19-0286; Rev 1; 8/94



# Precision Operational Amplifier

## General Description

The MXL1001 offers significant specification improvement over earlier precision operational amplifiers and is pin-compatible with the industry-standard LT1001. Particular attention has been paid to the optimization of key parameters such as input offset voltage, common-mode rejection, and power-supply rejection. In addition, the high-performance MXL1001C commercial temperature device provides considerable cost savings when compared to equivalent grades of competing precision amplifiers.

The input offset voltage of all units is less than 60µV, allowing the premium military device, the MXL1001AM, to be specified at 15µV max. Power dissipation is close to half that of the industry-standard OP-07 precision op amp, without sacrificing noise or speed performance. A useful by-product of lower dissipation is decreased warm-up drift.

## Applications

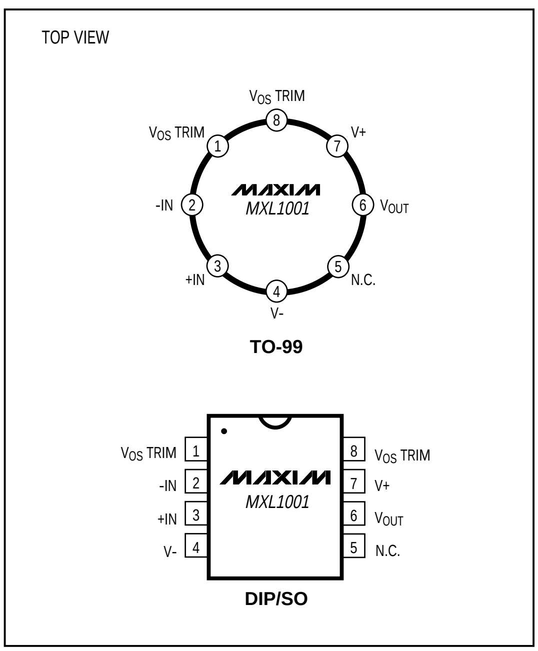
Thermocouple Amplifiers

Low-Level Signal Processing

Strain Gauge Amplifiers

High-Accuracy Data Acquisition

## Pin Configuration



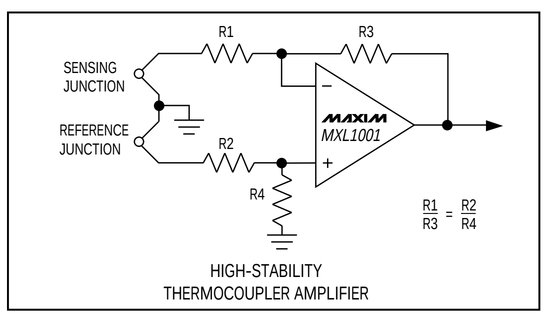

## Features

- ♦ **Guaranteed Low Offset Voltage**
  **MXL1001AM: 15µV max**
  **MXL1001C: 60µV max**
- ♦ **Guaranteed Low Drift**
  **MXL1001AM: 0.6µV/°C max**
  **MXL1001C: 1.0µV/°C max**
- ♦ **Guaranteed Low Bias Current**
  **MXL1001AM: 2nA max**
  **MXL1001C: 4nA max**
- ♦ **Guaranteed CMRR**
  **MXL1001AM: 114dB min**
  **MXL1001C: 110dB min**
- ♦ **Guaranteed PSRR**
  **MXL1001AM: 110dB min**
  **MXL1001C: 106dB min**
- ♦ **Low Power Dissipation**
  **MXL1001AM: 75mW max**
  **MXL1001C: 80mW max**
- ♦ **Low Noise: 0.3µV$_{p-p}$**

## Ordering Information

| PART | TEMP. RANGE | PIN-PACKAGE |
|---|---|---|
| MXL1001ACN8 | 0°C to +70°C | 8 Plastic DIP |
| MXL1001CN8 | 0°C to +70°C | 8 Plastic DIP |
| MXL1001ACS8 | 0°C to +70°C | 8 SO |
| MXL1001CS8 | 0°C to +70°C | 8 SO |
| MXL1001ACJ8 | 0°C to +70°C | 8 CERDIP |
| MXL1001CJ8 | 0°C to +70°C | 8 CERDIP |
| MXL1001ACH | 0°C to +70°C | 8 TO-99 |
| MXL1001CH | 0°C to +70°C | 8 TO-99 |
| MXL1001AMJ8 | -55°C to +125°C | 8 CERDIP |
| MXL1001MJ8 | -55°C to +125°C | 8 CERDIP |
| MXL1001AMH | -55°C to +125°C | 8 TO-99 |
| MXL1001MH | -55°C to +125°C | 8 TO-99 |

## Typical Operating Circuit



# Precision Operational Amplifier

## ABSOLUTE MAXIMUM RATINGS

Total Supply Voltage (V+ to V-) ..........................................±22V
Continuous Power Dissipation ........................................500mW
TO-99(H)—derate at 7.1mW/°C above +80°C
CERDIP(J)—derate at 6.7mW/°C above +75°C
Plastic DIP(P)—derate at 5.6mW/°C above +36°C
Small Outline(S)—derate at 5mW/°C above +55°C
Differential Input Voltage ....................................................±30V
Input Voltage (Note 1).........................................................±22V
Duration of Output Short Circuit ...................................Indefinite
Operating Temperature Ranges:
MXL1001C_/AC_................................................0°C to +70°C
MXL1001M_/AM_..........................................-55°C to +125°C
Junction Temperature ($T_J$)................................-65°C to +160°C
Storage Temperature Range ............................-65°C to +150°C
Lead Temperature (soldering, 10sec) ............................+300°C

**Note 1:** For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.

*Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

## ELECTRICAL CHARACTERISTICS

($V_S$ = ±15V, $T_A$ = +25°C, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | | MXL1001AM MXL1001AC | | | MXL1001M MXL1001C | | | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Input Offset Voltage | $V_{OS}$ | (Note 2) | MXL1001AM | | 7 | 15 | | 18 | 60 | µV |
| | | | MXL1001AC | | 10 | 25 | | 18 | 60 | |
| Long-Term Input Offset Voltage Stability | $V_{OS}$/Time | (Note 3) | | | 0.2 | 1.0 | | 0.3 | 1.5 | µV/ Month |
| Input Offset Current | $I_{OS}$ | | | | 0.3 | 2.0 | | 0.4 | 3.8 | nA |
| Input Bias Current | $I_B$ | | | | ±0.5 | ±2.0 | | ±0.7 | ±4.0 | nA |
| Input Noise Voltage | $e_{N\ p\text{-}p}$ | 0.1Hz to 10Hz (Note 4) | | | 0.3 | 0.6 | | 0.3 | 0.6 | $µV_{p\text{-}p}$ |
| Input Noise Voltage Density | $e_N$ | $f_O$ = 10Hz (Note 4) | | | 10.3 | 18.0 | | 10.5 | 18.0 | nV/√Hz |
| | | $f_O$ = 100Hz (Note 4) | | | 10.0 | 13.0 | | 10.0 | 13.0 | |
| | | $f_O$ = 1000Hz (Note 4) | | | 9.6 | 11.0 | | 9.8 | 11.0 | |
| Input Resistance (Differential Mode) | $R_{IN}$ | (Note 5) | | 30 | 100 | | 15 | 80 | | MΩ |
| Input Voltage Range | IVR | | | ±13 | ±14 | | ±13 | ±14 | | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM}$ = ±13V | | 114 | 126 | | 110 | 126 | | dB |
| Power-Supply Rejection Ratio | PSRR | $V_S$ = ±3V to ±18V | | 110 | 123 | | 106 | 123 | | dB |
| Large-Signal Voltage Gain | $A_{VO}$ | $R_L \geq 2kΩ$, $V_O$ = ±12V | | 450 | 800 | | 400 | 800 | | V/mV |
| | | $R_L \geq 1kΩ$, $V_O$ = ±10V | | 300 | 500 | | 250 | 500 | | |
| Output Voltage Swing | $V_O$ | $R_L \geq 2kΩ$ | | ±13.0 | ±14.0 | | ±13.0 | ±14.0 | | V |
| | | $R_L \geq 1kΩ$ | | ±12.0 | ±13.5 | | ±12.0 | ±13.5 | | |
| Slew Rate | SR | $R_L \geq 2kΩ$ (Note 4) | | 0.1 | 0.25 | | 0.1 | 0.25 | | V/µs |
| Closed-Loop Bandwidth | BW | $A_{VCL}$ = +1V (Note 4) | | 0.4 | 0.8 | | 0.4 | 0.8 | | MHz |
| Power Consumption | $P_D$ | $V_S$ = ±15V, no load | | | 46 | 75 | | 48 | 80 | mW |
| | | $V_S$ = ±3V, no load | | | 4 | 6 | | 4 | 8 | |

**Note 2:** MXL1001A grade $V_{OS}$ is measured one minute after application of power. For all other grades $V_{OS}$ is measured approximately 0.5 seconds after application of power.
**Note 3:** Long-Term Input Offset Voltage Stability refers to the average trend line of $V_{OS}$ vs. Time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in $V_{OS}$ during the first 30 operating days are typically 2.5µV. Parameter is sample tested.
**Note 4:** Sample tested.
**Note 5:** Guaranteed by design.

## ELECTRICAL CHARACTERISTICS

($V_S$ = ±15V, -55°C ≤ $T_A$ ≤ +125°C, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | MXL1001AM | | | MXL1001M | | | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Input Offset Voltage | $V_{OS}$ | (Note 6) | | 30 | 60 | | 45 | 160 | µV |
| Average Temperature Coefficient of Input Offset Voltage | $TCV_{OS}$ | | | 0.2 | 0.6 | | 0.3 | 1.0 | µV/°C |
| Input Offset Current | $I_{OS}$ | | | 0.8 | 4.0 | | 1.2 | 7.6 | nA |
| Input Bias Current | $I_B$ | | | ±1.0 | ±4.0 | | ±1.5 | ±8.0 | nA |
| Input Voltage Range | IVR | | ±13 | ±14 | | ±13 | ±14 | | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM}$ = ±13V | 110 | 122 | | 106 | 120 | | dB |
| Power-Supply Rejection Ratio | PSRR | $V_S$ = ±3V to ±18V | 104 | 117 | | 100 | 117 | | dB |
| Large-Signal Voltage Gain | $A_{VO}$ | $R_L$ ≥ 2kΩ, $V_O$ = ±10V | 300 | 700 | | 200 | 700 | | V/mV |
| Output Voltage Swing | $V_O$ | $R_L$ ≥ 2kΩ | ±12.5 | ±13.5 | | ±12.5 | ±13.5 | | V |
| Power Dissipation | $P_D$ | No load | | 55 | 90 | | 60 | 100 | mW |

## ELECTRICAL CHARACTERISTICS

($V_S$ = ±15V, 0°C ≤ $T_A$ ≤ +70°C, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | MXL1001AC | | | MXL1001C | | | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Input Offset Voltage | $V_{OS}$ | (Note 6) | | 20 | 60 | | 30 | 110 | µV |
| Average Temperature Coefficient of Input Offset Voltage | $TCV_{OS}$ | | | 0.2 | 0.6 | | 0.3 | 1.0 | µV/°C |
| Input Offset Current | $I_{OS}$ | | | 0.5 | 3.5 | | 0.6 | 5.3 | nA |
| Input Bias Current | $I_B$ | | | ±0.7 | ±3.5 | | ±1.0 | ±5.5 | nA |
| Input Voltage Range | IVR | | ±13 | ±14 | | ±13 | ±14 | | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM}$ = ±13V | 110 | 124 | | 106 | 123 | | dB |
| Power-Supply Rejection Ratio | PSRR | $V_S$ = ±3V to ±18V | 106 | 120 | | 103 | 120 | | dB |
| Large-Signal Voltage Gain | $A_{VO}$ | $R_L$ ≥ 2kΩ, $V_O$ = ±10V | 350 | 750 | | 250 | 750 | | V/mV |
| Output Voltage Swing | $V_O$ | $R_L$ ≥ 2kΩ | ±12.5 | ±13.8 | | ±12.5 | ±13.8 | | V |
| Power Dissipation | $P_D$ | No load | | 50 | 85 | | 55 | 90 | mW |

**Note 6:** MXL1001A grade offset voltage is measured one minute after application of power. For all other grades $V_{OS}$ is measured 0.5 seconds after power on.

## Applications Information

The MXL1001 series devices are pin-compatible with the OP-07, OP-05, 725, 108A or 101A amplifiers. The MXL1001 amplifiers can be used to upgrade older designs using these devices, with or without removal of external frequency compensation or nulling components. The MXL1001 can also be used in 741, LF156 or OP-15 applications provided the nulling circuitry is removed.

The MXL1001 is specified over a wide supply voltage range from ±3V to ±18V. Operation with lower supplies is possible down to ±1.2V (two NiCd batteries), however, at this level the device is stable only in closed-loop gains of +2 and above (or inverting gain of one or higher). Unless proper care is exercised, thermocouple effects caused by temperature gradients across dissimilar metals at the input terminal connections, can exceed the inherent offset-voltage drift of the amplifier. Air currents over the device leads should be minimized, package leads should be short, and the two input leads should be as close together as possible and maintained at the same temperature.

### Offset-Voltage Adjustment

The input offset voltage of the MXL1001, and its temperature drift, are minimized by zener-zap trimming at the wafer level. If further nulling of $V_{OS}$ is required, this can be performed using a 10kΩ or 20kΩ potentiometer with no degradation of $V_{OS}$ drift with temperature. Trimming to a value other than zero creates a drift of ($V_{OS}$/300)µV/°C; i.e., if $V_{OS}$ is adjusted to 300µV, the change in drift will be 1µV/°C. The adjustment range with a 10kΩ or 20kΩ potentiometer is approximately ±2.5mV. If less adjustment range is needed, the sensitivity and resolution of the offset nulling can be improved by using a potentiometer of lower ohmic value in conjunction with fixed resistors.

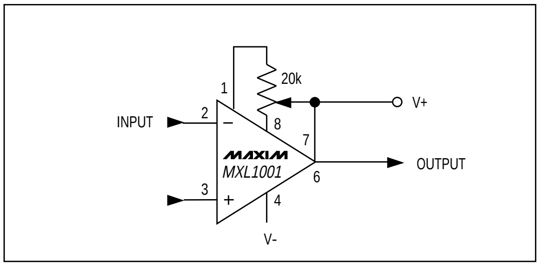
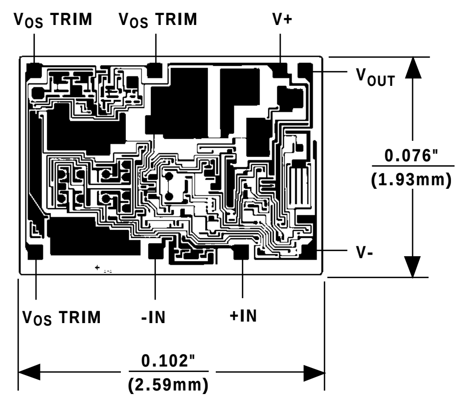



*Figure 1. Optional Offset Nulling Circuit*

## Chip Topography




SUBSTRATE IS CONNECTED TO V-