25°C	25	100		V/mV		
		Full range	15					
CMRR	Common-mode rejection ratio	25°C	65	80		dB		
$k_{SVR}$	Supply-voltage rejection ratio ( $\Delta V_{DD} / \Delta V_{IO}$ )	25°C	65	100		dB		
$V_{O1} / V_{O2}$	Crosstalk attenuation	$f = 1\text{ kHz}$ to $20\text{ kHz}$	25°C	120		dB		
$I_O$	Output current	$V_{CC} = 15\text{ V}$ , $V_{ID} = 1\text{ V}$ , $V_O = 0$	Source	25°C	-20	-30	-60	mA
			Full range	-10				
		$V_{CC} = 15\text{ V}$ , $V_{ID} = -1\text{ V}$ , $V_O = 15\text{ V}$	Sink	25°C	10	20		
			Full range	5				
$I_{OS}$	Short-circuit output current $V_{CC}$ at $5\text{ V}$ , GND at $-5\text{ V}$ , $V_O = 0$	25°C		$\pm 40$	$\pm 60$	mA		
$I_{CC}$	Supply current (four amplifiers)	$V_O = 2.5\text{ V}$ , No load	Full range	0.7	1.2	mA		
		$V_{CC} = \text{MAX V}$ , $V_O = 0.5\text{ V}$ , No load	Full range	1	2			

**6.9 Operating Conditions**
 $V_{CC} = \pm 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$ 

PARAMETER	TEST CONDITIONS	TYP	UNIT
SR Slew rate at unity gain	$R_L = 1\text{ M}\Omega$ , $C_L = 30\text{ pF}$ , $V_I = \pm 10\text{ V}$ (see Figure 11)	0.3	V/ $\mu\text{s}$
$B_1$ Unity-gain bandwidth	$R_L = 1\text{ M}\Omega$ , $C_L = 20\text{ pF}$ (see Figure 11)	0.7	MHz
$V_n$ Equivalent input noise voltage	$R_S = 100\ \Omega$ , $V_I = 0\text{ V}$ , $f = 1\text{ kHz}$ (see Figure 12)	40	nV/ $\sqrt{\text{Hz}}$

6.10 Typical Characteristics





Typical Characteristics (continued)

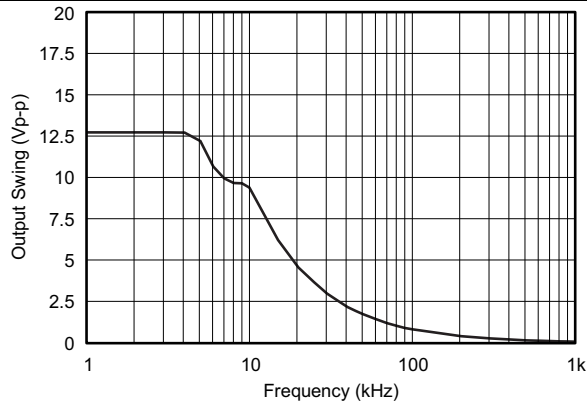


Figure 7. Maximum Output Swing vs. Frequency ( $V_{CC} = 15\text{ V}$ )

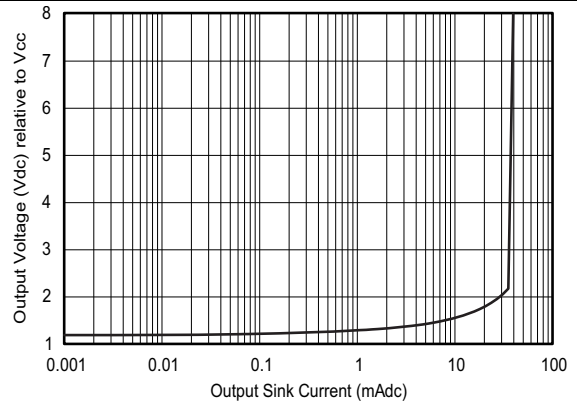


Figure 8. Output Sourcing Characteristics

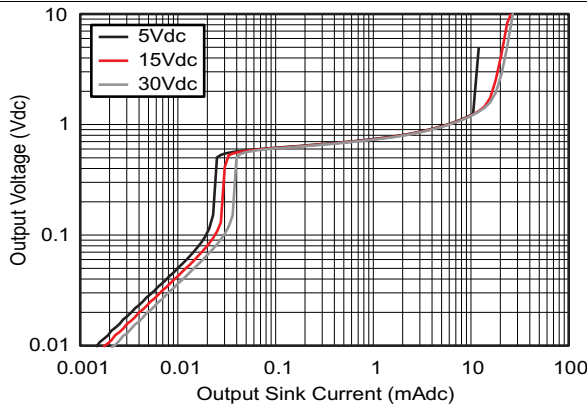


Figure 9. Output Sinking Characteristics

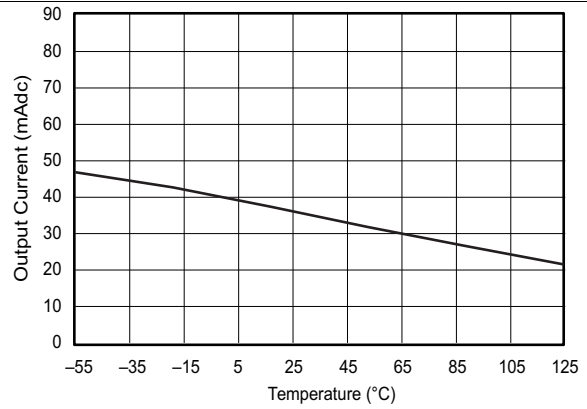


Figure 10. Source Current Limiting

## 7 Parameter Measurement Information

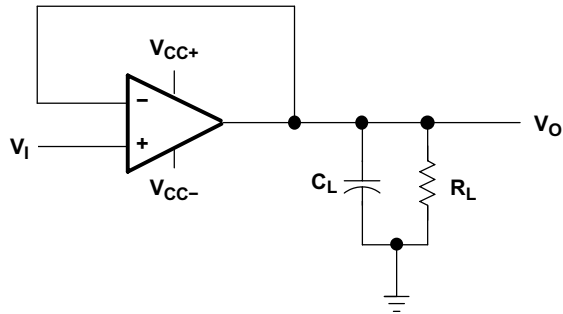


Figure 11. Unity-Gain Amplifier

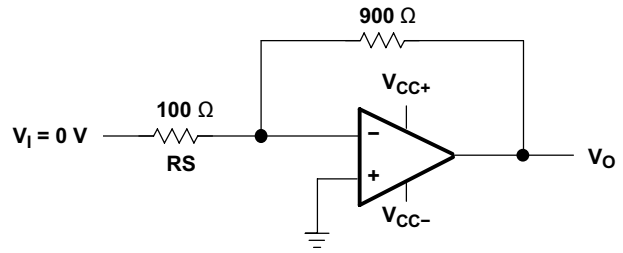


Figure 12. Noise-Test Circuit

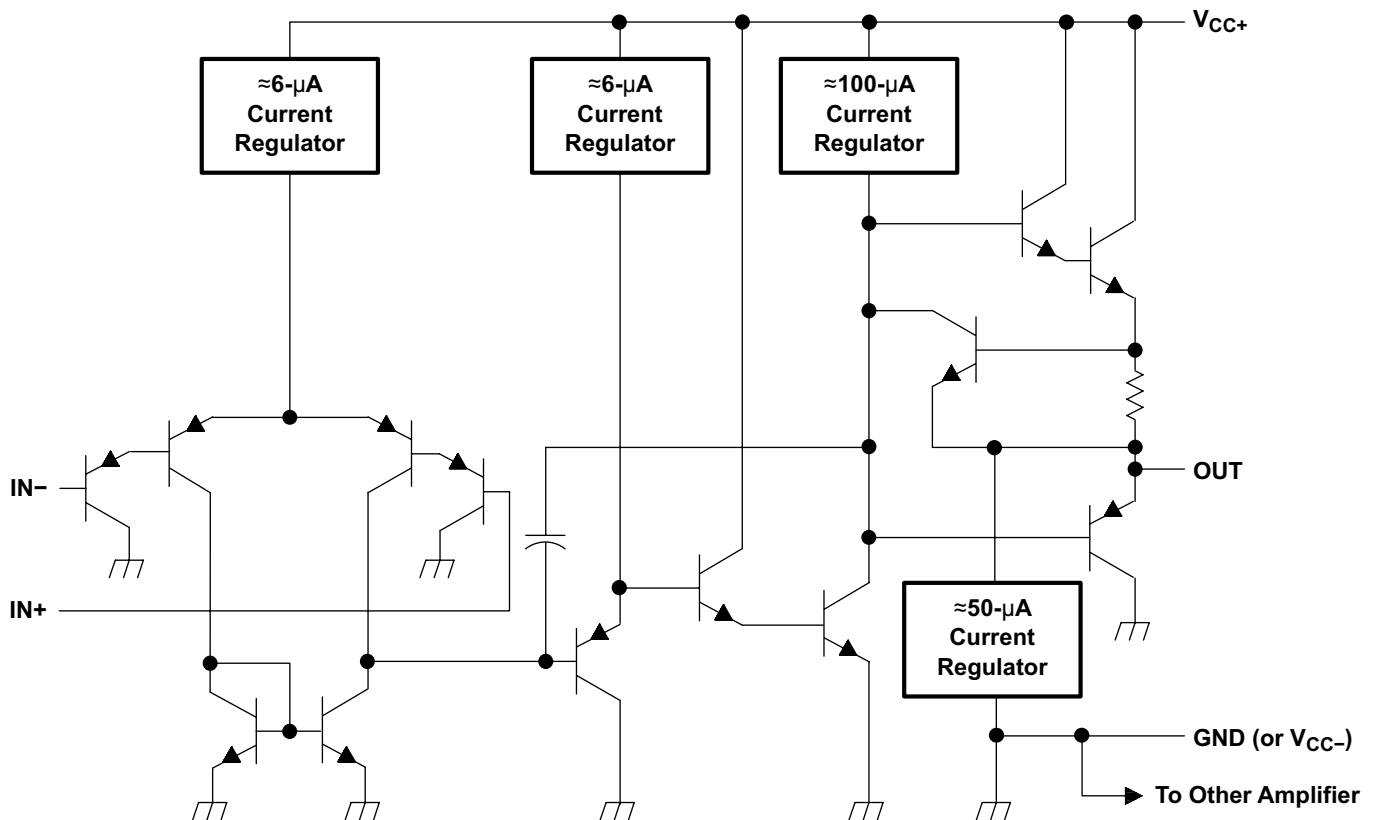
## 8 Detailed Description

### 8.1 Overview

These devices consist of two independent, high-gain frequency-compensated operational amplifiers designed to operate from a single supply over a wide range of voltages. Operation from split supplies also is possible if the difference between the two supplies is 3 V to 32 V (3 V to 26 V for the LM2904 device), and  $V_{CC}$  is at least 1.5 V more positive than the input common-mode voltage. The low supply-current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, DC amplification blocks, and all the conventional operational amplifier circuits that now can be implemented more easily in single-supply-voltage systems. For example, these devices can be operated directly from the standard 5-V supply used in digital systems and easily can provide the required interface electronics without additional  $\pm 5$ -V supplies.

### 8.2 Functional Block Diagram



COMPONENT COUNT	
Epi-FET	1
Diodes	2
Resistors	7
Transistors	51
Capacitors	2

### 8.3 Feature Description

#### 8.3.1 Unity-Gain Bandwidth

The unity-gain bandwidth is the frequency up to which an amplifier with a unity gain may be operated without greatly distorting the signal. These devices have a 0.7-MHz unity-gain bandwidth.

#### 8.3.2 Slew Rate

The slew rate is the rate at which an operational amplifier can change its output when there is a change on the input. These devices have a 0.3-V/ $\mu$ s slew rate.

#### 8.3.3 Input Common Mode Range

The valid common mode range is from device ground to  $V_{CC} - 1.5$  V ( $V_{CC} - 2$  V across temperature). Inputs may exceed  $V_{CC}$  up to the maximum  $V_{CC}$  without device damage. At least one input must be in the valid input common mode range for output to be correct phase. If both inputs exceed valid range then output phase is undefined. If either input is less than -0.3 V then input current should be limited to 1mA and output phase is undefined.

### 8.4 Device Functional Modes

These devices are powered on when the supply is connected. This device can be operated as a single supply operational amplifier or dual supply amplifier depending on the application.

## 9 Application and Implementation

### NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI'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 LMx58 and LM2904 operational amplifiers are useful in a wide range of signal conditioning applications. Inputs can be powered before  $V_{CC}$  for flexibility in multiple supply circuits.

### 9.2 Typical Application

A typical application for an operational amplifier in an inverting amplifier. This amplifier takes a positive voltage on the input, and makes it a negative voltage of the same magnitude. In the same manner, it also makes negative voltages positive.

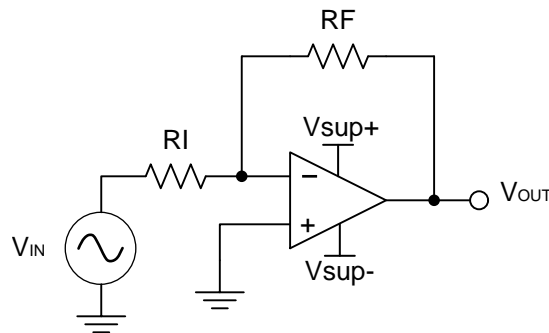


Figure 13. Application Schematic

#### 9.2.1 Design Requirements

The supply voltage must be chosen such that it is larger than the input voltage range and output range. For instance, this application will scale a signal of  $\pm 0.5$  V to  $\pm 1.8$  V. Setting the supply at  $\pm 12$  V is sufficient to accommodate this application.

#### 9.2.2 Detailed Design Procedure

Determine the gain required by the inverting amplifier using [Equation 1](#) and [Equation 2](#):

$$A_v = \frac{V_{OUT}}{V_{IN}} \quad (1)$$

$$A_v = \frac{1.8}{-0.5} = -3.6 \quad (2)$$

Once the desired gain is determined, choose a value for  $R_I$  or  $R_F$ . Choosing a value in the kilohm range is desirable because the amplifier circuit will use currents in the milliamp range. This ensures the part will not draw too much current. This example will choose 10 k $\Omega$  for  $R_I$  which means 36 k $\Omega$  will be used for  $R_F$ . This was determined by [Equation 3](#).

$$A_v = -\frac{R_F}{R_I} \quad (3)$$

## Typical Application (continued)

### 9.2.3 Application Curve

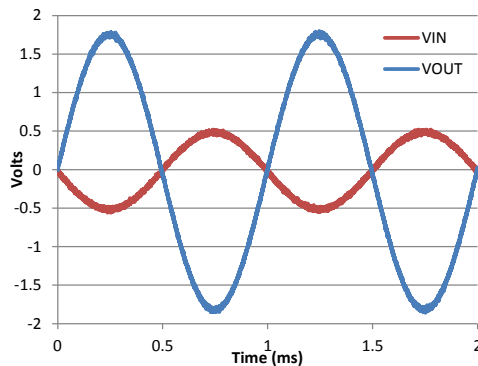


Figure 14. Input and Output Voltages of the Inverting Amplifier

## 10 Power Supply Recommendations

### CAUTION

Supply voltages larger than 32 V for a single supply (26 V for the LM2904), or outside the range of  $\pm 16$  V for a dual supply ( $\pm 13$  V for the LM2904) can permanently damage the device (see the [Absolute Maximum Ratings](#)).

Place 0.1- $\mu$ F bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high impedance power supplies. For more detailed information on bypass capacitor placement, refer to the [Layout](#).

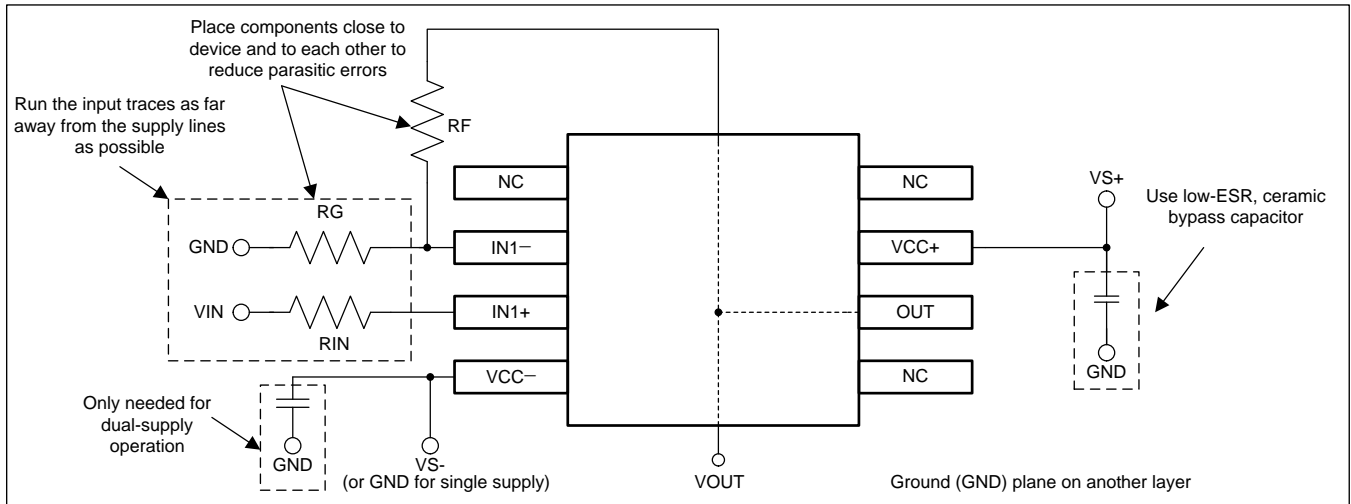
## 11 Layout

### 11.1 Layout Guidelines

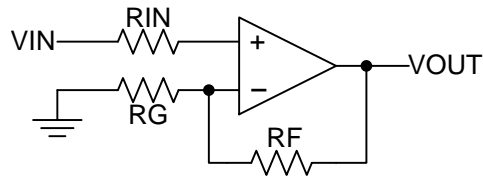
For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole, as well as the operational amplifier. 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- $\mu$ F 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.
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If it is not possible to keep them separate, it is much better to cross the sensitive trace perpendicular as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. Keeping RF and RG close to the inverting input minimizes parasitic capacitance, as shown in [Layout Examples](#).
- 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.

## 11.2 Layout Examples



**Figure 15. Operational Amplifier Board Layout for Noninverting Configuration**



**Figure 16. Operational Amplifier Schematic for Noninverting Configuration**