

# LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

## Quad Differential Input, Low Power Operational Amplifiers

The LM324 series are low-cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V with quiescent currents about one-fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V (LM224, LM324, LM324A)
- Low Input Bias Currents: 100 nA Maximum (LM324A)
- Four Amplifiers Per Package
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Industry Standard Pinouts
- ESD Clamps on the Inputs Increase Ruggedness without Affecting Device Operation

MAXIMUM RATINGS ( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

Rating	Symbol	LM224 LM324, LM324A	LM2902, LM2902V	Unit
Power Supply Voltages				
Single Supply	$V_{CC}$	32	26	Vdc
Split Supplies	$V_{CC}, V_{EE}$	$\pm 16$	$\pm 13$	
Input Differential Voltage Range (Note 1)	$V_{IDR}$	$\pm 32$	$\pm 26$	Vdc
Input Common Mode Voltage Range	$V_{ICR}$	-0.3 to 32	-0.3 to 26	Vdc
Output Short Circuit Duration	$t_{SC}$	Continuous		
Junction Temperature	$T_J$	150		$^\circ\text{C}$
Storage Temperature Range	$T_{stg}$	-65 to +150		$^\circ\text{C}$
Operating Ambient Temperature Range	$T_A$			$^\circ\text{C}$
LM224		-25 to +85		
LM324, 324A		0 to +70		
LM2902			-40 to +105	
LM2902V, NCV2902			-40 to +125	

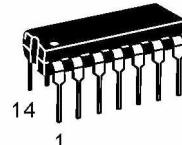
1. Split Power Supplies.

This document contains information on a new product. Specifications and information herein are subject to change without notice.

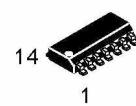


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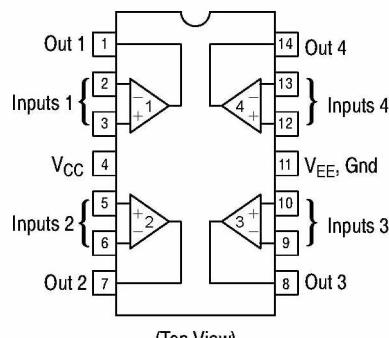


PDIP-14  
N SUFFIX  
CASE 646



SO-14  
D SUFFIX  
CASE 751A

### PIN CONNECTIONS



### ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 2565 of this data sheet.

### DEVICE MARKING INFORMATION

See general marking information in the device marking section on page 2566 of this data sheet.

# LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

**ELECTRICAL CHARACTERISTICS** ( $V_{CC} = 5.0$  V,  $V_{EE} = \text{Gnd}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.)

Characteristics	Symbol	LM224			LM324A			LM324			LM2902			LM2902V			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage $V_{CC} = 5.0$ V to 30 V (26 V for LM2902, V), $V_{ICR} = 0$ V to $V_{CC} - 1.7$ V, $V_O = 1.4$ V, $R_S = 0$ $\Omega$ $T_A = 25^\circ\text{C}$ $T_A = T_{\text{high}}$ (Note 2) $T_A = T_{\text{low}}$ (Note 2)	$V_{IO}$	—	2.0	5.0	—	2.0	3.0	—	2.0	7.0	—	2.0	7.0	—	2.0	7.0	mV
		—	—	7.0	—	—	5.0	—	—	9.0	—	—	10	—	—	13	
		—	—	7.0	—	—	5.0	—	—	9.0	—	—	10	—	—	10	
Average Temperature Coefficient of Input Offset Voltage $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Notes 2 and 4)	$\Delta V_{IO}/\Delta T$	—	7.0	—	—	7.0	30	—	7.0	—	—	7.0	—	—	7.0	—	$\mu\text{V}/^\circ\text{C}$
Input Offset Current $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 2)	$I_{IO}$	—	3.0	30	—	5.0	30	—	5.0	50	—	5.0	50	—	5.0	50	nA
Average Temperature Coefficient of Input Offset Current $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Notes 2 and 4)	$\Delta I_{IO}/\Delta T$	—	10	—	—	10	300	—	10	—	—	10	—	—	10	—	pA/ $^\circ\text{C}$
		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Input Bias Current $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 2)	$I_{IB}$	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	nA
Input Common Mode Voltage Range (Note 3) $V_{CC} = 30$ V (26 V for LM2902, V) $T_A = +25^\circ\text{C}$ $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 2)	$V_{ICR}$	0	—	28.3	0	—	28.3	0	—	28.3	0	—	24.3	0	—	24.3	V
		0	—	28	0	—	28	0	—	28	0	—	24	0	—	24	
		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Differential Input Voltage Range	$V_{IDR}$	—	—	$V_{CC}$	—	—	$V_{CC}$	—	—	$V_{CC}$	—	—	$V_{CC}$	—	—	$V_{CC}$	V
Large Signal Open Loop Voltage Gain $R_L = 2.0$ k $\Omega$ , $V_{CC} = 15$ V, for Large $V_O$ Swing $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 2)	$A_{VOL}$	50	100	—	25	100	—	25	100	—	25	100	—	25	100	—	V/mV
		25	—	—	15	—	—	15	—	—	15	—	—	15	—	—	
Channel Separation 10 kHz $\leq f \leq$ 20 kHz, Input Referenced	CS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	dB
Common Mode Rejection, $R_S \leq 10$ k $\Omega$	CMR	70	85	—	65	70	—	65	70	—	50	70	—	50	70	—	dB
Power Supply Rejection	PSR	65	100	—	65	100	—	65	100	—	50	100	—	50	100	—	dB

2. LM224:  $T_{\text{low}} = -25^\circ\text{C}$ ,  $T_{\text{high}} = +85^\circ\text{C}$   
           LM324/LM324A:  $T_{\text{low}} = 0^\circ\text{C}$ ,  $T_{\text{high}} = +70^\circ\text{C}$   
           LM2902:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +105^\circ\text{C}$   
           LM2902V:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +125^\circ\text{C}$   
           NCV2902:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +125^\circ\text{C}$ . Guaranteed by design. NCV prefix is for automotive and other applications requiring site and change control.
3. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is  $V_{CC} - 1.7$  V.
4. Guaranteed by design.

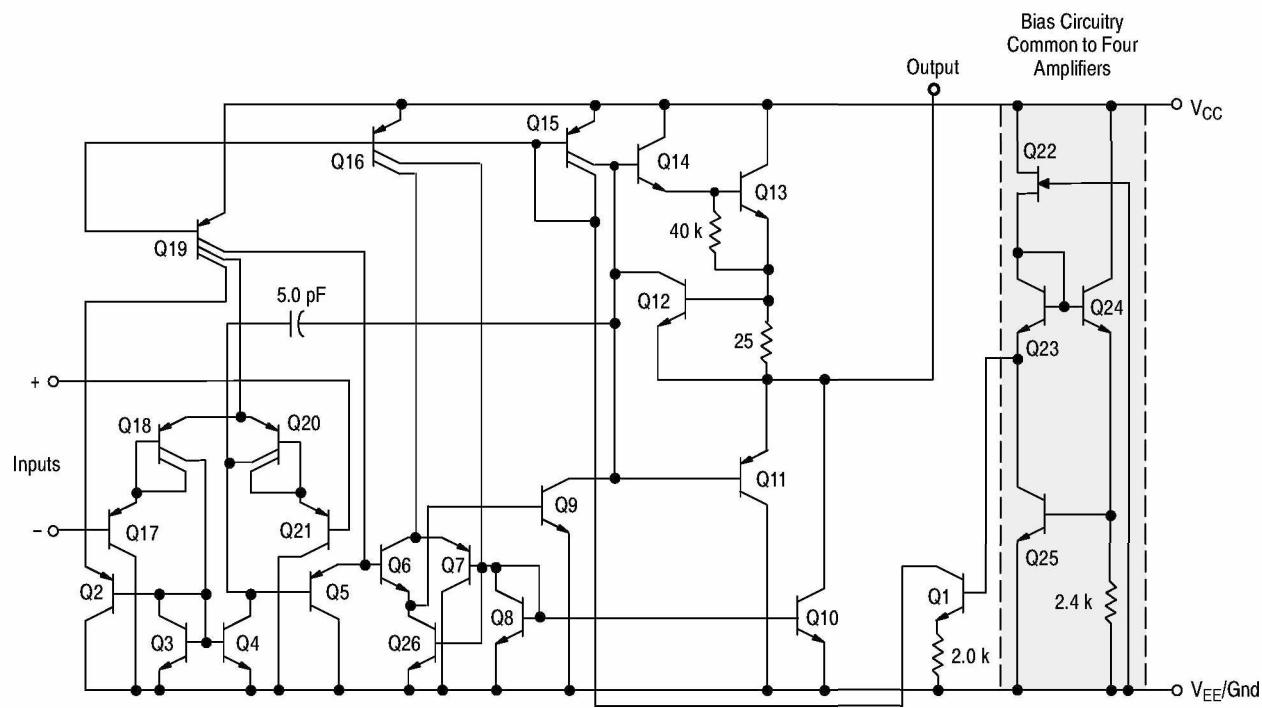
# LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

**ELECTRICAL CHARACTERISTICS** ( $V_{CC} = 5.0$  V,  $V_{EE} = \text{Gnd}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.)

Characteristics	Symbol	LM224			LM324A			LM324			LM2902			LM2902V			Unit	
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max		
Output Voltage— High Limit ( $T_A = T_{\text{high}}$ to $T_{\text{low}}$ ) (Note 5)	$V_{OH}$	3.3	3.5	—	3.3	3.5	—	3.3	3.5	—	3.3	3.5	—	3.3	3.5	—	V	
$V_{CC} = 5.0$ V, $R_L = 2.0$ k $\Omega$ , $T_A = 25^\circ\text{C}$		26	—	—	26	—	—	26	—	—	22	—	—	22	—	—		
$V_{CC} = 30$ V (26 V for LM2902, V), $R_L = 2.0$ k $\Omega$		27	28	—	27	28	—	27	28	—	23	24	—	23	24	—		
Output Voltage – Low Limit, $V_{CC} = 5.0$ V, $R_L = 10$ k $\Omega$ , $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)	$V_{OL}$	—	5.0	20	—	5.0	20	—	5.0	20	—	5.0	100	—	5.0	100	mV	
Output Source Current ( $V_{ID} = +1.0$ V, $V_{CC} = 15$ V) $T_A = 25^\circ\text{C}$ $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)	$I_{O+}$	20	40	—	20	40	—	20	40	—	20	40	—	20	40	—	mA	
		10	20	—	10	20	—	10	20	—	10	20	—	10	20	—		
Output Sink Current ( $V_{ID} = -1.0$ V, $V_{CC} = 15$ V) $T_A = 25^\circ\text{C}$ $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5) ( $V_{ID} = -1.0$ V, $V_O = 200$ mV, $T_A = 25^\circ\text{C}$ )	$I_{O-}$	10	20	—	10	20	—	10	20	—	10	20	—	10	20	—	mA	
		5.0	8.0	—	5.0	8.0	—	5.0	8.0	—	5.0	8.0	—	5.0	8.0	—		
Output Short Circuit to Ground (Note 6)	$I_{SC}$	—	40	60	—	40	60	—	40	60	—	40	60	—	40	60	mA	
Power Supply Current ( $T_A = T_{\text{high}}$ to $T_{\text{low}}$ ) (Note 5) $V_{CC} = 30$ V (26 V for LM2902, V), $V_O = 0$ V, $R_L = \infty$ $V_{CC} = 5.0$ V, $V_O = 0$ V, $R_L = \infty$	$I_{CC}$	—	—	3.0	—	1.4	3.0	—	—	3.0	—	—	3.0	—	—	mA		
		—	—	1.2	—	0.7	1.2	—	—	1.2	—	—	1.2	—	—			

- LM224:  $T_{\text{low}} = -25^\circ\text{C}$ ,  $T_{\text{high}} = +85^\circ\text{C}$   
 LM324/LM324A:  $T_{\text{low}} = 0^\circ\text{C}$ ,  $T_{\text{high}} = +70^\circ\text{C}$   
 LM2902:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +105^\circ\text{C}$   
 LM2902V:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +125^\circ\text{C}$   
 NCV2902:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +125^\circ\text{C}$ . Guaranteed by design. NCV prefix is for automotive and other applications requiring site and change control.
- The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is  $V_{CC} - 1.7$  V.

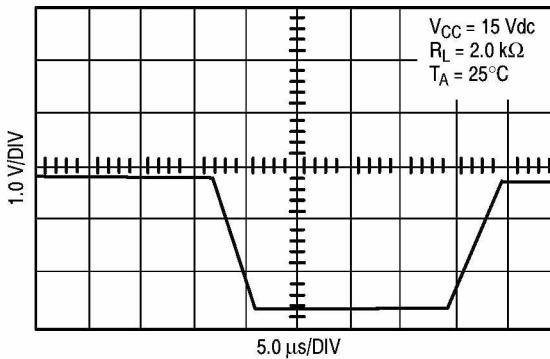
# LM324, LM324A, LM224, LM2902, LM2902V, NCV2902



**Figure 1. Representative Circuit Diagram**  
(One-Fourth of Circuit Shown)

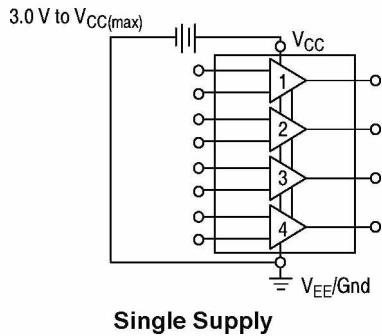
### CIRCUIT DESCRIPTION

The LM324 series is made using four internally compensated, two-stage operational amplifiers. The first stage of each consists of differential input devices Q20 and Q18 with input buffer transistors Q21 and Q17 and the differential to single ended converter Q3 and Q4. The first stage performs not only the first stage gain function but also performs the level shifting and transconductance reduction functions. By reducing the transconductance, a smaller compensation capacitor (only 5.0 pF) can be employed, thus saving chip area. The transconductance reduction is accomplished by splitting the collectors of Q20 and Q18. Another feature of this input stage is that the input common mode range can include the negative supply or ground, in single supply operation, without saturating either the input devices or the differential to single-ended converter. The second stage consists of a standard current source load amplifier stage.

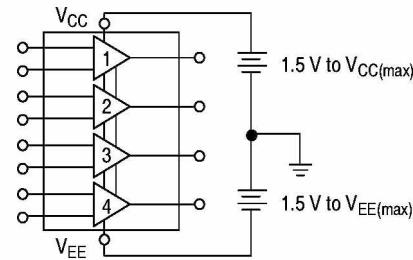


**Figure 2. Large Signal Voltage Follower Response**

Each amplifier is biased from an internal-voltage regulator which has a low temperature coefficient thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.



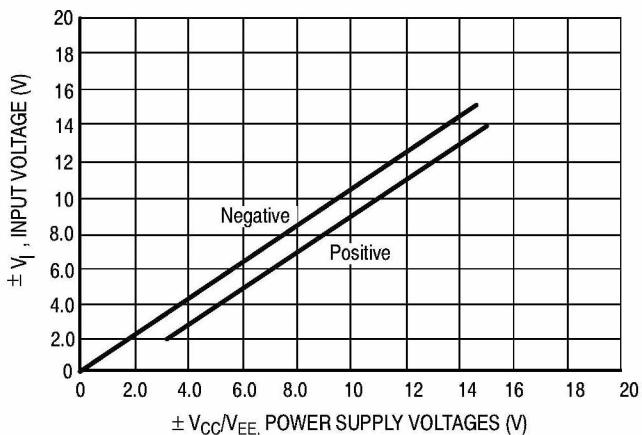
**Single Supply**



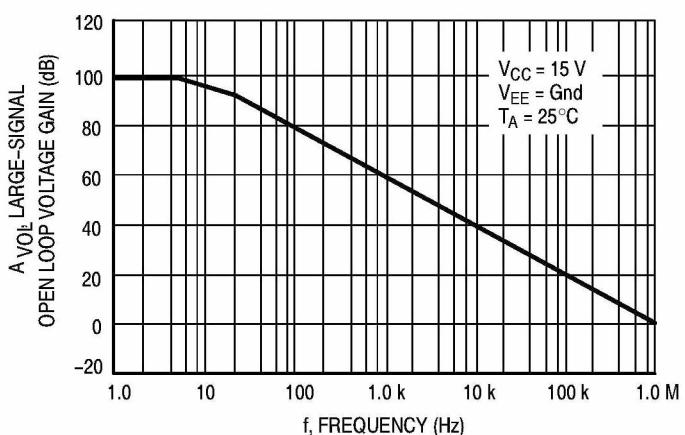
**Split Supplies**

**Figure 3.**

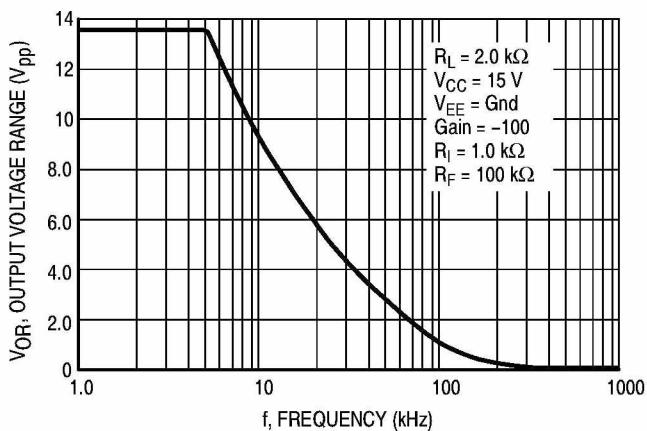
# LM324, LM324A, LM224, LM2902, LM2902V, NCV2902



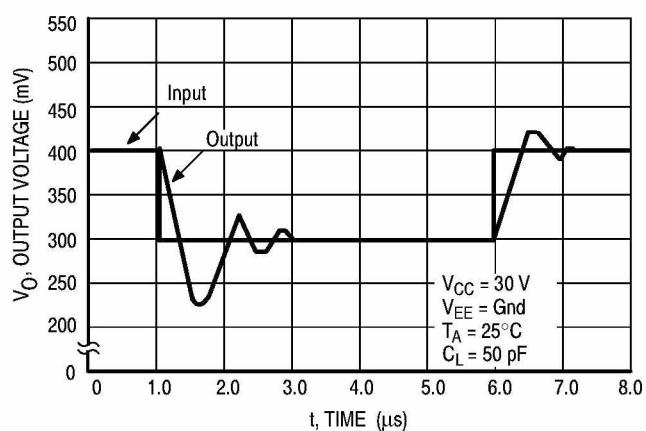
**Figure 4. Input Voltage Range**



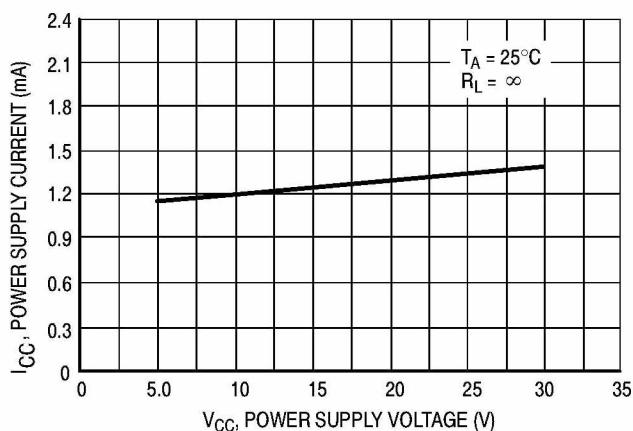
**Figure 5. Open Loop Frequency**



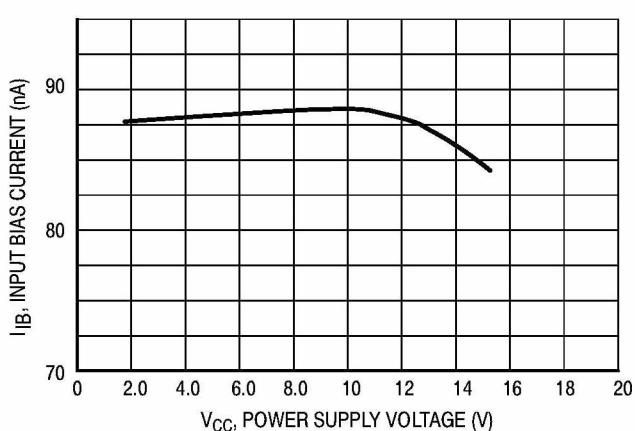
**Figure 6. Large-Signal Frequency Response**



**Figure 7. Small-Signal Voltage Follower  
Pulse Response (Noninverting)**

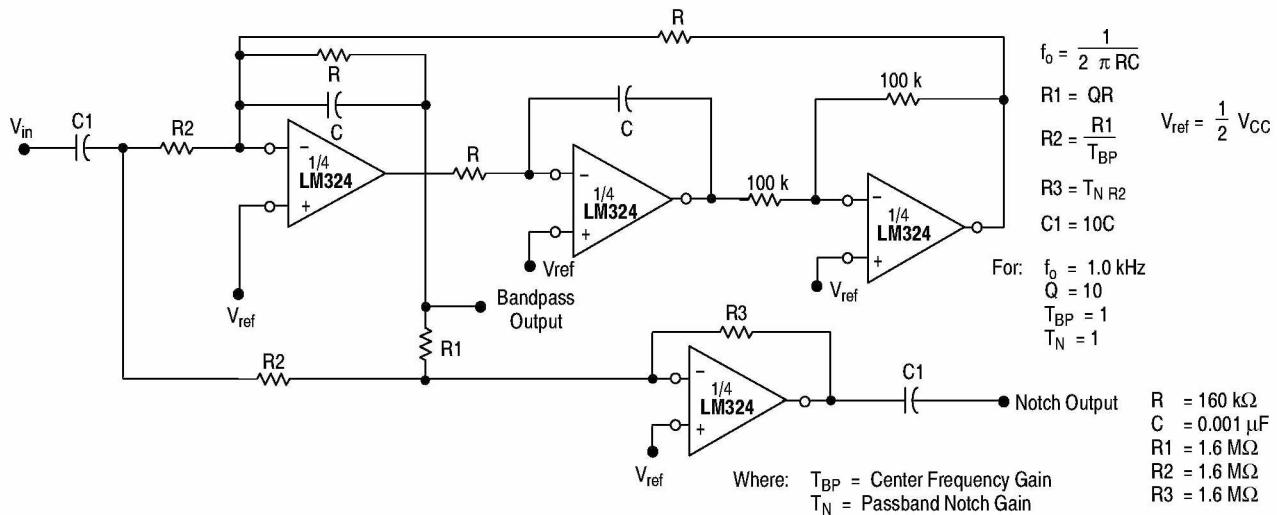
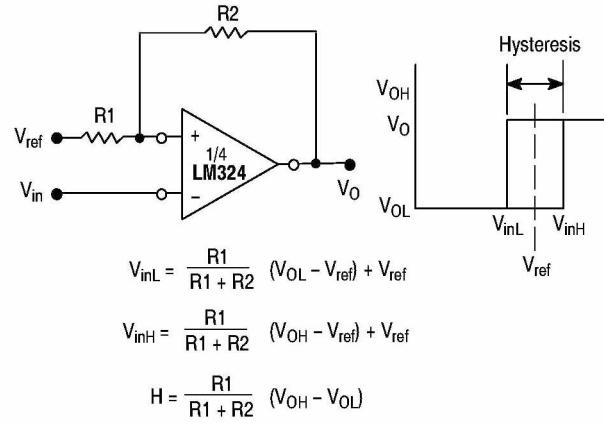
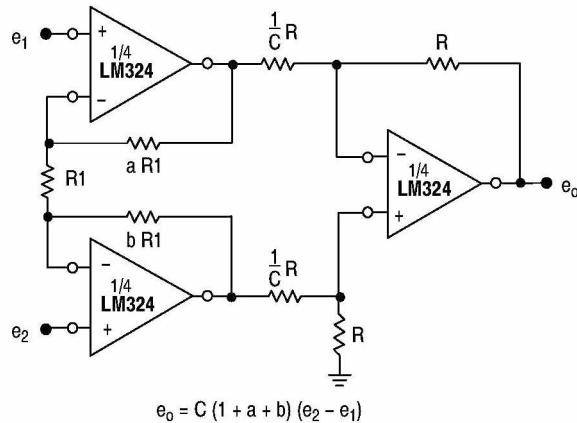
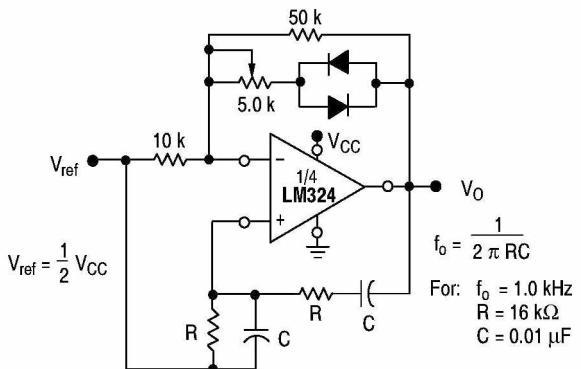
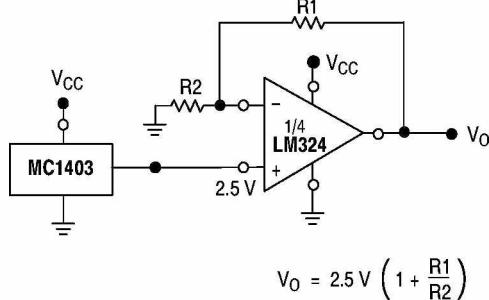


**Figure 8. Power Supply Current versus  
Power Supply Voltage**



**Figure 9. Input Bias Current versus  
Power Supply Voltage**

## LM324, LM324A, LM224, LM2902, LM2902V, NCV2902



## LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

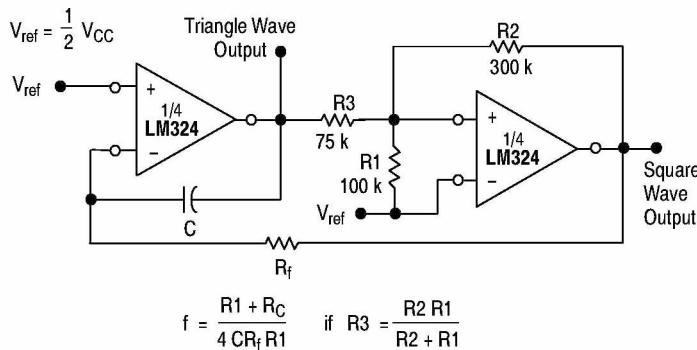


Figure 15. Function Generator

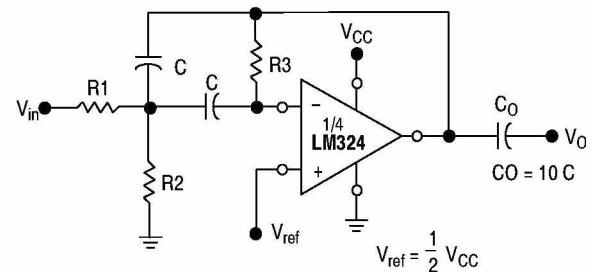


Figure 16. Multiple Feedback Bandpass Filter

Given:  $f_0$  = center frequency  
 $A(f_0)$  = gain at center frequency

Choose value  $f_0, C$

$$\text{Then: } R3 = \frac{Q}{\pi f_0 C}$$

$$R1 = \frac{R3}{2 A(f_0)}$$

$$R2 = \frac{R1 R3}{4 Q^2 R1 - R3}$$

For less than 10% error from operational amplifier,  $\frac{Q_0 f_0}{BW} < 0.1$   
 where  $f_0$  and BW are expressed in Hz.

If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.

# LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

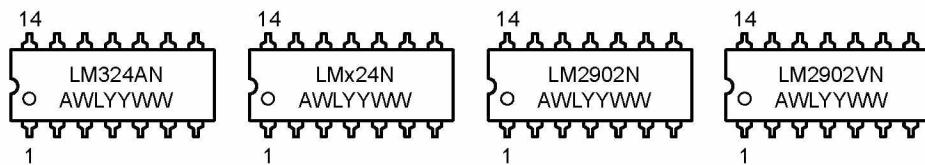
## ORDERING INFORMATION

Device	Package	Operating Temperature Range	Shipping
LM224D	SO-14	−25° to +85°C	55 Units/Rail
LM224DR2	SO-14		2500 Tape & Reel
LM224N	PDIP-14		25 Units/Rail
LM324D	SO-14	0° to +70°C	55 Units/Rail
LM324DR2	SO-14		2500 Tape & Reel
LM324N	PDIP-14		25 Units/Rail
LM324AD	SO-14		55 Units/Rail
LM324ADR2	SO-14		2500 Tape & Reel
LM324AN	PDIP-14		25 Units/Rail
LM2902D	SO-14	−40° to +105°C	55 Units/Rail
LM2902DR2	SO-14		2500 Tape & Reel
LM2902N	PDIP-14		25 Units/Rail
LM2902VD	SO-14	−40° to +125°C	55 Units/Rail
LM2902VDR2	SO-14		2500 Tape & Reel
LM2902VN	PDIP-14		25 Units/Rail
NCV2902DR2	SO-14		2500 Tape & Reel

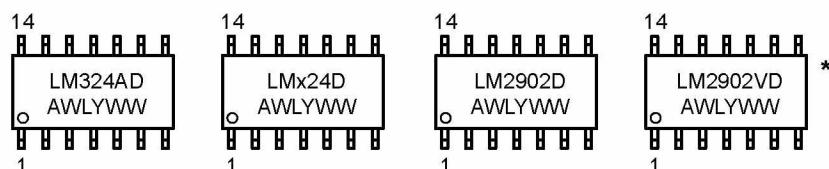
# LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

## MARKING DIAGRAMS

PDIP-14  
N SUFFIX  
CASE 646



SO-14  
D SUFFIX  
CASE 751A



X = 2 or 3  
A = Assembly Location  
WL = Wafer Lot  
YY, Y = Year  
WW, W = Work Week

\*This marking diagram also applies to NCV2902.