











LM124-N, LM224-N LM2902-N, LM324-N

SNOSC16D - MARCH 2000 - REVISED JANUARY 2015

# LMx24-N, LM2902-N Low-Power, Quad-Operational Amplifiers

#### **Features**

- Internally Frequency Compensated for Unity Gain
- Large DC Voltage Gain 100 dB
- Wide Bandwidth (Unity Gain) 1 MHz (Temperature Compensated)
- Wide Power Supply Range:
  - Single Supply 3 V to 32 V
  - or Dual Supplies ±1.5 V to ±16 V
- Very Low Supply Current Drain (700 μA) —Essentially Independent of Supply Voltage
- Low Input Biasing Current 45 nA (Temperature Compensated)
- Low Input Offset Voltage 2 mV and Offset Current: 5 nA
- Input Common-Mode Voltage Range Includes Ground
- Differential Input Voltage Range Equal to the Power Supply Voltage
- Large Output Voltage Swing 0 V to V<sup>+</sup> 1.5 V

#### Advantages:

- Eliminates Need for Dual Supplies
- Four Internally Compensated Op Amps in a Single Package
- Allows Direct Sensing Near GND and V<sub>OUT</sub> also Goes to GND
- Compatible With All Forms of Logic
- Power Drain Suitable for Battery Operation
- In the Linear Mode the Input Common-Mode. Voltage Range Includes Ground and the **Output Voltage**
- Can Swing to Ground, Even Though Operated from Only a Single Power Supply Voltage
- Unity Gain Cross Frequency is Temperature Compensated
- Input Bias Current is Also Temperature Compensated

## **Applications**

- **Transducer Amplifiers**
- DC Gain Blocks
- Conventional Op Amp Circuits

## 3 Description

The LM124-N series consists of four independent, frequency high-gain, internally compensated operational amplifiers designed to operate from a single power supply over a wide range of voltages. Operation from split-power supplies is also possible and the low-power supply current drain is independent of the magnitude of the power supply voltage.

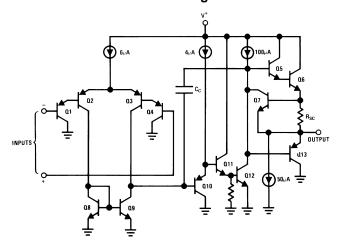
Application areas include transducer amplifiers, DC gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM124-N series can directly operate off of the standard 5-V power supply voltage which is used in digital systems and easily provides the required interface electronics without requiring the additional ±15 V power supplies.

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

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM124-N	CDID (4.4)	19.56 mm × 6.67 mm
LM224-N	CDIP (14)	19.50 IIIII X 0.07 IIIIII
	CDIP (14)	19.56 mm × 6.67 mm
LM324-N	PDIP (14)	19.177 mm × 6.35 mm
LIVI324-IN	SOIC (14)	8.65 mm × 3.91 mm
	TSSOP (14)	5.00 mm × 4.40 mm
	PDIP (14)	19.177 mm × 6.35 mm
LM2902-N	SOIC (14)	8.65 mm × 3.91 mm
	TSSOP (14)	5.00 mm × 4.40 mm

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

#### Schematic Diagram





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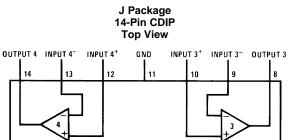
# 4 Revision History

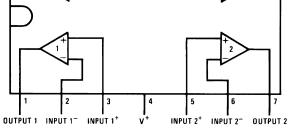
#### Changes from Revision C (November 2012) to Revision D

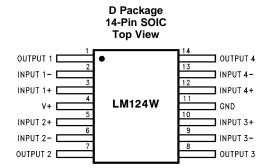
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# 5 Pin Configuration and Functions







**Pin Functions** 

Р	IN	TVDE	DESCRIPTION				
NAME	NO.	TYPE	DESCRIPTION				
OUTPUT1	1	0	Output, Channel 1				
INPUT1-	2	1	Inverting Input, Channel 1				
INPUT1+	3	1	Noninverting Input, Channel 1				
V+	4	Р	Positive Supply Voltage				
INPUT2+	5	I	Nonnverting Input, Channel 2				
INPUT2-	6	1	Inverting Input, Channel 2				
OUTPUT2	7	0	Output, Channel 2				
OUTPUT3	8	0	Output, Channel 3				
INPUT3-	9	1	Inverting Input, Channel 3				
INPUT3+	10	I	Noninverting Input, Channel 3				
GND	11	Р	Ground or Negative Supply Voltage				
INPUT4+	12	1	Noninverting Input, Channel 4				
INPUT4-	13	1	Inverting Input, Channel 4				
OUTPUT4	14	0	Output, Channel 4				



## 6 Specifications

#### 6.1 Absolute Maximum Ratings

See (1)(2)

			LM124-N/LM22 LM124A/LM2		LM2902-N			
			MIN	MAX	MIN	MAX	UNIT	
Supply Voltage,	<b>/</b> +			32		26	V	
Differential Input	Voltage			32		26		
Input Voltage			-0.3	32	-0.3	26	V	
Input Current (VII	v < -0.3 V) <sup>(3)</sup>			50		50	mA	
Power Dissipation <sup>(4)</sup>	PDIP			1130		1130	mW	
	CDIP			1260		1260	mW	
	SOIC Packag	ge		800		800	mW	
Output Short-Circ (One Amplifier) <sup>(5)</sup>	cuit to GND	V <sup>+</sup> ≤ 15 V and T <sub>A</sub> = 25°C	Contir	nuous	C	Continuous		
Lead Temperatu	e (Soldering, 10	) seconds)		260		260	°C	
Soldering	Dual-In-Line Package	Soldering (10 seconds)		260		260	°C	
Information	Small	Vapor Phase (60 seconds)		215		215	°C	
	Outline Package	Infrared (15 seconds)		220		220	°C	
Storage tempera	ture, T <sub>stg</sub>		-65	150	-65	150	°C	

- (1) Refer to RETS124AX for LM124A military specifications and refer to RETS124X for LM124-N military specifications.
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
- (3) This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the op amps to go to the V⁺voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than −0.3 V (at 25°C).
- (4) For operating at high temperatures, the LM324-N/LM324A/LM2902-N must be derated based on a 125°C maximum junction temperature and a thermal resistance of 88°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM224-N/LM224A and LM124-N/LM124A can be derated based on a 150°C maximum junction temperature. The dissipation is the total of all four amplifiers—use external resistors, where possible, to allow the amplifier to saturate of to reduce the power which is dissipated in the integrated circuit.
- (5) Short circuits from the output to V<sup>+</sup> can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V<sup>+</sup>. At values of supply voltage in excess of 15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

#### 6.2 ESD Ratings

			VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	±250	V

(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)

	MIN	MAX	UNIT
Supply Voltage (V <sup>+</sup> - V <sup>-</sup> ): LM124-N/LM124A/LM224-N/LM224A/LM324-N/LM324A	3	32	V
Supply Voltage (V <sup>+</sup> - V <sup>-</sup> ): LM2902-N	3	26	V
Operating Input Voltage on Input pins	0	V+	V
Operating junction temperature, T <sub>J</sub> : LM124-N/LM124A	-55	125	°C
Operating junction temperature, T <sub>J</sub> : L2902-N	-40	85	°C
Operating junction temperature, T <sub>J</sub> : LM224-N/LM224A	-25	85	°C
Operating junction temperature, T <sub>J</sub> : LM324-N/LM324A	0	70	°C

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#### 6.4 Thermal Information

		LM124-N / LM324-N / LM224-N LM2902-N			
	THERMAL METRIC <sup>(1)</sup>	J/CDIP D/SOIC		UNIT	
		14 PINS	14 PINS		
$R_{\theta JA}$	Junction-to-ambient thermal resistance	88	88	°C/W	

<sup>(1)</sup> For more information about traditional and new thermal metrics, see the IC Package Thermal Metrics application report, SPRA953.

#### 6.5 Electrical Characteristics: LM124A/224A/324A

 $V^+ = 5.0 \text{ V}$ , (1), unless otherwise stated

			L	.M124A		ı	LM224A			LM324A		UNIT
PAR	AMETER	TEST CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNII
Input Offse	t Voltage	$T_A = 25^{\circ}C^{(2)}$		1	2		1	3	*	2	3	mV
Input Bias	Current <sup>(3)</sup>	$I_{IN(+)}$ or $I_{IN(-)}$ , $V_{CM} = 0$ V, $T_A = 25$ °C		20	50		40	80		45	100	nA
Input Offse	t Current	$I_{IN(+)}$ or $I_{IN(-)}$ , $V_{CM} = 0$ V, $T_A = 25$ °C		2	10		2	15		5	30	nA
Input Comr Voltage Ra		V <sup>+</sup> = 30 V, (LM2902-N, V <sup>+</sup> = 26 V), T <sub>A</sub> = 25°C	0		V+-1.5	0		V <sup>+</sup> -1.5	0		V+-1.5	V
Supply Cur	rent	Over Full Temperature Range, $R_L = \infty$ On All Op Amps V <sup>+</sup> = 30 V (LM2902-N V <sup>+</sup> = 26 V)		1.5	3		1.5	3		1.5	3	mA
		V <sup>+</sup> = 5 V		0.7	1.2		0.7	1.2		0.7	1.2	
Large Signa Voltage Ga		$V^+$ = 15 V, R <sub>L</sub> ≥ 2 kΩ, (V <sub>O</sub> = 1 V to 11 V), T <sub>A</sub> = 25°C	50	100		50	100		25	100		V/mV
Common-M Rejection F		DC, $V_{CM} = 0 \text{ V to V}^+ - 1.5 \text{ V}$ , $T_A = 25^{\circ}\text{C}$	70	85		70	85		65	85		dB
Power Sup Rejection R		$V^{+} = 5 \text{ V to } 30 \text{ V, (LM2902-N,}$ $V^{+} = 5 \text{V to } 26 \text{ V),}$ $T_{A} = 25^{\circ}\text{C}$	65	100		65	100		65	100		dB
Amplifier-to Coupling (5)		f = 1 kHz to 20 kHz, T <sub>A</sub> = 25°C, (Input Referred)		-120			-120			-120		dB
	Source	V <sub>IN</sub> <sup>+</sup> = 1 V, V <sub>IN</sub> <sup>-</sup> = 0 V, V <sup>+</sup> = 15 V, V <sub>O</sub> = 2 V, T <sub>A</sub> = 25°C	20	40		20	40		20	40		mA
Output Current	Sink	$V_{IN}^- = 1 \text{ V}, V_{IN}^+ = 0 \text{ V},$ $V^+ = 15 \text{ V}, V_O = 2 \text{ V}, T_A = 25^{\circ}\text{C}$	10	20		10	20		10	20		
	SILIK	V <sub>IN</sub> <sup>-</sup> = 1 V, V <sub>IN</sub> <sup>+</sup> = 0 V, V <sup>+</sup> = 15 V, V <sub>O</sub> = 200 mV, T <sub>A</sub> = 25°C	12	50		12	50		12	50		μA
Short Circu	it to Ground	$V^{+} = 15 \text{ V},$ $T_{A} = 25^{\circ}C^{(6)}$		40	60		40	60		40	60	mA
Input Offse	t Voltage	See <sup>(2)</sup>			4			4			5	mV
V <sub>OS</sub> Drift		$R_S = 0 \Omega$	·	7	20		7	20		7	30	μV/°C
Input Offse	t Current	$I_{IN(+)} - I_{IN(-)}, V_{CM} = 0 V$			30			30			75	nA

<sup>(1)</sup> These specifications are limited to −55°C ≤ T<sub>A</sub> ≤ +125°C for the LM124-N/LM124A. With the LM224-N/LM224A, all temperature specifications are limited to −25°C ≤ T<sub>A</sub> ≤ +85°C, the LM324-N/LM324A temperature specifications are limited to 0°C ≤ T<sub>A</sub> ≤ +70°C, and the LM2902-N specifications are limited to −40°C ≤ T<sub>A</sub> ≤ +85°C.

<sup>(2)</sup>  $V_0 \approx 1.4V$ ,  $R_S = 0$   $\Omega$  with V<sup>+</sup> from 5 V to 30 V; and over the full input common-mode range (0 V to V<sup>+</sup> - 1.5 V) for LM2902-N, V<sup>+</sup> from 5 V to 26 V.

<sup>(3)</sup> The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

<sup>(4)</sup> The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3 V (at 25°C). The upper end of the common-mode voltage range is V<sup>+</sup> – 1.5 V (at 25°C), but either or both inputs can go to 32 V without damage (26 V for LM2902-N), independent of the magnitude of V<sup>+</sup>.

<sup>(5)</sup> Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.

<sup>(6)</sup> Short circuits from the output to V+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V+. At values of supply voltage in excess of 15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.



## Electrical Characteristics: LM124A/224A/324A (continued)

 $V^{+} = 5.0 \text{ V}$ . (1), unless otherwise stated

DAE		TEST OF	NUNTIONS	L	.M124A		L	M224A		LM324A			UNIT	
PAR	RAMETER	TEST CO	ONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNIT	
I <sub>OS</sub> Drift		$R_S = 0 \Omega$			10	200		10	200	·	10	300	300 pA/°C	
Input Bias	Current	$I_{IN(+)}$ or $I_{IN(-)}$			40	100		40	100		40	200	nA	
Input Com Voltage Ra	mon-Mode ange <sup>(4)</sup>	V <sup>+</sup> = 30 V, (LM2902-N, V <sup>+</sup> =	= 26 V)	0		V+-2	0		V+-2	0		V+-2	/+-2 V	
Large Sigr Voltage Ga		$V^{+} = 15 \text{ V } (V_{O}Sw$ $R_{L} \ge 2 \text{ k}\Omega$	ving = 1 V to 11 V),	25			25			15			V/mV	
_		V <sup>+</sup> = 30 V	$R_L = 2 k\Omega$	26			26			26				
Output Voltage Swing	V <sub>OH</sub>	$(LM2902-N, V^+ = 26 V)$	$R_L = 10 \text{ k}\Omega$	27	28		27	28		27	28		V	
Swirig	V <sub>OL</sub>	$V^{+} = 5 \text{ V}, \text{ R}_{L} = 10 \text{ k}\Omega$			5	20		5	20		5	20	mV	
Output	Source	V 2V	$V_{IN}^{+} = +1V,$ $V_{IN}^{-} = 0V,$ $V^{+} = 15V$	10	20		10	20		10	20		A	
Current	Sink	V <sub>O</sub> = 2 V	$V_{IN}^{-} = +1V,$ $V_{IN}^{+} = 0V,$ $V^{+} = 15V$	10	15		5	8		5	8		mA	

#### 6.6 Electrical Characteristics: LM124-N/224-N/324-N/2902-N

 $V^+ = +5.0V$ . (1) unless otherwise stated

DADAMETED	TEST CONDITIONS	LM124	-N / LM	224-N	L	M324-N	I	LN	/12902-1	N	UNIT	
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	ONIT	
Input Offset Voltage	$T_A = 25^{\circ}C^{(2)}$		2	5		2	7		2	7	mV	
Input Bias Current <sup>(3)</sup>	$I_{IN(+)}$ or $I_{IN(-)}$ , $V_{CM}=0$ V, $T_A=25^{\circ}C$		45	150		45	250		45	250	nA	
Input Offset Current	$I_{IN(+)}$ or $I_{IN(-)}$ , $V_{CM} = 0$ V, $T_A = 25$ °C		3	30		5	50		5	50	nA	
Input Common-Mode Voltage Range (4)	V <sup>+</sup> = 30 V, (LM2902-N, V <sup>+</sup> = 26V), T <sub>A</sub> = 25°C	0		V <sup>+</sup> −1. 5	0		V <sup>+</sup> −1. 5	0		V <sup>+</sup> −1. 5	V	
Supply Current	Over Full Temperature Range $R_L = \infty$ On All Op Amps, $V^+ = 30 \text{ V (LM2902-N V}^+ = 26 \text{ V)}$		1.5	3		1.5	3		1.5	3	mA	
	V <sup>+</sup> = 5 V		0.7	1.2		0.7	1.2		0.7	1.2		
Large Signal Voltage Gain	$V^+ = 15V$ , $R_L \ge 2 kΩ$ , $(V_O = 1 V to 11 V)$ , $T_A = 25$ °C	50	100		25	100		25	100		V/mV	
Common-Mode Rejection Ratio	DC, $V_{CM} = 0 \text{ V to V}^+ - 1.5 \text{ V}$ , $T_A = 25^{\circ}\text{C}$	70	85		65	85		50	70		dB	
Power Supply Rejection Ratio	V <sup>+</sup> = 5 V to 30 V (LM2902-N, V <sup>+</sup> = 5 V to 26 V), T <sub>A</sub> = 25°C	65	100		65	100		50	100		dB	
Amplifier-to-Amplifier Coupling <sup>(5)</sup>	f = 1 kHz to 20 kHz, T <sub>A</sub> = 25°C (Input Referred)		-120			-120			-120		dB	

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<sup>(1)</sup> These specifications are limited to -55°C ≤ T<sub>A</sub> ≤ +125°C for the LM124-N/LM124A. With the LM224-N/LM224A, all temperature specifications are limited to -25°C ≤ T<sub>A</sub> ≤ +85°C, the LM324-N/LM324A temperature specifications are limited to 0°C ≤ T<sub>A</sub> ≤ +70°C, and the LM2902-N specifications are limited to -40°C ≤ T<sub>A</sub> ≤ +85°C.

<sup>(2)</sup>  $V_0 \approx 1.4V$ ,  $R_S = 0$   $\Omega$  with V<sup>+</sup> from 5 V to 30 V; and over the full input common-mode range (0 V to V<sup>+</sup> - 1.5 V) for LM2902-N, V<sup>+</sup> from 5 V to 26 V.

<sup>(3)</sup> The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

<sup>(4)</sup> The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3 V (at 25°C). The upper end of the common-mode voltage range is V<sup>+</sup> – 1.5 V (at 25°C), but either or both inputs can go to 32 V without damage (26 V for LM2902-N), independent of the magnitude of V<sup>+</sup>.

<sup>(5)</sup> Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.



# Electrical Characteristics: LM124-N/224-N/324-N/2902-N (continued)

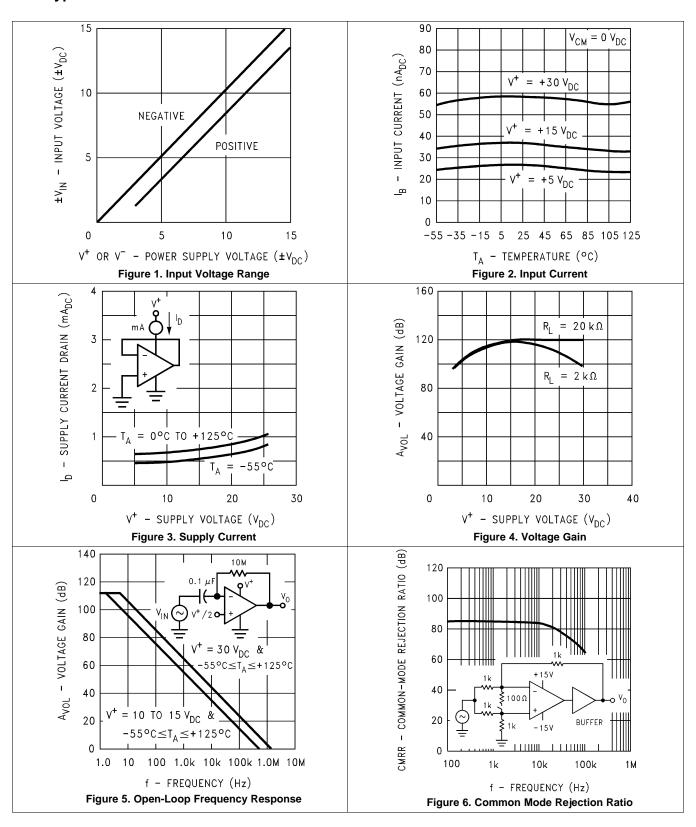
 $V^+ = +5.0V$ , (1), unless otherwise stated

D.4.D		TEGT CONDITI	0110	LM124	N / LM	224-N	L	M324-N		LN	/12902-1	١	
PAR	AMETER	TEST CONDITI	ONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNIT
	Source	$V_{IN}^{+} = 1 \text{ V, } V_{IN}^{-} = 0 \text{ V,}$ $V^{+} = 15 \text{ V, } V_{O} = 2 \text{ V, } T_{A} = 25^{\circ}\text{C}$		20	40		20	40		20	40		mA
Output Current	Sink	$V_{IN}^- = 1 \text{ V}, V_{IN}^+ = 0 \text{ V},$ $V^+ = 15 \text{ V}, V_O = 2 \text{ V}, T_A = 2$	25°C	10	20		10	20		10	20		mA
	SIIIK	$V_{IN}^- = 1 \text{ V}, V_{IN}^+ = 0 \text{ V},$ $V^+ = 15 \text{ V}, V_O = 200 \text{ mV}, \text{ T}$	A = 25°C	12	50		12	50		12	50		μΑ
Short Circuit	to Ground	$V^{+} = 15 \text{ V}, T_{A} = 25^{\circ}\text{C}^{(6)}$			40	60		40	60		40	60	mA
Input Offset	Voltage	See (2)				7			9			10	mV
V <sub>OS</sub> Drift	S Drift $R_S = 0 \Omega$			7			7			7		μV/°C	
Input Offset	ut Offset Current $I_{IN(+)} - I_{IN(-)}, V_{CM} = 0 \text{ V}$				100			150		45	200	nA	
I <sub>OS</sub> Drift	Drift $R_S = 0 \Omega$			10			10			10		pA/°C	
Input Bias C	urrent	I <sub>IN(+)</sub> or I <sub>IN(-)</sub>			40	300		40	500		40	500	nA
Input Commo Range (4)	on-Mode Voltage	V <sup>+</sup> = 30 V, (LM2902-N, V <sup>+</sup>	= 26 V)	0		V+-2	0		V+-2	0		V+-2	V
Large Signal	Voltage Gain	$V^+ = 15 \text{ V } (V_0 \text{Swing} = 1 \text{ V } \text{t}$ $R_L \ge 2 \text{ k}\Omega$	o 11V),	25			15			15			V/mV
Output		V+ = 30 V (LM2902-N,	$R_L = 2 k\Omega$	26			26			22			V
Voltage	V <sub>OH</sub>	V <sup>+</sup> = 26 V)	$R_L = 10 \text{ k}\Omega$	27	28		27	28		23	24		V
Swing	V <sub>OL</sub>	$V^{+} = 5 \text{ V}, \text{ R}_{L} = 10 \text{ k}\Omega$			5	20		5	20		5	100	mV
Output	Source	V <sub>O</sub> = 2 V	$V_{IN}^{+} = 1 \text{ V},$ $V_{IN}^{-} = 0 \text{ V},$ $V^{+} = 15 \text{ V}$	10	20		10	20		10	20		mA
Current	Sink		$V_{IN}^{-} = 1 \text{ V},$ $V_{IN}^{+} = 0 \text{ V},$ $V^{+} = 15 \text{ V}$	5	8		5	8		5	8		mA

<sup>(6)</sup> Short circuits from the output to V<sup>+</sup> can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V<sup>+</sup>. At values of supply voltage in excess of 15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

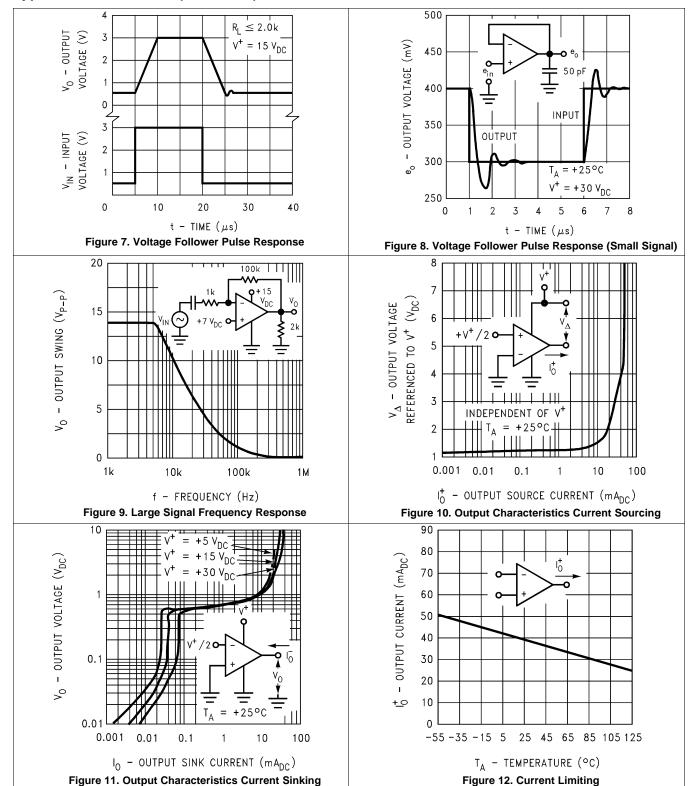


## 6.7 Typical Characteristics



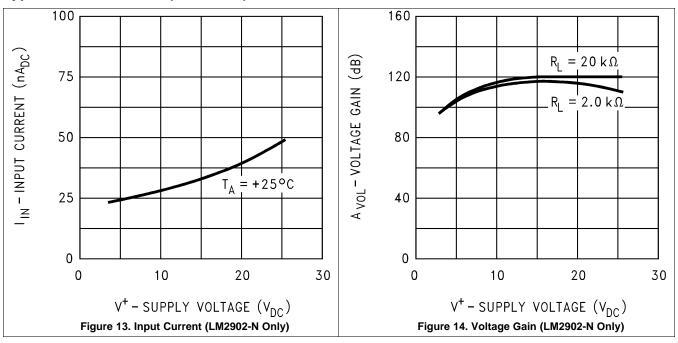


## **Typical Characteristics (continued)**





# **Typical Characteristics (continued)**



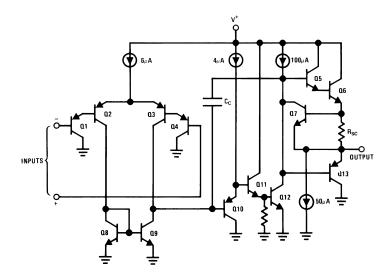


## 7 Detailed Description

#### 7.1 Overview

The LM124-N series are op amps which operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 V<sub>DC</sub>. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3 V<sub>DC</sub>.

## 7.2 Functional Block Diagram



## 7.3 Feature Description

The LM124 provides a compelling balance of performance versus current consumption. The 700  $\mu$ A of supply current draw over the wide operating conditions with a 1-MHz gain-bandwidth and temperature compensated bias currents makes the LM124 an effective solution for large variety of applications. The input offset voltage of 2 mV and offset current of 5 nA, along with the 45n-A bias current across a wide supply voltage means a single design can be used in a large number of different implementations.

## 7.4 Device Functional Modes

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than  $V^+$  without damaging the device. Protection should be provided to prevent the input voltages from going negative more than  $-0.3~V_{DC}$  (at  $25^{\circ}C$ ). An input clamp diode with a resistor to the IC input terminal can be used.

To reduce the power supply drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion.

Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.



## **Device Functional Modes (continued)**

The bias network of the LM124-N establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 3  $V_{DC}$  to 30  $V_{DC}$ .

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see *Typical Characteristics*) than a standard IC op amp.



## 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.

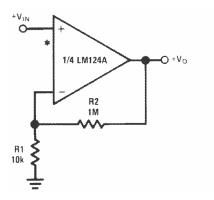
## 8.1 Application Information

The LM124 series of amplifiers is specified for operation from 3 V to 32 V (±1.5 V to ±16 V). Many of the specifications apply from -40°C to 125°C. Parameters that can exhibit significant variance with regards to operating voltage or temperature are presented in *Typical Characteristics*.

## 8.2 Typical Applications

Figure 15 emphasizes operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of V<sup>+</sup>/2) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

#### 8.2.1 Non-Inverting DC Gain (0 V Input = 0 V Output)



<sup>\*</sup>R not needed due to temperature independent I<sub>IN</sub>

Figure 15. Non-Inverting Amplifier with G=100

#### 8.2.1.1 Design Requirements

For this example application, the required signal gain is a non-inverting 100x±5% with a supply voltage of 5 V.

#### 8.2.1.2 Detailed Design Procedure

Using the equation for a non-inverting gain configuration, Av = 1+R2/R1. Setting the R1 to 10 k $\Omega$ , R2 is 99 times larger than R1, which is 990 k $\Omega$ . A 1M $\Omega$  is more readily available, and provides a gain of 101, which is within the desired specification.

The gain-frequency characteristic of the amplifier and its feedback network must be such that oscillation does not occur. To meet this condition, the phase shift through amplifier and feedback network must never exceed 180° for any frequency where the gain of the amplifier and its feedback network is greater than unity. In practical applications, the phase shift should not approach 180° since this is the situation of conditional stability. Obviously the most critical case occurs when the attenuation of the feedback network is zero.



# 8.2.1.3 Application Curve

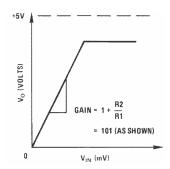
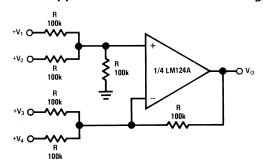


Figure 16. Non-Inverting Amplified Response Curve

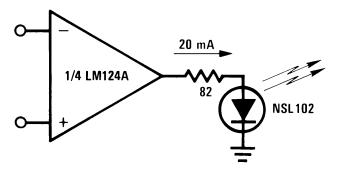


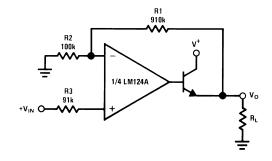
## 8.2.2 Other Application Circuits at $V^+ = 5.0 V_{DC}$



Where: 
$$V_0 = V_1 + V_2 - V_3 - V_4$$
  
 $(V_1 + V_2) \ge (V_3 + V_4)$  to keep  $V_0 > 0$   $V_{DC}$ 

Figure 17. DC Summing Amplifier  $(V_{IN'S} \ge 0 \ V_{DC} \ And \ V_O \ge V_{DC})$ 





Where:  $V_0 = 0 V_{DC}$  for  $V_{IN} = 0 V_{DC}$  $A_V = 10$ 

Figure 18. Power Amplifier

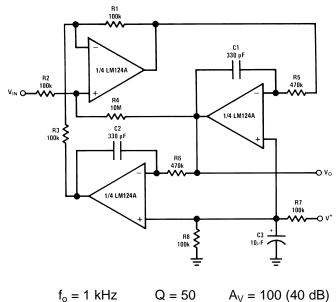
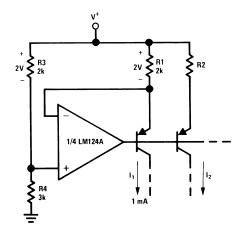


Figure 19. LED Driver

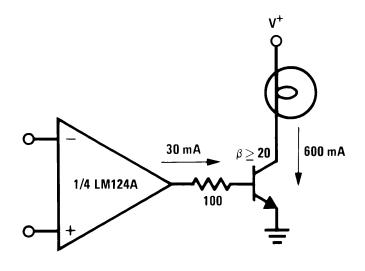
Figure 20. "BI-QUAD" RC Active Bandpass Filter

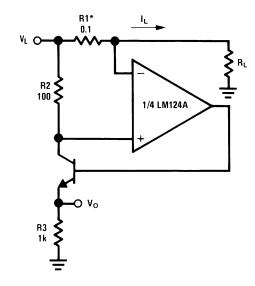




$$I_2 = \left(\frac{R1}{R2}\right)I_1$$

Figure 21. Fixed Current Sources





\*(Increase R1 for  $I_L$  small)

Figure 22. Lamp Driver

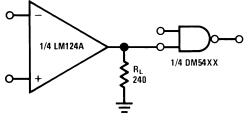


Figure 24. Driving TTL

Figure 23. Current Monitor

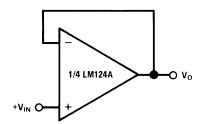


Figure 25. Voltage Follower



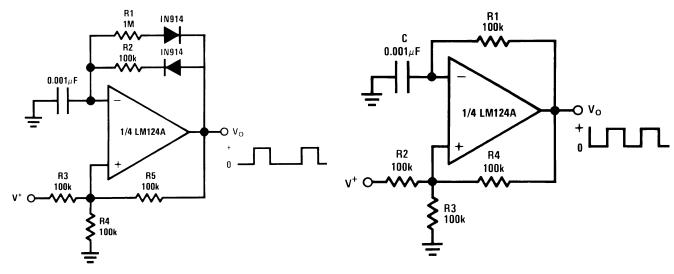


Figure 26. Pulse Generator

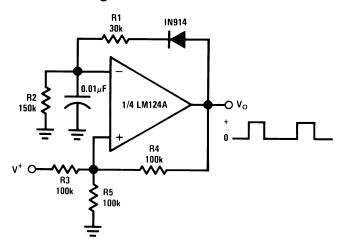
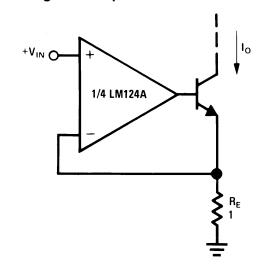


Figure 27. Squarewave Oscillator



 $I_O = 1$  amp/volt  $V_{IN}$  (Increase  $R_E$  for  $I_o$  small)

Figure 28. Pulse Generator

Figure 29. High Compliance Current Sink



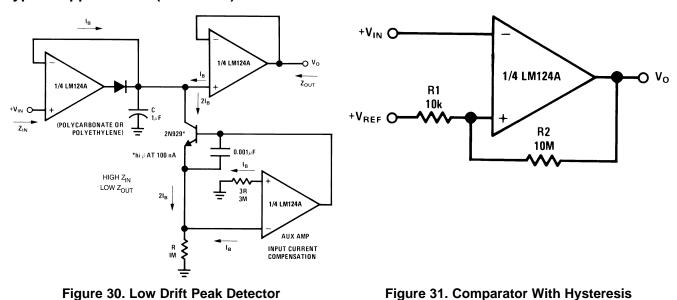


Figure 30. Low Drift Peak Detector

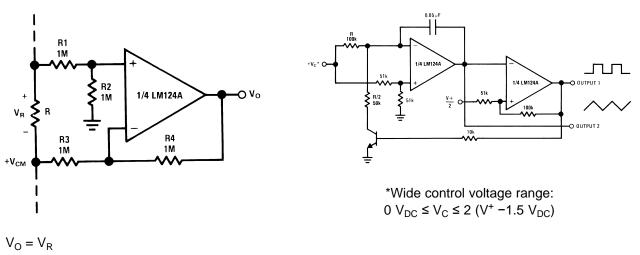


Figure 32. Ground Referencing a Differential Input **Signal** 

Figure 33. Voltage Controlled Oscillator Circuit



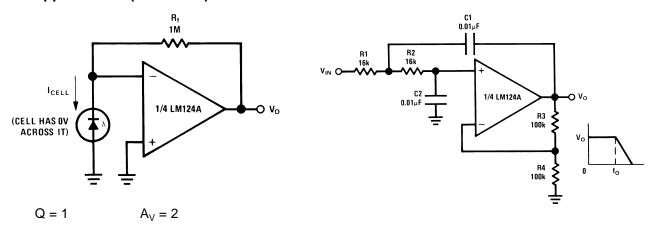


Figure 34. Photo Voltaic-Cell Amplifier

Figure 35. DC Coupled Low-Pass RC Active Filter

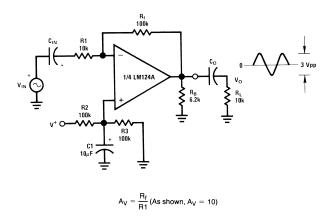


Figure 36. AC Coupled Inverting Amplifier

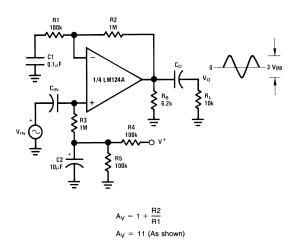


Figure 37. AC Coupled Non-Inverting Amplifier



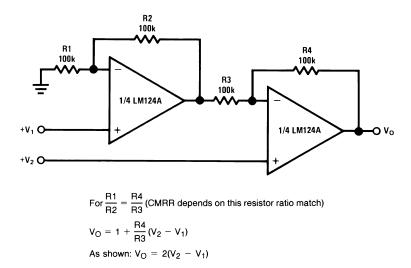


Figure 38. High Input Z, DC Differential Amplifier

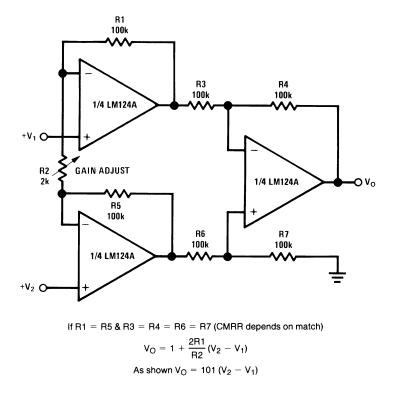


Figure 39. High Input Z Adjustable-Gain DC Instrumentation Amplifier



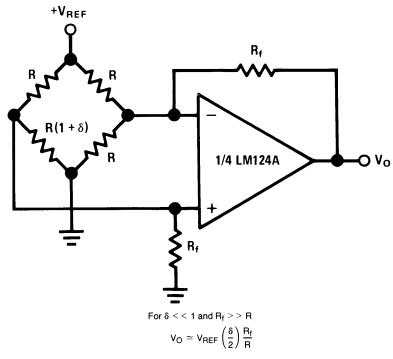


Figure 40. Bridge Current Amplifier

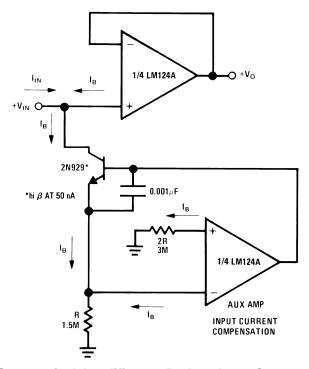


Figure 41. Using Symmetrical Amplifiers to Reduce Input Current (General Concept)



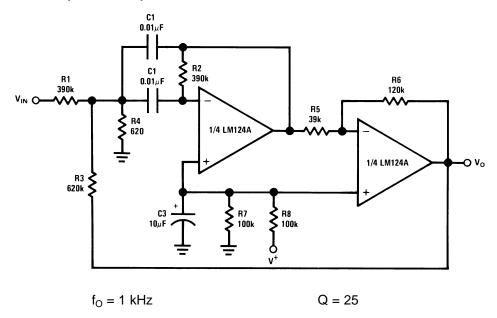


Figure 42. Bandpass Active Filter



## 9 Power Supply Recommendations

The pinouts of the package have been designed to simplify PC board layouts. Inverting inputs are adjacent to outputs for all of the amplifiers and the outputs have also been placed at the corners of the package (pins 1, 7, 8, and 14).

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

## 10 Layout

## 10.1 Layout Guidelines

The V + pin should be bypassed to ground with a low-ESR capacitor. The optimum placement is closest to the V + and ground pins.

Take care to minimize the loop area formed by the bypass capacitor connection between V + and ground.

The ground pin should be connected to the PCB ground plane at the pin of the device.

The feedback components should be placed as close to the device as possible minimizing strays.

## 10.2 Layout Example

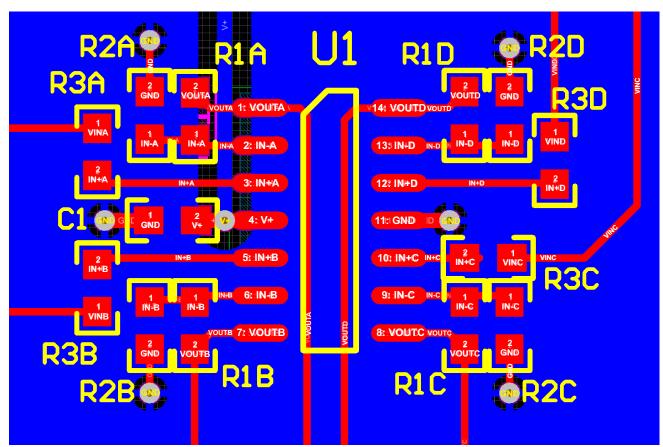


Figure 43. Layout Example



## 11 Device and Documentation Support

#### 11.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 1. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LM124-N	Click here	Click here	Click here	Click here	Click here
LM224-N	Click here	Click here	Click here	Click here	Click here
LM2902-N	Click here	Click here	Click here	Click here	Click here
LM324-N	Click here	Click here	Click here	Click here	Click here

#### 11.2 Trademarks

All trademarks are the property of their respective owners.

#### 11.3 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## 11.4 Glossary

SLYZ022 — TI Glossary.

This glossary lists and explains terms, acronyms, and definitions.

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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## **PACKAGING INFORMATION**

Orderable part number	Status (1)	Material type	Package   Pins	Package qty   Carrier	<b>RoHS</b> (3)	Lead finish/ Ball material	MSL rating/ Peak reflow	Op temp (°C)	Part marking (6)
LM124AJ/PB	Active	Production	CDIP (J)   14	25   TUBE	No	Call TI	Level-1-NA-UNLIM	-55 to 125	LM124AJ
LM124J/PB	Active	Production	CDIP (J)   14	25   TUBE	No	Call TI	Level-1-NA-UNLIM	-55 to 125	LM124J
LM224J	Active	Production	CDIP (J)   14	25   TUBE	No	Call TI	Level-1-NA-UNLIM	-25 to 85	LM224J
LM2902M/NOPB	Active	Production	SOIC (D)   14	55   TUBE	Yes	NIPDAU   SN	Level-1-260C-UNLIM	-40 to 85	LM2902M
LM2902M/NOPB.B	Active	Production	SOIC (D)   14	55   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	LM2902M
LM2902MT/NOPB	Active	Production	TSSOP (PW)   14	94   TUBE	Yes	SN	Level-1-260C-UNLIM	-40 to 85	LM290 2MT
LM2902MT/NOPB.B	Active	Production	TSSOP (PW)   14	94   TUBE	Yes	SN	Level-1-260C-UNLIM	-40 to 85	LM290 2MT
LM2902MTX/NOPB	Active	Production	TSSOP (PW)   14	2500   LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 85	LM290 2MT
LM2902MTX/NOPB.B	Active	Production	TSSOP (PW)   14	2500   LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 85	LM290 2MT
LM2902MX/NOPB	Active	Production	SOIC (D)   14	2500   LARGE T&R	Yes	NIPDAU   SN	Level-1-260C-UNLIM	-40 to 85	LM2902M
LM2902MX/NOPB.B	Active	Production	SOIC (D)   14	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	LM2902M
LM2902N/NOPB	Active	Production	PDIP (N)   14	25   TUBE	Yes	Call TI   Nipdau	Level-1-NA-UNLIM	-40 to 85	LM2902N
LM2902N/NOPB.B	Active	Production	PDIP (N)   14	25   TUBE	Yes	NIPDAU	Level-1-NA-UNLIM	-40 to 85	LM2902N
LM324AM/NOPB	Active	Production	SOIC (D)   14	55   TUBE	Yes	NIPDAU   SN	Level-1-260C-UNLIM	0 to 70	LM324AM
LM324AM/NOPB.B	Active	Production	SOIC (D)   14	55   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	LM324AM
LM324AMX/NOPB	Active	Production	SOIC (D)   14	2500   LARGE T&R	Yes	NIPDAU   SN	Level-1-260C-UNLIM	0 to 70	LM324AM
LM324AMX/NOPB.B	Active	Production	SOIC (D)   14	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	LM324AM
LM324AN/NOPB	Active	Production	PDIP (N)   14	25   TUBE	Yes	NIPDAU	Level-1-NA-UNLIM	0 to 70	LM324AN
LM324AN/NOPB.B	Active	Production	PDIP (N)   14	25   TUBE	Yes	NIPDAU	Level-1-NA-UNLIM	0 to 70	LM324AN
LM324M/NOPB	Active	Production	SOIC (D)   14	55   TUBE	Yes	NIPDAU   SN	Level-1-260C-UNLIM	0 to 70	LM324M
LM324M/NOPB.B	Active	Production	SOIC (D)   14	55   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	LM324M
LM324MT/NOPB	Active	Production	TSSOP (PW)   14	94   TUBE	Yes	SN	Level-1-260C-UNLIM	0 to 70	LM324 MT
LM324MT/NOPB.B	Active	Production	TSSOP (PW)   14	94   TUBE	Yes	SN	Level-1-260C-UNLIM	0 to 70	LM324 MT
LM324MTX/NOPB	Active	Production	TSSOP (PW)   14	2500   LARGE T&R	Yes	SN	Level-1-260C-UNLIM	0 to 70	LM324 MT

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20 May 2020

Orderable part number	Status	Material type	Package   Pins	Package qty   Carrier	RoHS	Lead finish/	MSL rating/	Op temp (°C)	Part marking
	(1)	(2)			(3)	Ball material	Peak reflow		(6)
						(4)	(5)		
LM324MTX/NOPB.B	Active	Production	TSSOP (PW)   14	2500   LARGE T&R	Yes	SN	Level-1-260C-UNLIM	0 to 70	LM324
									MT
LM324MX/NOPB	Active	Production	SOIC (D)   14	2500   LARGE T&R	Yes	NIPDAU   SN	Level-1-260C-UNLIM	0 to 70	LM324M
LM324MX/NOPB.B	Active	Production	SOIC (D)   14	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	LM324M
LM324N/NOPB	Active	Production	PDIP (N)   14	25   TUBE	Yes	Call TI   Nipdau	Level-1-NA-UNLIM	0 to 70	LM324N
LM324N/NOPB.B	Active	Production	PDIP (N)   14	25   TUBE	Yes	NIPDAU	Level-1-NA-UNLIM	0 to 70	LM324N

<sup>(1)</sup> Status: For more details on status, see our product life cycle.

- (3) RoHS values: Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.
- (4) Lead finish/Ball material: Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.
- (5) MSL rating/Peak reflow: The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.
- (6) Part marking: There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

#### OTHER QUALIFIED VERSIONS OF LM124-N. LM2902-N:

<sup>(2)</sup> Material type: When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.



## **PACKAGE OPTION ADDENDUM**

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• Automotive : LM2902-Q1

● Enhanced Product : LM2902-EP

• Space : LM124-SP

#### NOTE: Qualified Version Definitions:

• Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

- Enhanced Product Supports Defense, Aerospace and Medical Applications
- Space Radiation tolerant, ceramic packaging and qualified for use in Space-based application



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## TAPE AND REEL INFORMATION



# TAPE DIMENSIONS + K0 - P1 - B0 W Cavity - A0 -

A0	Dimension designed to accommodate the component width
В0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

#### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



#### \*All dimensions are nominal

Device	Package Type	Package Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM2902MTX/NOPB	TSSOP	PW	14	2500	330.0	12.4	6.95	5.6	1.6	8.0	12.0	Q1
LM2902MX/NOPB	SOIC	D	14	2500	330.0	16.4	6.5	9.35	2.3	8.0	16.0	Q1
LM324AMX/NOPB	SOIC	D	14	2500	330.0	16.4	6.5	9.35	2.3	8.0	16.0	Q1
LM324MTX/NOPB	TSSOP	PW	14	2500	330.0	12.4	6.95	5.6	1.6	8.0	12.0	Q1
LM324MX/NOPB	SOIC	D	14	2500	330.0	16.4	6.5	9.35	2.3	8.0	16.0	Q1



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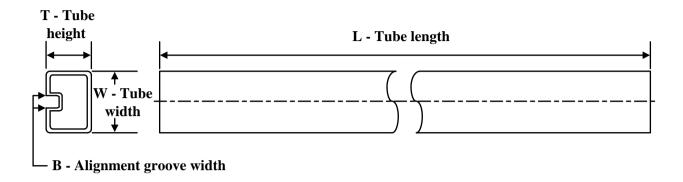
\*All dimensions are nominal

7 111 011110110110110 0110 11011111101							
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM2902MTX/NOPB	TSSOP	PW	14	2500	367.0	367.0	35.0
LM2902MX/NOPB	SOIC	D	14	2500	356.0	356.0	35.0
LM324AMX/NOPB	SOIC	D	14	2500	367.0	367.0	35.0
LM324MTX/NOPB	TSSOP	PW	14	2500	367.0	367.0	35.0
LM324MX/NOPB	SOIC	D	14	2500	356.0	356.0	35.0



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## **TUBE**



\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
LM124AJ/PB	J	CDIP	14	25	502	14	11938	4.32
LM124J/PB	J	CDIP	14	25	502	14	11938	4.32
LM224J	J	CDIP	14	25	502	14	11938	4.32
LM2902M/NOPB	D	SOIC	14	55	495	8	4064	3.05
LM2902M/NOPB.B	D	SOIC	14	55	495	8	4064	3.05
LM2902MT/NOPB	PW	TSSOP	14	94	495	8	2514.6	4.06
LM2902MT/NOPB.B	PW	TSSOP	14	94	495	8	2514.6	4.06
LM2902N/NOPB	N	PDIP	14	25	502	14	11938	4.32
LM2902N/NOPB.B	N	PDIP	14	25	502	14	11938	4.32
LM324AM/NOPB	D	SOIC	14	55	495	8	4064	3.05
LM324AM/NOPB.B	D	SOIC	14	55	495	8	4064	3.05
LM324AN/NOPB	N	PDIP	14	25	502	14	11938	4.32
LM324AN/NOPB.B	N	PDIP	14	25	502	14	11938	4.32
LM324M/NOPB	D	SOIC	14	55	495	8	4064	3.05
LM324M/NOPB.B	D	SOIC	14	55	495	8	4064	3.05
LM324MT/NOPB	PW	TSSOP	14	94	495	8	2514.6	4.06
LM324MT/NOPB.B	PW	TSSOP	14	94	495	8	2514.6	4.06
LM324N/NOPB	N	PDIP	14	25	502	14	11938	4.32
LM324N/NOPB.B	N	PDIP	14	25	502	14	11938	4.32

CERAMIC DUAL IN LINE PACKAGE



Images above are just a representation of the package family, actual package may vary. Refer to the product data sheet for package details.

4040083-5/G





CERAMIC DUAL IN LINE PACKAGE



#### NOTES:

- 1. All controlling linear dimensions are in inches. Dimensions in brackets are in millimeters. Any dimension in brackets or parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
- 2. This drawing is subject to change without notice.
- 3. This package is hermitically sealed with a ceramic lid using glass frit.
- His package is remitted by sealed with a ceramic its using glass mit.
   Index point is provided on cap for terminal identification only and on press ceramic glass frit seal only.
   Falls within MIL-STD-1835 and GDIP1-T14.



CERAMIC DUAL IN LINE PACKAGE



# 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.





SMALL OUTLINE INTEGRATED CIRCUIT



#### NOTES:

- 1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

  2. This drawing is subject to change without notice.

  3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not
- exceed 0.15 mm, per side.
- 4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm, per side.
- 5. Reference JEDEC registration MS-012, variation AB.



SMALL OUTLINE INTEGRATED CIRCUIT



NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SMALL OUTLINE INTEGRATED CIRCUIT



NOTES: (continued)

- 8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
- 9. Board assembly site may have different recommendations for stencil design.





SMALL OUTLINE PACKAGE



#### NOTES:

- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

  2. This drawing is subject to change without notice.

  3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not
- exceed 0.15 mm per side.
- 4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
- 5. Reference JEDEC registration MO-153.



SMALL OUTLINE PACKAGE



NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SMALL OUTLINE PACKAGE



NOTES: (continued)

- 8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
- 9. Board assembly site may have different recommendations for stencil design.



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