

August 1991

**Features**

- Operation from Single or Dual Supplies
- Unity-Gain Bandwidth ..... 1MHz (Typ.)
- DC Voltage Gain ..... 100dB (Typ.)
- Input Bias Current ..... 45nA (Typ.)
- Input Offset Voltage ..... 2mV (Typ.)
- Input Offset Current
  - ▶ CA224, CA324, CA2902, LM324, LM2902 ..... 5nA (Typ.)
  - ▶ CA124 ..... 3nA (Typ.)
- Replacement for Industry Types 124, 224, 324

**Applications**

- Summing Amplifiers
- Multivibrators
- Oscillators
- Transducer Amplifiers
- DC Gain Blocks

**Description**

The CA124, CA224, CA324, CA2902, LM324, and LM2902 consist of four independent, high-gain operational amplifiers on a single monolithic substrate. An on-chip capacitor in each of the amplifiers provides frequency compensation for unity gain. These devices are designed specially to operate from either single or dual supplies, and the differential voltage range is equal to the power-supply voltage. Low power drain and an input common-mode voltage range from 0 V to V+ - 1.5 V (single-supply operation) make these devices suitable for battery operation.

The CA124, CA224, CA324, CA2902, LM324 and LM2902 are supplied in both 14-lead dual-in-line plastic (E suffix) and 14-lead (150 mil) small outline (M suffix) packages. The CA324 is available in chip form (H suffix).

**Pinout**

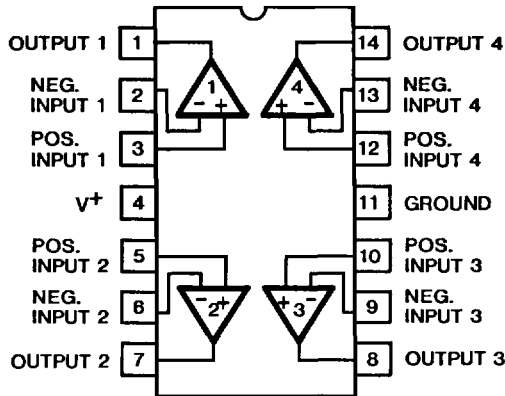


FIGURE 1.

\* Technical Data on LM Branded types is identical to the corresponding CA Branded types.  
CAUTION: These devices are sensitive to electrostatic discharge. Proper I.C. handling procedures should be followed.  
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# CA124, CA224, CA324, CA2902, LM324, LM2902

## MAXIMUM RATINGS, Absolute-Maximum Values at $T_A = 25^\circ\text{C}$

SUPPLY VOLTAGE	32 V or $\pm 16$ V
DIFFERENTIAL INPUT VOLTAGE	$\pm 32$ V
INPUT VOLTAGE	-0.3 V to +32 V
INPUT CURRENT ( $V_I < -0.3$ V) <sup>†</sup>	50 mA
OUTPUT SHORT CIRCUIT TO GROUND ( $V^+ \leq 15$ V) <sup>*</sup>	Continuous
DEVICE DISSIPATION:	
Up to $T_A = 55^\circ\text{C}$	750 mW
Above $T_A = 55^\circ\text{C}$	derate linearly at 6.67 mW/ $^\circ\text{C}$
AMBIENT TEMPERATURE RANGE:	
Operating	-55 to +125 $^\circ\text{C}$
Storage	-65 to +150 $^\circ\text{C}$
LEAD TEMPERATURE (DURING SOLDERING):	
At distance 1/16 $\pm$ 1/32 in. (1.59 $\pm$ 0.79 mm)	
from case for 10 seconds max.	+265 $^\circ\text{C}$

\*The maximum output current is approximately 40 mA independent of the magnitude of  $V^+$ . Continuous short circuits at  $V^+ > 15$  V can cause excessive power dissipation and eventual destruction. Short circuits from the output to  $V^+$  can cause overheating and eventual destruction of the device.

†This input current will only exist when the voltage at any of the input leads is driven negative. This current is due to the collector-base junction of the input p-n-p transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral n-p-n parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the amplifiers 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 transistor action 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 dc.

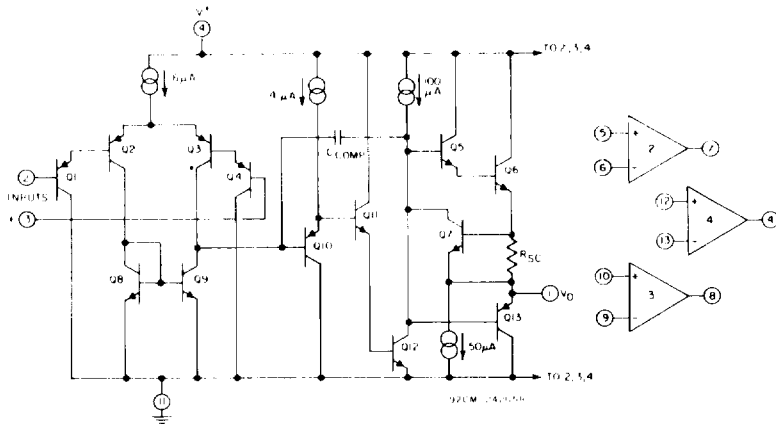


Fig. 2—Schematic diagram—one of four operational amplifiers.

CA124, CA224, CA324, CA2902, LM324, LM2902

ELECTRICAL CHARACTERISTICS (Values Apply For Each Operational Amplifier)

CHARACTERISTIC	TEST CONDITIONS Supply Voltage (V <sup>+</sup> ) = 5 V Unless Otherwise Specified	CA124 LIMITS			UNITS
		Min.	Typ.	Max.	
<b>T<sub>A</sub> = 25°C</b>					
Input Offset Voltage, V <sub>IO</sub>	Note 3	–	2	5	mV
Output Voltage Swing, V <sub>OPP</sub>	R <sub>L</sub> = 2 kΩ	0	–	V <sup>+</sup> – 1.5	V
Input Common-Mode Voltage Range, V <sub>ICR</sub>	Note 2, V <sup>+</sup> = 30 V	0	–	V <sup>+</sup> – 1.5	V
Input Offset Current, I <sub>IO</sub>	I <sub>1</sub> <sup>+</sup> – I <sub>1</sub> <sup>–</sup>	–	3	30	nA
Input Bias Current, I <sub>IB</sub>	I <sub>1</sub> <sup>+</sup> or I <sub>1</sub> <sup>–</sup> , Note 1	–	45	150	nA
Output Current (Source), I <sub>O</sub>	V <sub>1</sub> <sup>+</sup> = +1 V, V <sub>1</sub> <sup>–</sup> = 0 V, V <sup>+</sup> = 15 V	20	40	–	mA
Output Current (Sink), I <sub>O</sub>	V <sub>1</sub> <sup>+</sup> = 0 V, V <sub>1</sub> <sup>–</sup> = 1 V, V <sup>+</sup> = 15 V	10	20	–	mA
	V <sub>1</sub> <sup>+</sup> = 0 V, V <sub>1</sub> <sup>–</sup> = 1 V, V <sub>O</sub> = 200 mV	12	50	–	μA
Large Signal Voltage Gain, A	R <sub>L</sub> ≥ 2 kΩ, V <sup>+</sup> = 15 V (For large V <sub>O</sub> swing)	94	100	–	dB
Common-Mode Rejection Ratio, CMRR	DC	70	85	–	dB
Power Supply Rejection Ratio, PSRR	DC	65	100	–	dB
Amplifier-to-Amplifier Coupling	f = 1 to 20 kHz (Input referred)	–	–120	–	dB
<b>T<sub>A</sub> = –55 to +125°C</b>					
Input Offset Voltage, V <sub>IO</sub>	Note 3	–	–	7	mV
Temperature Coefficient of Input Offset Voltage, αV <sub>IO</sub>	R <sub>S</sub> = 0	–	7	–	μV/°C
Input Offset Current, I <sub>IO</sub>	I <sub>1</sub> <sup>+</sup> – I <sub>1</sub> <sup>–</sup>	–	–	100	nA
Temperature Coefficient of Input Offset Current, αI <sub>IO</sub>		–	10	–	ρA/°C
Input Bias Current, I <sub>IB</sub>	I <sub>1</sub> <sup>+</sup> or I <sub>1</sub> <sup>–</sup>	–	–	300	nA
Total Supply Current, I <sup>+</sup>	R <sub>L</sub> = ∞ On All Ampl.	–	0.8	2	mA
Input Common-Mode Voltage Range, V <sub>ICR</sub>	V <sup>+</sup> = 30 V	0	–	V <sup>+</sup> – 2	V
Large-Signal Voltage Gain, A	R <sub>L</sub> ≥ 2 kΩ, V <sup>+</sup> = 15 V (For large V <sub>O</sub> swing)	88	–	–	dB
Output Voltage Swing:	R <sub>L</sub> = 2 kΩ, V <sup>+</sup> = 30 V	26	–	–	V
		R <sub>L</sub> = 10 kΩ	27	28	
Low-Level, V <sub>OL</sub>	R <sub>L</sub> = 10 kΩ	–	5	20	mV
Output Current:	V <sub>1</sub> <sup>+</sup> = 1 V <sub>DC</sub> , V <sub>1</sub> <sup>–</sup> = 0, V <sup>+</sup> = 15 V	10	20	–	mA
		Source, I <sub>O</sub>			
Sink, I <sub>O</sub>	V <sub>1</sub> <sup>–</sup> = 1 V <sub>DC</sub> , V <sub>1</sub> <sup>+</sup> = 0, V <sup>+</sup> = 15 V	5	8	–	mA
Differential Input Voltage	Note 2	–	–	V <sup>+</sup>	V

NOTE 1: Due to the p–n–p input stage the direction of the input current is out of the IC. No loading change exists on the input lines because the current is essentially constant, independent of the state of the output.

NOTE 2: The input signal voltage and the input common-mode voltage should not be allowed to go negative by more than 0.3 V. The positive limit of the common-mode voltage range is V<sup>+</sup> – 1.5 V, but either or both inputs can go to +32 V without damage.

NOTE 3: V<sub>O</sub> = 1.4 V<sub>DC</sub>, R<sub>S</sub> = 0 Ω with V<sup>+</sup> from 5 V to 30 V; and over the full input common-mode voltage range (0 V to V<sup>+</sup> – 1.5 V).

**CA124, CA224, CA324, CA2902, LM324, LM2902**

**ELECTRICAL CHARACTERISTICS (Values apply for each operational amplifier)**

CHARACTERISTIC	TEST CONDITIONS Supply Voltage (V <sup>+</sup> ) = 5 V Unless Otherwise Specified	CA224, CA324 LIMITS			UNITS	
		Min.	Typ.	Max.		
<b>T<sub>A</sub> = 25°C</b>						
Input Offset Voltage, V <sub>IO</sub>	Note 3	–	2	7	mV	
Output Voltage Swing, V <sub>OPP</sub>	R <sub>L</sub> = 2 kΩ	0	–	V <sup>+</sup> – 1.5	V	
Input Common-Mode Voltage Range, V <sub>ICR</sub>	Note 2, V <sup>+</sup> = 30 V	0	–	V <sup>+</sup> – 1.5	V	
Input Offset Current, I <sub>IO</sub>	I <sub>I</sub> <sup>+</sup> – I <sub>I</sub> <sup>–</sup>	–	5	50	nA	
Input Bias Current, I <sub>IB</sub>	I <sub>I</sub> <sup>+</sup> or I <sub>I</sub> <sup>–</sup> , Note 1	–	45	250	nA	
Output Current (Source), I <sub>O</sub>	V <sub>I</sub> <sup>+</sup> = +1 V, V <sub>I</sub> <sup>–</sup> = 0 V, V <sup>+</sup> = 15 V	20	40	–	mA	
Output Current (Sink), I <sub>O</sub>	V <sub>I</sub> <sup>+</sup> = 0 V, V <sub>I</sub> <sup>–</sup> = 1 V, V <sup>+</sup> = 15 V	10	20	–	mA	
	V <sub>I</sub> <sup>+</sup> = 0 V, V <sub>I</sub> <sup>–</sup> = 1 V, V <sub>O</sub> = 200 mV	12	50	–	μA	
Large Signal Voltage Gain, A	R <sub>L</sub> ≥ 2 kΩ, V <sup>+</sup> = 15 V (For large V <sub>O</sub> swing)	88	100	–	dB	
Common-Mode Rejection Ratio, CMRR	DC	65	70	–	dB	
Power Supply Rejection Ratio, PSRR	DC	65	100	–	dB	
Amplifier-to-Amplifier Coupling	f = 1 to 20 kHz (Input referred)	–	–120	–	dB	
<b>T<sub>A</sub> = –40 to +85°C (CA224), T<sub>A</sub> = 0 to 70°C (CA324)</b>						
Input Offset Voltage, V <sub>IO</sub>	Note 3	–	–	9	mV	
Temperature Coefficient of Input Offset Voltage, αV <sub>IO</sub>	R <sub>S</sub> = 0	–	7	–	μV/°C	
Input Offset Current, I <sub>IO</sub>	I <sub>I</sub> <sup>+</sup> – I <sub>I</sub> <sup>–</sup>	–	–	150	nA	
Temperature Coefficient of Input Offset Current, αI <sub>IO</sub>		–	10	–	pA/°C	
Input Bias Current, I <sub>IB</sub>	I <sub>I</sub> <sup>+</sup> or I <sub>I</sub> <sup>–</sup>	–	–	500	nA	
Total Supply Current, I <sup>+</sup>	R <sub>L</sub> = ∞ On All Ampl.	–	0.8	2	mA	
Input Common-Mode Voltage Range, V <sub>ICR</sub>	V <sup>+</sup> = 30 V	0	–	V <sup>+</sup> – 2	V	
Large Signal Voltage Gain, A	R <sub>L</sub> ≥ 2 kΩ, V <sup>+</sup> = 15 V (For large V <sub>O</sub> swing)	83	–	–	dB	
Output Voltage Swing:	R <sub>L</sub> = 2 kΩ, V <sup>+</sup> = 30 V	High-Level, V <sub>OH</sub>	R <sub>L</sub> = 10 kΩ	26	–	V
			R <sub>L</sub> = 10 kΩ	27	28	
		Low-Level, V <sub>OL</sub>	R <sub>L</sub> = 10 kΩ	–	5	20
Output Current:	V <sub>I</sub> <sup>+</sup> = 1 V <sub>DC</sub> , V <sub>I</sub> <sup>–</sup> = 0, V <sup>+</sup> = 15 V	Source, I <sub>O</sub>	10	20	–	mA
		Sink, I <sub>O</sub>	5	8	–	mA
Differential Input Voltage	Note 2	–	–	V <sup>+</sup>	V	

**NOTE 1:** Due to the p–n–p input stage the direction of the input current is out of the IC. No loading change exists on the input lines because the current is essentially constant, independent of the state of the output.

**NOTE 2:** The input signal voltage and the input common-mode voltage should not be allowed to go negative by more than 0.3 V. The positive limit of the common-mode voltage range is V<sup>+</sup> – 1.5 V, but either or both inputs can go to +32 V without damage.

**NOTE 3:** V<sub>O</sub> = 1.4 V<sub>DC</sub>, R<sub>S</sub> = 0 Ω with V<sup>+</sup> from 5 V to 30 V; and over the full input common-mode voltage range (0 V to V<sup>+</sup> – 1.5 V).

ELECTRICAL CHARACTERISTICS (Values apply for each operational amplifier)

CHARACTERISTIC	TEST CONDITIONS	2902 LIMITS			UNITS
		Supply Voltage ( $V^+$ ) = 5 V Unless Otherwise Specified	Min.	Typ.	
$T_A = -40$ to $+85^\circ\text{C}$ (CA2902)					
Input Offset Voltage, $V_{IO}$	Note 3	-	-	10	mV
Temperature Coefficient of Input Offset Voltage, $\alpha V_{IO}$	$R_S = 0$	-	7	-	$\mu\text{V}/^\circ\text{C}$
Input Offset Current, $I_{IO}$	$I_{I^+} - I_{I^-}$	-	45	200	nA
Temperature Coefficient of Input Offset Current, $\alpha I_{IO}$		-	10	-	$\text{pA}/^\circ\text{C}$
Input Bias Current, $I_B$	$I_{I^+}$ or $I_{I^-}$ , Note 1	-	40	500	nA
Input Common-Mode Voltage Range, $V_{ICR}$	$V^+ = 26$ V, Note 2	0	-	$V^+ - 2$	V
Supply Current, $I^+$	$R_L = \infty$ On All Ampl.	-	0.7	1.2	mA
	$R_L = \infty$ , $V^+ = 26$ V	-	1.5	3	
Large-Signal Voltage Gain, A	$R_L > 2$ k $\Omega$ , $V^+ = 15$ V (For large $V_O$ swing)	83	-	-	dB
Output Voltage Swing: High-Level, $V_{OH}$	$R_L = 2$ k $\Omega$ , $V^+ = 26$ V	22	-	-	V
	$R_L = 10$ k $\Omega$	23	28	-	
Low-Level, $V_{OL}$	$R_L = 10$ k $\Omega$	-	5	100	mV
Output Current: Source, $I_O$	$V_I^+ = 1$ $V_{DC}$ , $V_I^- = 0$ , $V^+ = 15$ V	10	20	-	mA
Sink, $I_O$	$V_I^- = 1$ $V_{DC}$ , $V_I^+ = 0$ , $V^+ = 15$ V	5	8	-	mA
Differential Input Voltage	Note 2	-	-	$V^+$	V

- NOTE 1: Due to the p-n-p input stage the direction of the input current is out of the IC. No loading change exists on the input lines because the current is essentially constant, independent of the state of the output.
- NOTE 2: The input signal voltage and the input common-mode voltage should not be allowed to go negative by more than 0.3 V. The positive limit of the common-mode voltage range is  $V^+ - 1.5$  V, but either or both inputs can go to +32 V without damage.
- NOTE 3:  $V_O = 1.4$   $V_{DC}$ ,  $R_S = 0$   $\Omega$  with  $V^+$  from 5 V to 30 V; and over the full input common-mode voltage range (0 V to  $V^+ - 1.5$  V).

# CA124, CA224, CA324, CA2902, LM324, LM2902

## TYPICAL CHARACTERISTICS CURVES

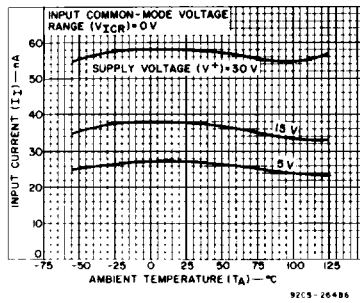


Fig. 3—Input current vs. ambient temperature.

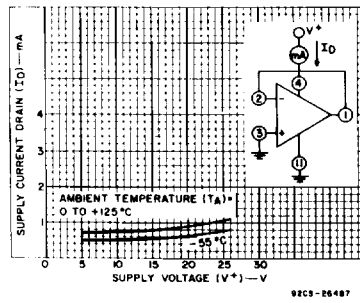


Fig. 4—Supply current drain vs. supply voltage.

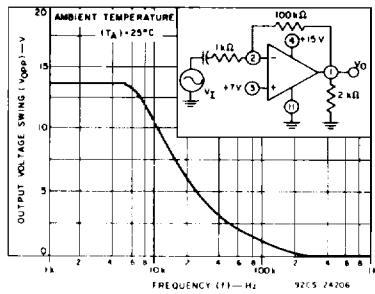


Fig. 5—Large-signal frequency response.

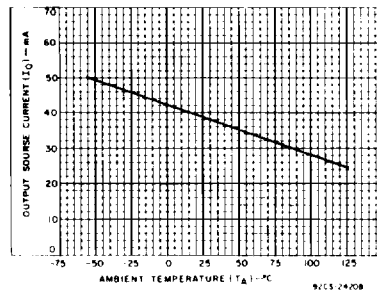


Fig. 6—Output current vs. ambient temperature.

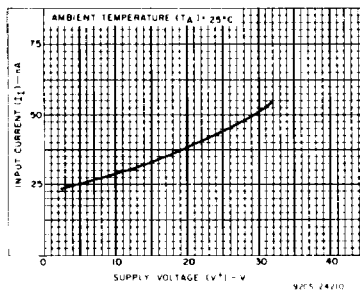


Fig. 7—Input current vs. supply voltage.

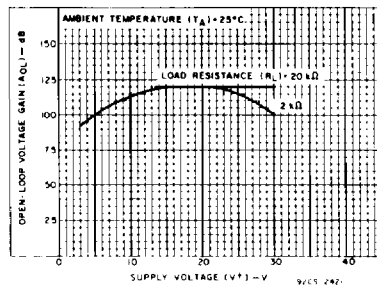


Fig. 8—Voltage gain vs. supply voltage.

# CA124, CA224, CA324, CA2902, LM324, LM2902

## TYPICAL CHARACTERISTICS CURVES (CONT'D)

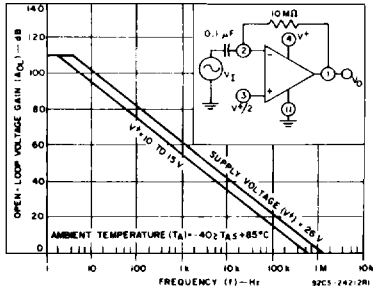


Fig. 9 - Open-loop frequency response.

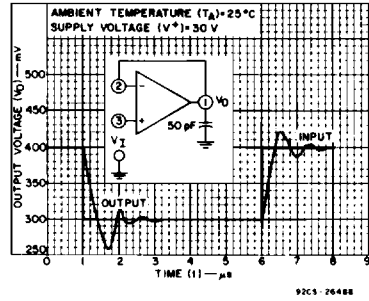


Fig. 10 - Voltage follower pulse response (small signal).

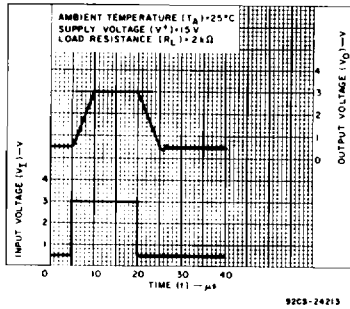


Fig. 11 - Voltage follower pulse response.