National Semiconductor

May 1998

# LM4250
# Programmable Operational Amplifier



## General Description

The LM4250 and LM4250C are extremely versatile programmable monolithic operational amplifiers. A single external master bias current setting resistor programs the input bias current, input offset current, quiescent power consumption, slew rate, input noise, and the gain-bandwidth product. The device is a truly general purpose operational amplifier.

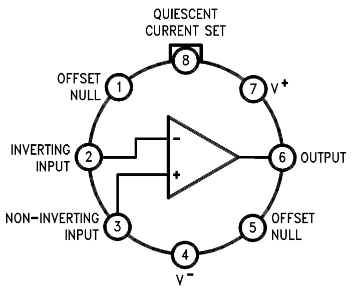
The LM4250C is identical to the LM4250 except that the LM4250C has its performance guaranteed over a 0˚C to +70˚C temperature range instead of the −55˚C to +125˚C temperature range of the LM4250.

## Features

- ±1V to ±18V power supply operation
- 3 nA input offset current
- Standby power consumption as low as 500 nW
- No frequency compensation required
- Programmable electrical characteristics
- Offset voltage nulling capability
- Can be powered by two flashlight batteries
- Short circuit protection

## Connection Diagrams

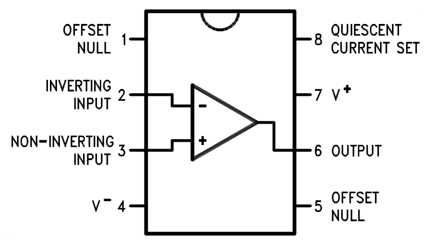
**Metal Can Package**




DS009300-2

**Top View**

**Dual-In-Line Package**




DS009300-5

**Top View**

## Ordering Information

| Temperature Range | | Package | NSC Package Number |
|---|---|---|---|
| **Military** $-55^\circ C \le T_A \le +125^\circ C$ | **Commercial** $0^\circ C \le T_A \le +70^\circ C$ | | |
| | LM4250CN | 8-Pin Molded DIP | N08E |
| | LM4250CM | 8-Pin Surface Mount | M08A |
| LM4250J<br>LM4250J-MIL | | 8-Pin Ceramic DIP | J08E |
| LM4250H<br>LM4250H-MIL | LM4250CH | 8-Pin Metal Can | H08C |

## Absolute Maximum Ratings (Note 1)

**If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.**

(Note 3)

| | LM4250 | LM4250C |
|---|---|---|
| Supply Voltage | ±18V | ±18V |
| Operating Temp. Range | $-55^{\circ}C \leq T_A \leq +125^{\circ}C$ | $0^{\circ}C \leq T_A \leq +70^{\circ}C$ |
| Differential Input Voltage | ±30V | ±30V |
| Input Voltage (Note 2) | ±15V | ±15V |
| $I_{SET}$ Current | 150 nA | 150 nA |
| Output Short Circuit Duration | Continuous | Continuous |
| $T_{JMAX}$ | | |
| H-Package | 150˚C | 100˚C |
| N-Package | | 100˚C |
| J-Package | 150˚C | 100˚C |
| M-Package | | 100˚C |
| Power Dissipation at $T_A$ = 25˚C | | |
| H-Package (Still Air) | 500 mW | 300 mW |
| (400 LF/Min Air Flow) | 1200 mW | 1200 mW |
| N-Package | | 500 mW |
| J-Package | 1000 mW | 600 mW |
| M-Package | | 350 mW |
| Thermal Resistance (Typical) $\theta_{JA}$ | | |
| H-Package (Still Air) | 165˚C/W | 165˚C/W |
| (400 LF/Min Air Flow) | 65˚C/W | 65˚C/W |
| N-Package | | 130˚C/W |
| J-Package | 108˚C/W | 108˚C/W |
| M-Package | | 190˚C/W |
| (Typical) $\theta_{JC}$ | | |
| H-Package | 21˚C/W | 21˚C/W |
| Storage Temperature Range | −65˚C to +150˚C | −65˚C to +150˚C |

| | |
|---|---|
| Soldering Information | |
| Dual-In-Line Package | |
| Soldering (10 seconds) | 260˚C |
| Small Outline Package | |
| Vapor Phase (60 seconds) | 215˚C |
| Infrared (15 seconds) | 220˚C |

See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” for other methods of soldering surface mount devices.

| | |
|---|---|
| ESD tolerance (Note 4) | 800V |

**Note 1:** “Absolute Maximum Ratings” indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

**Note 2:** For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

**Note 3:** Refer to RETS4250X for military specifications.

**Note 4:** Human body model, 1.5 kΩ in series with 100 pF.

## Resistor Biasing

## Set Current Setting Resistor to $V^-$

| | $I_{SET}$ | | | | |
|---|---|---|---|---|---|
| $V_S$ | 0.1 µA | 0.5 µA | 1.0 µA | 5 µA | 10 µA |
| ±1.5V | 25.6 MΩ | 5.04 MΩ | 2.5 MΩ | 492 kΩ | 244 kΩ |
| ±3.0V | 55.6 MΩ | 11.0 MΩ | 5.5 MΩ | 1.09 MΩ | 544 kΩ |
| ±6.0V | 116 MΩ | 23.0 MΩ | 11.5 MΩ | 2.29 MΩ | 1.14 MΩ |
| ±9.0V | 176 MΩ | 35.0 MΩ | 17.5 MΩ | 3.49 MΩ | 1.74 MΩ |
| ±12.0V | 236 MΩ | 47.0 MΩ | 23.5 MΩ | 4.69 MΩ | 2.34 MΩ |
| ±15.0V | 296 MΩ | 59.0 MΩ | 29.5 MΩ | 5.89 MΩ | 2.94 MΩ |

## Electrical Characteristics

LM4250 (−55˚C ≤ $T_A$ ≤ +125˚C unless otherwise specified.) $T_A = T_J$

| Parameter | Conditions | $V_S$ = ±1.5V | | | |
|---|---|---|---|---|---|
| | | $I_{SET}$ = 1 µA | | $I_{SET}$ = 10 µA | |
| | | Min | Max | Min | Max |
| $V_{OS}$ | $R_S$ ≤ 100 kΩ, $T_A$ = 25˚C | | 3 mV | | 5 mV |
| $I_{OS}$ | $T_A$ = 25˚C | | 3 nA | | 10 nA |
| $I_{bias}$ | $T_A$ = 25˚C | | 7.5 nA | | 50 nA |
| Large Signal Voltage Gain | $R_L$ = 100 kΩ, $T_A$ = 25˚C | 40k | | | |
| | $V_O$ = ±0.6V, $R_L$ = 10 kΩ | | | 50k | |
| Supply Current | $T_A$ = 25˚C | | 7.5 µA | | 80 µA |
| Power Consumption | $T_A$ = 25˚C | | 23 µW | | 240 µW |
| $V_{OS}$ | $R_S$ ≤ 100 kΩ | | 4 mV | | 6 mV |
| $I_{OS}$ | $T_A$ = +125˚C | | 5 nA | | 10 nA |
| | $T_A$ = −55˚C | | 3 nA | | 10 nA |
| $I_{bias}$ | | | 7.5 nA | | 50 nA |
| Input Voltage Range | | ±0.6V | | ±0.6V | |
| Large Signal Voltage Gain | $V_O$ = ±0.5V, $R_L$ = 100 kΩ | 30k | | | |
| | $R_L$ = 10 kΩ | | | 30k | |
| Output Voltage Swing | $R_L$ = 100 kΩ | ±0.6V | | | |
| | $R_L$ = 10 kΩ | | | ±0.6V | |
| Common Mode Rejection Ratio | $R_S$ ≤ 10 kΩ | 70 dB | | 70 dB | |
| Supply Voltage Rejection Ratio | $R_S$ ≤ 10 kΩ | 76 dB | | 76 dB | |
| Supply Current | | | 8 µA | | 90 µA |

| Parameter | Conditions | $V_S$ = ±15V | | | |
|---|---|---|---|---|---|
| | | $I_{SET}$ = 1 µA | | $I_{SET}$ = 10 µA | |
| | | Min | Max | Min | Max |
| $V_{OS}$ | $R_S$ ≤ 100 kΩ, $T_A$ = 25˚C | | 3 mV | | 5 mV |
| $I_{OS}$ | $T_A$ = 25˚C | | 3 nA | | 10 nA |
| $I_{bias}$ | $T_A$ = 25˚C | | 7.5 nA | | 50 nA |
| Large Signal Voltage Gain | $R_L$ = 100 kΩ, $T_A$ = 25˚C | 100k | | | |
| | $V_O$ = ±10V, $R_L$ = 10 kΩ | | | 100k | |
| Supply Current | $T_A$ = 25˚C | | 10 µA | | 90 µA |
| Power Consumption | $T_A$ = 25˚C | | 300 µW | | 2.7 mW |
| $V_{OS}$ | $R_S$ ≤ 100 kΩ | | 4 mV | | 6 mV |
| $I_{OS}$ | $T_A$ = +125˚C | | 25 nA | | 25 nA |
| | $T_A$ = −55˚C | | 3 nA | | 10 nA |
| $I_{bias}$ | | | 7.5 nA | | 50 nA |
| Input Voltage Range | | ±13.5V | | ±13.5V | |

## Electrical Characteristics (Continued)

| Parameter | Conditions | $V_S = \pm15V$ | | | |
|---|---|---|---|---|---|
| | | $I_{SET} = 1\ \mu A$ | | $I_{SET} = 10\ \mu A$ | |
| | | Min | Max | Min | Max |
| Large Signal Voltage | $V_O = \pm10V$, $R_L = 100\ k\Omega$ | 50k | | | |
| Gain | $R_L = 10\ k\Omega$ | | | 50k | |
| Output Voltage Swing | $R_L = 100\ k\Omega$ | ±12V | | | |
| | $R_L = 10\ k\Omega$ | | | ±12V | |
| Common Mode Rejection Ratio | $R_S \leq 10\ k\Omega$ | 70 dB | | 70 dB | |
| Supply Voltage Rejection Ratio | $R_S \leq 10\ k\Omega$ | 76 dB | | 76 dB | |
| Supply Current | | | 11 µA | | 100 µA |
| Power Consumption | | | 330 µW | | 3 mW |

## Electrical Characteristics

LM4250C (0˚C ≤ $T_A$ ≤ +70˚C unless otherwise specified.) $T_A = T_J$

| Parameter | Conditions | $V_S = \pm1.5V$ | | | |
|---|---|---|---|---|---|
| | | $I_{SET} = 1\ \mu A$ | | $I_{SET} = 10\ \mu A$ | |
| | | Min | Max | Min | Max |
| $V_{OS}$ | $R_S \leq 100\ k\Omega$, $T_A = 25˚C$ | | 5 mV | | 6 mV |
| $I_{OS}$ | $T_A = 25˚C$ | | 6 nA | | 20 nA |
| $I_{bias}$ | $T_A = 25˚C$ | | 10 nA | | 75 nA |
| Large Signal Voltage Gain | $R_L = 100\ k\Omega$, $T_A = 25˚C$ | 25k | | | |
| | $V_O = \pm0.6V$, $R_L = 10\ k\Omega$ | | | 25k | |
| Supply Current | $T_A = 25˚C$ | | 8 µA | | 90 µA |
| Power Consumption | $T_A = 25˚C$ | | 24 µW | | 270 µW |
| $V_{OS}$ | $R_S \leq 10\ k\Omega$ | | 6.5 mV | | 7.5 mV |
| $I_{OS}$ | | | 8 nA | | 25 nA |
| $I_{bias}$ | | | 10 nA | | 80 nA |
| Input Voltage Range | | ±0.6V | | ±0.6V | |
| Large Signal Voltage | $V_O = \pm0.5V$, $R_L = 100\ k\Omega$ | 25k | | | |
| Gain | $R_L = 10\ k\Omega$ | | | 25k | |
| Output Voltage Swing | $R_L = 100\ k\Omega$ | ±0.6V | | | |
| | $R_L = 10\ k\Omega$ | | | ±0.6V | |
| Common Mode Rejection Ratio | $R_S \leq 10\ k\Omega$ | 70 dB | | 70 dB | |
| Supply Voltage Rejection Ratio | $R_S \leq 10\ k\Omega$ | 74 dB | | 74 dB | |
| Supply Current | | | 8 µA | | 90 µA |
| Power Consumption | | | 24 µW | | 270 µW |

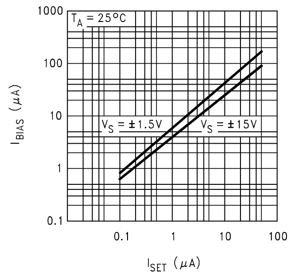
| Parameter | Conditions | $V_S = \pm15V$ | | | |
|---|---|---|---|---|---|
| | | $I_{SET} = 1\ \mu A$ | | $I_{SET} = 10\ \mu A$ | |
| | | Min | Max | Min | Max |
| $V_{OS}$ | $R_S \leq 100\ k\Omega$, $T_A = 25˚C$ | | 5 mV | | 6 mV |
| $I_{OS}$ | $T_A = 25˚C$ | | 6 nA | | 20 nA |
| $I_{bias}$ | $T_A = 25˚C$ | | 10 nA | | 75 nA |
| Large Signal Voltage | $R_L = 100\ k\Omega$, $T_A = 25˚C$ | 60k | | | |
| Gain | $V_O = \pm10V$, $R_L = 10\ k\Omega$ | | | 60k | |
| Supply Current | $T_A = 25˚C$ | | 11 µA | | 100 µA |
| Power Consumption | $T_A = 25˚C$ | | 330 µW | | 3 mW |
| $V_{OS}$ | $R_S \leq 100\ k\Omega$ | | 6.5 mV | | 7.5 mV |
| $I_{OS}$ | | | 8 nA | | 25 nA |
| $I_{bias}$ | | | 10 nA | | 80 nA |

## Electrical Characteristics (Continued)

| Parameter | Conditions | $V_S = \pm 15V$ | | | |
|---|---|---|---|---|---|
| | | $I_{SET} = 1\ \mu A$ | | $I_{SET} = 10\ \mu A$ | |
| | | Min | Max | Min | Max |
| Input Voltage Range | | ±13.5V | | ±13.5V | |
| Large Signal Voltage Gain | $V_O = \pm 10V$, $R_L = 100\ k\Omega$ | 50k | | | |
| | $R_L = 10\ k\Omega$ | | | 50k | |
| Output Voltage Swing | $R_L = 100\ k\Omega$ | ±12V | | | |
| | $R_L = 10\ k\Omega$ | | | ±12V | |
| Common Mode Rejection Ratio | $R_S \leq 10\ k\Omega$ | 70 dB | | 70 dB | |
| Supply Voltage Rejection Ratio | $R_S \leq 10\ k\Omega$ | 74 dB | | 74 dB | |
| Supply Current | | | 11 µA | | 100 µA |
| Power Consumption | | | 330 µW | | 3 mW |

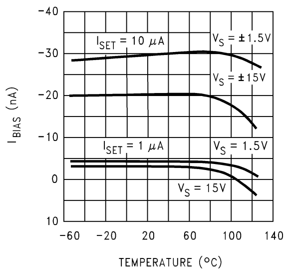
## Typical Performance Characteristics

**Input Bias Current vs $I_{SET}$**



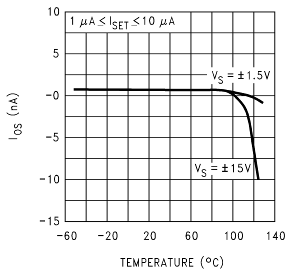

DS009300-15

**Input Bias Current vs Temperature**



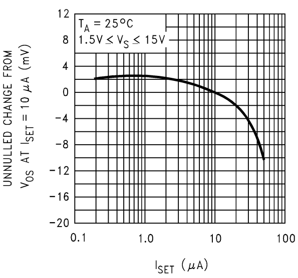

DS009300-16

**Input Offset Current vs Temperature**



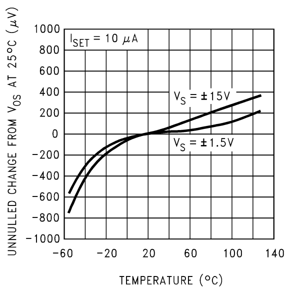

DS009300-17

**Unnulled Input Offset Voltage Change vs $I_{SET}$**



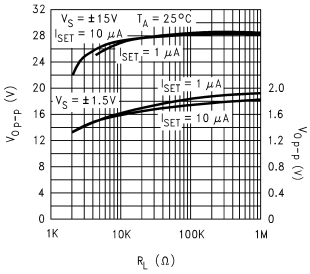

DS009300-18

**Unnulled Input Offset Voltage Change vs Temperature**




DS009300-19

**Peak to Peak Output Voltage Swing vs Load Resistance**

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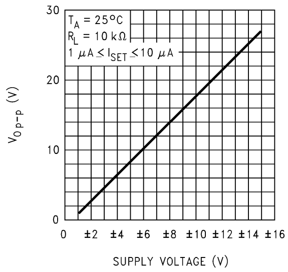
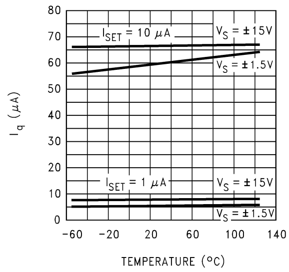
## Typical Performance Characteristics (Continued)

**Peak to Peak Output Voltage Swing vs Supply Voltage**



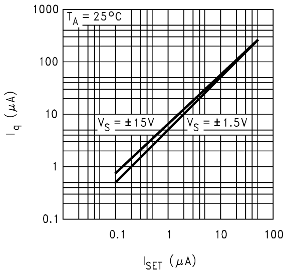

DS009300-21

**Quiescent Current ($I_q$) vs Temperature**



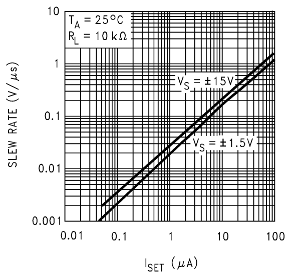

DS009300-22

**Quiescent Current ($I_q$) vs $I_{SET}$**



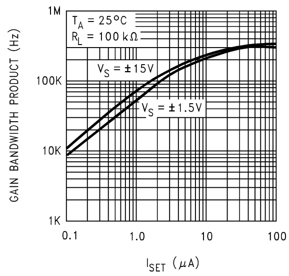

DS009300-23

**Slew Rate vs $I_{SET}$**



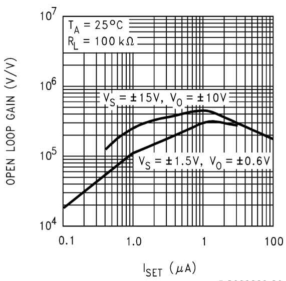

DS009300-24

**Gain Bandwidth Product vs $I_{SET}$**



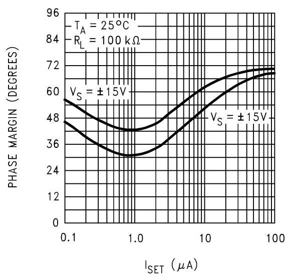

DS009300-25

**Open Loop Voltage Gain vs $I_{SET}$**



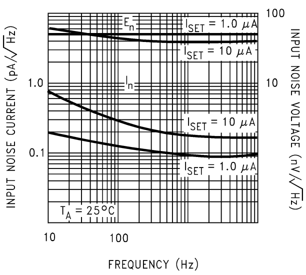

DS009300-26

**Phase Margin vs $I_{SET}$**



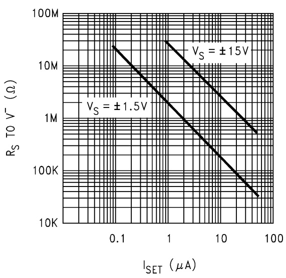

DS009300-27

**Input Noise Current ($I_n$) and Voltage ($E_n$) vs Frequency**




DS009300-28

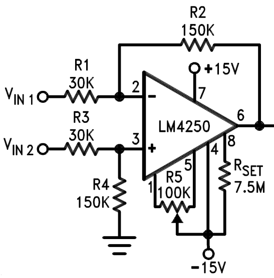
**$R_{SET}$ vs $I_{SET}$**




DS009300-29

## Typical Applications

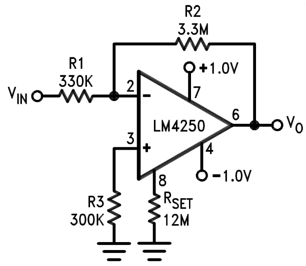
**X5 Difference Amplifier**




DS009300-3

Quiescent $P_D$ = 0.6 mW

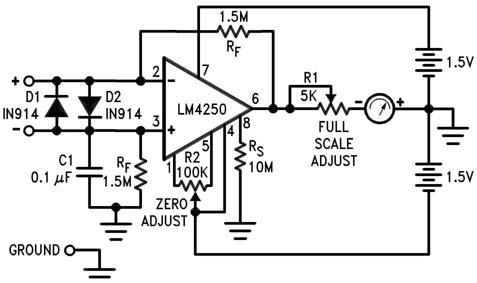
**500 Nano-Watt X10 Amplifier**




DS009300-4

Quiescent $P_D$ = 500 nW

**Floating Input Meter Amplifier**
**100 nA full Scale**

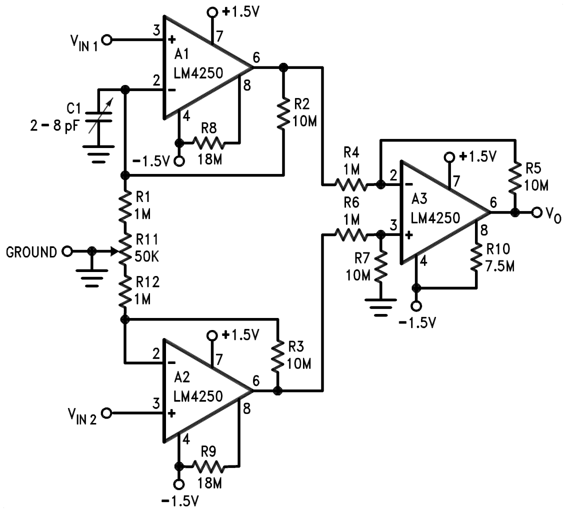



DS009300-8

Quiescent $P_D$ = 1.8 µW
*Meter movement (0–100 µA, 2 kΩ) marked for 0–100 nA full scale.

## Typical Applications (Continued)

### X100 Instrumentation Amplifier 10 µW



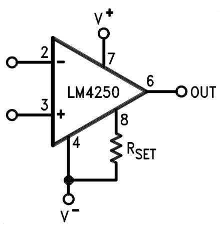

DS009300-9

**Note 5:** Quiescent $P_D$ = 10 µW.

**Note 6:** R2, R3, R4, R5, R6 and R7 are 1% resistors.

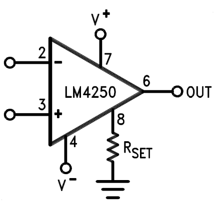
**Note 7:** R11 and C1 are for DC and AC common mode rejection adjustments.

### $R_{SET}$ Connected to $V^-$




DS009300-10

### $R_{SET}$ Connected to Ground




DS009300-11

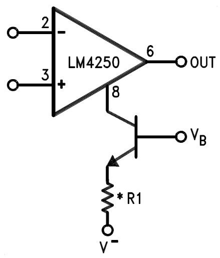
$I_{SET}$ Equations:

$$I_{SET} \approx \frac{V^+ + |V^-| - 0.5}{R_{SET}}$$ where $R_{SET}$ is connected to $V^-$.

$$I_{SET} \approx \frac{V^+ - 0.5}{R_{SET}}$$ where $R_{SET}$ is connected to ground.

DS009300-30

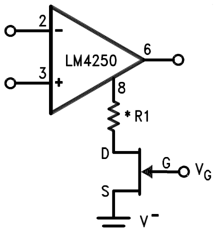
### Transistor Current Sourcing Biasing




DS009300-12

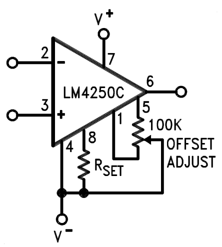
*R1 limits $I_{SET}$ maximum

### FET Current Sourcing Biasing



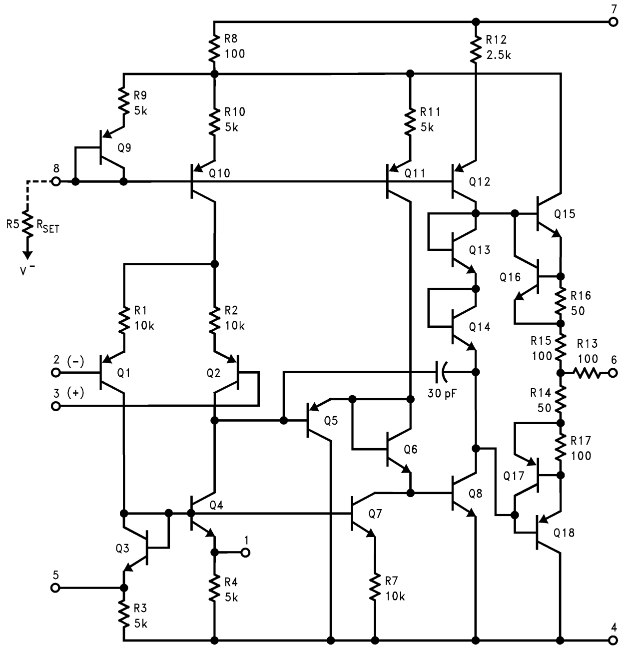

DS009300-13

### Offset Null Circuit



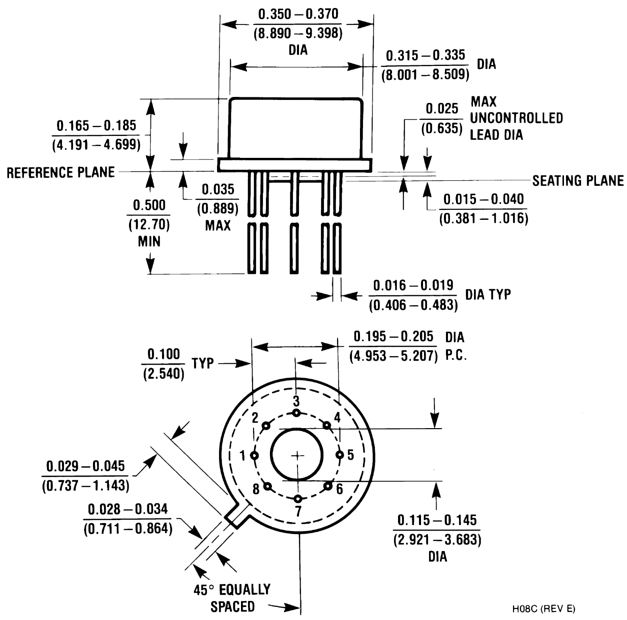

DS009300-14

## Schematic Diagram

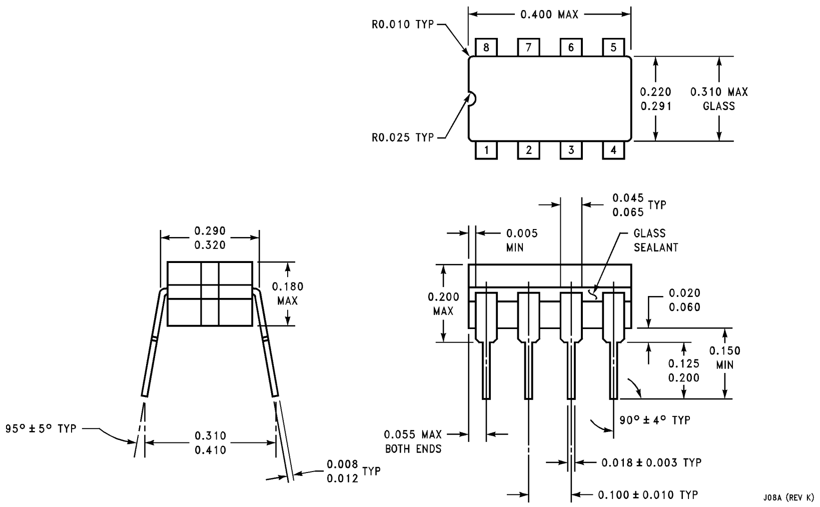


DS009300-1

## Physical Dimensions inches (millimeters) unless otherwise noted

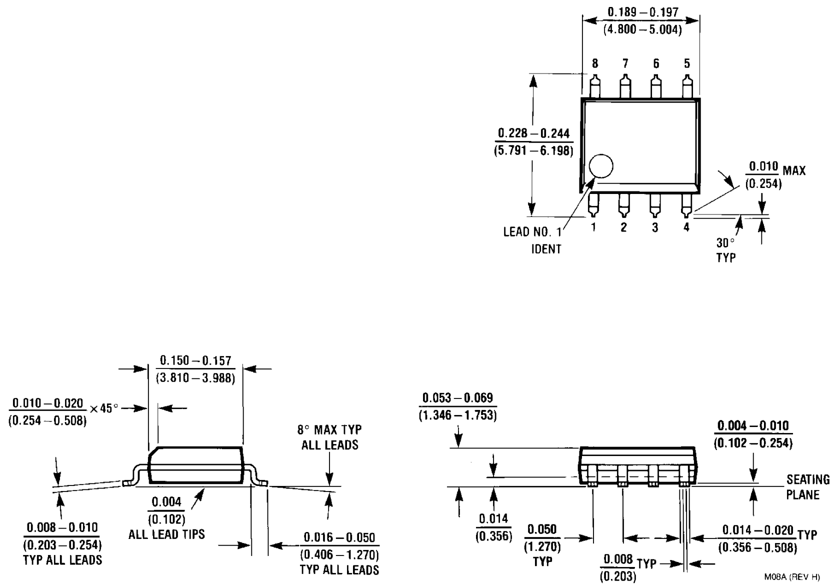



**Metal Can Package (H)**
**Order Number LM4250H, LM4250CH or LM4250H-MIL**
**NS Package Number H08C**

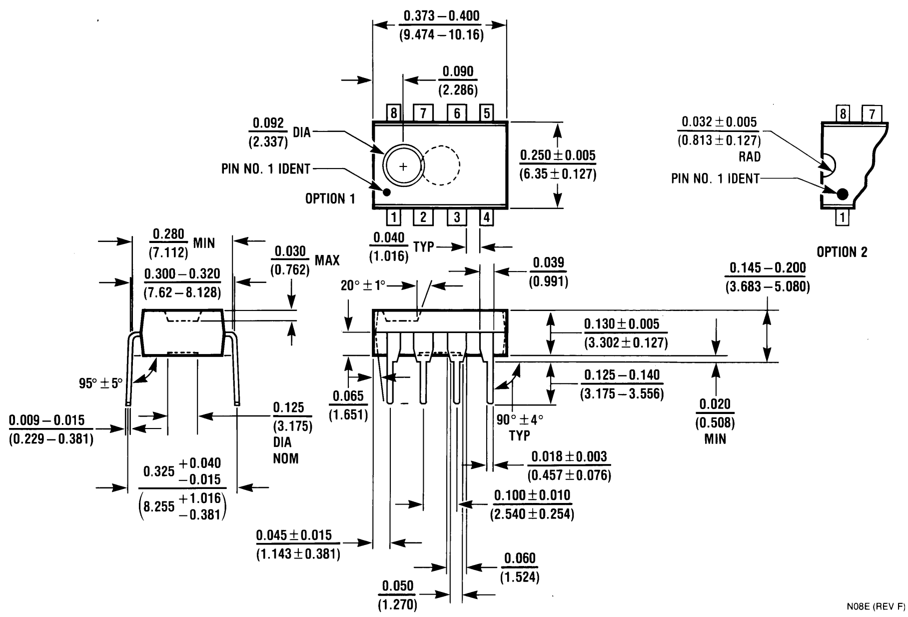



**Ceramic Dual-In-Line Package (J)**
**Order Number LM4250J, or LM4250J-MIL**
**NS Package Number J08A**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)




**Small Outline Package (M)**
**Order Number LM4250M**
**NS Package Number M08A**




**Molded Dual-In-Line Package (N)**
**Order Number LM4250CN**
**NS Package Number N08E**

## Notes



**National Semiconductor Corporation**
Americas
Tel: 1-800-272-9959
Fax: 1-800-737-7018
Email: support@nsc.com

www.national.com

**National Semiconductor Europe**
Fax: +49 (0) 1 80-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 1 80-530 85 85
English Tel: +49 (0) 1 80-532 78 32
Français Tel: +49 (0) 1 80-532 93 58
Italiano Tel: +49 (0) 1 80-534 16 80

**National Semiconductor Asia Pacific Customer Response Group**
Tel: 65-2544466
Fax: 65-2504466
Email: sea.support@nsc.com

**National Semiconductor Japan Ltd.**
Tel: 81-3-5639-7560
Fax: 81-3-5639-7507