

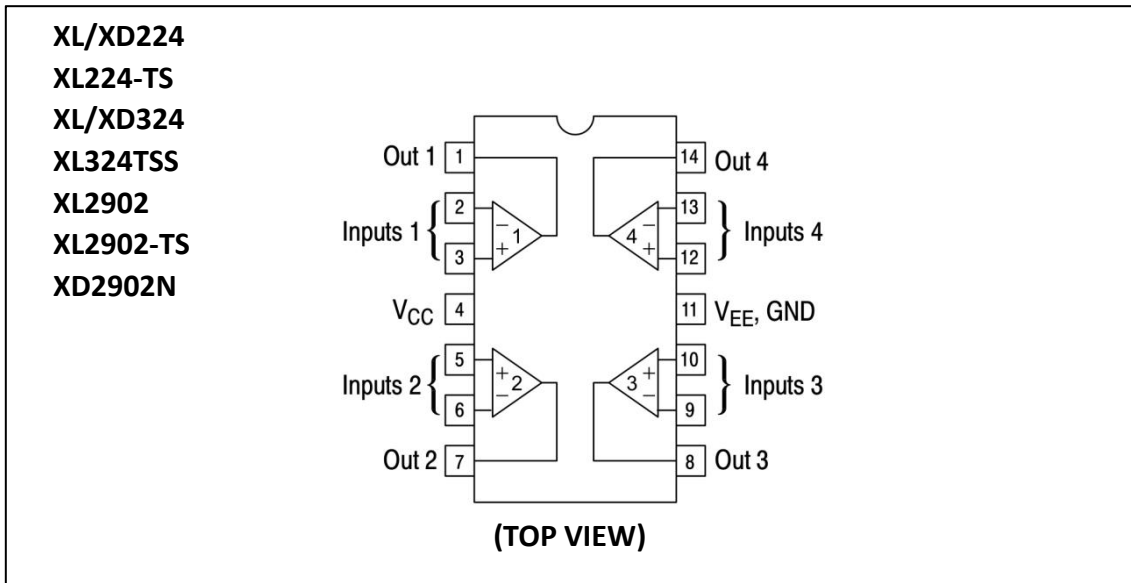
## 1. DESCRIPTION

The XL324 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. 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.

## 2. FEATURES

- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- 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
- These Devices are Pb-Free and RoHS Compliant

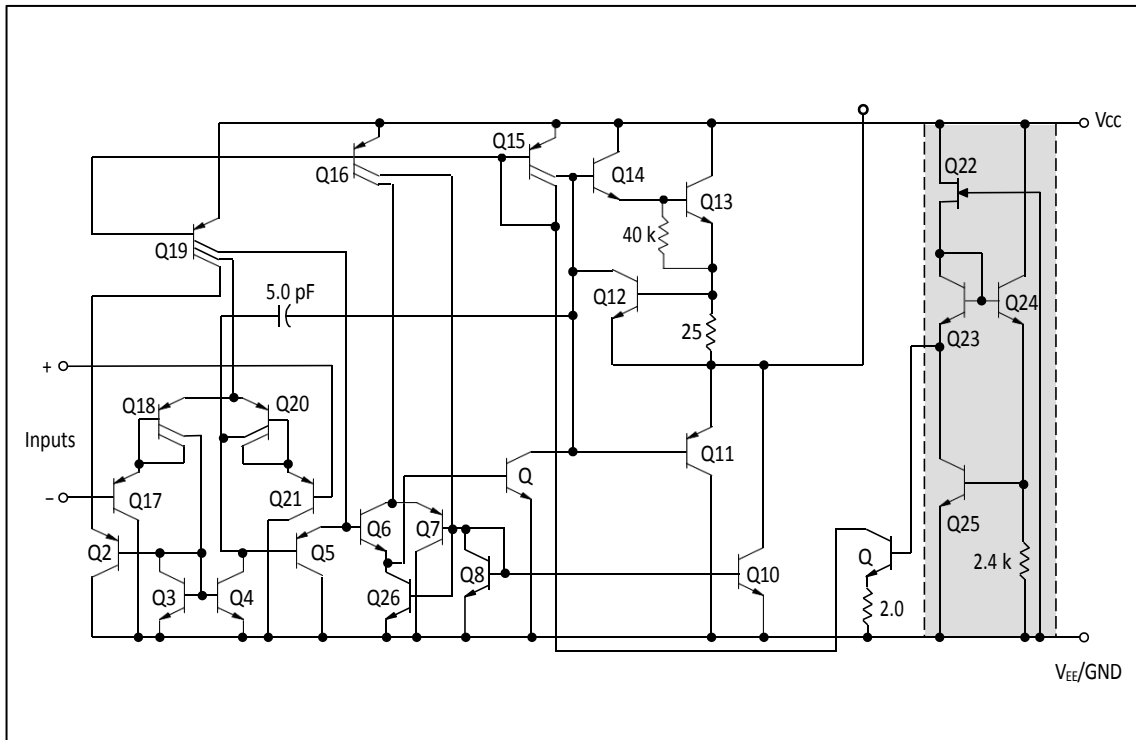
### 3. PIN CONFIGURATIONS AND FUNCTIONS



#### Pin Functions

PIN		I/O	DESCRIPTION
NAME	SOP14, DIP14, TSSOP14		
Out 1	1	O	Output
1IN -	2	I	Negative input
1IN +	3	I	Positive input
VCC	4	-	Positive (Maximum) Power
2IN +	5	I	Positive input
2IN -	6	I	Negative input
Out 2	7	O	Output
Out 3	8	O	Output
3IN -	9	I	Negative input
3IN +	10	I	Positive input
VEE,GND	11	-	Negative (lowest) power or ground (for single power supply)
4IN +	12	I	Positive input
4IN -	13	I	Negative input
Out 4	14	O	Output

#### 4. FUNCTIONAL BLOCK DIAGRAM



**Representative Circuit Diagram**  
(one-Fourth of Circuit Shown)

## 5. SPECIFICATIONS

### 5.1. Absolute Maximum Ratings

(TA = + 25°C, unless otherwise noted.)

Rating	Symbol	Value	Unit
Power Supply Voltages	V <sub>CC</sub>	32	Vdc
Single Supply Split Supplies	V <sub>CC</sub> , V <sub>EE</sub>	±16	
Input Differential Voltage Range (Note 1)	V <sub>IDR</sub>	±32	Vdc
Input Common Mode Voltage Range (Note 2)	V <sub>ICR</sub>	-0.3 to 32	Vdc
Output Short Circuit Duration	t <sub>SC</sub>	Continuous	
Junction Temperature	T <sub>J</sub>	150	°C
Thermal Resistance, Junction-to-Air (Note 3)			
Case 646 (DIP14)	R <sub>θJA</sub>	118	°C/W
Case 751A (SOP14)		156	
Case 948G (TSSOP14)		190	
Storage Temperature Range	T <sub>stg</sub>	-50 to +150	°C
ESD Protection at any Pin			
Human Body Model	V <sub>esd</sub>	2000	V
Machine Model		200	
Operating Ambient Temperature Range			
XL/XD224, XL224-TS	T <sub>A</sub>	-25 to +85	°C
XL/XD324, XL324TSS		0 to +70	
XL2902, XD2902N, XL2902-TS		-40 to +105	

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

- [1] Split Power Supplies.
- [2] For supply voltages less than 32 V, the absolute maximum input voltage is equal to the supply voltage.
- [3] All R<sub>θJA</sub> measurements made on evaluation board with 1 oz. copper traces of minimum pad size. All device outputs were active.

### 5.2. Operating Conditions

V<sub>CC</sub> = ±15 V, T<sub>A</sub> = 25°C

PARAMETER	TEST CONDITIONS	TYP	UNIT
SR Slew rate at unity gain	R <sub>L</sub> = 1 MΩ, C <sub>L</sub> = 30 pF, V <sub>I</sub> = ±10 V (see Figure 5-1)	0.5	V/μs
B <sub>1</sub> Unity-gain bandwidth	R <sub>L</sub> = 1 MΩ, C <sub>L</sub> = 20 pF (see Figure 5-1)	1.2	MHz

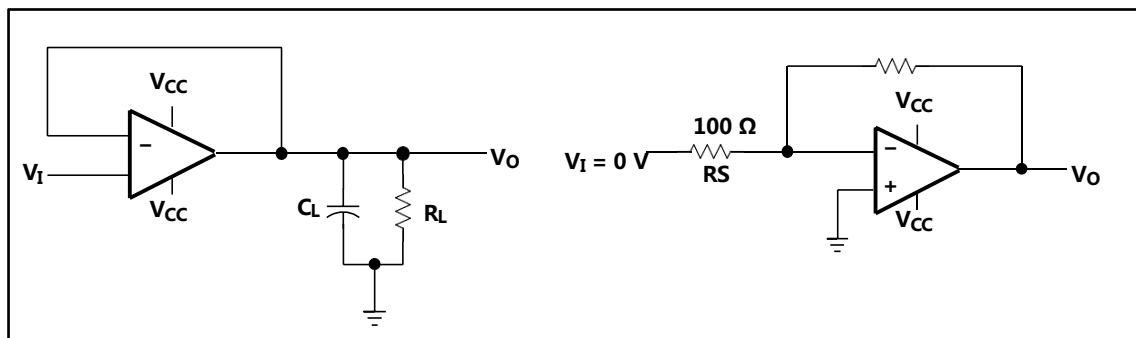


Figure 5-1. Unity-Gain Amplifier

Figure 5-2. Noise-Test Circuit

### 5.3. Electrical Characteristics

(VCC = 5 V, VEE = GND, TA = 25 °C (unless otherwise specified))

Characteristics	Symbol	XL224, XD224, XL224-TS			XL324, XD324, XL324TSS			XL2902, XD2902N, XL2902-TS			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage VCC = 5.0 V to 30 V VICR = 0 V to VCC -1.7 V, VO = 1.4 V, RS = 0 Ω TA = 25°C TA = Thigh (Note 4) TA = Tlow (Note 4)	VIO	-	2.0	5.0	-	2.0	7.0	-	2.0	7.0	mV
Average Temperature Coefficient of Input Offset Voltage TA = Thigh to Tlow (Notes 4 and 6)	ΔVIO/ΔT	-	7.0	-	-	7.0	-	-	7.0	-	μV/°C
Input Offset Current TA = Thigh to Tlow (Note 4)	IIO	-	3.0	30	-	5.0	50	-	5.0	50	nA
Average Temperature Coefficient of Input Offset Current TA = Thigh to Tlow (Notes 4 and 6)	ΔIIO/ΔT	-	10	-	-	10	-	-	10	-	pA/°C
Input Bias Current TA = Thigh to Tlow (Note 4)	IIB	-	-90	-150	-	-90	-250	-	-90	-250	nA
Input Common Mode Voltage Range (Note 5) VCC = 30 V TA = +25°C TA = Thigh to Tlow (Note 4)	VICR	0	-	28.3	0	-	28.3	0	-	28.3	V
Differential Input Voltage Range	VIDR	-	-	VCC	-	-	VCC	-	-	VCC	V
Large Signal Open Loop Voltage Gain RL = 2.0 kΩ, VCC = 15 V, for Large VO Swing TA = Thigh to Tlow (Note 4)	AVOL	50	100	-	25	100	-	25	100	-	V/mV
Channel Separation 10 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	-	-120	-	-	-120	-	-	-120	-	dB
Common Mode Rejection, RS ≤ 10 kΩ	CMR	70	85	-	65	70	-	50	70	-	dB
Power Supply Rejection	PSR	65	100	-	65	100	-	50	100	-	dB

[4] XL/XD224, XL224-TS: Tlow = -25°C, Thigh = +85°C

XL/XD324, XL324TSS: Tlow = 0°C, Thigh = +70°C

XL2902, XD2902N, XL2902-TS: Tlow = -40°C, Thigh = +105°C

[5] 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 VCC -1.7 V, but either or both inputs can go to +32 V without damage, independent of the magnitude of VCC.

[6] Guaranteed by design.

## Electrical Characteristics

(VCC = 5 V, VEE = GND, TA = 25 °C (unless otherwise specified))

Characteristics	Symbol	XL224, XD224, XL224-TS			XL324, XD324, XL324TSS			XL2902, XD2902N, XL2902-TS			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Output Voltage – High Limit VCC = 5.0 V, RL = 2.0 kΩ, TA = 25°C VCC = 30 V RL = 2.0 kΩ (TA = Thigh to Tlow) (Note 7) VCC = 30 V RL = 10 kΩ (TA = Thigh to Tlow) (Note 7)	VOH	3.3	3.5	–	3.3	3.5	–	3.3	3.5	–	V
Output Voltage – Low Limit, VCC = 5.0 V, RL = 10 kΩ, TA = Thigh to Tlow (Note 7)	VOL	–	5.0	20	–	5.0	20	–	5.0	100	mV
Output Source Current (VID = +1.0 V, VCC = 15 V) TA = 25°C TA = Thigh to Tlow (Note 7)	IO +	20	40	–	20	40	–	20	40	–	mA
Output Sink Current (VID = –1.0 V, VCC = 15 V) TA = 25°C TA = Thigh to Tlow (Note 7) (VID = –1.0 V, VO = 200 mV, TA = 25°C)	IO –	10	20	–	10	20	–	10	20	–	mA
		5.0	8.0	–	5.0	8.0	–	5.0	8.0	–	
		12	50	–	12	50	–	–	–	–	μA
Output Short Circuit to Ground	ISC	–	40	60	–	40	60	–	40	60	mA
Power Supply Current (TA = Thigh to Tlow) (Note 7) VCC = 30 V VO = 0 V, RL = ∞ VCC = 5.0 V, VO = 0 V, RL = ∞	ICC	–	–	3.0	–	–	3.0	–	–	3.0	mA
		–	–	1.2	–	–	1.2	–	–	1.2	

[7] XL/XD224, XL224-TS: Tlow = –25°C, Thigh = +85°C

XL/XD324, XL324TSS: Tlow = 0°C, Thigh = +70°C

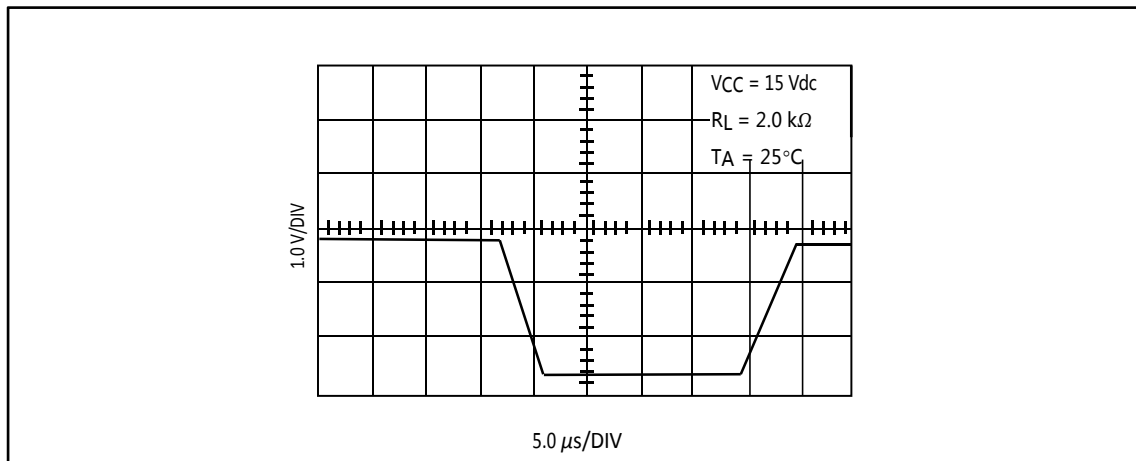
XL2902, XD2902N, XL2902-TS: Tlow = –40°C, Thigh = +105°C

[8] 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 VCC –1.7 V, but either or both inputs can go to +32 V without damage, independent of the magnitude of VCC.

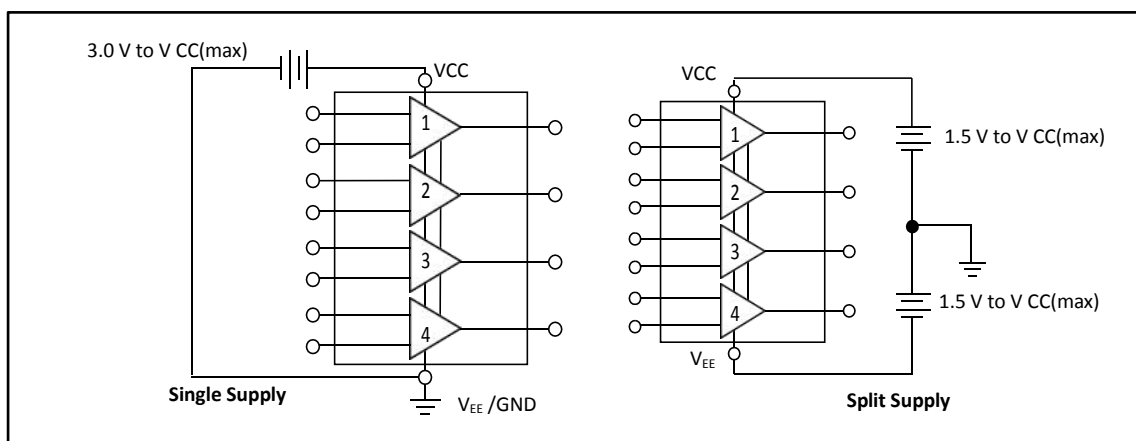
## 6. CIRCUIT DESCRIPTION

The XL324 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 5.0pF) 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.

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.



**Figure 6-1. Large Signal Voltage Follower Response**



**Figure 6-2.**

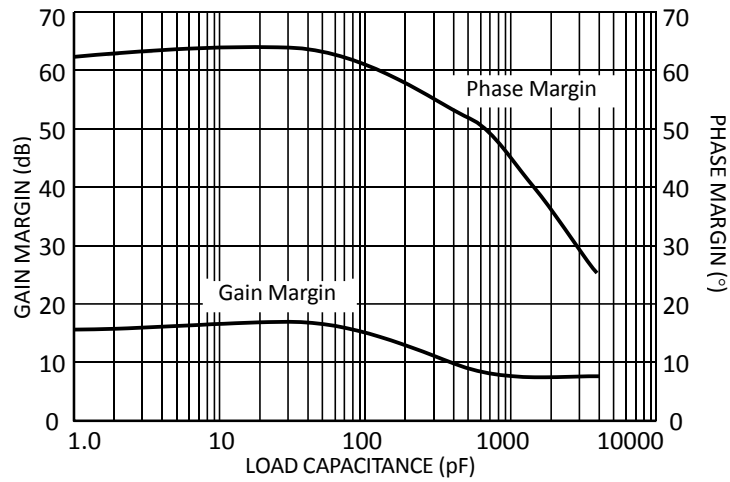


Figure 6-3. Gain and Phase Margin

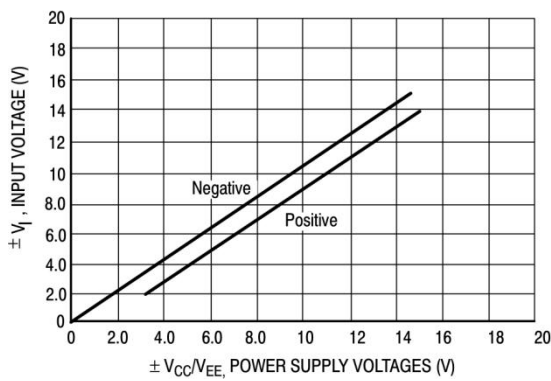


Figure 6-4. Input Voltage Range

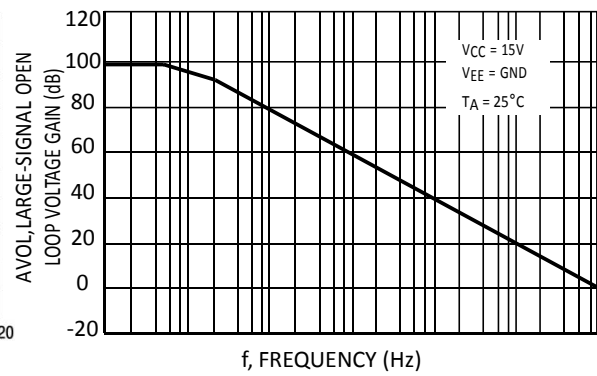


Figure 6-5. Open Loop Frequency

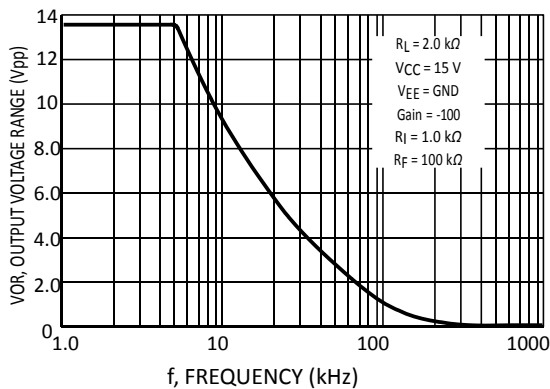


Figure 6-6. Large-Signal Frequency Response

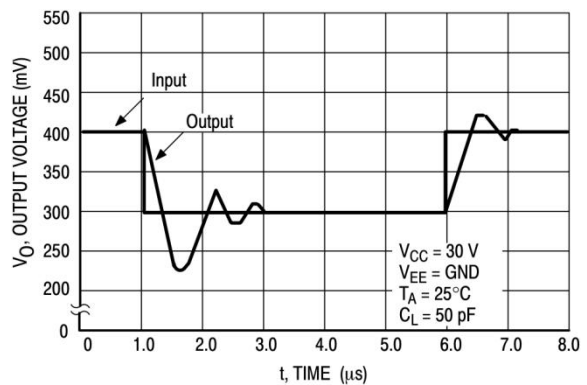


Figure 6-7. Small-Signal Voltage Follower Pulse Response (Noninverting)



### 6.1. Electrical characteristic curve

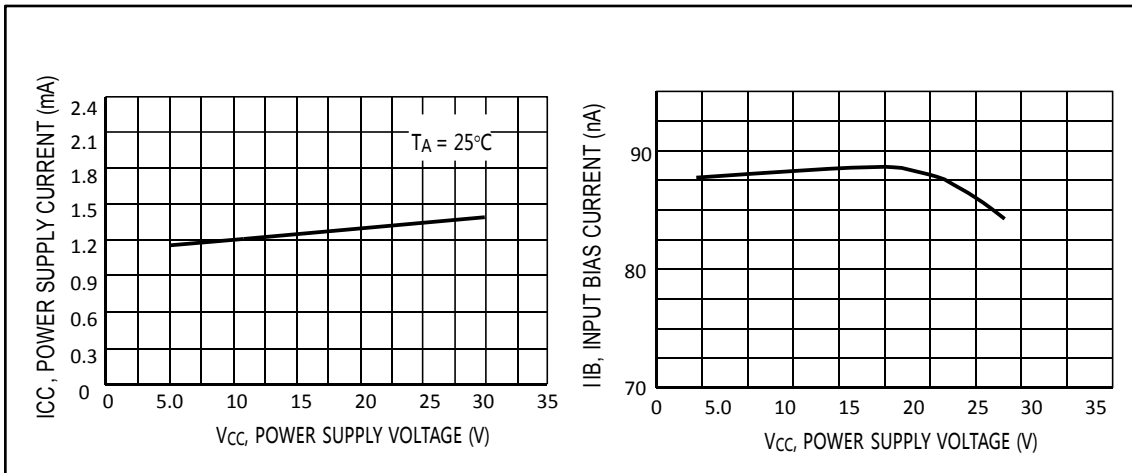


Figure 6-8. Power Supply Current versus Power Supply Voltage

Figure 6-9. Input Bias Current versus Power Supply Voltage

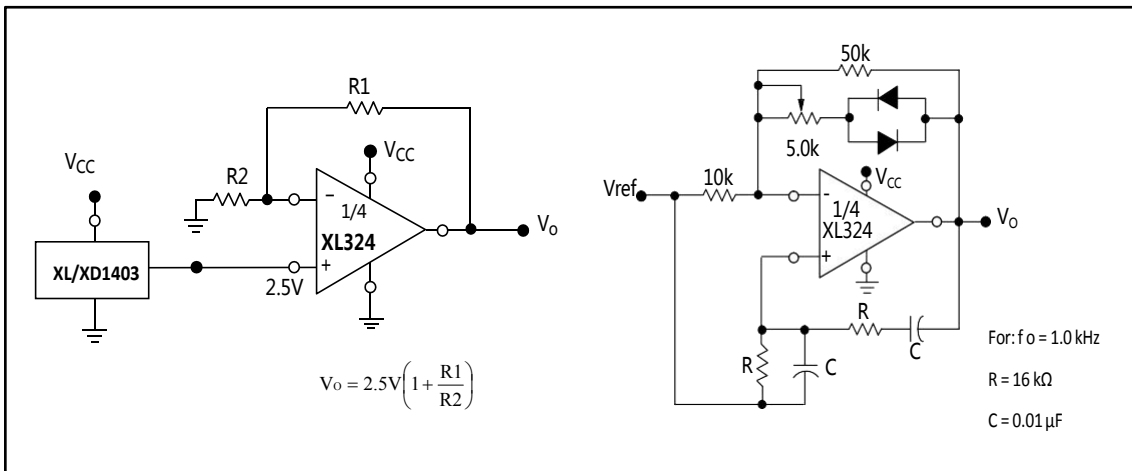


Figure 6-10. Voltage Reference

Figure 6-11. Wien Bridge Oscillator

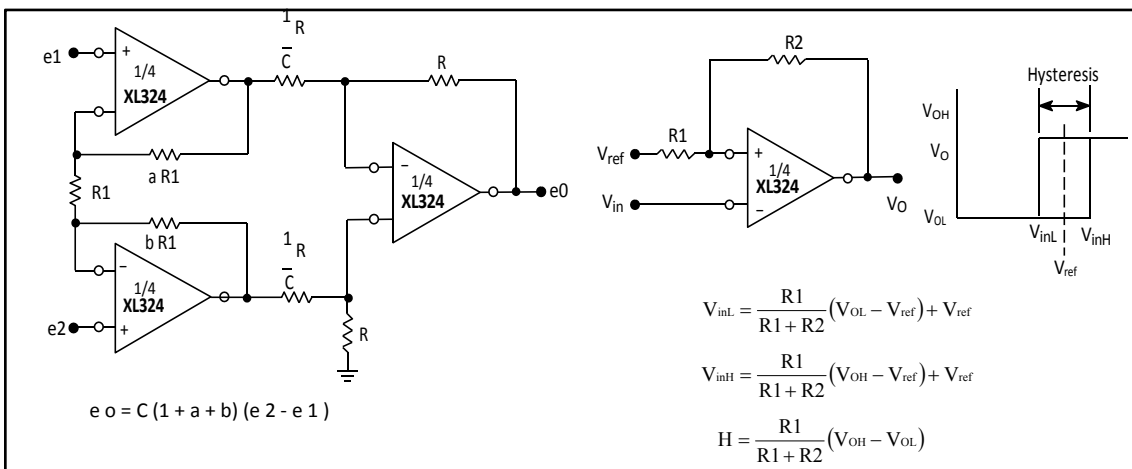
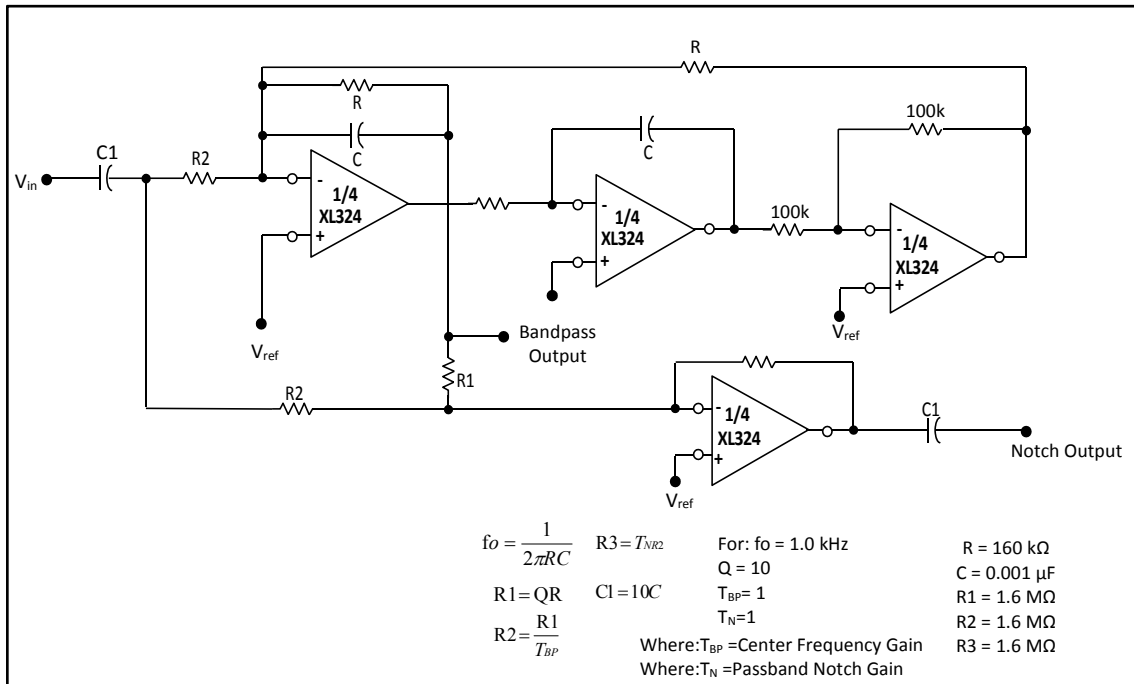
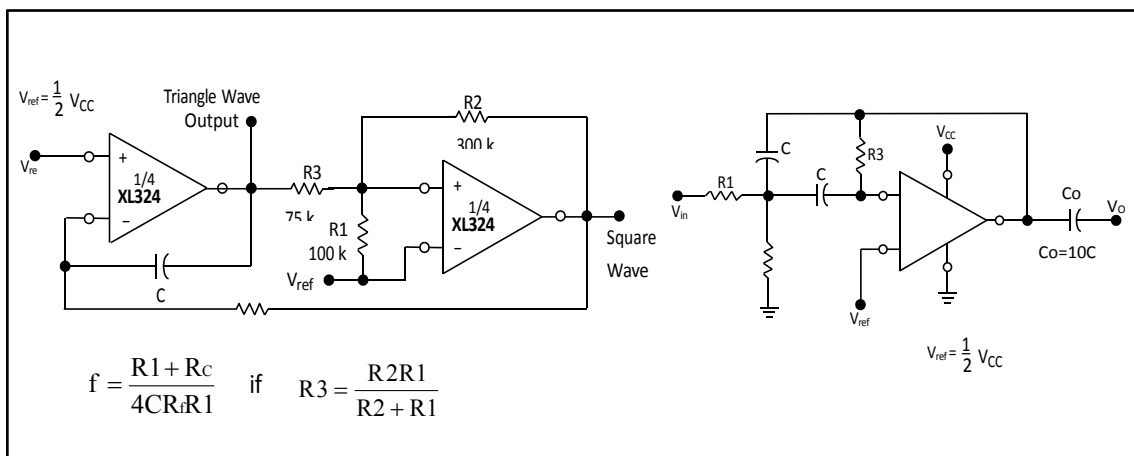


Figure 6-12. High Impedance Differential Amplifier

Figure 6-13. Comparator with Hysteresis



**Figure 6-13. Bi-Quad Filter**



**Figure 6-14. Function Generator**

**Figure 6-15. Multiple Feedback Bandpass Filter**

Given:  $f_o$  = center frequency  
 $A(f_o)$  = gain at center frequency  
 Choose value  $f_o$ ,  $C$

Then:

$$R3 = \frac{Q}{\pi f_o C}$$

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

$$R2 = \frac{R1R3}{4Q^2R1 - R3}$$

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

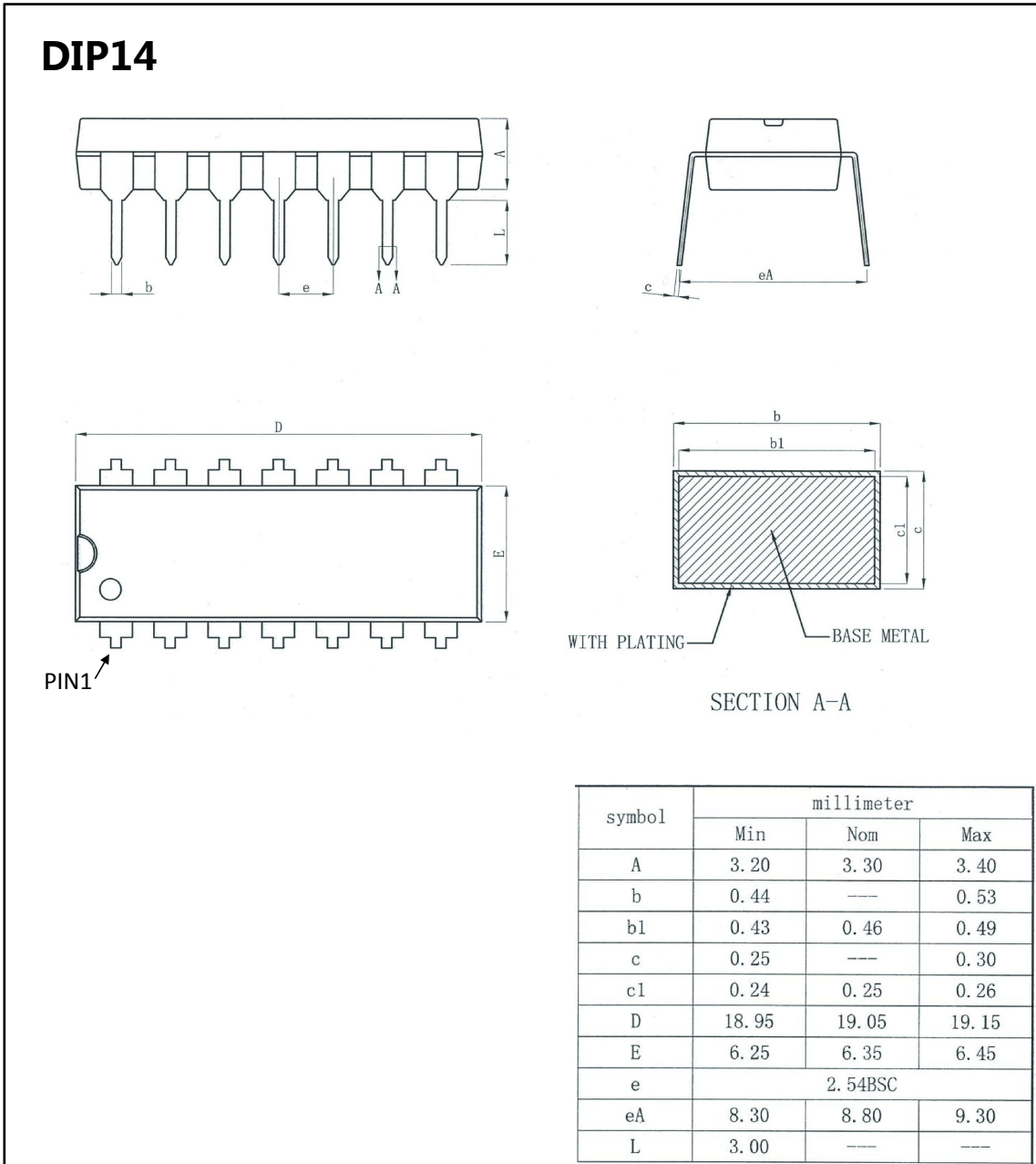
If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.

## 7. ORDERING INFORMATION

### Ordering Information

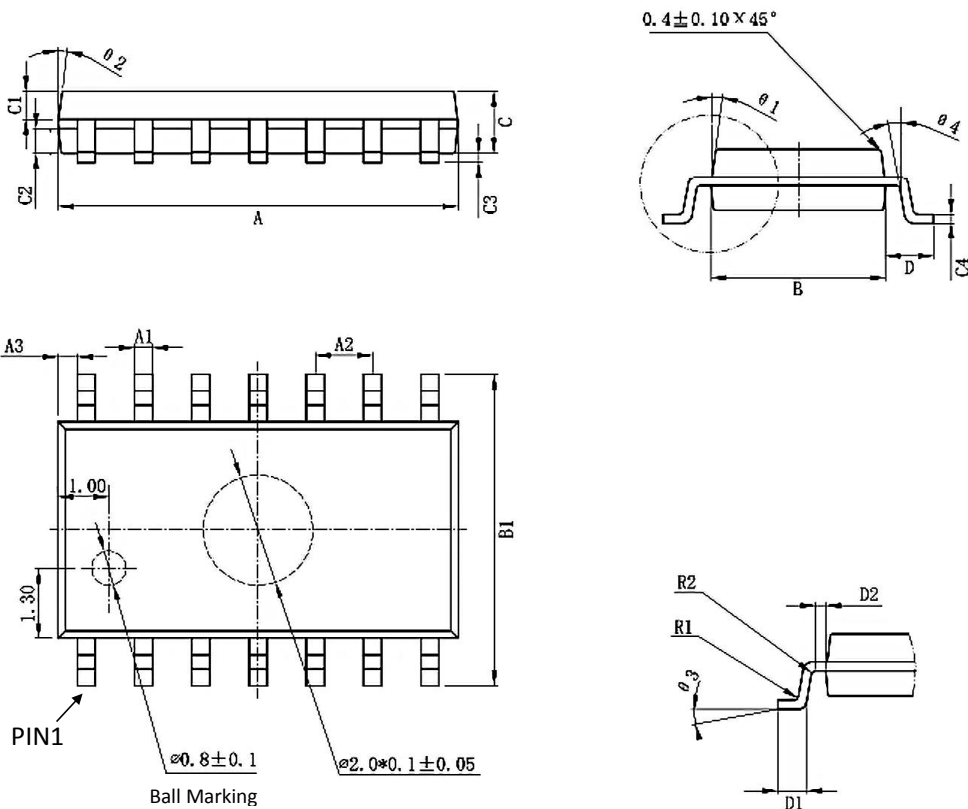
Part Number	Device Marking	Package Type	Body size (mm)	Temperature (°C)	MSL	Transport Media	Package Quantity
XL324	XL324	SOP14	8.75 * 4.00	-40 to +85	MSL3	T&R	2500
XL324TSS	XL324TSS	TSSOP14	5.00 * 4.40	-40 to +85	MSL3	T&R	2500
XD324	XD324	DIP14	19.05 * 6.35	-40 to +85	MSL3	Tube 25	1000
XL224	XL224	SOP14	8.75 * 4.00	-40 to +85	MSL3	T&R	2500
XL224-TS	XL224-TS	TSSOP14	5.00 * 4.40	-40 to +85	MSL3	T&R	2500
XD224	XD224	DIP14	19.05 * 6.35	-40 to +85	MSL3	Tube 25	1000
XL2902	XL2902	SOP14	8.75 * 4.00	-40 to +85	MSL3	T&R	2500
XL2902-TS	XL2902-TS	TSSOP14	5.00 * 4.40	-40 to +85	MSL3	T&R	2500
XD2902N	XD2902N	DIP14	19.05 * 6.35	-40 to +85	MSL3	Tube 25	1000

**8. DIMENSIONAL DRAWINGS**

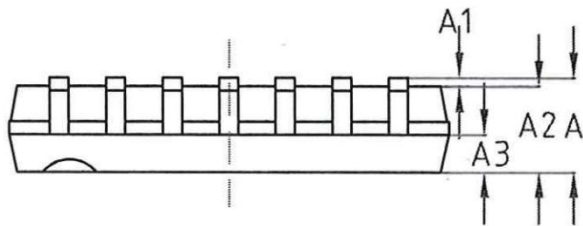
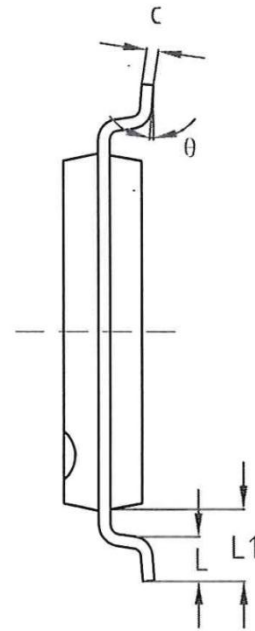
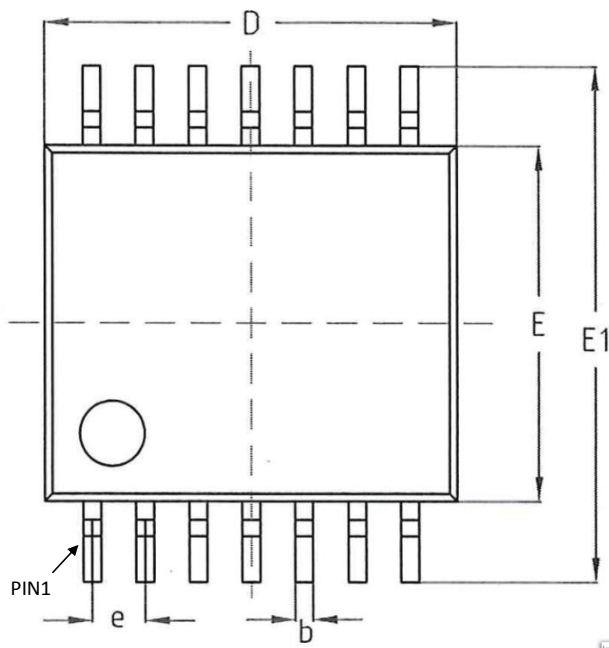


**SOP14**

Mark	Size	Min (mm)	Max (mm)	Mark	Size	Min (mm)	Max (mm)
A		8.55	8.75	C4		0.193	0.213
A1		0.356	0.456	D		0.95	1.15
A2		1.27TYP		D1		0.40	0.70
A3		0.312TYP		D2		0.20TYP	
B		3.80	4.00	R1		0.20TYP	
B1		5.80	6.20	R2		0.20TYP	
C		1.40	1.60	θ1		8° ~ 12° TYP4	
C1		0.60	0.70	θ2		8° ~ 12° TYP4	
C2		0.55	0.65	θ3		0° ~ 8°	
C3		0.05	0.25	θ4		4° ~ 12°	



### TSSOP14



机械尺寸/mm Dimensions			
字符 SYMBOL	最小值 MIN	典型值 NOMINAL	最大值 MAX
A	-	-	1.20
A1	0.05	-	0.15
A2	0.90	1.00	1.05
A3	0.39	0.44	0.49
b	0.20	-	0.28
c	0.13	-	0.17
D	4.90	5.00	5.10
E	4.30	4.40	4.50
E1	6.20	6.40	6.60
e	0.65 BSC		
L1	1.00REF		
L	0.45	0.60	0.75
$\theta$	0°	-	8°

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[E2-A](#) [UPC458G2-E1-A](#) [UPC824G2-E2-A](#) [UPC4574G2-E2-A](#) [UPC4558G2-E2-A](#) [UPC4560G2-E1-A](#) [UPC258G2-E1-A](#) [UPC4742GR-9LG-](#)  
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[E2-A](#) [UPC259G2-E1-A](#) [UPC4741G2-E1-A](#) [UPC4558G2-E1-A](#) [UPC1251GR-9LG-E1-A](#) [UPC4744G2-E1-A](#) [UPC4092G2-E1-A](#)  
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