Quadruple Operational Amplifiers

1 Features

- 2-kV ESD Protection for:
  - LM224K, LM224KA
  - LM324K, LM324KA
  - LM2902K, LM2902KV, LM2902KAV
- Wide Supply Ranges
  - Single Supply: 3 V to 32 V (26 V for LM2902)
  - Dual Supplies: ±1.5 V to ±16 V (±13 V for LM2902)
- Low Supply-Current Drain Independent of Supply Voltage: 0.8 mA Typical
- 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 LM2902)
- Open-Loop Differential Voltage Amplification: 100 V/mV 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.

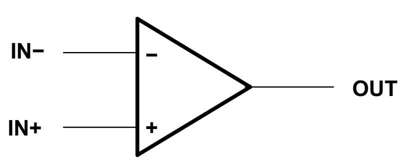
2 Applications

- Blu-ray Players and Home Theaters
- Chemical and Gas Sensors
- DVD Recorders 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

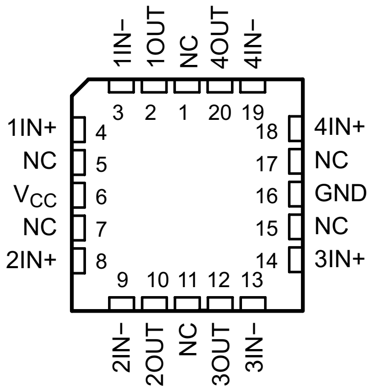
These devices consist of four independent high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single supply or split supply over a wide range of voltages.

Symbol (Each Amplifier)

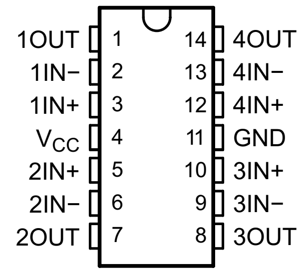


4 Pin Configuration and Functions

FK Package
20-Pin LCCC
(Top View)



D, DB, J, N, NS, PW, W
14-Pin SOIC, SSOP, CDIP, PDIP, SO, TSSOP, CFP
(Top View)



Pin Functions

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

5 Specifications

5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[1]

		LM2902		LMx24, LMx24x, LMx24xx, LM2902x, LM2902xx, LM2902xxx		UNIT
		MIN	MAX	MIN	MAX	
Supply voltage, V_{CC} [2]		±13	26	±16	32	V
Differential input voltage, V_{ID} [3]			±26		±32	V
Input voltage, V_I (either input)		–0.3	26	–0.3	to 32	V
Duration of output short circuit (one amplifier) to ground at (or below) T_A = 25°C, V_{CC} ≤ 15 V [4]		Unlimited		Unlimited		
Operating virtual junction temperature, T_J			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	J or W package		300		300	°C
Storage temperature, T_{stg}		–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 VCC can cause excessive heating and eventual destruction.

5.2 ESD Ratings

			VALUE	UNIT
LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV				
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101	±1000	
LM124, LM124A, LM224, LM224A, LM324, LM324A, LM2902, LM2902V				
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±500	V
		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.

5.3 Recommended Operating Conditions

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

		LM2902		LMx24, LMx24x, LMx24xx, LM2902x, LM2902xx, LM2902xxx		UNIT
		MIN	MAX	MIN	MAX	
V_{CC} Supply voltage		3	26	3	30	V
V_{CM} Common-mode voltage		0	V_{CC} – 2	0	V_{CC} – 2	V
T_A Operating free air temperature	LM124			–55	125	°C
	LM2904	–40	125			
	LM324			0	70	
	LM224			–25	85	

5.4 Thermal Information

THERMAL METRIC(1)		LMx24, LM2902					LMx24			UNIT
		D (SOIC)	DB (SSOP)	N (PDIP)	NS (SO)	PW (TSSOP)	FK (LCCC)	J (CDIP)	W (CFP)	
		14 PINS	14 PINS	14 PINS	14 PINS	14 PINS	20 PINS	14 PINS	14 PINS	
$R_{\theta JA}$ (2)(3)	Junction-to-ambient thermal resistance	86	86	80	76	113	—	—	—	°C/W
$R_{\theta JC}$ (4)	Junction-to-case (top) thermal resistance	—	—	—	—	—	5.61	15.05	14.65	°C/W

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.
(2) Short circuits from outputs to VCC can cause excessive heating and eventual destruction.
(3) Maximum power dissipation is a function of $T_{J(max)}$, $R_{\theta JA}$, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_{J(max)} - T_A)/R_{\theta JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
(4) Maximum power dissipation is a function of $T_{J(max)}$, $R_{\theta JA}$, and T_C. The maximum allowable power dissipation at any allowable case temperature is $P_D = (T_{J(max)} - T_C)/R_{\theta JC}$. Operating at the absolute maximum T_J of 150°C can affect reliability.

5.5 Electrical Characteristics for LMx24 and LM324K

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

PARAMETER		TEST CONDITIONS(1)		T_A(2)	LM124, LM224			LM324, LM324K			UNIT
					MIN	TYP(3)	MAX	MIN	TYP(3)	MAX	
V_{IO}	Input offset voltage	V_{CC} = 5 V to MAX, $V_{IC} = V_{ICR}$min, V_O = 1.4 V		25°C		3	5		3	7	mV
				Full range			7			9	
I_{IO}	Input offset current	V_O = 1.4 V		25°C		2	30		2	50	nA
				Full range			100			150	
I_{IB}	Input bias current	V_O = 1.4 V		25°C		–20	–150		–20	–250	nA
				Full range			–300			–500	
V_{ICR}	Common-mode input voltage range	V_{CC} = 5 V to MAX		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 = 2 kΩ		25°C	V_{CC} – 1.5			V_{CC} – 1.5			V
		R_L = 10 kΩ		25°C							
		V_{CC} = MAX	R_L = 2 kΩ	Full range	26			26			
			R_L ≥ 10 kΩ	Full range	27	28		27	28		
V_{OL}	Low-level output voltage	R_L ≤ 10 kΩ		Full range		5	20		5	20	mV
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1 V to 11 V, R_L ≥ 2 kΩ		25°C	50	100		25	100		V/mV
				Full range	25			15			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min		25°C	70	80		65	80		dB
k_{SVR}	Supply-voltage rejection ratio (ΔV_{CC} /ΔVIO)			25°C	65	100		65	100		dB
V_{O1}/ V_{O2}	Crosstalk attenuation	f = 1 kHz to 20 kHz		25°C		120			120		dB
I_O	Output current	V_{CC} = 15 V, V_{ID} = 1 V, V_O = 0	Source	25°C	–20	–30	–60	–20	–30	–60	mA
				Full range	–10			–10			
		V_{CC} = 15 V, V_{ID} = –1 V, V_O = 15 V	Sink	25°C	10	20		10	20		
				Full range	5			5			
		V_{ID} = –1 V, V_O = 200 mV		25°C	12	30		12	30		μA
I_{OS}	Short-circuit output current	V_{CC} at 5 V, V_O = 0, GND at –5 V		25°C		±40	±60		±40	±60	mA
I_{CC}	Supply current (four amplifiers)	V_O = 2.5 V, no load		Full range		0.7	1.2		0.7	1.2	mA
		V_{CC} = MAX, V_O = 0.5 V_{CC}, no load		Full range		1.4	3		1.4	3	

(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 30 V for the others.
(2) Full range is –55°C to 125°C for LM124, –25°C to 85°C for LM224, and 0°C to 70°C for LM324.
(3) All typical values are at T_A = 25°C

Electrical Characteristics for LMx24A and LM324KA (continued)

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

PARAMETER		TEST CONDITIONS[1]		T_A[2]	LM124A MIN	LM124A TYP[3]	LM124A MAX	LM224A MIN	LM224A TYP[3]	LM224A MAX	LM324A, LM324KA MIN	LM324A, LM324KA TYP[3]	LM324A, LM324KA MAX	UNIT
V_{ICR}	Common-mode input voltage range	V_{CC} = 30 V		25°C	0 to V_{CC} − 1.5			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			0 to V_{CC} − 2			
V_{OH}	High-level output voltage	R_L = 2 kΩ		25°C	V_{CC} − 1.5			V_{CC} − 1.5			V_{CC} − 1.5			V
		V_{CC} = 30 V	R_L = 2 kΩ	Full range	26			26			26			
			R_L ≥ 10 kΩ	Full range	27			27	28		27	28		
V_{OL}	Low-level output voltage	R_L ≤ 10 kΩ		Full range			20		5	20		5	20	mV
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1 V to 11 V, R_L ≥ 2 kΩ		25°C	50	100		50	100		25	100		V/mV
				Full range	25			25			15			
CMRR	Common-mode rejection ratio	V_{IC} = V_{ICR}min		25°C	70			70	80		65	80		dB
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$)			25°C	65			65	100		65	100		dB
V_{O1}/V_{O2}	Crosstalk attenuation	f = 1 kHz to 20 kHz		25°C		120			120			120		dB
I_O	Output current	V_{CC} = 15 V, V_{ID} = 1 V, V_O = 0	Source	25°C	–20			–20	–30	–60	–20	–30	–60	mA
				Full range	–10			–10			–10			
		V_{CC} = 15 V, V_{ID} = –1 V, V_O = 15 V	Sink	25°C	10			10	20		1	20		
				Full range	5			5			5			
		V_{ID} = −1 V, V_O = 200 mV		25°C	12			12	30		12	30		μA
I_{OS}	Short-circuit output current	V_{CC} at 5 V, GND at –5 V, V_O = 0		25°C		±40	±60		±40	±60		±40	±60	mA
I_{CC}	Supply current (four amplifiers)	V_O = 2.5 V, no load		Full range		0.7	1.2		0.7	1.2		0.7	1.2	mA
		V_{CC} = 30 V, V_O = 15 V, no load		Full range		1.4	3.		1.4	3		1.4	3	

5.6 Operating Conditions

V_{CC} = ±15 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	TYP	UNIT
SR	Slew rate at unity gain	R_L = 1 MΩ, C_L = 30 pF, V_I = ±10 V (see Figure 7)	0.5	V/μs
B_1	Unity-gain bandwidth	R_L = 1 MΩ, C_L = 20 pF (see Figure 7)	1.2	MHz
V_n	Equivalent input noise voltage	R_S = 100 Ω, V_I = 0 V, f = 1 kHz (see Figure 8)	35	nV/√Hz

5.7 Typical Characteristics

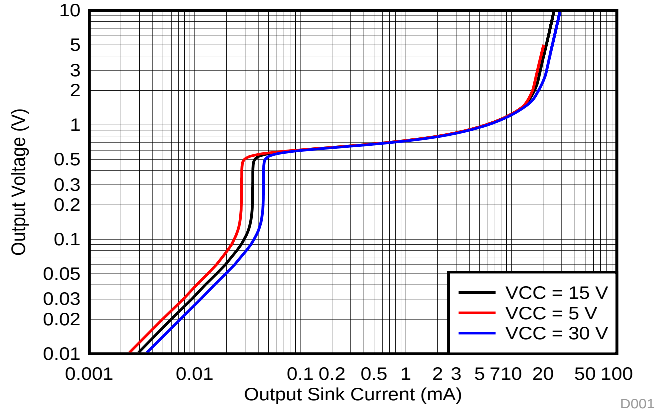


Figure 1. Output Sinking Characteristics

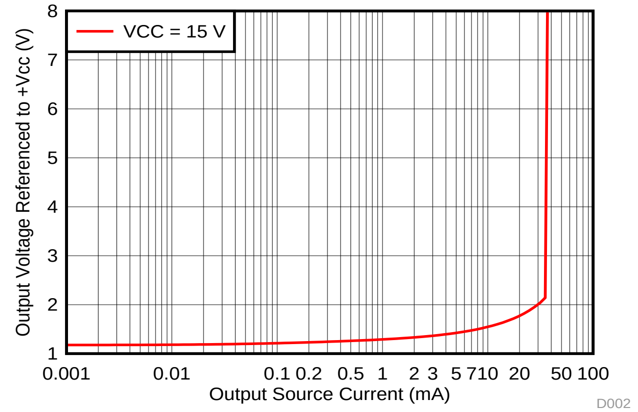


Figure 2. Output Sourcing Characteristics

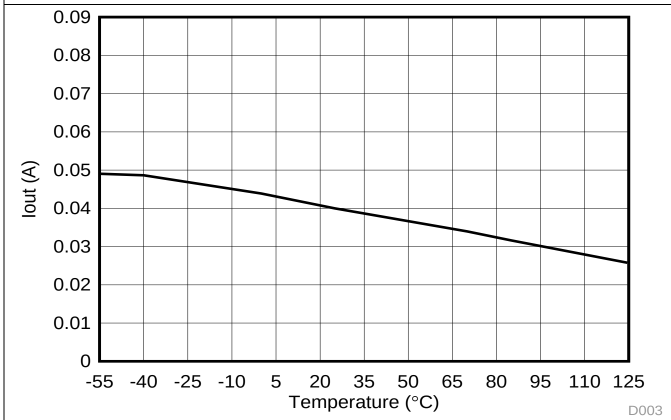


Figure 3. Source Current Limiting

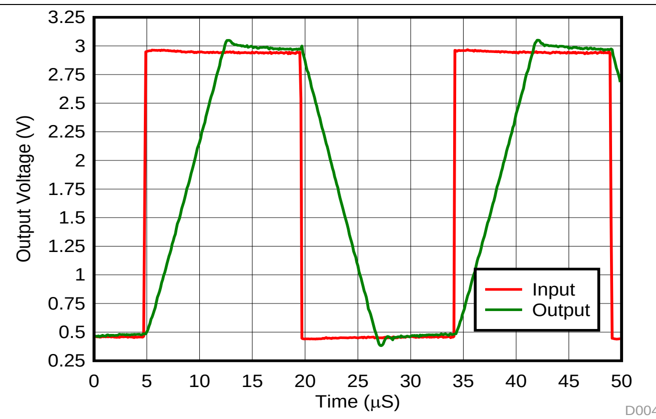


Figure 4. Voltage Follower Large Signal Response (50 pF)

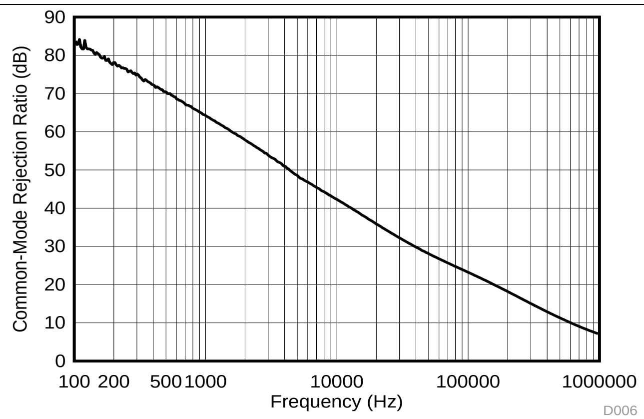


Figure 5. Common-Mode Rejection Ratio

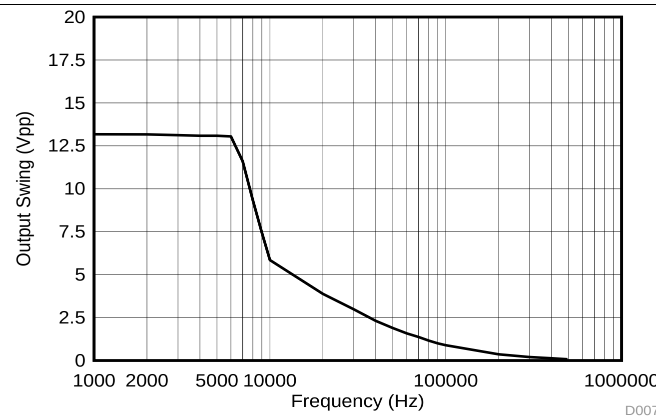


Figure 6. Maximum Output Swing vs. Frequency (VCC = 15 V)

6 Parameter Measurement Information

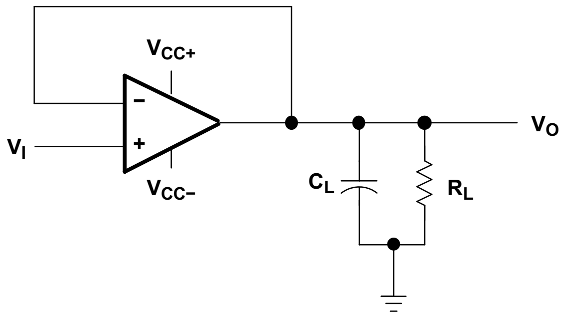


Figure 7. Unity-Gain Amplifier

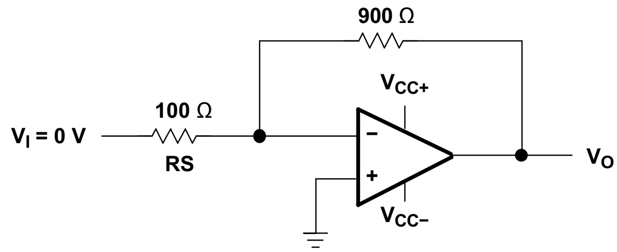


Figure 8. Noise-Test Circuit

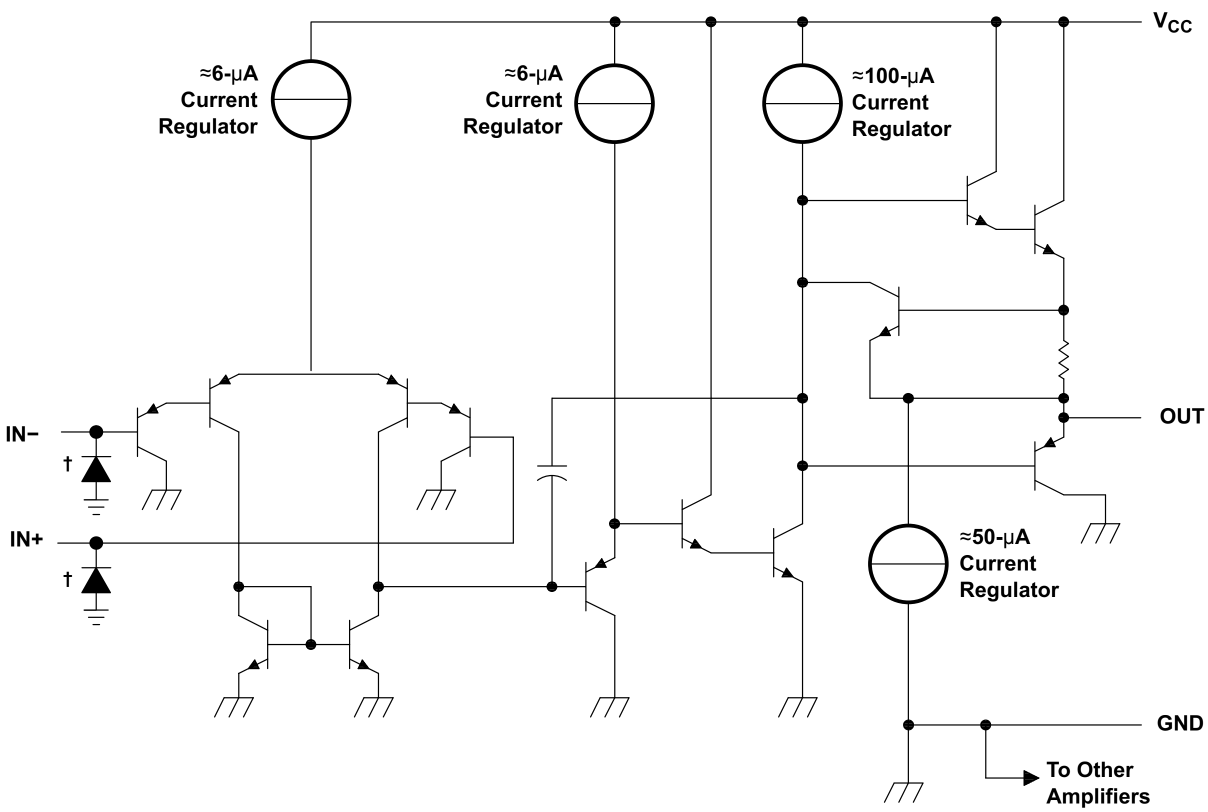
7 Detailed Description

7.1 Overview

These devices consist of four independent high-gain frequency-compensated operational amplifiers that are designed specifically 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 LM2902 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 more easily implemented in single-supply-voltage systems. For example, the LM124 device can be operated directly from the standard 5-V supply that is used in digital systems and provides the required interface electronics, without requiring additional ±15-V supplies.

7.2 Functional Block Diagram



COMPONENT COUNT (total device)	
Epi-FET	1
Transistors	95
Diodes	4
Resistors	11
Capacitors	4

† ESD protection cells - available on LM324K and LM324KA only

8 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.

8.1 Application Information

The LMx24 and LM2902 operational amplifiers are useful in a wide range of signal conditioning applications. Inputs can be powered before VCC for flexibility in multiple supply circuits.

8.2 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.

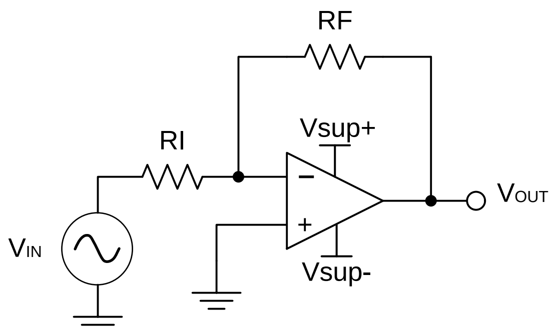


Figure 9. Application Schematic

8.2.1 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 ±0.5 V to ±1.8 V. Setting the supply at ±12 V is sufficient to accommodate this application.

8.2.2 Detailed Design Procedure

Determine the gain required by the inverting amplifier using Equation 1 and Equation 2:

$$A_v = \frac{VOUT}{VIN} \quad (1)$$

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

Once the desired gain is determined, choose a value for RI or RF. 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 kΩ for RI which means 36 kΩ will be used for RF. This was determined by Equation 3.

$$A_v = -\frac{RF}{RI} \quad (3)$$