

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.

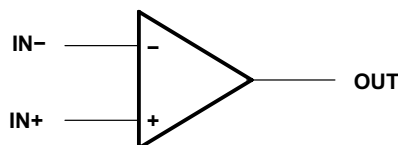
2 Applications

- 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)



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) $T_A = 25^\circ\text{C}$, $V_{CC} \leq 15\text{ V}$ ⁽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		°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	

- (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, $V_{CC} = 5\text{ V}$ (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	$V_{CC} = 5\text{ V}$ to MAX, $V_{IC} = V_{ICRmin}$, $V_O = 1.4\text{ V}$	25°C	3	5	3	7	mV			
			Full range		7		9				
I_{IO}	Input offset current	$V_O = 1.4\text{ V}$	25°C	2	30	2	50	nA			
			Full range		100		150				
I_{IB}	Input bias current	$V_O = 1.4\text{ V}$	25°C	-20	-150	-20	-250	nA			
			Full range		-300		-500				
V_{ICR}	Common-mode input voltage range	$V_{CC} = 5\text{ V}$ 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	$R_L = 2\text{ k}\Omega$	25°C	$V_{CC} - 1.5$		$V_{CC} - 1.5$		V			
		$R_L = 10\text{ k}\Omega$	25°C								
		$V_{CC} = \text{MAX}$	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 V, $R_L \geq 2\text{ k}\Omega$	25°C	50	100	25	100	V/mV			
			Full range	25		15					
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$	25°C	70	80	65	80	dB			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$)		25°C	65	100	65	100	dB			
V_{O1}/V_{O2}	Crosstalk attenuation	$f = 1\text{ kHz}$ to 20 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	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)	$V_O = 2.5\text{ V}$, no load	Full range	0.7	1.2	0.7	1.2	mA			
		$V_{CC} = \text{MAX}$, $V_O = 0.5 V_{CC}$, 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 $T_A = 25^\circ\text{C}$

Electrical Characteristics for LMx24A and LM324KA (continued)

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

PARAMETER	TEST CONDITIONS ⁽¹⁾	T_A ⁽²⁾	LM124A			LM224A			LM324A, LM324KA			UNIT	
			MIN	TYP ⁽³⁾	MAX	MIN	TYP ⁽³⁾	MAX	MIN	TYP ⁽³⁾	MAX		
V_{ICR} Common-mode input voltage range	$V_{CC} = 30\text{ V}$	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	$R_L = 2\text{ k}\Omega$ $V_{CC} = 30\text{ V}$	25°C	$V_{CC} - 1.5$			$V_{CC} - 1.5$			$V_{CC} - 1.5$			V	
		Full range	26			26			26				
			$R_L \geq 10\text{ k}\Omega$			27			27 28				27 28
V_{OL} Low-level output voltage	$R_L \leq 10\text{ k}\Omega$	Full range	20			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		25	100		V/mV	
		Full range	25			25			15				
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$	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	$f = 1\text{ kHz to }20\text{ kHz}$	25°C	120			120			120			dB	
I_O Output current	$V_{CC} = 15\text{ V}$, $V_{ID} = 1\text{ V}$, $V_O = 0$	Source	25°C	-20			-20 -30 -60			-20 -30 -60			mA
			Full range	-10			-10			-10			
	$V_{CC} = 15\text{ V}$, $V_{ID} = -1\text{ V}$, $V_O = 15\text{ V}$	Sink	25°C	10			10 20			1 20			
			Full range	5			5			5			
	$V_{ID} = -1\text{ V}$, $V_O = 200\text{ mV}$	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)	$V_O = 2.5\text{ V}$, no load	Full range	0.7 1.2			0.7 1.2			0.7 1.2			mA	
	$V_{CC} = 30\text{ V}$, $V_O = 15\text{ V}$, no load	Full range	1.4 3.			1.4 3			1.4 3				

5.6 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 7)	0.5	V/ μs
B_1 Unity-gain bandwidth	$R_L = 1\text{ M}\Omega$, $C_L = 20\text{ pF}$ (see Figure 7)	1.2	MHz
V_n Equivalent input noise voltage	$R_S = 100\ \Omega$, $V_I = 0\text{ V}$, $f = 1\text{ kHz}$ (see Figure 8)	35	nV/ $\sqrt{\text{Hz}}$

5.7 Typical Characteristics

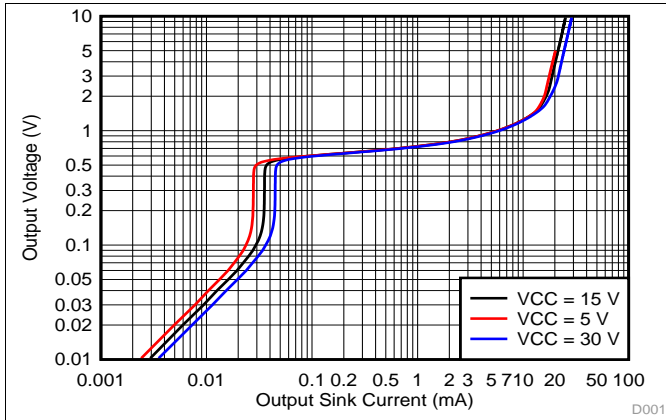


Figure 1. Output Sinking Characteristics

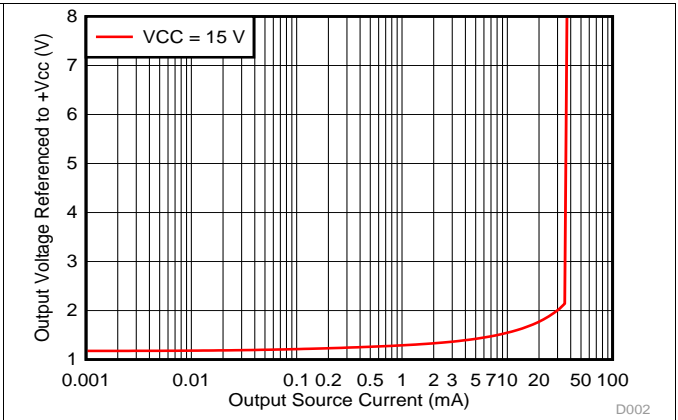


Figure 2. Output Sourcing Characteristics

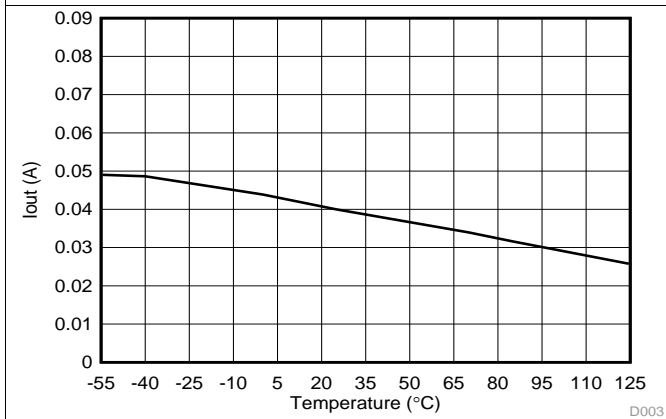


Figure 3. Source Current Limiting

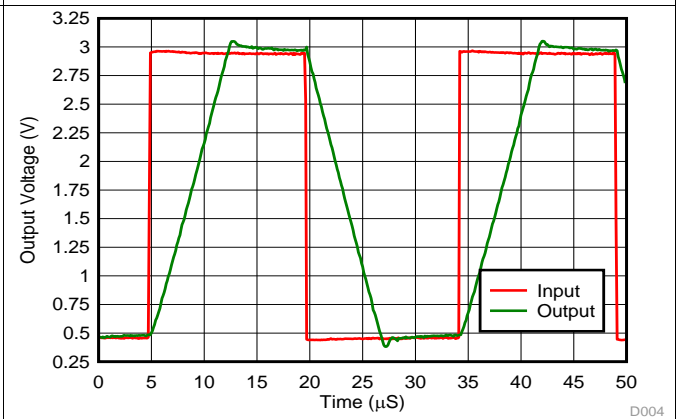


Figure 4. Voltage Follower Large Signal Response (50 pF)

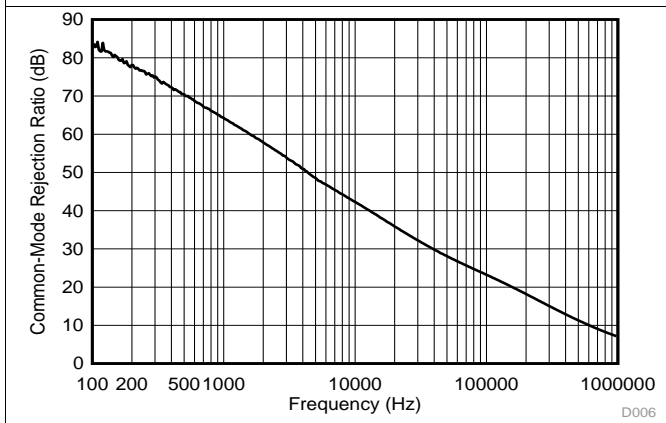


Figure 5. Common-Mode Rejection Ratio

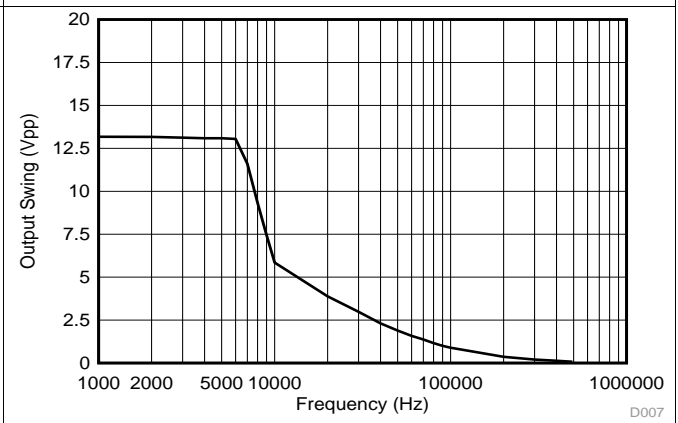


Figure 6. Maximum Output Swing vs. Frequency (VCC = 15 V)

6 Parameter Measurement Information

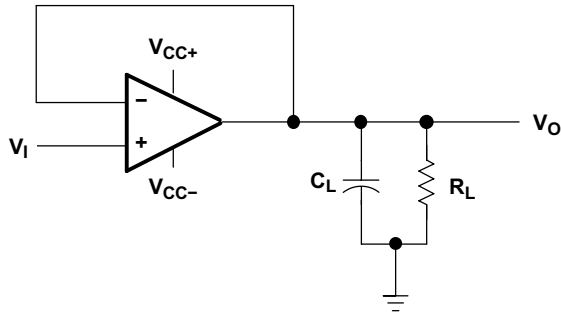


Figure 7. Unity-Gain Amplifier

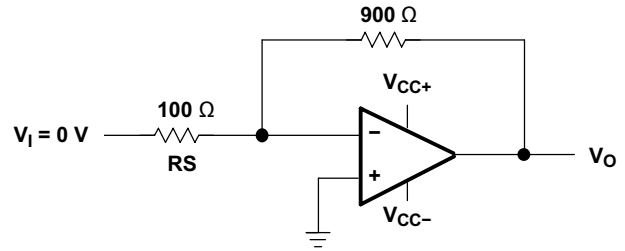


Figure 8. Noise-Test Circuit

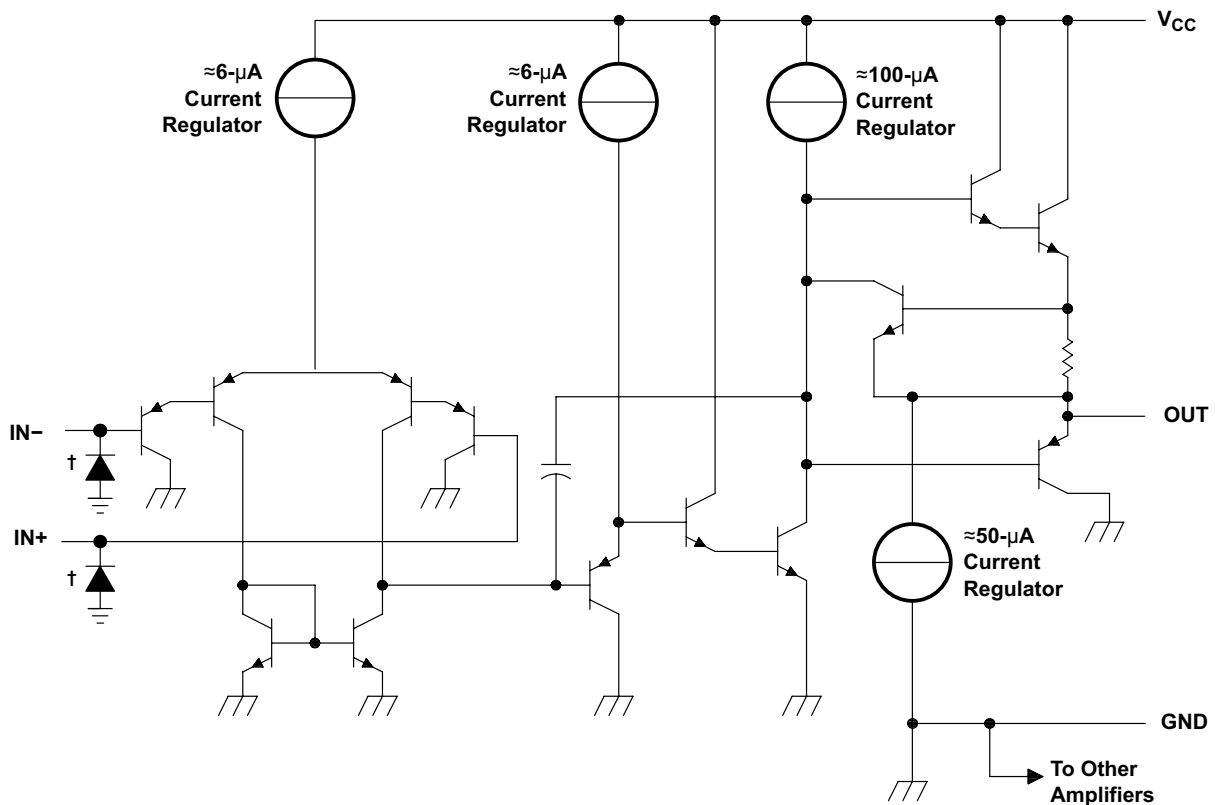
7 Detailed Description

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

Important statement:

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