

LM124, LM124A, LM224, LM224A LM324, LM324A, LM324K, LM324KA, LM2902 QUADRUPLE OPERATIONAL AMPLIFIERS

SLOS066J – SEPTEMBER 1975 – REVISED SEPTEMBER 2003

- 2-kV HBM ESD Protection (LM324K, LM324KA)
- Wide Range of Supply Voltages:
Single Supply . . . 3 V to 30 V
(LM2902, 3 V to 26 V) or Dual Supplies
- 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

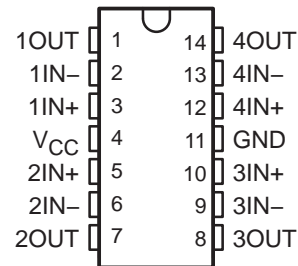
description/ordering information

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 when the difference between the two supplies is 3 V to 30 V (for the LM2902, 3 V to 26 V) 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.

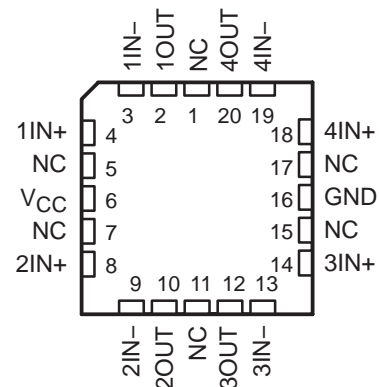
Applications include transducer amplifiers, dc amplification blocks, and all the conventional operational-amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the LM124 can be operated directly from the standard 5-V supply that is used in digital systems and easily provides the required interface electronics without requiring additional ± 15 -V supplies.

LM124 . . . D, J, OR W PACKAGE
LM124A . . . J PACKAGE
LM224, LM224A . . . 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

(TOP VIEW)



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



NC – No internal connection

**LM124, LM124A, LM224, LM224A
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description/ordering information (continued)

ORDERING INFORMATION

TA	V _{IO} max AT 25°C	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING	
0°C to 70°C	7 mV	PDIP (N)	Tube of 25	LM324N	LM324N	
				LM324KN	LM324KN	
		SOIC (D)	Tube of 50	LM324D	LM324	
				LM324DR		
				Reel of 2500	LM324KD	LM324K
					LM324KDR	
		SOP (NS)	Reel of 2000	LM324NSR	LM324	
				Tube of 50	LM324KNS	LM324K
					LM324KNSR	
		TSSOP (PW)	Tube of 90	LM324PW	L324	
				LM324PWR		
			Reel of 2000	LM324KPW	L324K	
	LM324KPWR					
	3 mV	PDIP (N)	Tube of 25	LM324AN	LM324AN	
				LM324KAN	LM324KAN	
		SOIC (D)	Tube of 50	LM324AD	LM324A	
				LM324ADR		
				Reel of 2500	LM324KAD	LM324KA
					LM324KADR	
		SOP (NS)	Reel of 2000	LM324ANSR	LM324A	
Tube of 50				LM324KANS	LM324KA	
				LM324KANSR		
SSOP (DB)		Reel of 2000	LM324ADBR	LM324A		
TSSOP (PW)		Tube of 90	LM324APW	L324A		
			LM324APWR			
	Reel of 2000	LM324KAPW	L324KA			
		LM324KAPWR				
-25°C to 85°C	5 mV	PDIP (N)	Tube of 25	LM224N	LM224N	
		SOIC (D)	Tube of 50	LM224D	LM224	
	LM224DR					
	3 mV	PDIP (N)	Tube of 25	LM224AN	LM224AN	
				SOIC (D)	Tube of 50	LM224AD
		Reel of 2500	LM224ADR			
-40°C to 125°C	7 mV	PDIP (N)	Tube of 25	LM2902N	LM2902N	
		SOIC (D)	Tube of 50	LM2902D	LM2902	
				LM2902DR		
		SOP (NS)	Reel of 2000	LM2902NSR	LM2902	
		TSSOP (PW)	Tube of 90	LM2902PW	L2902	
				LM2902PWR		

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



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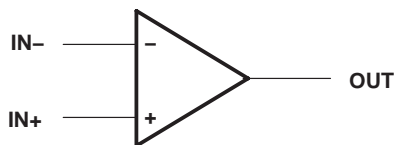
description/ordering information (continued)

ORDERING INFORMATION

T _A	V _{IO} max AT 25°C	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
-55°C to 125°C	5 mV	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	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.

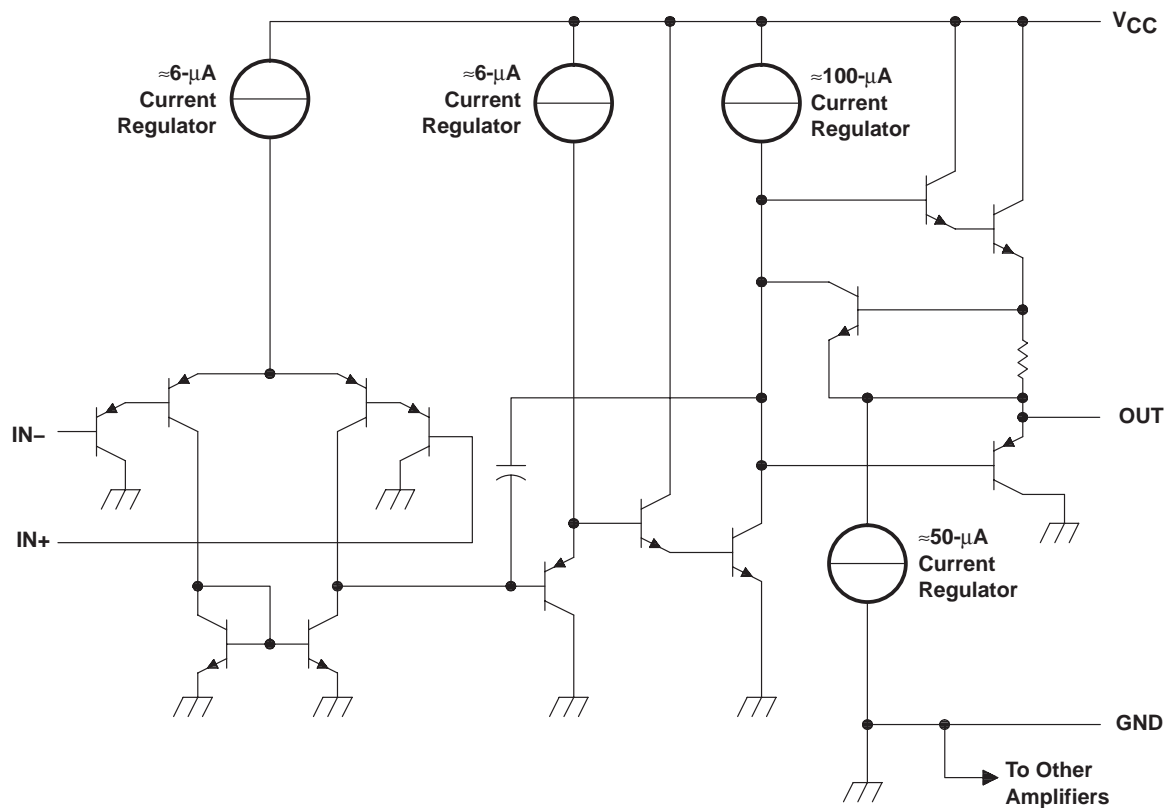
symbol (each amplifier)



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schematic (each amplifier)



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

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

		LM124, LM124A LM224, LM224A LM324, LM324A	LM2902	UNIT
Supply voltage, V_{CC} (see Note 1)		±16 or 32	±13 or 26	V
Differential input voltage, V_{ID} (see Note 2)		±32	±26	V
Input voltage, V_I (either input)		–0.3 to 32	–0.3 to 26	V
Duration of output short circuit (one amplifier) to ground at (or below) $T_A = 25^\circ\text{C}$, $V_{CC} \leq 15\text{ V}$ (see Note 3)		Unlimited	Unlimited	
Package thermal impedance, θ_{JA} (see Notes 4 and 5)	D package	86	86	°C/W
	DB package	96		
	N package	80	80	
	NS package	76	76	
	PW package	113	113	
Package thermal impedance, θ_{JC} (see Notes 6 and 7)	FK package	5.61		°C/W
	J package	15.05		
	W package	14.65		
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 CONDITION		TYP	UNIT
Human Body Model	LM324K, LM324KA	±2	kV



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

PARAMETER	TEST CONDITIONST	TA †	LM124, LM224			LM324, LM324K			LM2902			UNIT
			MIN	TYP ‡	MAX	MIN	TYP ‡	MAX	MIN	TYP ‡	MAX	
V _{IO}	V _{CC} = 5 V to MAX, V _I C = V _I CR _{min} , V _O = 1.4 V	25°C	3	5	7	3	5	7	3	5	7	mV
		Full range		7			9			10		
I _{IO}	V _O = 1.4 V	25°C	2	30	50	2	50	2	50	2	50	nA
		Full range		100			150			300		
I _{IB}	V _O = 1.4 V	25°C	-20	-150	-250	-20	-250	-20	-250	-20	-250	nA
		Full range		-300			-500			-500		
V _I CR	V _{CC} = 5 V to MAX	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}	R _L = 2 kΩ	25°C	V _{CC} - 1.5			V _{CC} - 1.5			V _{CC} - 1.5			V
		Full range		26			26			22		
V _{OL}	R _L = 10 kΩ	25°C	26			26			26			V
		Full range	27	28	28	27	28	28	24	23	24	
A _V D	V _{CC} = MAX, R _L ≥ 10 kΩ	25°C	5	20	20	5	20	20	5	20	20	mV
		Full range		100			100			100		
CMRR	V _I C = V _I CR _{min}	25°C	70	80	80	65	80	80	65	80	80	dB
		Full range	25			15			15			
k _{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$)	25°C	65	100	100	65	100	100	65	100	100	dB
		Full range		120			120			120		
V _{O1} /V _{O2}	Crosstalk attenuation	25°C	-20	-30	-60	-20	-30	-60	-20	-30	-60	dB
		Full range	-10			-10			-10			
I _O	Output current	25°C	10	20	20	10	20	20	10	20	20	mA
		Full range	5			5			5			
I _{OS}	Short-circuit output current	25°C	12	30	30	12	30	30	12	30	30	μA
		Full range	±40	±60	±60	±40	±60	±60	±40	±60	±60	
I _{CC}	Supply current (four amplifiers)	25°C	0.7	1.2	1.2	0.7	1.2	1.2	0.7	1.2	1.2	mA
		Full range	1.4	3	3	1.4	3	3	1.4	3	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, 30 V for the others.
 ‡ Full range is -55°C to 125°C for LM124, -25°C to 85°C for LM224, 0°C to 70°C for LM324, and -40°C to 125°C for LM2902.
 § All typical values are at T_A = 25°C.



LM124, LM124A, LM224, LM224A
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electrical characteristics at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted) (continued)

PARAMETER	TEST CONDITION†	T _A ‡	LM124A			LM224A			LM324A, LM324KA			UNIT
			MIN	TYP§	MAX	MIN	TYP§	MAX	MIN	TYP§	MAX	
V _{IO}	V _{CC} = 5 V to 30 V, V _{IC} = V _{ICRmin} , V _O = 1.4 V	25°C		2	2	3						mV
I _{IO}	V _O = 1.4 V	25°C		10	2	15						nA
I _{IB}	V _O = 1.4 V	25°C		30		30						nA
V _{ICR}	V _O = 1.4 V	25°C		-50		-80						nA
V _{OH}	V _{CC} = 30 V	25°C	0 to V _{CC} - 1.5		0 to V _{CC} - 1.5		0 to V _{CC} - 1.5		0 to V _{CC} - 1.5			V
V _{OL}	R _L = 2 kΩ	25°C	0 to V _{CC} - 1.5		0 to V _{CC} - 2		0 to V _{CC} - 2		0 to V _{CC} - 2			V
A _{VD}	V _{CC} = 30 V, R _L = 2 kΩ	Full range	26		26		26		26			V
CMRR	V _{CC} = 30 V, R _L ≥ 10 kΩ	Full range	27		27		27		27			V
k _{SVR}	R _L ≤ 10 kΩ	Full range		20		20						mV
V _{O1} /V _{O2}	V _{CC} = 15 V, V _O = 1 V to 11 V, R _L = ≥ 2 kΩ	Full range	25		25		25		25			V/mV
k _{SVR}	V _{IC} = V _{ICRmin}	25°C	70		70		70		70			dB
V _{O1} /V _{O2}	f = 1 kHz to 20 kHz	25°C	65		65		65		65			dB
I _O	V _{CC} = 15 V, V _{ID} = 1 V, V _O = 0	25°C	-20		-20		-20		-20			dB
I _O	V _{CC} = 15 V, V _{ID} = -1 V, V _O = 15 V	Full range	-10		-10		-10		-10			mA
I _O	V _{ID} = -1 V, V _O = 200 mV	25°C	10		10		10		10			mA
I _O	V _{CC} at 5 V, GND at -5 V, V _O = 0	Full range	5		5		5		5			μA
I _{OS}	V _O = 2.5 V, No load	25°C	12		12		12		12			μA
I _{CC}	V _{CC} = 30 V, No load	25°C	±40		±60		±40		±60			mA
I _{CC}	V _{CC} = 30 V, V _O = 15 V, No load	Full range	0.7		1.2		0.7		1.2			mA
I _{CC}	V _{CC} = 30 V, V _O = 15 V, No load	Full range	1.4		3		1.4		3			mA

† 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°C.



**LM124, LM124A, LM224, LM224A
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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	$\text{nV}/\sqrt{\text{Hz}}$

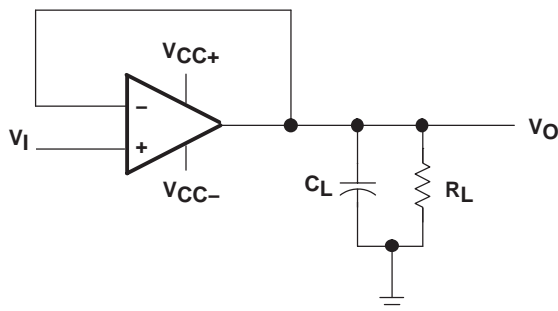


Figure 1. Unity-Gain Amplifier

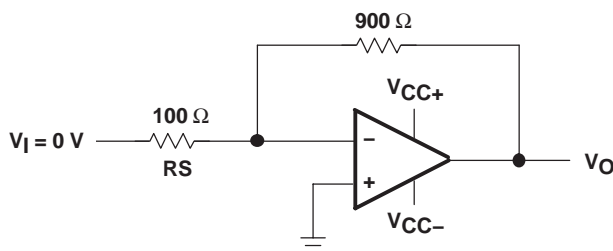
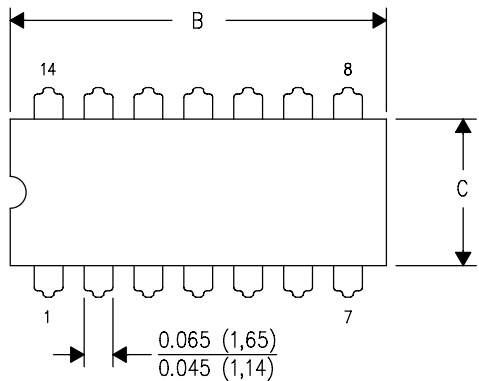


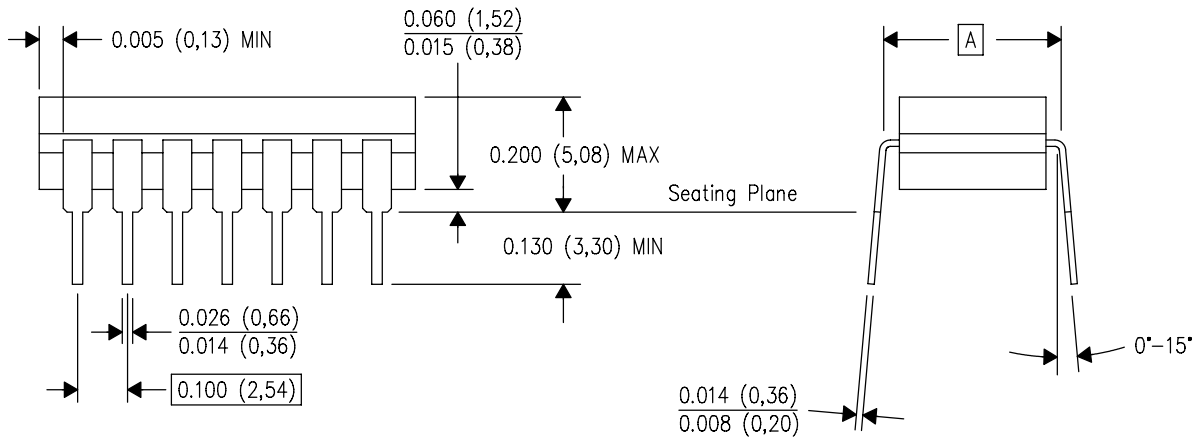
Figure 2. Noise-Test Circuit

J (R-GDIP-T**) 14 LEADS SHOWN

CERAMIC DUAL IN-LINE PACKAGE



DIM \ PINS **	14	16	18	20
A	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC
B MAX	0.785 (19,94)	.840 (21,34)	0.960 (24,38)	1.060 (26,92)
B MIN	—	—	—	—
C MAX	0.300 (7,62)	0.300 (7,62)	0.310 (7,87)	0.300 (7,62)
C MIN	0.245 (6,22)	0.245 (6,22)	0.220 (5,59)	0.245 (6,22)

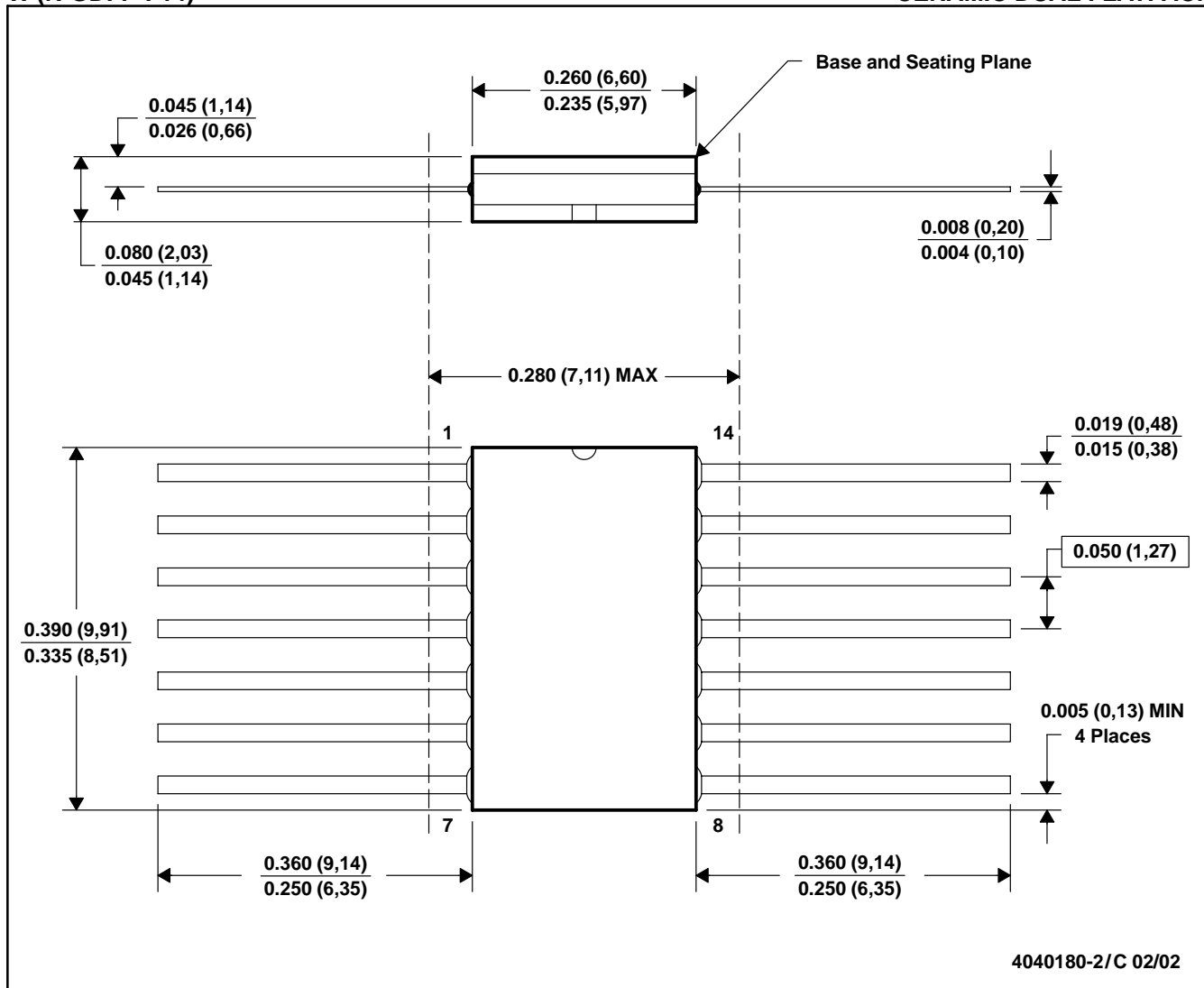


4040083/F 03/03

- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. This package is hermetically sealed with a ceramic lid using glass frit.
 - D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
 - E. Falls within MIL STD 1835 GDIP1-T14, GDIP1-T16, GDIP1-T18 and GDIP1-T20.

W (R-GDFP-F14)

CERAMIC DUAL FLATPACK

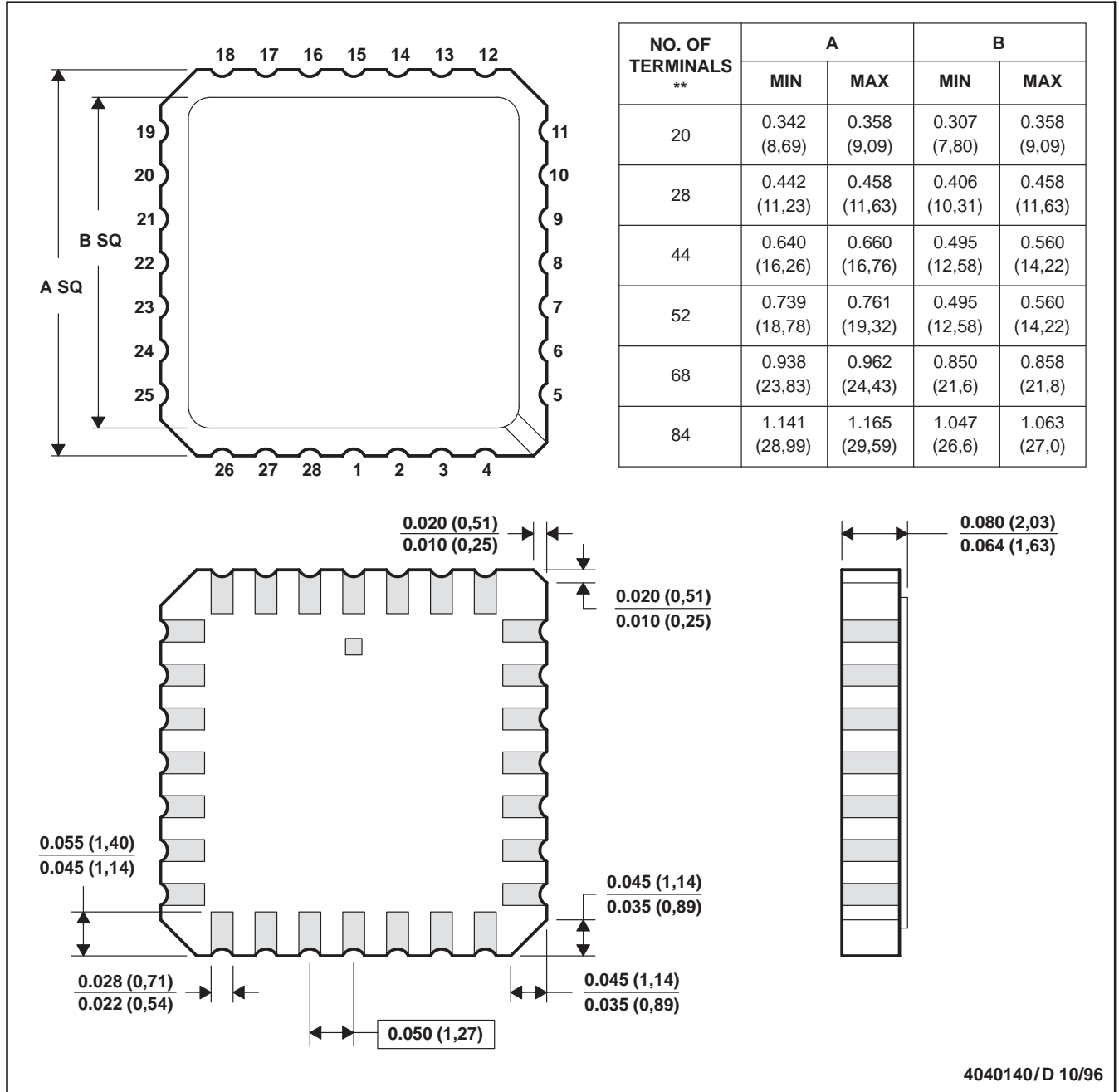


- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. This package can be hermetically sealed with a ceramic lid using glass frit.
 - D. Index point is provided on cap for terminal identification only.
 - E. Falls within MIL STD 1835 GDFP1-F14 and JEDEC MO-092AB

FK (S-CQCC-N**)

LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN

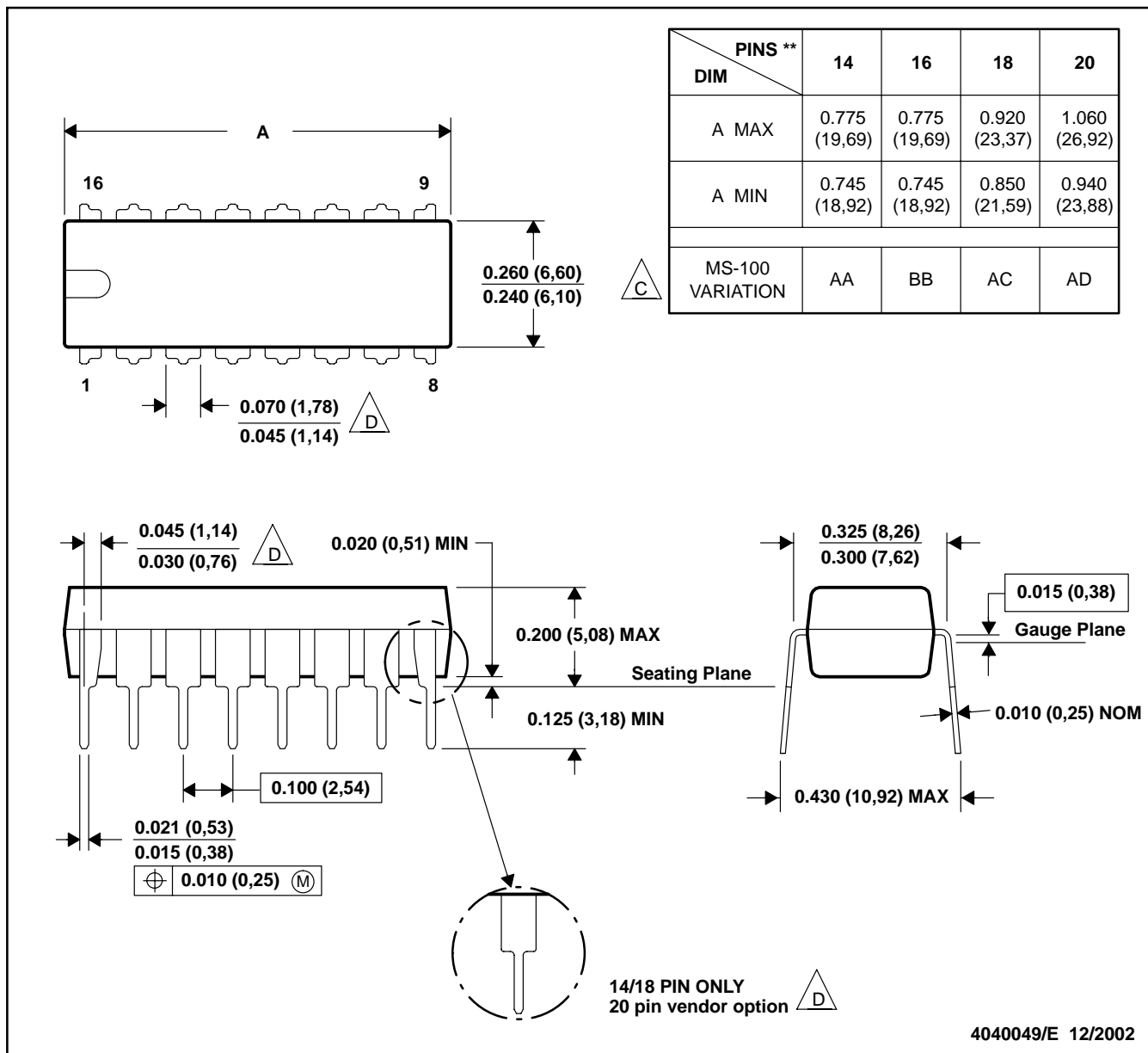


- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. This package can be hermetically sealed with a metal lid.
 - D. The terminals are gold plated.
 - E. Falls within JEDEC MS-004

N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN

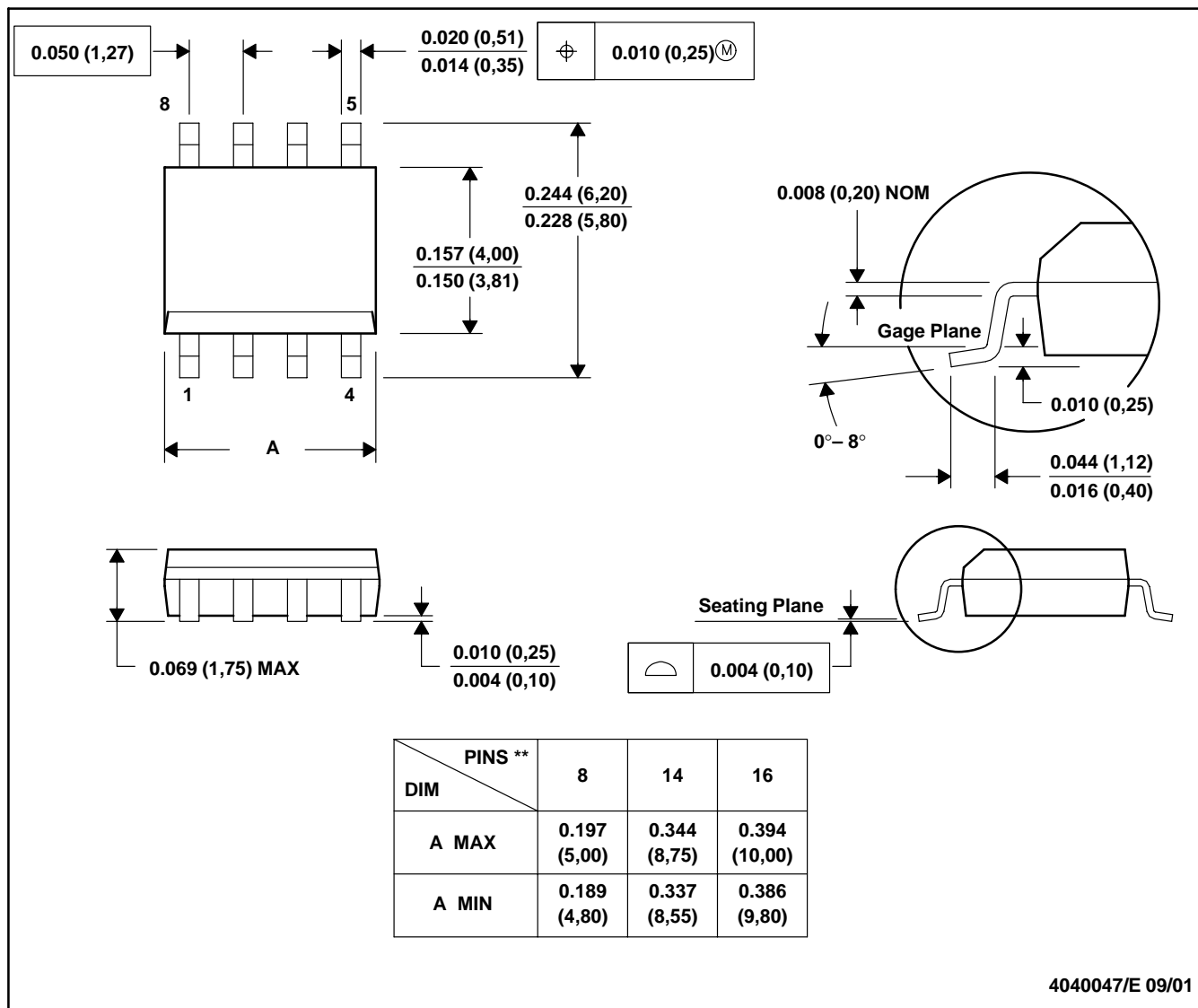


- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 (C) Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
 (D) The 20 pin end lead shoulder width is a vendor option, either half or full width.

D (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

8 PINS SHOWN



4040047/E 09/01

- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
 D. Falls within JEDEC MS-012

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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