

LM124, LM124A, LM224, LM224A, LM324, LM324A, LM2902, LM2902V, LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV QUADRUPLE OPERATIONAL AMPLIFIERS

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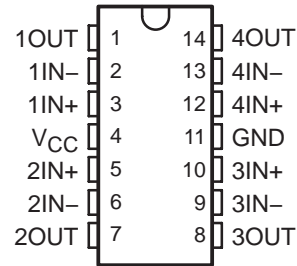
- **2-kV ESD Protection for:**
 - LM224K, LM224KA
 - LM324K, LM324KA
 - LM2902K, LM2902KV, LM2902KAV
- **Wide Supply Ranges**
 - Single Supply . . . 3 V to 32 V
(26 V for LM2902)
 - Dual Supplies . . . ± 1.5 V to ± 16 V
(± 13 V for LM2902)
- **Low Supply-Current Drain Independent of Supply Voltage . . . 0.8 mA Typ**
- **Common-Mode Input Voltage Range Includes Ground, Allowing Direct Sensing Near Ground**
- **Low Input Bias and Offset Parameters**
 - Input Offset Voltage . . . 3 mV Typ
A Versions . . . 2 mV Typ
 - Input Offset Current . . . 2 nA Typ
 - Input Bias Current . . . 20 nA Typ
A Versions . . . 15 nA Typ
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . 32 V (26 V for LM2902)**
- **Open-Loop Differential Voltage Amplification . . . 100 V/mV Typ**
- **Internal Frequency Compensation**

description/ordering information

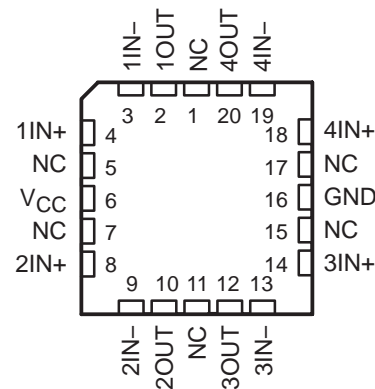
These devices consist of four independent high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies also is possible if the difference between the two supplies is 3 V to 32 V (3 V to 26 V for the LM2902), 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 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.

LM124 . . . D, J, OR W PACKAGE
LM124A . . . J PACKAGE
LM224, LM224A, LM224K, LM224KA . . . D OR N PACKAGE
LM324, LM324K . . . D, N, NS, OR PW PACKAGE
LM324A . . . D, DB, N, NS, OR PW PACKAGE
LM324KA . . . D, N, NS, OR PW PACKAGE
LM2902 . . . D, N, NS, OR PW PACKAGE
LM2902K . . . D, DB, N, NS, OR PW PACKAGE
LM2902KV, LM2902KAV . . . D OR PW PACKAGE
(TOP VIEW)



LM124, LM124A . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection

**LM124, LM124A, LM224, LM224A, LM324, LM324A, LM2902, LM2902V,
LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV
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description/ordering information (continued)

ORDERING INFORMATION

TA	V _{IO} max AT 25°C	MAX TESTED V _{CC}	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 70°C	7 mV	30 V	PDIP (N)	Tube of 25	LM324N	LM324N
						LM324KN
			SOIC (D)	Tube of 50	LM324D	LM324
				Reel of 2500	LM324DR	
				Tube of 50	LM324KD	LM324K
				Reel of 2500	LM324KDR	
			SOP (NS)	Reel of 2000	LM324NSR	LM324
				Tube of 50	LM324KNS	LM324K
				Reel of 2000	LM324KNSR	
			TSSOP (PW)	Tube of 90	LM324PW	L324
				Reel of 2000	LM324PWR	
				Tube of 90	LM324KPW	L324K
	Reel of 2000	LM324KPWR				
	3 mV	30 V	PDIP (N)	Tube of 25	LM324AN	LM324AN
						LM324KAN
			SOIC (D)	Tube of 50	LM324AD	LM324A
				Reel of 2500	LM324ADR	
				Tube of 50	LM324KAD	LM324KA
				Reel of 2500	LM324KADR	
			SOP (NS)	Reel of 2000	LM324ANSR	LM324A
				Tube of 50	LM324KANS	LM324KA
				Reel of 2000	LM324KANSR	
			SSOP (DB)	Reel of 2000	LM324ADBR	LM324A
			TSSOP (PW)	Tube of 90	LM324APW	L324A
Reel of 2000				LM324APWR		
Tube of 90	LM324KAPW	L324KA				
Reel of 2000	LM324KAPWR					
-25°C to 85°C	5 mV	30 V	PDIP (N)	Tube of 25	LM224N	LM224N
						LM224KN
			SOIC (D)	Tube of 50	LM224D	LM224
				Reel of 2500	LM224DR	
				Tube of 50	LM224KD	LM224K
				Reel of 2500	LM224KDR	
	3 mV	30 V	PDIP (N)	Tube of 25	LM224AN	LM224AN
						LM224KAN
			SOIC (D)	Tube of 50	LM224AD	LM224A
				Reel of 2500	LM224ADR	
				Tube of 50	LM224KAD	LM224KA
				Reel of 2500	LM224KADR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.



**LM124, LM124A, LM224, LM224A, LM324, LM324A, LM2902, LM2902V,
LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV
QUADRUPLE OPERATIONAL AMPLIFIERS**

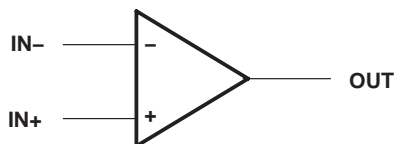
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ORDERING INFORMATION (CONTINUED)

TA	V _{IO} max AT 25°C	MAX TESTED V _{CC}	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
-40°C to 125°C	7 mV	26 V	PDIP (N)	Tube of 25	LM2902N	LM2902N
				Tube of 25	LM2902KN	LM2902KN
			SOIC (D)	Tube of 50	LM2902D	LM2902
				Reel of 2500	LM2902DR	
				Tube of 50	LM2902KD	LM2902K
				Reel of 2500	LM2902KDR	
			SOP (NS)	Reel of 2000	LM2902NSR	LM2902
				Tube of 50	LM2902KNS	LM2902K
				Reel of 2000	LM2902KNSR	
			SSOP (DB)	Tube of 80	LM2902KDB	L2902K
				Reel of 2000	LM2902KDBR	
			TSSOP (PW)	Tube of 90	LM2902PW	L2902
	Reel of 2000	LM2902PWR				
	Tube of 90	LM2902KPW		L2902K		
	Reel of 2000	LM2902KPWR				
	32 V	SOIC (D)	Reel of 2500	LM2902KVQDR	L2902KV	
TSSOP (PW)		Reel of 2000	LM2902KVQPWR	L2902KV		
2 mV	32 V	SOIC (D)	Reel of 2500	LM2902KAVQDR	L2902KA	
		TSSOP (PW)	Reel of 2000	LM2902KAVQPWR	L2902KA	
-55°C to 125°C	5 mV	30 V	CDIP (J)	Tube of 25	LM124J	LM124J
			CFP (W)	Tube of 25	LM124W	LM124W
			LCCC (FK)	Tube of 55	LM124FK	LM124FK
			SOIC (D)	Tube of 50	LM124D	LM124
	Reel of 2500	LM124DR				
	2 mV	30 V	CDIP (J)	Tube of 25	LM124AJ	LM124AJ
LCCC (FK)			Tube of 55	LM124AFK	LM124AFK	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

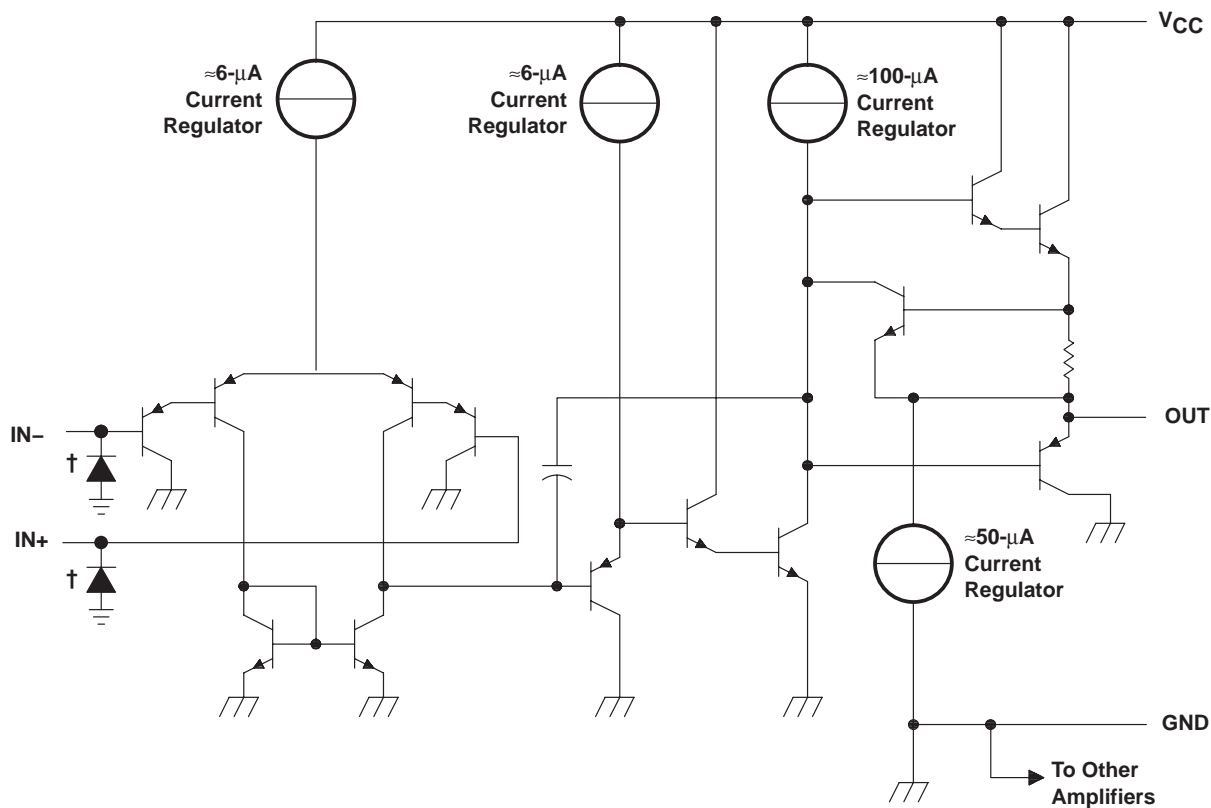
symbol (each amplifier)



**LM124, LM124A, LM224, LM224A, LM324, LM324A, LM2902, LM2902V,
LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV**
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schematic (each amplifier)



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

† ESD protection cells - available on LM324K and LM324KA only



**LM124, LM124A, LM224, LM224A, LM324, LM324A, LM2902, LM2902V,
LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV
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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

	LM2902	ALL OTHER DEVICES	UNIT	
Supply voltage, V_{CC} (see Note 1)	±13 or 26	±16 or 32	V	
Differential input voltage, V_{ID} (see Note 2)	±26	±32	V	
Input voltage, V_I (either input)	–0.3 to 26	–0.3 to 32	V	
Duration of output short circuit (one amplifier) to ground at (or below) $T_A = 25^\circ\text{C}$, $V_{CC} \leq 15\text{ V}$ (see Note 3)	Unlimited	Unlimited		
Package thermal impedance, θ_{JA} (see Notes 4 and 5)	D package	86	°C/W	
	DB package	96		
	N package	80		
	NS package	76		
	PW package	113		
Package thermal impedance, θ_{JC} (see Notes 6 and 7)	FK package		°C/W	
	J package			
	W package			
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 range, T_{stg}	–65 to 150	–65 to 150	°C	

† 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.

- NOTES:
1. All voltage values (except differential voltages and V_{CC} specified for the measurement of I_{OS}) are with respect to the network GND.
 2. Differential voltages are at $IN+$, with respect to $IN-$.
 3. Short circuits from outputs to V_{CC} can cause excessive heating and eventual destruction.
 4. Maximum power dissipation is a function of $T_J(\text{max})$, θ_{JA} , and T_A . The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(\text{max}) - T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
 5. The package thermal impedance is calculated in accordance with JESD 51-7.
 6. Maximum power dissipation is a function of $T_J(\text{max})$, θ_{JC} , and T_C . The maximum allowable power dissipation at any allowable case temperature is $P_D = (T_J(\text{max}) - T_C)/\theta_{JC}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
 7. The package thermal impedance is calculated in accordance with MIL-STD-883.

ESD protection

TEST CONDITIONS		TYP	UNIT
Human-Body Model	LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV	±2	kV



LM124, LM124A, LM224, LM224A, LM324, LM324A, LM2902, LM2902V, LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV QUADRUPLE OPERATIONAL AMPLIFIERS

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

PARAMETER	TEST CONDITIONS†	T_A ‡	LM124 LM224			LM324 LM324K			UNIT		
			MIN	TYP§	MAX	MIN	TYP§	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									
	$V_{CC} = \text{MAX}$	$R_L = 2\text{ k}\Omega$	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		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	$f = 1\text{ kHz to }20\text{ kHz}$	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			
	$V_{CC} = 15\text{ V}$, $V_{ID} = -1\text{ V}$, $V_O = 15\text{ V}$	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			

† 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.

‡ 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.

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



**LM124, LM124A, LM224, LM224A, LM324, LM324A, LM2902, LM2902V,
LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV**
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electrical characteristics at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		T_A ‡	LM2902			LM2902V			UNIT
				MIN	TYP§	MAX	MIN	TYP§	MAX	
V_{IO} Input offset voltage	$V_{CC} = 5\text{ V}$ to MAX, $V_{IC} = V_{ICRmin}$, $V_O = 1.4\text{ V}$	Non-A-suffix devices	25°C	3		7	3		7	mV
			Full range				10			
		A-suffix devices	25°C				1		2	
			Full range				4			
$\Delta V_{IO}/\Delta T$ Input offset voltage temperature drift	$R_S = 0\ \Omega$		Full range				7		$\mu\text{V}/^\circ\text{C}$	
I_{IO} Input offset current	$V_O = 1.4\text{ V}$		25°C	2	50		2	50		nA
			Full range				150			
$\Delta I_{IO}/\Delta T$ Input offset current temperature drift			Full range				10		$\text{pA}/^\circ\text{C}$	
I_{IB} Input bias current	$V_O = 1.4\text{ V}$		25°C	-20		-250	-20		-250	nA
			Full range				-500			
V_{ICR} Common-mode input voltage range	$V_{CC} = 5\text{ V}$ to MAX		25°C	0 to $V_{CC} - 1.5$			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	$R_L = 2\text{ k}\Omega$ $R_L = 10\text{ k}\Omega$ $V_{CC} = \text{MAX}$		25°C							V
			25°C	$V_{CC} - 1.5$		$V_{CC} - 1.5$				
		$R_L \geq 10\text{ k}\Omega$	Full range	22			26			
			Full range	23	24		27			
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	25	100		25	100		V/mV
			Full range	15			15			
CMRR Common-mode rejection ratio	$V_{IC} = V_{ICRmin}$		25°C	50	80		60	80		dB
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$)			25°C	50	100		60	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			
	$V_{CC} = 15\text{ V}$, $V_{ID} = -1\text{ V}$, $V_O = 15\text{ V}$	Sink	25°C	10	20		10	20		
			Full range	5			5			
	$V_{ID} = -1\text{ V}$, $V_O = 200\text{ mV}$		25°C	30		12	40		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	mA
I_{CC} Supply current (four amplifiers)	$V_O = 2.5\text{ V}$, $V_{CC} = \text{MAX}$, $V_O = 0.5 V_{CC}$	No load	Full range	0.7		1.2	0.7		1.2	mA
		No load	Full range	1.4		3	1.4		3	

† 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.

‡ Full range is -40°C to 125°C for LM2902.

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



**LM124, LM124A, LM224, LM224A, LM324, LM324A, LM2902, LM2902V,
LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV**
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electrical characteristics at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	T_A ‡	LM124A			LM224A			LM324A, LM324KA			UNIT
			MIN	TYP§	MAX	MIN	TYP§	MAX	MIN	TYP§	MAX	
V_{IO}	$V_{CC} = 5\text{ V to }30\text{ V},$ $V_{IC} = V_{ICRmin}, V_O = 1.4\text{ V}$	25°C										mV
		Full range										
I_{IO}	$V_O = 1.4\text{ V}$	25°C										nA
		Full range										
I_{IB}	$V_O = 1.4\text{ V}$	25°C										nA
		Full range										
V_{ICR}	$V_{CC} = 30\text{ V}$	25°C	0 to $V_{CC} - 1.5$			0 to $V_{CC} - 1.5$			0 to $V_{CC} - 1.5$			V
		Full range										
V_{OH}	$R_L = 2\text{ k}\Omega$	25°C										V
		Full range	26			26			26			
	$V_{CC} = 30\text{ V}$	Full range	27			27			27			
		Full range										
V_{OL}	$R_L \leq 10\text{ k}\Omega$	Full range										mV
		Full range										
A/D	$V_{CC} = 15\text{ V}, V_O = 1\text{ V to }11\text{ V},$ $R_L \geq 2\text{ k}\Omega$	25°C		100			100			100		V/mV
		Full range										
CMRR	$V_{IC} = V_{ICRmin}$	25°C										dB
		Full range										
kSVR	Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$)	25°C										dB
		Full range										
V_{O1}/V_{O2}	Crosstalk attenuation	25°C										dB
		Full range										
I_O	Output current	25°C										mA
		Full range										
I_{OS}	Short-circuit output current	25°C										μA
		Full range										
I_{CC}	Supply current (four amplifiers)	Full range										mA
		Full range										

† All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified.

‡ Full range is -55°C to 125°C for LM124A, -25°C to 85°C for LM224A, and 0°C to 70°C for LM324A.

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



**LM124, LM124A, LM224, LM224A, LM324, LM324A, LM2902, LM2902V,
LM224K, LM224KA, LM324K, LM324KA, LM2902K, LM2902KV, LM2902KAV**
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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 1)	0.5	$\text{V}/\mu\text{s}$
B_1	Unity-gain bandwidth	$R_L = 1\text{ M}\Omega$, $C_L = 20\text{ pF}$ (see Figure 1)	1.2	MHz
V_n	Equivalent input noise voltage	$R_S = 100\ \Omega$, $V_I = 0\text{ V}$, $f = 1\text{ kHz}$ (see Figure 2)	35	$\text{nV}/\sqrt{\text{Hz}}$

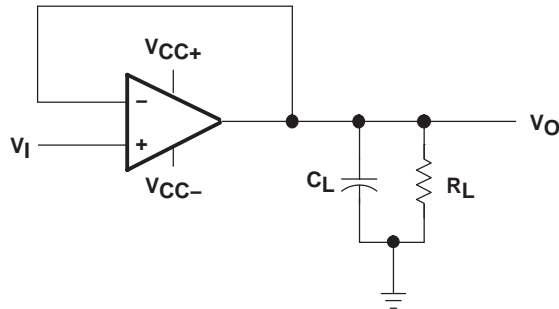


Figure 1. Unity-Gain Amplifier

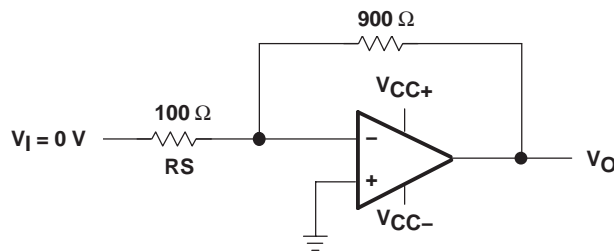


Figure 2. Noise-Test Circuit

FK (S-CQCC-N**)

LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



4040140/D 10/96

- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. This package can be hermetically sealed with a metal lid.
 - D. The terminals are gold plated.
 - E. Falls within JEDEC MS-004

N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
 - The 20 pin end lead shoulder width is a vendor option, either half or full width.

MECHANICAL DATA

NS (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14-PINS SHOWN



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

DB (R-PDSO-G**)

PLASTIC SMALL-OUTLINE

28 PINS SHOWN



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
 D. Falls within JEDEC MO-150

PW (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



4040064/F 01/97

- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
 D. Falls within JEDEC MO-153

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