MOTOROLA
SEMICONDUCTOR
TECHNICAL DATA

2

LM124, LM224, LM324, LM324A, LM2902

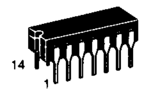
Quad Low Power Operational Amplifiers

QUAD DIFFERENTIAL INPUT OPERATIONAL AMPLIFIERS

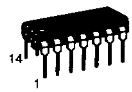
SILICON MONOLITHIC INTEGRATED CIRCUIT

The LM124 series are low-cost, quad operational amplifiers with true differential inputs. These 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 Max (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



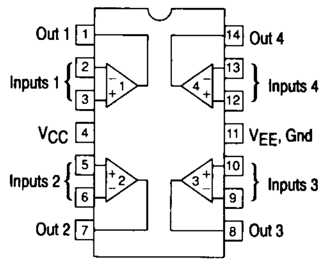
J SUFFIX
CERAMIC PACKAGE
CASE 632



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

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

PIN CONNECTIONS



(Top View)

MAXIMUM RATINGS (T_A = +25°C, unless otherwise noted.)

Rating	Symbol	LM124 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 (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 Ceramic Package Plastic Packages	T_J	 175 150		°C
Storage Temperature Range Ceramic Package Plastic Packages	T_{stg}	 –65 to +150 –55 to +125		°C
Operating Ambient Temperature Range	T_A	–55 to +125 –25 to +85 0 to +70 —	— — — –40 to +105	°C

NOTE: 1. Split Power Supplies.

ORDERING INFORMATION

Device	Temperature Range	Package
LM124J	–55° to +125°C	Ceramic DIP
LM2902D	–40° to +105°C	SO-14
LM2902N		Plastic DIP
LM2902J	–40° to +85°C	Ceramic DIP
LM224D	–25° to +85°C	SO-14
LM224J		Ceramic DIP
LM224N		Plastic DIP
LM324AD	0° to +70°C	SO-14
LM324AN		Plastic DIP
LM324D		SO-14
LM324J		Ceramic DIP
LM324N		Plastic DIP

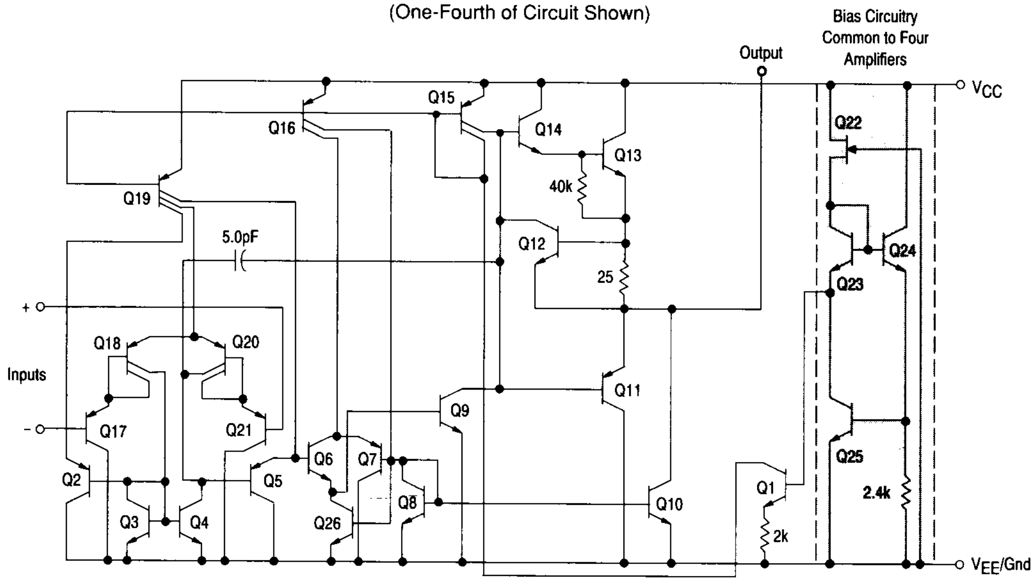
ELECTRICAL CHARACTERISTICS (V_{CC} = 5.0 V, V_{EE} = GND, T_A = 25°C, unless otherwise noted.)

Characteristics	Symbol	LM124/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 7.0	— —	2.0 —	3.0 5.0	— —	2.0 —	7.0 9.0	— —	2.0 —	7.0 10	mV
Average Temperature Coefficient of Input Offset Voltage T_A = T_{high} to T_{low} (Note 1)	$\Delta V_{IO}/\Delta T$	—	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 —	30 100	— —	5.0 —	30 75	— —	5.0 —	50 150	— —	5.0 —	50 200	nA
Average Temperature Coefficient of Input Offset Current T_A = T_{high} to T_{low} (Note 1)	$\Delta I_{IO}/\Delta T$	—	10	—	—	10	300	—	10	—	—	10	—	pA/°C
Input Bias Current T_A = T_{high} to T_{low} (Note 1)	I_{IB}	— —	−90 —	−150 −300	— —	−45 —	−100 −200	— —	−90 —	−250 −500	— —	−90 —	−250 −500	nA
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 0	— —	28.3 28	0 0	— —	28.3 28	0 0	— —	28.3 28	0 0	— —	24.3 24	V
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 25	100 —	— —	25 15	100 —	— —	25 15	100 —	— —	25 15	100 —	— —	V/mV
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 26 27	3.5 — 28	— — —	3.3 26 27	3.5 — 28	— — —	3.3 26 27	3.5 — 28	— — —	3.3 22 23	3.5 — 24	— — —	V
Output Voltage — Low Limit V_{CC} = 5.0 V, R_L = 10 kΩ, T_A = T_{high} to T_{low} (Note1)	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 10	40 20	— —	20 10	40 20	— —	20 10	40 20	— —	20 10	40 20	— —	mA
Output Sink Current (V_{ID} = −1.0 V, V_{CC} = 15 V) T_A = 25°C T_A = T_{high} to T_{low} (Note 1) (V_{ID} = −1.0 V, V_O = 200 mV, T_A = 25°C)	I_{O-}	10 5.0 12	20 8.0 50	— — —	10 5.0 12	20 8.0 50	— — —	10 5.0 12	20 8.0 50	— — —	10 5.0 —	20 8.0 —	— — —	mA 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_{high} to T_{low}) (Note 1) V_{CC} = 30 V (26 V for LM2902), V_O = 0 V, R_L = ∞ V_{CC} = 5.0 V, V_O = 0 V, R_L = ∞	I_{CC}	— —	— —	3.0 1.2	— —	1.4 0.7	3.0 1.2	— —	— —	3.0 1.2	— —	— —	3.0 1.2	mA

NOTES:
1. T_{low} = −55°C for LM124; = −25°C for LM224; = 0°C for LM324, A; = −40°C for LM2902
   T_{high} = +125°C for LM124; = +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.
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.

LM124, LM224, LM324,A, LM2902

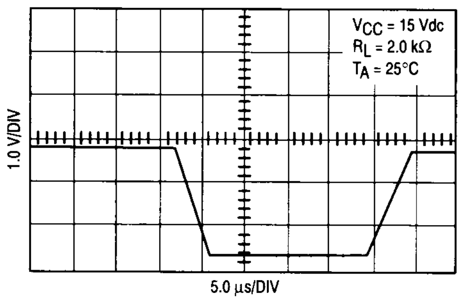
Representative Circuit Schematic
(One-Fourth of Circuit Shown)



CIRCUIT DESCRIPTION

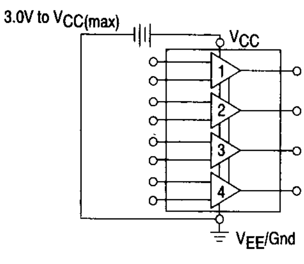
The LM124 series is made using four internally compensated, two-stage operational amplifiers. The first stage of each consists of differential input devices Q20 and Q18 with input buffer transistors Q21 and Q17 and the differential to single ended converter Q3 and Q4. The first stage performs not only 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

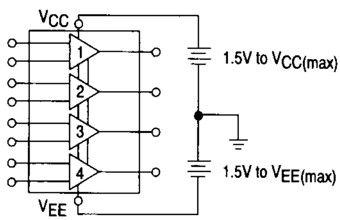


Figure 1. Input Voltage Range

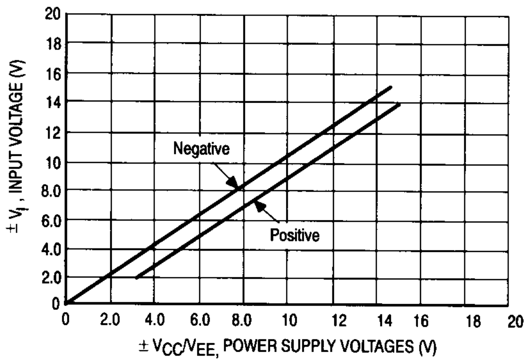


Figure 2. Open-Loop Frequency

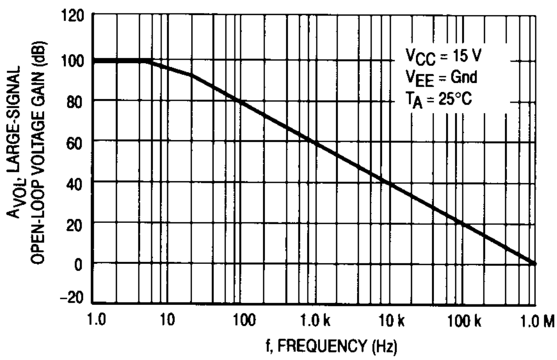


Figure 3. Large-Signal Frequency Response

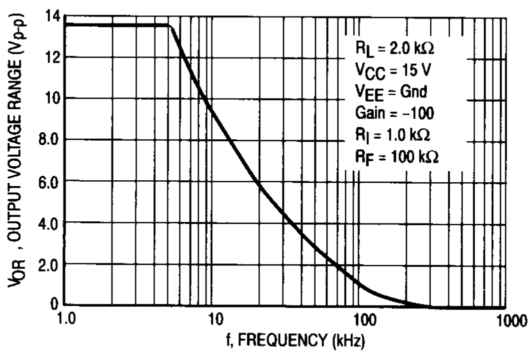


Figure 4. Small-Signal Voltage Follower Pulse Response (Noninverting)

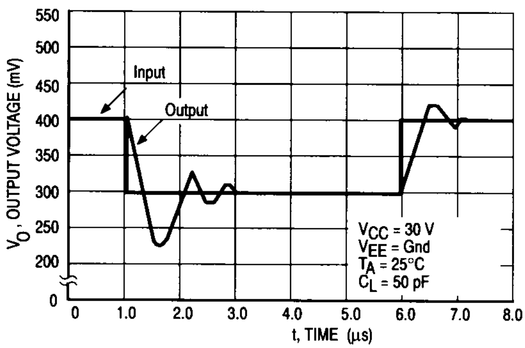


Figure 5. Power Supply Current versus Power Supply Voltage

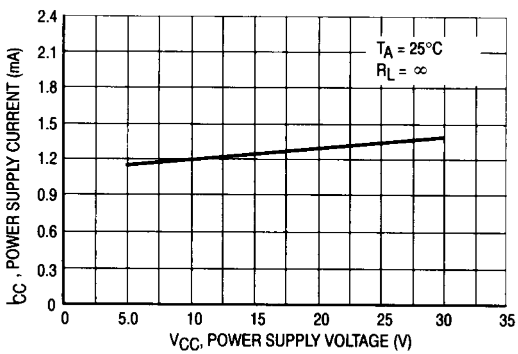


Figure 6. Input Bias Current versus Power Supply Voltage

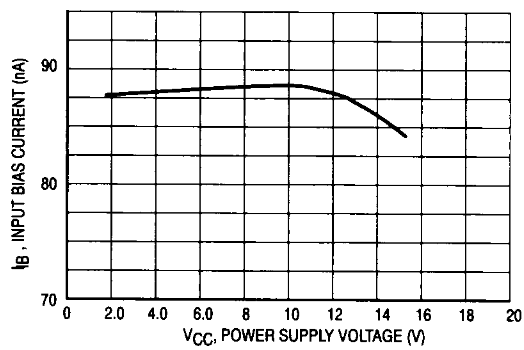
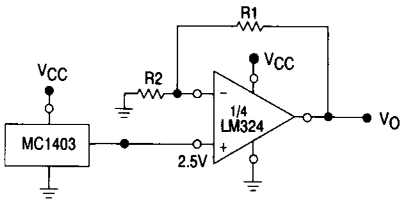
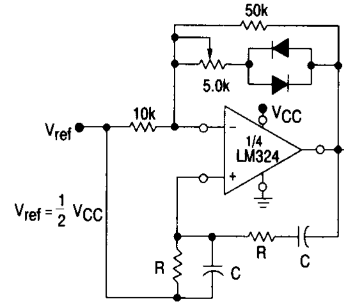


Figure 7. Voltage Reference



$$V_O = 2.5\,V\left(1 + \frac{R1}{R2}\right)$$

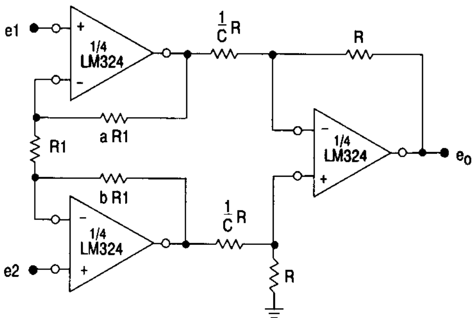
Figure 8. Wien Bridge Oscillator



$$f_o = \frac{1}{2\,\pi\,RC}$$

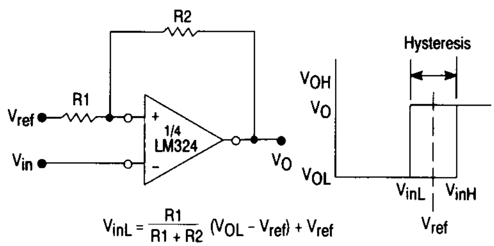
For: $f_o = 1.0\ kHz$
$R = 16\ k\Omega$
$C = 0.01\ \mu F$

Figure 9. High Impedance Differential Amplifier



$$e_o = C\,(1 + a + b)\,(e2 - e1)$$

Figure 10. Comparator with Hysteresis

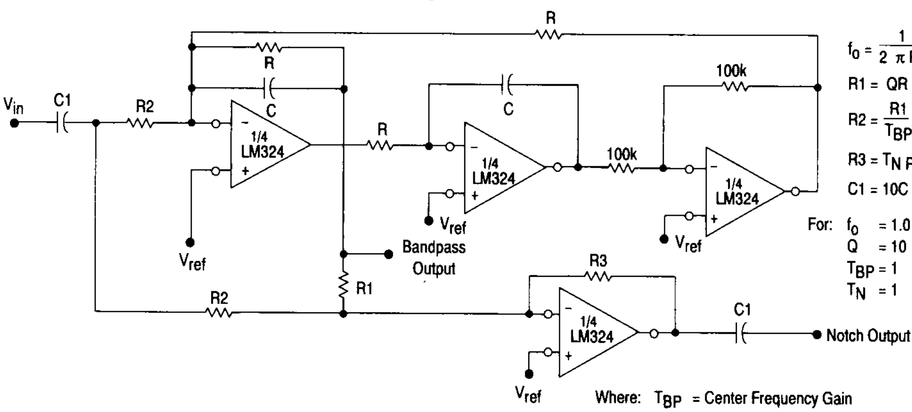


$$V_{inL} = \frac{R1}{R1 + R2}\,(V_{OL} - V_{ref}) + V_{ref}$$

$$V_{inH} = \frac{R1}{R1 + R2}\,(V_{OH} - V_{ref}) + V_{ref}$$

$$H = \frac{R1}{R1 + R2}\,(V_{OH} - V_{OL})$$

Figure 11. Bi-Quad Filter



$$f_o = \frac{1}{2\,\pi\,RC}$$

$R1 = QR$

$R2 = \frac{R1}{T_{BP}}$

$R3 = T_N\,R2$

$C1 = 10C$

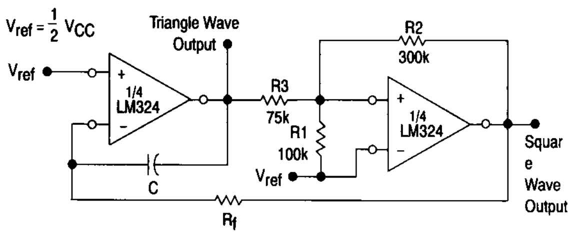
$V_{ref} = \frac{1}{2}\,V_{CC}$

For: $f_o = 1.0\ kHz$
$Q = 10$
$T_{BP} = 1$
$T_N = 1$

$R = 160\ k\Omega$
$C = 0.001\ \mu F$
$R1 = 1.6\ M\Omega$
$R2 = 1.6\ M\Omega$
$R3 = 1.6\ M\Omega$

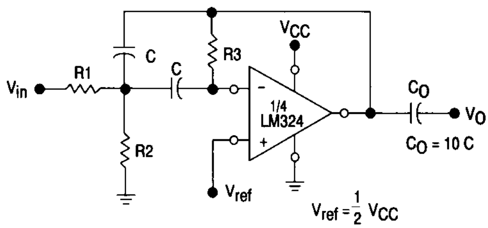
Where: T_{BP} = Center Frequency Gain
T_N = Passband Notch Gain

Figure 12. Function Generator



$$f = \frac{R1 + R_C}{4\,CR_f\,R1} \quad \text{if} \quad R3 = \frac{R2\,R1}{R2 + R1}$$

Figure 13. Multiple Feedback Bandpass Filter



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

Choose value f_o, C
Then:

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

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

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

For less than 10% error from operational amplifier,

$$\frac{Q_o f_o}{BW} < 0.1$$ 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.