## 1 Features

- Wide Supply Ranges
  - Single Supply: 3 V to 32 V (26 V for LM2902)
  - Dual Supplies: ±1.5 V to ±16 V (±13 V for LM2902)
- Low Supply-Current Drain Independent of Supply Voltage: 0.8 mA Typical
- Common-Mode Input Voltage Range Includes Ground, Allowing Direct Sensing Near Ground
- Low Input Bias and Offset Parameters
  - Input Offset Voltage: 3 mV Typical
  - Input Offset Current: 2 nA Typical
  - Input Bias Current: 20 nA Typical
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage: 32 V (26 V for LM2902)
- Open-Loop Differential Voltage Amplification: 100 V/mV Typical
- Internal Frequency Compensation
- On Products Compliant to MIL-PRF-38535, All Parameters are Tested Unless Otherwise Noted. On All Other Products, Production Processing Does Not Necessarily Include Testing of All Parameters.

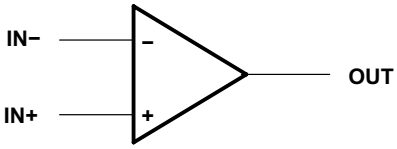
## 2 Applications

- Blu-ray Players and Home Theaters
- Chemical and Gas Sensors
- DVD Recorders and Players
- Digital Multimeter: Bench and Systems
- Digital Multimeter: Handhelds
- Field Transmitter: Temperature Sensors
- Motor Control: AC Induction, Brushed DC, Brushless DC, High-Voltage, Low-Voltage, Permanent Magnet, and Stepper Motor
- Oscilloscopes
- TV: LCD and Digital
- Temperature Sensors or Controllers Using Modbus
- Weigh Scales

## 3 Description

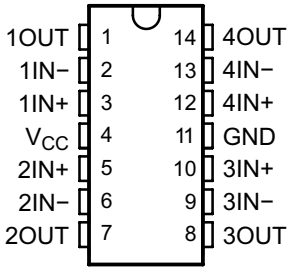
These devices consist of four independent high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single supply or split supply over a wide range of voltages.

**Symbol (Each Amplifier)**



## 4 Pin Configuration and Functions

**DR**
**14-Pin SOP, DIP**




**Pin Functions**

| PIN | | | I/O | DESCRIPTION |
|---|---|---|---|---|
| NAME | LCCC NO. | SOP, DIP | | |
| 1IN– | | 2 | I | Negative input |
| 1IN+ | | 3 | I | Positive input |
| 1OUT | | 1 | O | Output |
| 2IN– | | 6 | I | Negative input |
| 2IN+ | | 5 | I | Positive input |
| 2OUT | | 7 | O | Output |
| 3IN– | | 9 | I | Negative input |
| 3IN+ | | 10 | I | Positive input |
| 3OUT | | 8 | O | Output |
| 4IN– | | 13 | I | Negative input |
| 4IN+ | | 12 | I | Positive input |
| 4OUT | | 14 | O | Output |
| GND | | 11 | — | Ground |
| $V_{CC}$ | 6 | 4 | — | Power supply |

# 5 Specifications

## 5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

| | LM2902 | | LM124, LM224 | | UNIT |
|---|---|---|---|---|---|
| | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{CC}$ (2) | ±13 | 26 | ±16 | 32 | V |
| Differential input voltage, $V_{ID}$ (3) | | ±26 | | ±32 | V |
| Input voltage, $V_I$ (either input) | –0.3 | 26 | –0.3 | to 32 | V |
| Duration of output short circuit (one amplifier) to ground at (or below) $T_A$ = 25°C, $V_{CC}$ ≤ 15 V(4) | Unlimited | | Unlimited | | |
| Operating virtual junction temperature, $T_J$ | | 150 | | 150 | °C |
| Storage temperature, $T_{stg}$ | –65 | 150 | –65 | 150 | °C |

(1) 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 under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values (except differential voltages and $V_{CC}$ specified for the measurement of $I_{OS}$) are with respect to the network GND.
(3) Differential voltages are at IN+, with respect to IN−.
(4) Short circuits from outputs to VCC can cause excessive heating and eventual destruction.

## 5.2 ESD

| LM124, LM224, LM2902 | | | |
|---|---|---|---|
| $V_{(ESD)}$ Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1) | ±500 | V |
| | Charged-device model (CDM), per JEDEC specification JESD22-C101 | ±1000 | |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

## 5.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

| | | LM2902 | | LM124, LM224 | | UNIT |
|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | |
| $V_{CC}$ Supply voltage | | 3 | 26 | 3 | 30 | V |
| $V_{CM}$ Common-mode voltage | | 0 | $V_{CC}$ – 2 | 0 | $V_{CC}$ – 2 | V |
| $T_A$ Operating free air temperature | LM124 | | | –55 | 125 | °C |
| | LM2902 | –40 | 105 | | | |
| | LM224 | | | –20 | 85 | |

## 5.4 Thermal Information

| THERMAL METRIC(1) | | LM124,LM224, LM2902 | | |
|---|---|---|---|---|
| | | (SOP) | (DIP) | UNIT |
| | | 14 PINS | 14 PINS | |
| $R_{\theta JA}$ (2) (3) | Junction-to-ambient thermal resistance | 86 | 80 | °C/W |
| $R_{\theta JC}$ (4) | Junction-to-case (top) thermal resistance | — | — | |

(1) Short circuits from outputs to VCC can cause excessive heating and eventual destruction.
(2) Maximum power dissipation is a function of $T_{J(max)}$, $R_{\theta JA}$, and $T_A$. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_{J(max)} – T_A)/R_{\theta JA}$. Operating at the absolute maximum $T_J$ of 150°C can affect reliability.
(3) Maximum power dissipation is a function of $T_{J(max)}$, $R_{\theta JA}$, and $T_C$. The maximum allowable power dissipation at any allowable case temperature is $P_D = (T_{J(max)} – T_C)/R_{\theta JC}$. Operating at the absolute maximum $T_J$ of 150°C can affect reliability.

## 5.5 Electrical Characteristics for LMx24

at specified free-air temperature, $V_{CC}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS(1) | | $T_A$(2) | LM124, LM224 | | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP(3) | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{CC}$ = 5 V to MAX, $V_{IC} = V_{ICR}$min, $V_O$ = 1.4 V | | 25°C | | 3 | 5 | mV |
| | | | | Full range | | | 7 | |
| $I_{IO}$ | Input offset current | $V_O$ = 1.4 V | | 25°C | | 2 | 30 | nA |
| | | | | Full range | | | 100 | |
| $I_{IB}$ | Input bias current | $V_O$ = 1.4 V | | 25°C | | –20 | –150 | nA |
| | | | | Full range | | | –300 | |
| $V_{ICR}$ | Common-mode input voltage range | $V_{CC}$ = 5 V to MAX | | 25°C | 0 to $V_{CC}$ – 1.5 | | | V |
| | | | | Full range | 0 to $V_{CC}$ – 2 | | | |
| $V_{OH}$ | High-level output voltage | $R_L$ = 2 kΩ | | 25°C | $V_{CC}$ – 1.5 | | | V |
| | | $R_L$ = 10 kΩ | | 25°C | | | | |
| | | $V_{CC}$ = MAX | $R_L$ = 2 kΩ | Full range | 26 | | | |
| | | | $R_L$ ≥ 10 kΩ | Full range | 27 | 28 | | |
| $V_{OL}$ | Low-level output voltage | $R_L$ ≤ 10 kΩ | | Full range | | 5 | 20 | mV |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{CC}$ = 15 V, $V_O$ = 1 V to 11 V, $R_L$ ≥ 2 kΩ | | 25°C | 50 | 100 | | V/mV |
| | | | | Full range | 25 | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR}$min | | 25°C | 70 | 80 | | dB |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta VIO$) | | | 25°C | 65 | 100 | | dB |
| $V_{O1}/V_{O2}$ | Crosstalk attenuation | f = 1 kHz to 20 kHz | | 25°C | | 120 | | dB |
| $I_O$ | Output current | $V_{CC}$ = 15 V, $V_{ID}$ = 1 V, $V_O$ = 0 | Source | 25°C | –20 | –30 | –60 | mA |
| | | | | Full range | –10 | | | |
| | | $V_{CC}$ = 15 V, $V_{ID}$ = –1 V, $V_O$ = 15 V | Sink | 25°C | 10 | 20 | | |
| | | | | Full range | 5 | | | |
| | | $V_{ID}$ = –1 V, $V_O$ = 200 mV | | 25°C | 12 | 30 | | µA |
| $I_{OS}$ | Short-circuit output current | $V_{CC}$ at 5 V, $V_O$ = 0, GND at –5 V | | 25°C | | ±40 | ±60 | mA |
| $I_{CC}$ | Supply current (four amplifiers) | $V_O$ = 2.5 V, no load | | Full range | | 0.7 | 1.2 | mA |
| | | $V_{CC}$ = MAX, $V_O$ = 0.5 $V_{CC}$, no load | | Full range | | 1.4 | 3 | |

(1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX $V_{CC}$ for testing purposes is 26 V for LM2902 and 30 V for the others.
(2) Full range is –55°C to 125°C for LM124, –20°C to 85°C for LM224
(3) All typical values are at $T_A$ = 25°C

## 5.6 Operating Conditions

$V_{CC}$ = ±15 V, $T_A$ = 25°C

| PARAMETER | | TEST CONDITIONS | TYP | UNIT |
|---|---|---|---|---|
| SR | Slew rate at unity gain | $R_L$ = 1 MΩ, $C_L$ = 30 pF, $V_I$ = ±10 V (see Figure 7) | 0.5 | V/μs |
| $B_1$ | Unity-gain bandwidth | $R_L$ = 1 MΩ, $C_L$ = 20 pF (see Figure 7) | 1.2 | MHz |
| $V_n$ | Equivalent input noise voltage | $R_S$ = 100 Ω, $V_I$ = 0 V, f = 1 kHz (see Figure 8) | 35 | nV/√Hz |

## 5.7 Typical Characteristics

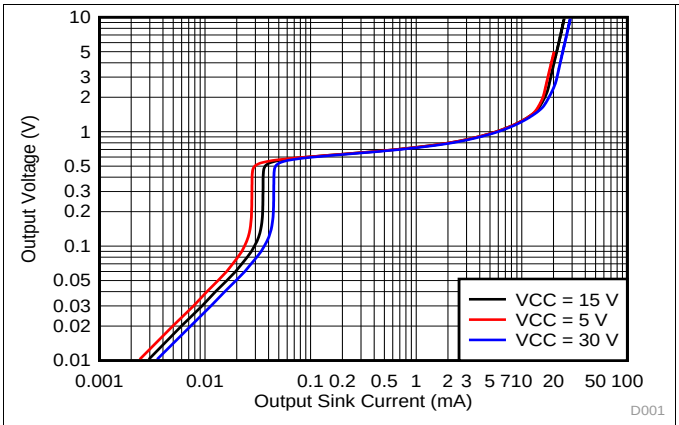



**Figure 1. Output Sinking Characteristics**

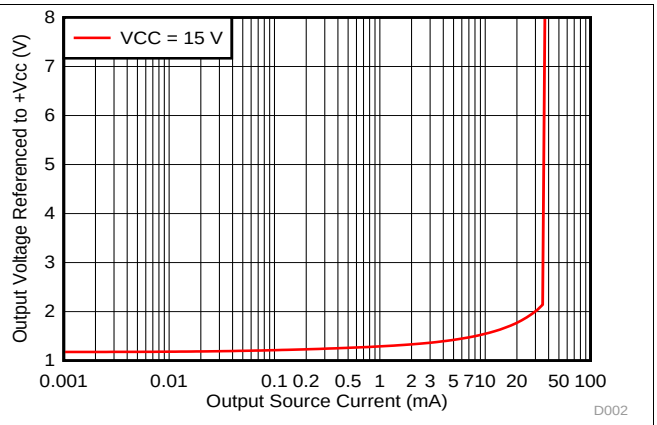



**Figure 2. Output Sourcing Characteristics**

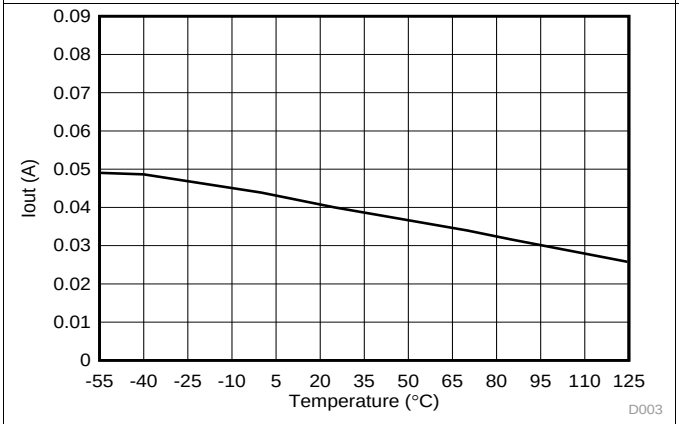



**Figure 3. Source Current Limiting**

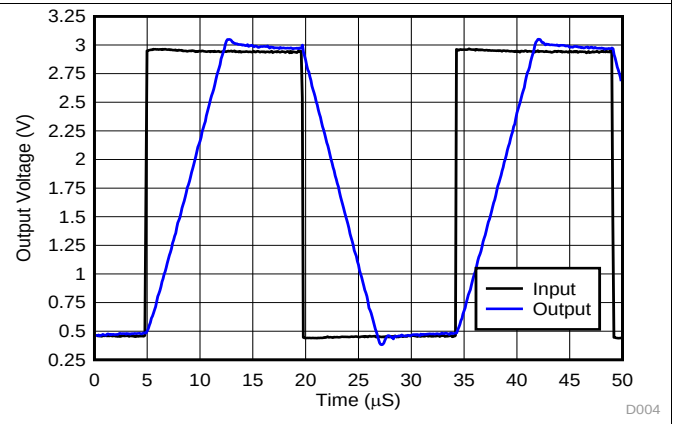



**Figure 4. Voltage Follower Large Signal Response (50 pF)**

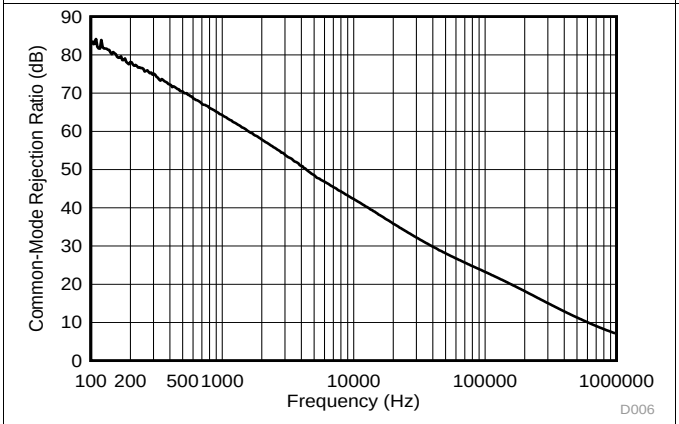



**Figure 5. Common-Mode Rejection Ratio**

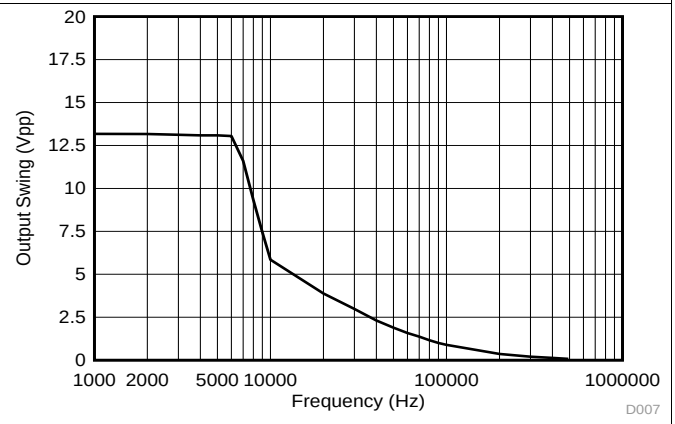



**Figure 6. Maximum Output Swing vs. Frequency (VCC = 15 V)**

## 6 Parameter Measurement Information

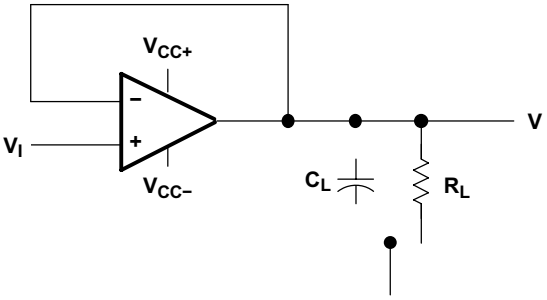



Figure 7. Unity-Gain Amplifier

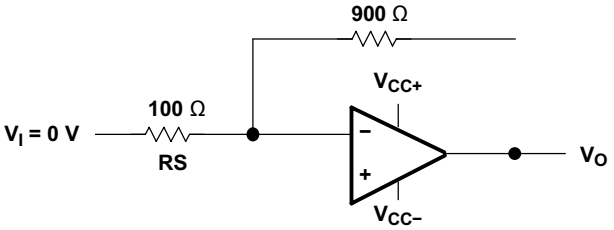



Figure 8. Noise-Test Circuit

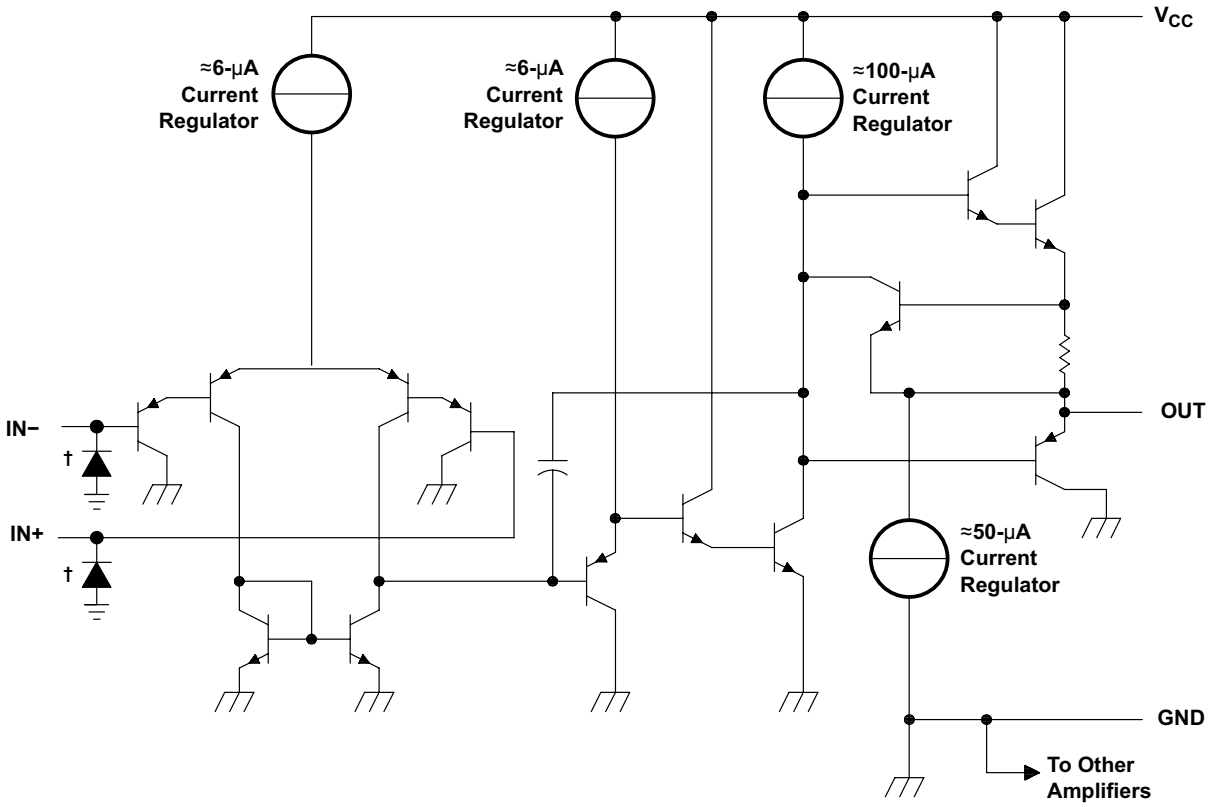
## 7 Detailed Description

### 7.1 Overview

These devices consist of four independent high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies also is possible if the difference between the two supplies is 3 V to 32 V (3 V to 26 V for the LM2902 device), and $V_{CC}$ is at least 1.5 V more positive than the input common-mode voltage. The low supply-current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, DC amplification blocks, and all the conventional operational-amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the LM124 device can be operated directly from the standard 5-V supply that is used in digital systems and provides the required interface electronics, without requiring additional ±15-V supplies.

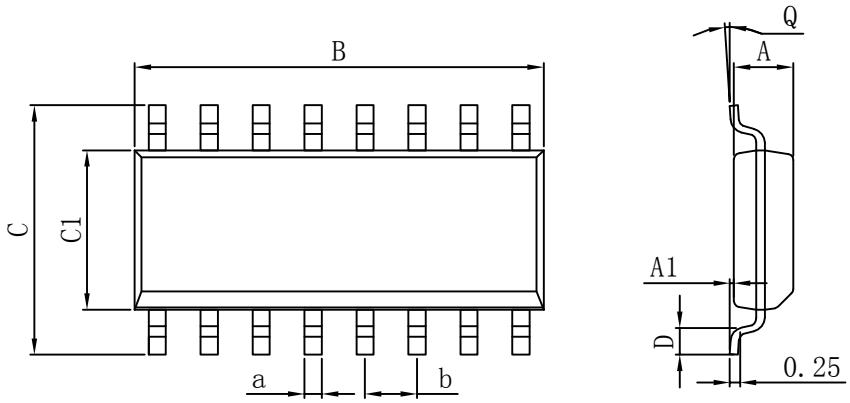
## 7.2 Functional Block Diagram




| COMPONENT COUNT (total device) | |
|---|---|
| Epi-FET | 1 |
| Transistors | 95 |
| Diodes | 4 |
| Resistors | 11 |
| Capacitors | 4 |

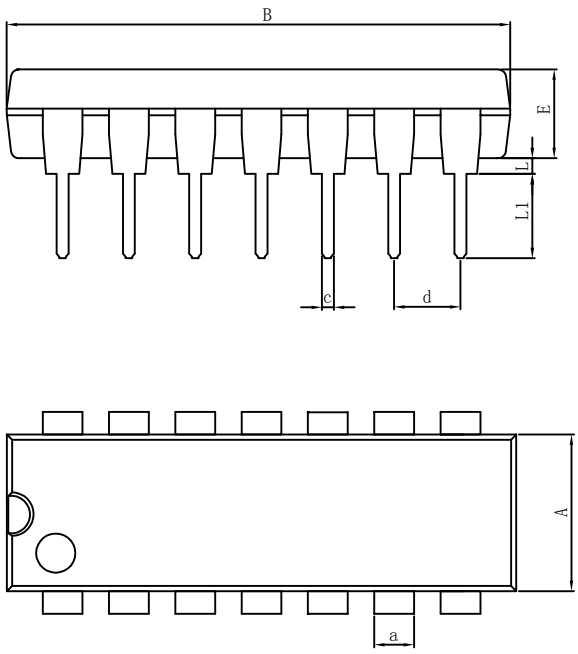
## PACKAGE

### SOP14




| UNIT: mm | | | | | | | |
|---|---|---|---|---|---|---|---|
| DIM. | MIN | TYP | MAX | DIM. | MIN | TYP | MAX |
| A | 4.520 | 4.570 | 4.620 | a | 0.400 | 0.420 | 0.440 |
| A1 | 0.100 | – | 0.250 | b | 1.260 | 1.270 | 1.280 |
| B | 8.500 | 8.750 | 9.000 | Q | 0° | – | 8° |
| C | 5.800 | 6.100 | 6.250 | | | | |
| C1 | 3.800 | 3.900 | 4.000 | | | | |
| D | 0.400 | – | 0.950 | | | | |

### DIP14




| UNIT: mm | | | | | | | |
|---|---|---|---|---|---|---|---|
| DIM. | MIN | TYP | MAX | DIM. | MIN | TYP | MAX |
| A | 6.100 | 6.300 | 6.680 | a | 1.504 | 1.524 | 1.544 |
| B | 18.940 | 19.200 | 19.560 | c | 0.437 | 0.457 | 0.477 |
| D | 8.200 | 8.700 | 9.200 | d | 2.530 | 2.540 | 2.550 |
| D1 | 7.42 | 7.62 | 7.82 | L | 0.500 | – | 0.800 |
| E | 3.100 | 3.300 | 3.550 | L1 | 3.000 | 3.200 | 3.600 |

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