Operational Amplifiers

LM121A/LM221A/LM321A precision preamplifiers

general description

The LM121A series are precision preamplifiers designed to operate with general purpose operational amplifiers to drastically decrease dc errors. Drift, bias current, common mode and supply rejection are more than a factor of 50 better than standard op amps alone. Further, the added dc gain of the LM121A decreases the closed loop gain error.

The LM121A operates with supply voltages from ±3V to ±20V and has sufficient supply rejection to operate from unregulated supplies. The operating current is programmable from 5μA to 200μA so bias current, offset current, gain and noise can be optimized for the particular application while still realizing very low drift. Super-gain transistors are used for the input stage so input error currents are lower than conventional amplifiers at the same operating current. Further, the initial offset voltage is easily nulled to zero.

advantages

- No chopper noise
- Allows optimized input characteristics
- Improves dc accuracy

features

- Guaranteed drift less than 0.2μV/°C when nulled
- Offset voltage less than 0.4 mV
- Bias current less than 10 nA at 10μA operating current
- CMRR 126 dB minimum
- 120 dB supply rejection
- Easily nulled offset voltage

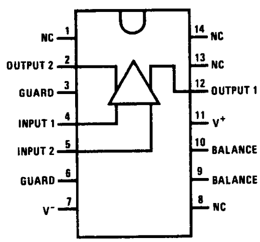
The extremely low drift of the LM121A will improve accuracy on almost any precision dc circuit. For example, instrumentation amplifier, strain gauge amplifiers and thermocouple amplifiers now using chopper amplifiers can be made with the LM121A. The full differential input and high common-mode rejection are another advantage over choppers. For applications where low bias current is more important than drift, the operating current can be reduced to low values. High operating currents can be used for low voltage noise with low source resistance. The programmable operating current of the LM121A allows tailoring the input characteristics to match those of specialized op amps.

The LM121A is specified over a −55°C to +125°C temperature range, the LM221A over a −25°C to +85°C range and the LM321A over a 0°C to +70°C temperature range.

2

connection diagrams

Dual-In-Line Package

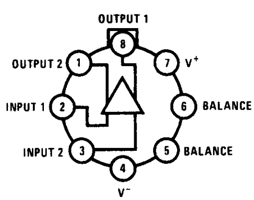


NOTE: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM121AD, LM221AD or LM321AD
See Package 1

Metal Can Package

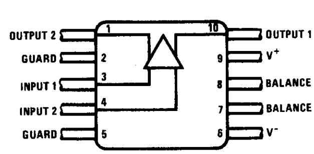


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM121AH, LM221AH or LM321AH
See Package 11

Flat Package



NOTE: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM121AF, LM221AF or LM321AF
See Package 3

Note: Outputs are inverting from the input of the same number.

absolute maximum ratings

Supply Voltage	±20V
Power Dissipation (Note 1)	500 mW
Differential Input Voltage (Notes 2 and 3)	±15V
Input Voltage (Note 3)	±15V
Operating Temperature Range	
LM121A	−55°C to +125°C
LM221A	−25°C to +85°C
LM321A	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	LM121A, LM221A			LM321A			UNI
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$, $6.4k \leq R_{SET} \leq 70k$		0.2	0.4		0.2	0.4	m
Input Offset Current	$T_A = 25°C$, $R_{SET} = 70k$		0.3	0.5		0.3	0.5	r
	$R_{SET} = 6.4k$			5			5	r
Input Bias Current	$T_A = 25°C$, $R_{SET} = 70k$		5	10		5	15	r
	$R_{SET} = 6.4k$		50	100		50	150	r
Input Resistance	$T_A = 25°C$, $R_{SET} = 70k$	4	8		2	8		M
	$R_{SET} = 6.4k$	0.4			0.2			M
Supply Current	$T_A = 25°C$, $R_{SET} = 70k$		0.8	1.5		0.8	2.2	m
Input Offset Voltage	$6.4k \leq R_{SET} \leq 70k$		0.5	0.65		0.5	0.65	m
Input Bias Current	$R_{SET} = 70k$		15	30		15	25	r
	$R_{SET} = 6.4k$		150	300		150	250	r
Input Offset Current	$R_{SET} = 70k$		0.5	1		0.5	1	r
	$R_{SET} = 6.4k$		5	10		5	10	r
Input Offset Current Drift	$R_{SET} = 70k$		3			3		pA/
Average Temperature Coefficient of Input Offset Voltage	$R_S \leq 200\Omega$, $6.4k \leq R_{SET} \leq 70k$ Offset Voltage Nulled		0.07	0.2		0.07	0.2	μV/
Long Term Stability			3			3		μV/
Supply Current			1	2.5		1	3.5	m
Input Voltage Range	$V_S = \pm 15V$, $R_{SET} = 70k$	±13			±13			
	(Note 5) $R_{SET} = 6.4k$	+7, −13			+7, −13			
Common-Mode Rejection Ratio	$R_{SET} = 70k$	126	140		126	140		d
	$R_{SET} = 6.4k$	120	130		120	130		d
Supply Voltage Rejection Ratio	$R_{SET} = 70k$	120	126		118	126		d
	$R_{SET} = 6.4k$	114	120		114	120		d
Voltage Gain	$T_A = 25°C$, $R_{SET} = 70k$, $R_L > 3$ meg	16	20		12	20		V/

Note 1: The maximum junction temperature of the LM121A is 150°C, while that of the LM221A is 100°C. The maximum junction temperatur of the LM321A is 85°C. For operating at elevated temperature, devices in the TO-5 package must be derated based on a thermal resistance o 150°C/W, junction to ambient, or 45°C/W, junction to case. For the flat package, the derating is based on a thermal resistance of 185°C/W whe mounted on a 1/6-inch-thick epoxy glass board with ten, 0.03-inch wide, 2-ounce copper conductors. The thermal resistance of the dual-in-lin package if 100°C/W junction to ambient.

Note 2: The inputs are shunted with back-to-back diodes in series with a 500Ω resistor for overvoltage protection. Therefore, excessive curren will flow if a differential input voltage in excess of 1V is applied between the inputs.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 4: These specifications apply for $\pm 5 \leq V_S \leq \pm 20V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM221A, however, al temperature specifications are limited to $-25°C \leq T_A \leq 85°C$, and for the LM321A the specifications apply over a 0°C to 70°C temperature range.

Note 5: External precision resistor—0.1%—can be placed from pins 1 and 8 to 7 to increase positive common-mode range.

equency compensation

IIVERSAL COMPENSATION

e additional gain of the LM121A preamplifier when ɜd with an operational amplifier usually necessitates ditional frequency compensation. When the closed ɔp gain of the op amp with the LM121A is less than ɜ gain of the LM121A alone, more compensation is eded. The worst case situation is when there is 100% ɜdback—such as a voltage follower or integrator—and ɜ gain of the LM121A is high. When high closed loop ins are used—for example A_V = 1000—and only an dition gain of 200 is inserted by the LM121A, the fre- ency compensation of the op amp will usually suffice.

ıe frequency compensation shown here is designed to ıerate with any unity-gain stable op amp. *Figure 1* ows the basic configuration of frequency stabilizing twork. In operation the output of the LM121A is ndered single ended by a 0.01μF bypass capacitor to ɔund. Overall frequency compensation then is achieved ' an integrating capacitor around the op amp.

$$\text{Bandwidth at unity-gain} \cong \frac{12}{2\pi R_{SET} C}$$

$$\text{for 0.5 MHz bandwidth } C = \frac{4}{10^6 R_{SET}}$$

ɔr use with higher frequency op amps such as the Ʌ118 the bandwidth may be increased to about 2 MHz.

the closed loop gain is greater than unity, "C" may be ɜcreased to:

$$C = \frac{4}{10^6 A_{CL} R_{SET}}$$

ALTERNATE COMPENSATION

The two compensation capacitors can be made equal for improved power supply rejection. In this case the formula for the compensation capacitor is:

$$C = \frac{8}{10^6 A_{CL} R_{SET}}$$

Table I shows typical values for the two compensating capacitors for various gains and operating currents.

TABLE I

CLOSED LOOP GAIN	CURRENT SET RESISTOR				
	120 kΩ	60 kΩ	30 kΩ	12 kΩ	6 kΩ
A_V = 1	68	130	270	680	1300
A_V = 5	15	27	56	130	270
A_V = 10	10	15	27	68	130
A_V = 50	1	3	5	15	27
A_V = 100	–	1	3	5	10
A_V = 500	–	–	1	1	3
A_V = 1000	–	–	–	–	–

This table applies for the LM108, LM101A, LM741, LM118. Capacitance is in pF.

DESIGN EQUATIONS FOR THE LM121A SERIES

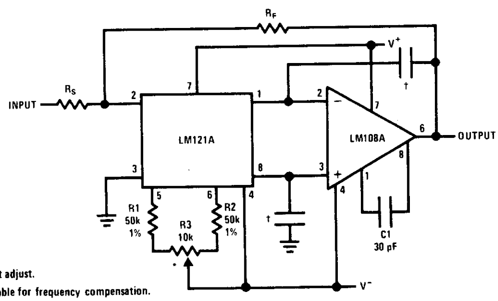
$$\text{Gain } A_V \approx \frac{1.2 \times 10^6}{R_{SET}}$$

Null Pot Value should be 10% of R_{SET}

$$\text{Operating Current} \approx \frac{2 \times 0.65V}{R_{SET}}$$

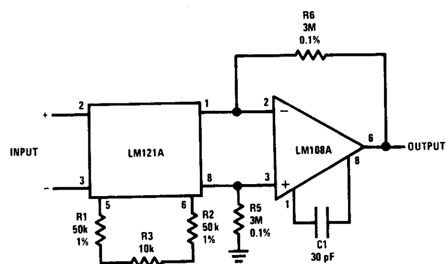
$$\text{Positive Common-Mode Limit} \approx V^+ - \left[0.6 - \frac{0.65V \times 50k}{R_{SET}}\right]$$

ypical applications



Offset adjust.
See table for frequency compensation.

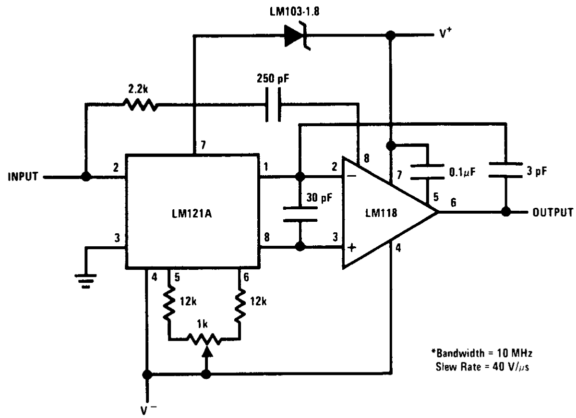
FIGURE 1. Low Drift Op Amp Using the LM121A as a Preamp



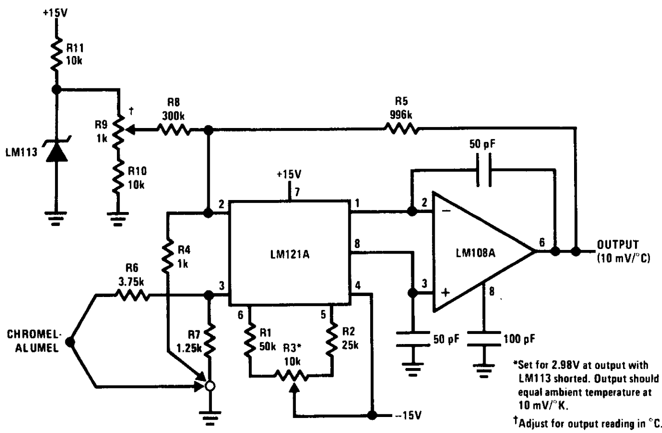
*Offset adjust
†Gain trim
‡Better than 1% linearity for input signals up to ±10 mV gain stability typical ±2% from –55 to 125°C
Match of R5 and R6 effect power supply rejection

Gain of 1000 Instrumentation Amplifier‡

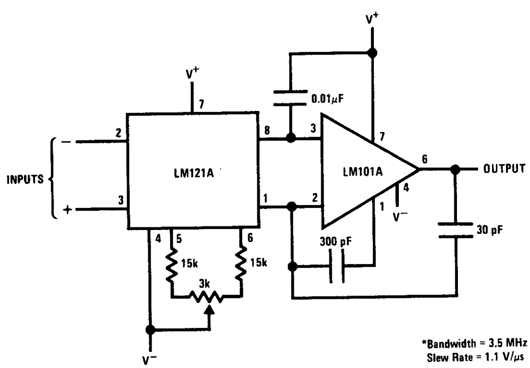
typical applications (con't)



High Speed* Inverting Amplifier with Low Drift

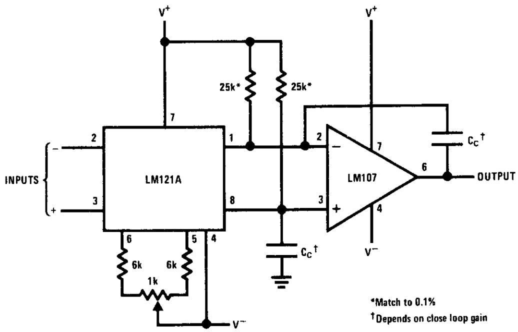


Thermocouple Amplifier with Cold Junction Compensation



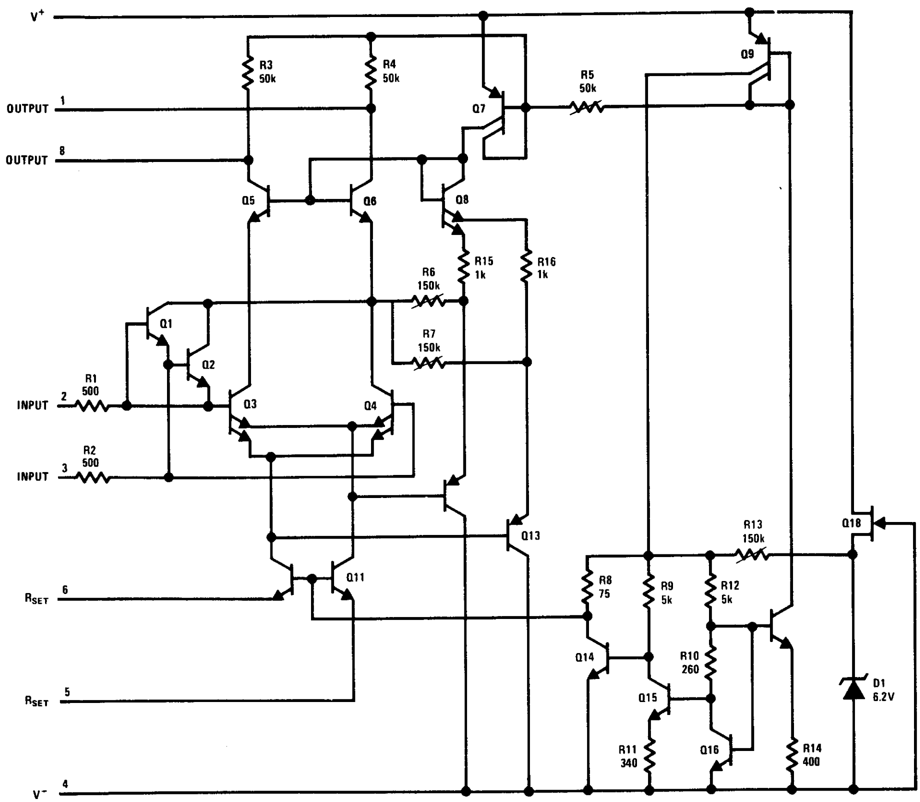
Medium Speed* General Purpose Amplifier

›ical applications (con't)



Increased Common-Mode Range at High Operating Currents

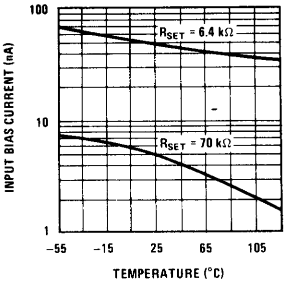
hematic diagram*



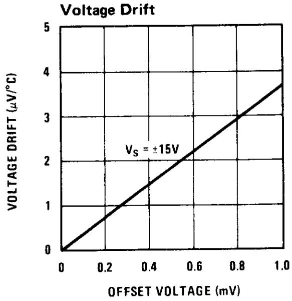
*Pin connections shown on schematic diagram and typical applications are for TO-5 package.

typical performance characteristics

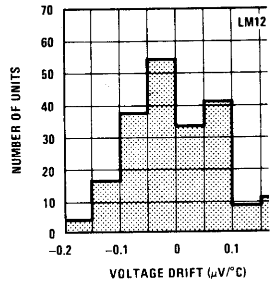
Input Bias Current



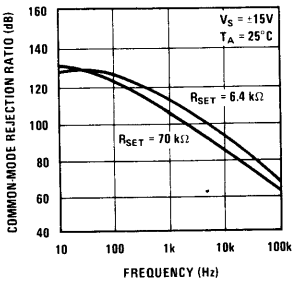
Voltage Drift



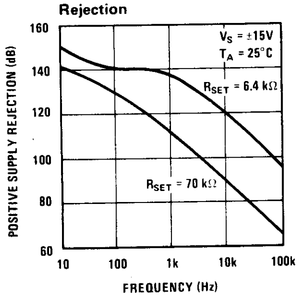
Distribution of Offset Voltage Drift (Nulled)



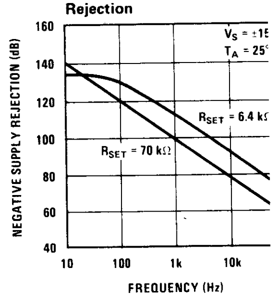
Common-Mode Rejection Ratio



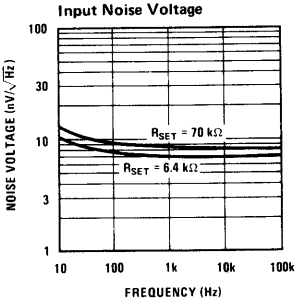
Positive Power Supply Rejection



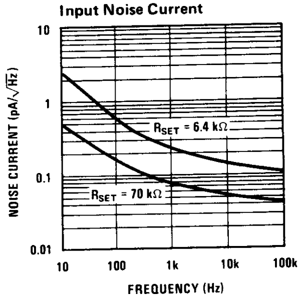
Negative Power Supply Rejection



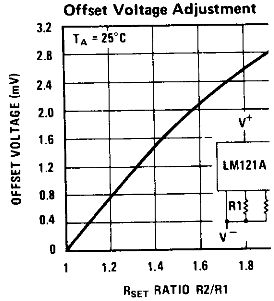
Input Noise Voltage



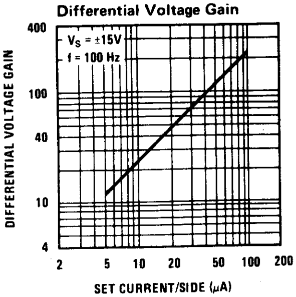
Input Noise Current



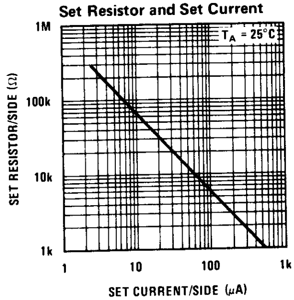
Offset Voltage Adjustment



Differential Voltage Gain



Set Resistor and Set Current



Set Current