

LM324, LM324A, LM224, LM2902

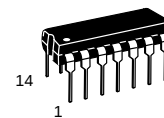
Quad Low Power Operational Amplifiers

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.

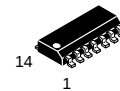
- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents: 100 nA Maximum (LM324A)
- Four Amplifiers Per Package
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Industry Standard Pinouts
- ESD Clamps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

QUAD DIFFERENTIAL INPUT OPERATIONAL AMPLIFIERS

SEMICONDUCTOR TECHNICAL DATA



N SUFFIX
PLASTIC PACKAGE
CASE 646
(LM224, LM324,
LM2902 Only)



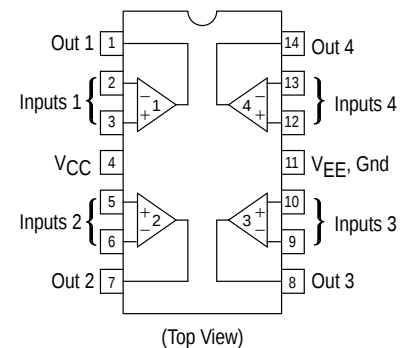
D SUFFIX
PLASTIC PACKAGE
CASE 751A
(SO-14)

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

Rating	Symbol	LM224 LM324,A	LM2902	Unit
Power Supply Voltages Single Supply Split Supplies	V_{CC} V_{CC}, V_{EE}	32 ± 16	26 ± 13	Vdc
Input Differential Voltage Range (See Note 1)	V_{IDR}	± 32	± 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	-25 to +85 0 to +70	-40 to +105	$^\circ\text{C}$

NOTE: 1. Split Power Supplies.

PIN CONNECTIONS



ORDERING INFORMATION

Device	Operating Temperature Range	Package
LM2902D	$T_A = -40^\circ$ to $+105^\circ\text{C}$	SO-14
LM2902N		Plastic DIP
LM224D	$T_A = -25^\circ$ to $+85^\circ\text{C}$	SO-14
LM224N		Plastic DIP
LM324AD	$T_A = 0^\circ$ to $+70^\circ\text{C}$	SO-14
LM324AN		Plastic DIP
LM324D		SO-14
LM324N		Plastic DIP

LM324, LM324A, LM224, LM2902

ELECTRICAL CHARACTERISTICS (V_{CC} = 5.0 V, V_{EE} = GND, T_A = 25°C, unless otherwise noted)

Characteristics	Symbol	LM224			LM324A			LM324			LM2902			Unit
		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 _{ICR} = 0 V to V _{CC} –1.7 V, V _O = 1.4 V, R _S = 0 Ω T _A = 25°C T _A = T _{high} to T _{low} (Note 1)	V _{IO}	–	2.0	5.0	–	2.0	3.0	–	2.0	7.0	–	2.0	7.0	mV
		–	–	7.0	–	–	5.0	–	–	9.0	–	–	10	
Average Temperature Coefficient of Input Offset Voltage T _A = T _{high} to T _{low} (Note 1)	ΔV _{IO} /ΔT	–	7.0	–	–	7.0	30	–	7.0	–	–	7.0	–	μV/°C
Input Offset Current T _A = T _{high} to T _{low} (Note 1)	I _{IO}	–	3.0	30	–	5.0	30	–	5.0	50	–	5.0	50	nA
		–	–	100	–	–	75	–	–	150	–	–	200	
Average Temperature Coefficient of Input Offset Current T _A = T _{high} to T _{low} (Note 1)	ΔI _{IO} /ΔT	–	10	–	–	10	300	–	10	–	–	10	–	pA/°C
Input Bias Current T _A = T _{high} to T _{low} (Note 1)	I _{IB}	–	–90	–150	–	–45	–100	–	–90	–250	–	–90	–250	nA
		–	–	–300	–	–	–200	–	–	–500	–	–	–500	
Input Common Mode Voltage Range (Note 2) V _{CC} = 30 V (26 V for LM2902) V _{CC} = 30 V (26 V for LM2902), T _A = T _{high} to T _{low}	V _{ICR}	0	–	28.3	0	–	28.3	0	–	28.3	0	–	24.3	V
		0	–	28	0	–	28	0	–	28	0	–	24	
Differential Input Voltage Range	V _{IDR}	–	–	V _{CC}	–	–	V _{CC}	–	–	V _{CC}	–	–	V _{CC}	V
Large Signal Open Loop Voltage Gain R _L = 2.0 kΩ, V _{CC} = 15 V, for Large V _O Swing, T _A = T _{high} to T _{low} (Note 1)	A _{VOL}	50	100	–	25	100	–	25	100	–	25	100	–	V/mV
		25	–	–	15	–	–	15	–	–	15	–	–	
Channel Separation 10 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	–	–120	–	–	–120	–	–	–120	–	–	–120	–	dB
Common Mode Rejection R _S ≤ 10 kΩ	CMR	70	85	–	65	70	–	65	70	–	50	70	–	dB
Power Supply Rejection	PSR	65	100	–	65	100	–	65	100	–	50	100	–	dB
Output Voltage – High Limit (T _A = T _{high} to T _{low}) (Note 1) V _{CC} = 5.0 V, R _L = 2.0 kΩ, T _A = 25°C V _{CC} = 30 V (26 V for LM2902), R _L = 2.0 kΩ V _{CC} = 30 V (26 V for LM2902), R _L = 10 kΩ	V _{OH}	3.3	3.5	–	3.3	3.5	–	3.3	3.5	–	3.3	3.5	–	V
		26	–	–	26	–	–	26	–	–	22	–	–	
		27	28	–	27	28	–	27	28	–	23	24	–	
Output Voltage – Low Limit V _{CC} = 5.0 V, R _L = 10 kΩ, T _A = T _{high} to T _{low} (Note 1)	V _{OL}	–	5.0	20	–	5.0	20	–	5.0	20	–	5.0	100	mV
Output Source Current (V _{ID} = +1.0 V, V _{CC} = 15 V) T _A = 25°C T _A = T _{high} to T _{low} (Note 1)	I _O +	20	40	–	20	40	–	20	40	–	20	40	–	mA
		10	20	–	10	20	–	10	20	–	10	20	–	

NOTES: 1. T_{low} = –25°C for LM224
= 0°C for LM324, A
= –40°C for LM2902
T_{high} = +85°C for LM224
= +70°C for LM324, A
= +105°C for LM2902

2. 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

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

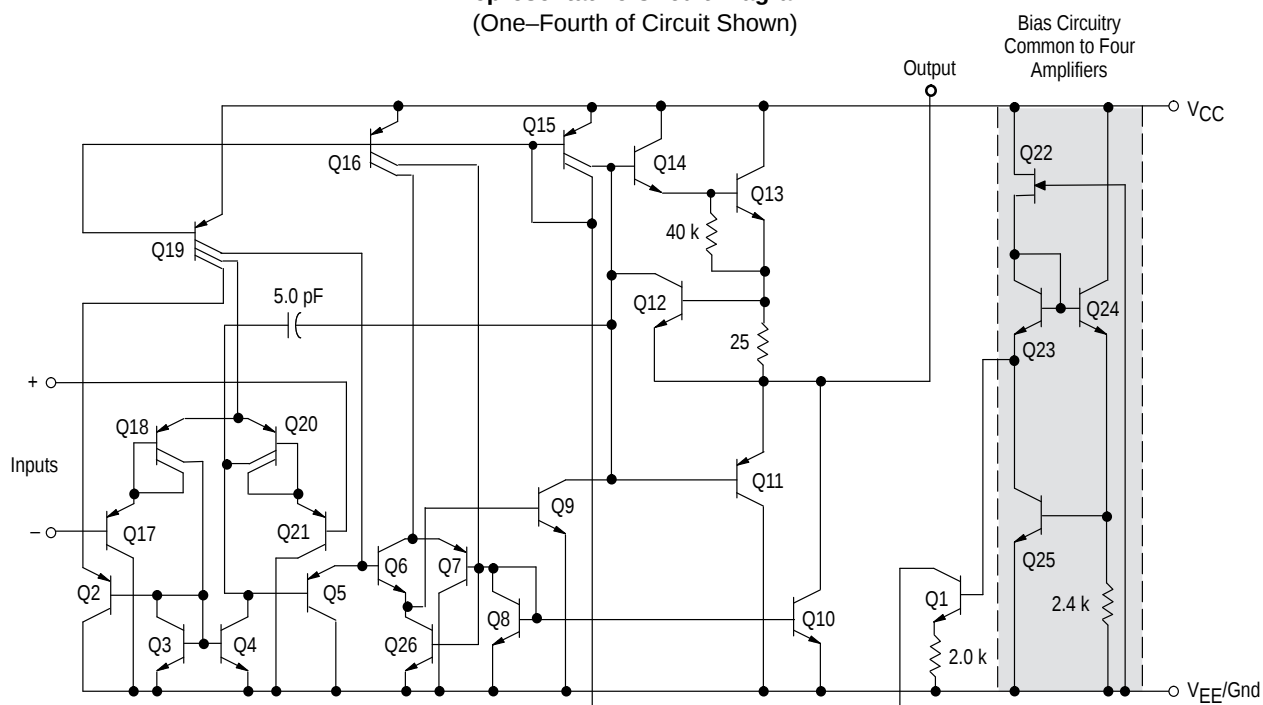
Characteristics	Symbol	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Unit
Output Sink Current ($V_{ID} = -1.0\text{ V}$, $V_{CC} = 15\text{ V}$) $T_A = 25^\circ\text{C}$	I_{O-}	10	20	—	10	20	—	10	20	—	10	20	—	mA
		5.0	8.0	—	5.0	8.0	—	5.0	8.0	—	5.0	8.0	—	μA
		12	50	—	12	50	—	12	50	—	—	—	—	μA
Output Short Circuit to Ground (Note 3)	I_{SC}	—	40	60	—	40	60	—	40	60	—	40	60	mA
Power Supply Current ($T_A = T_{\text{high}}$ to T_{low}) (Note 1) $V_{CC} = 30\text{ V}$ (26 V for LM2902), $V_O = 0\text{ V}$, $R_L = \infty$	I_{CC}	—	—	3.0	—	1.4	3.0	—	—	3.0	—	—	3.0	mA
		—	—	1.2	—	0.7	1.2	—	—	1.2	—	—	1.2	mA
		—	—	1.2	—	0.7	1.2	—	—	1.2	—	—	1.2	mA

NOTES: 1. $T_{\text{low}} = -25^\circ\text{C}$ for LM224
 $= 0^\circ\text{C}$ for LM324, A
 $= -40^\circ\text{C}$ for LM2902

$T_{\text{high}} = +85^\circ\text{C}$ for LM224
 $= +70^\circ\text{C}$ for LM324, A
 $= +105^\circ\text{C}$ for LM2902

3. Short circuits from the output to V_{CC} can cause excessive heating and eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

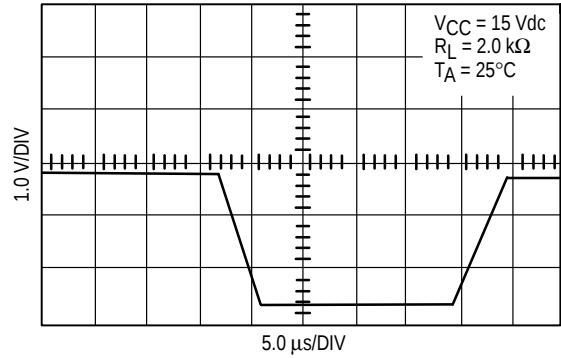
Representative Circuit Diagram
(One-Fourth of Circuit Shown)



CIRCUIT DESCRIPTION

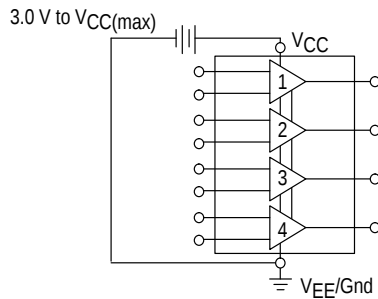
The LM324 series is made using four internally compensated, two-stage operational amplifiers. The first stage of each consists of differential input devices Q20 and Q18 with input buffer transistors Q21 and Q17 and the differential to single ended converter Q3 and Q4. The first stage performs not only 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.

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

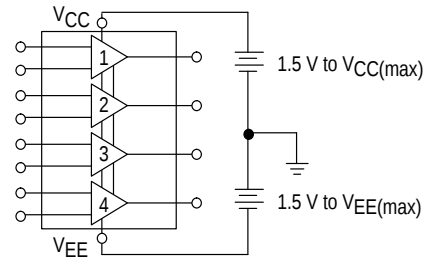


Figure 1. Input Voltage Range

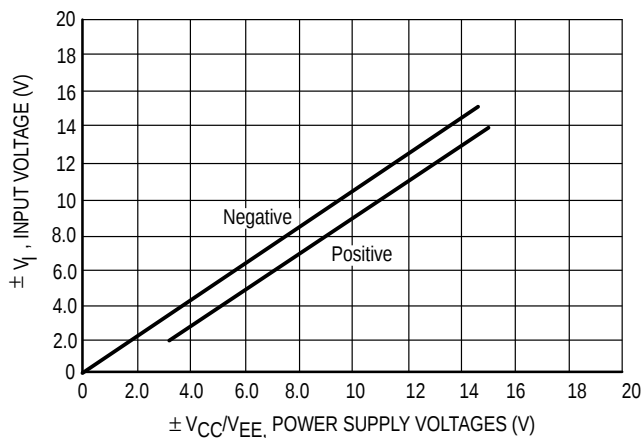


Figure 2. Open Loop Frequency

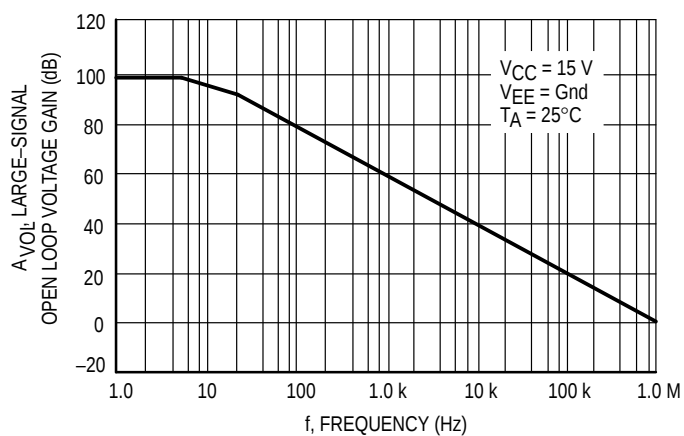


Figure 3. Large-Signal Frequency Response

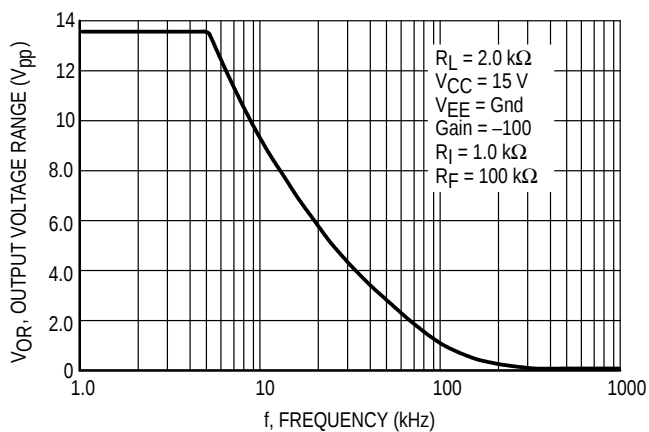


Figure 4. Small-Signal Voltage Follower Pulse Response (Noninverting)

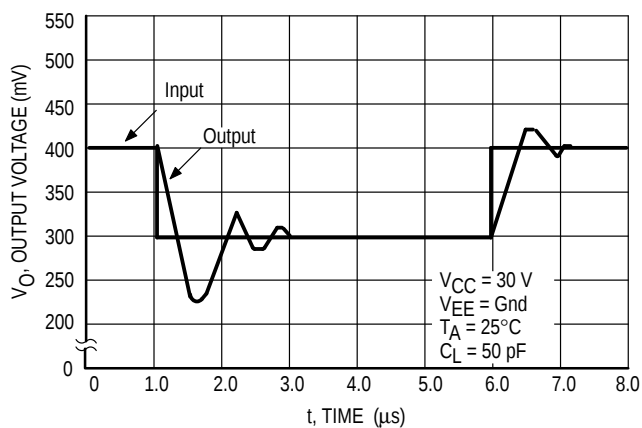


Figure 5. Power Supply Current versus Power Supply Voltage

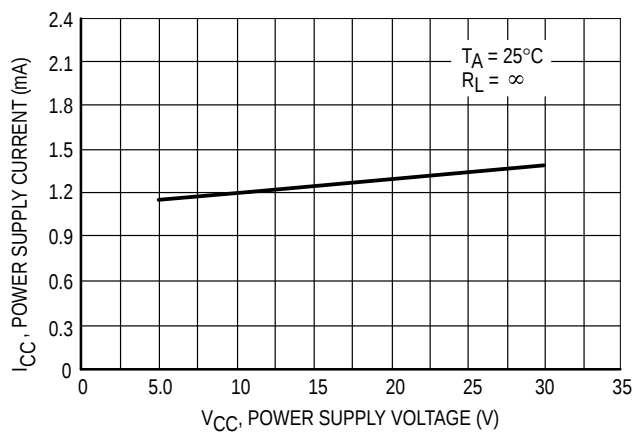


Figure 6. Input Bias Current versus Power Supply Voltage

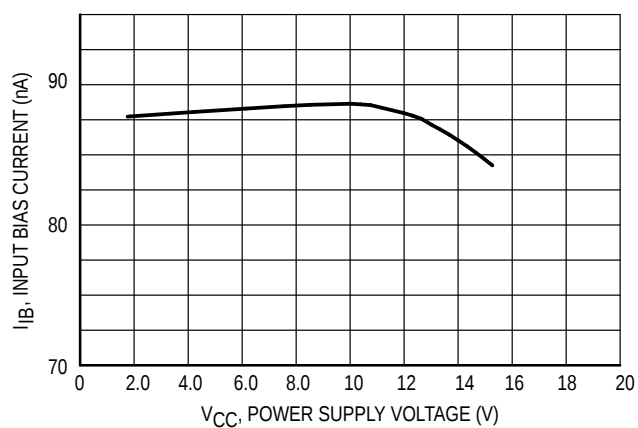


Figure 7. Voltage Reference

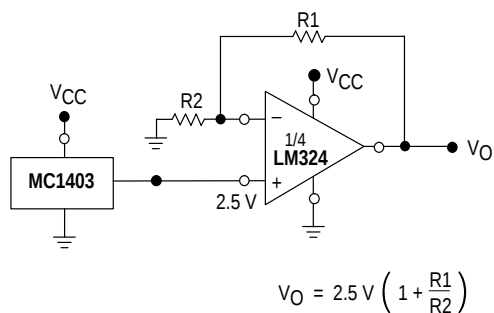


Figure 8. Wien Bridge Oscillator

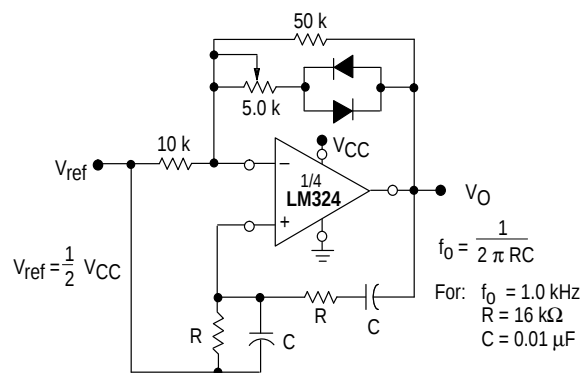


Figure 9. High Impedance Differential Amplifier

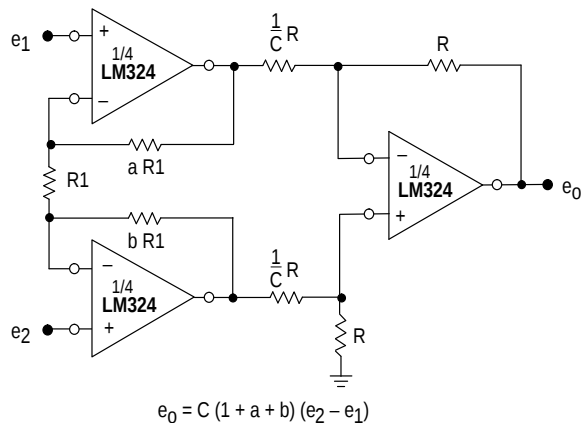


Figure 10. Comparator with Hysteresis

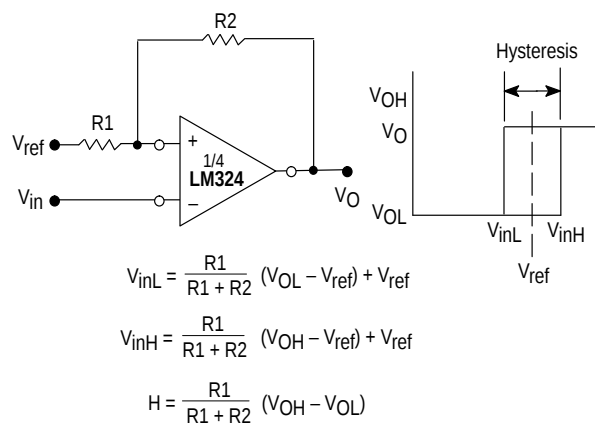


Figure 11. Bi-Quad Filter

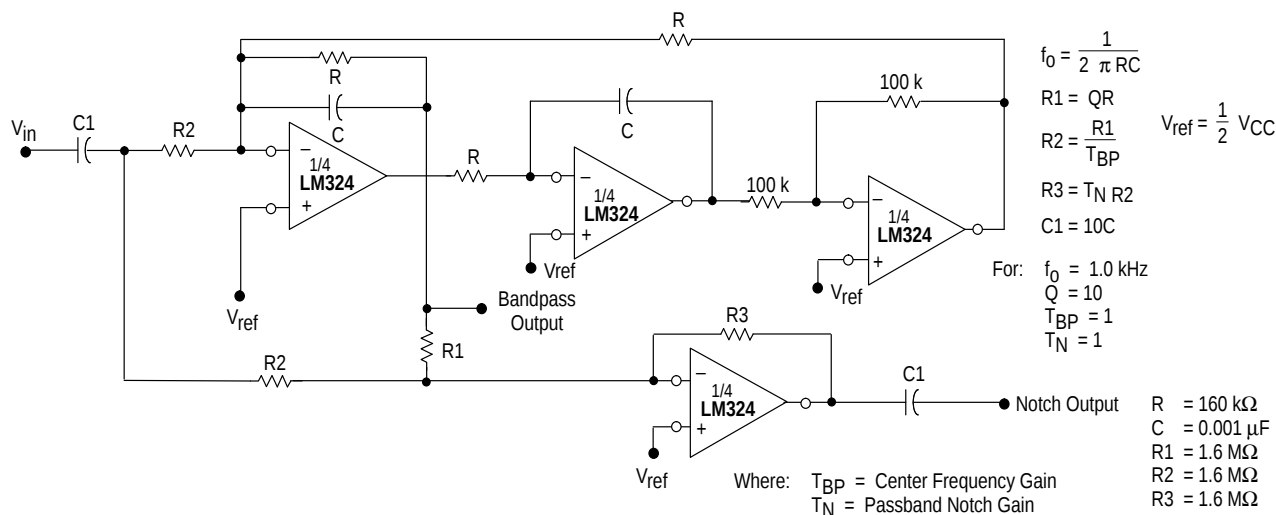


Figure 12. Function Generator

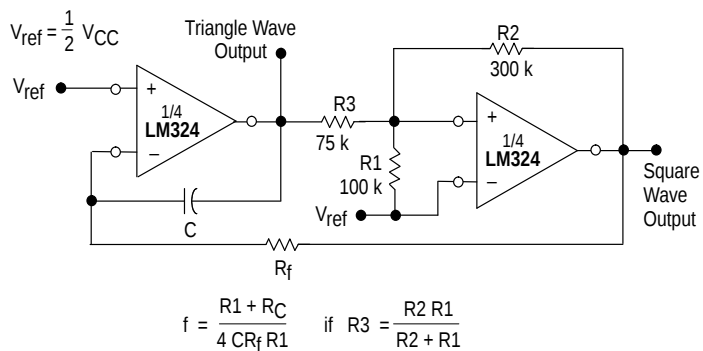
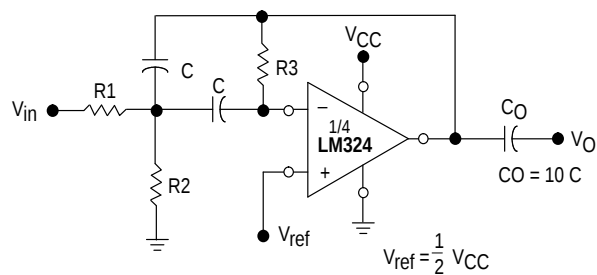


Figure 13. Multiple Feedback Bandpass Filter



Given: f_0 = center frequency

$A(f_0)$ = gain at center frequency

Choose value f_0 , C

Then: $R_3 = \frac{Q}{\pi f_0 C}$

$R_1 = \frac{R_3}{2 A(f_0)}$

$R_2 = \frac{R_1 R_3}{4 Q^2 R_1 - R_3}$

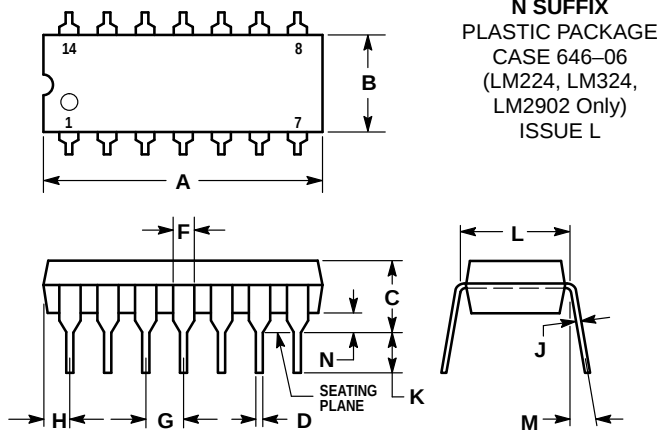
For less than 10% error from operational amplifier, $\frac{Q_0 f_0}{BW} < 0.1$

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

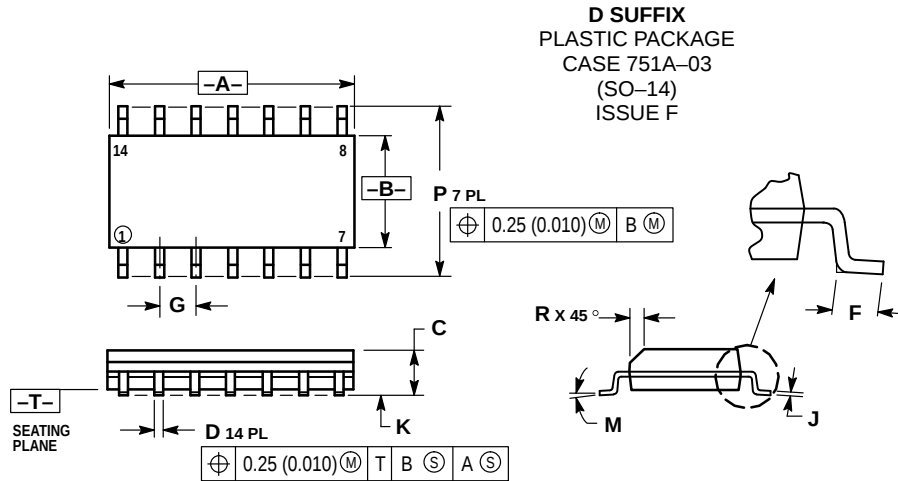
OUTLINE DIMENSIONS



NOTES:

- LEADS WITHIN 0.13 (0.005) RADIUS OF TRUE POSITION AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.
- DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
- DIMENSION B DOES NOT INCLUDE MOLD FLASH.
- ROUNDED CORNERS OPTIONAL.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.715	0.770	18.16	19.56
B	0.240	0.260	6.10	6.60
C	0.145	0.185	3.69	4.69
D	0.015	0.021	0.38	0.53
F	0.040	0.070	1.02	1.78
G	0.100 BSC		2.54 BSC	
H	0.052	0.095	1.32	2.41
J	0.008	0.015	0.20	0.38
K	0.115	0.135	2.92	3.43
L	0.300 BSC		7.62 BSC	
M	0°	10°	0°	10°
N	0.015	0.039	0.39	1.01



NOTES:

- DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
- CONTROLLING DIMENSION: MILLIMETER.
- DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
- MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
- DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	8.55	8.75	0.337	0.344
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27 BSC		0.050 BSC	
J	0.19	0.25	0.008	0.009
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.228	0.244
R	0.25	0.50	0.010	0.019

Motorola reserves the right to make changes without further notice to any products herein. Motorola makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Motorola assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters can and do vary in different applications. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. Motorola does not convey any license under its patent rights nor the rights of others. Motorola products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Motorola product could create a situation where personal injury or death may occur. Should Buyer purchase or use Motorola products for any such unintended or unauthorized application, Buyer shall indemnify and hold Motorola and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that Motorola was negligent regarding the design or manufacture of the part. Motorola and are registered trademarks of Motorola, Inc. Motorola, Inc. is an Equal Opportunity/Affirmative Action Employer.

How to reach us:

USA / EUROPE: Motorola Literature Distribution;
P.O. Box 20912; Phoenix, Arizona 85036. 1-800-441-2447

MFAX: RMFA00@email.sps.mot.com – TOUCHTONE (602) 244-6609
INTERNET: <http://Design-NET.com>

JAPAN: Nippon Motorola Ltd.; Tatsumi-SPD-JLDC, Toshikatsu Otsuki,
6F Seibu-Butsuryu-Center, 3-14-2 Tatsumi Koto-Ku, Tokyo 135, Japan. 03-3521-8315

HONG KONG: Motorola Semiconductors H.K. Ltd.; 8B Tai Ping Industrial Park,
51 Ting Kok Road, Tai Po, N.T., Hong Kong. 852-26629298



◇ CODELINE TO BE PLACED HERE

LM324/D

