

# Dual Operational Amplifier

## FEATURES

- **Unity-gain bandwidth:1.1MHZ**
- **Low input offset voltage:2mV (Typical)**
- **Supply Range: 3V to 36V**
- **Quiescent current:350uA per amplifier**
- **Low input bias current: 20nA (Typical)**
- **Common-mode input voltage range includes ground**
- **Output Swing:0V~Vcc-1.5V**
- **SPECIFIED UP TO +85°C**
- **Micro SIZE PACKAGES: SOIC-8(SOP8)**

## APPLICATIONS

- **SENSORS**
- **PHOTODIODE AMPLIFICATION**
- **ACTIVE FILTERS**
- **TEST EQUIPMENT**
- **DRIVING A/D CONVERTERS**

## DESCRIPTION

The LM358 include two high-voltage(36-V) operational amplifiers. These devices provide outstanding value for Cost sensitive applications, with features including low offset 2mV(Typical),Common-mode input range to ground. the LM358 simplify circuit design with enhanced features such as unity-gain stability, lower quiescent current of 350uA per amplifier (Typical).

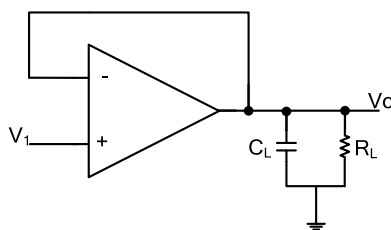
The LM358 amplifier are specified at the full temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  under single or dual power supplies of 3V to 36V.

### Device Information <sup>(1)</sup>

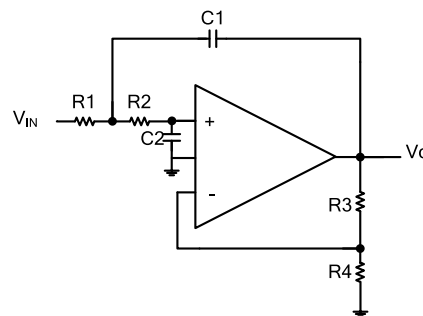
| PART NUMBER | PACKAGE  | BODY SIZE(NOM)  |
|-------------|----------|-----------------|
| LM321       | SOT23-5  | 2.90mm x 1.60mm |
| LM358       | SOIC-8   | 4.90mm x 3.90mm |
| LM324       | SOIC-14  | 8.65mm x 3.90mm |
|             | TSSOP-14 | 5.00mm x 4.40mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.

## Typical applications

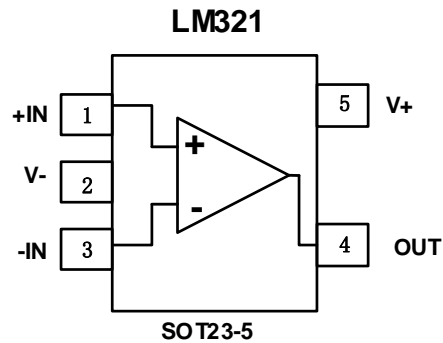


Unity-Gain Amplifier



DC Coupled Low-Pass RC Active Filter

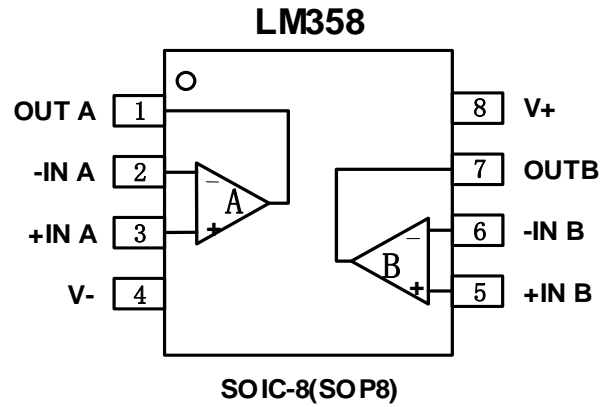
## Pin Configuration and Functions (Top View)



### Pin Description

| NAME | PIN     | I/O | DESCRIPTION                     |
|------|---------|-----|---------------------------------|
|      | LM321   |     |                                 |
|      | SOT23-5 |     |                                 |
| +IN  | 1       | I   | Positive (noninverting) input   |
| V-   | 2       | -   | Negative (lowest) power supply  |
| -IN  | 3       | I   | Negative (inverting) input      |
| OUT  | 4       | O   | Output                          |
| V+   | 5       | -   | Positive (highest) power supply |

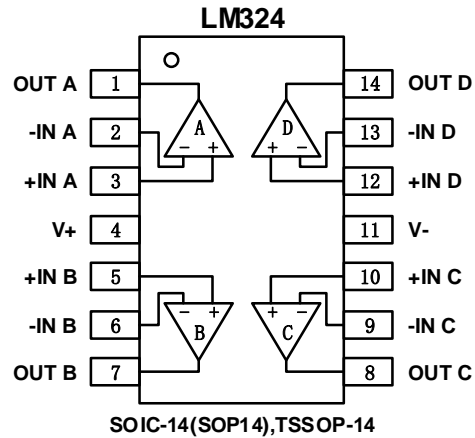
## Pin Configuration and Functions (Top View)



### Pin Description

| NAME | PIN          | I/O | DESCRIPTION  |
|------|--------------|-----|--|
|      | SOIC-8(SOP8) |     |  |
| -INA | 2            | I   | Inverting input, channel A   |
| +INA | 3            | I   | Noninverting input, channel A  |
| -INB | 6            | I   | Inverting input, channel B   |
| +INB | 5            | I   | Noninverting input, channel B  |
| OUTA | 1            | O   | Output, channel A  |
| OUTB | 7            | O   | Output, channel B  |
| V-   | 4            | -   | Negative (lowest) power supply or ground (for single supply operation) |
| V+   | 8            | -   | Positive (highest) power supply  |

## Pin Configuration and Functions (Top View)



### Pin Description

| NAME | PIN                     | I/O | DESCRIPTION                     |
|------|-------------------------|-----|---------------------------------|
|      | SOIC-14(SOP14)/TSSOP-14 |     |                                 |
| -INA | 2                       | I   | Inverting input, channel A      |
| +INA | 3                       | I   | Noninverting input, channel A   |
| -INB | 6                       | I   | Inverting input, channel B      |
| +INB | 5                       | I   | Noninverting input, channel B   |
| -INC | 9                       | I   | Inverting input, channel C      |
| +INC | 10                      | I   | Noninverting input, channel C   |
| -IND | 13                      | I   | Inverting input, channel D      |
| +IND | 12                      | I   | Noninverting input, channel D   |
| OUTA | 1                       | O   | Output, channel A               |
| OUTB | 7                       | O   | Output, channel B               |
| OUTC | 8                       | O   | Output, channel C               |
| OUTD | 14                      | O   | Output, channel D               |
| V-   | 11                      | -   | Negative (lowest) power supply  |
| V+   | 4                       | -   | Positive (highest) power supply |

## SPECIFICATIONS

### Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

|             |                                     | MIN        | MAX       | UNIT |
|-------------|-------------------------------------|------------|-----------|------|
| Voltage     | Supply, $V_s=(V+) - (V-)$           |            | 40        | V    |
|             | Signal input pin <sup>(2)</sup>     | (V-)-0.5   | (V+) +0.5 |      |
|             | Signal output pin <sup>(3)</sup>    | (V-)-0.5   | (V+) +0.5 |      |
| Current     | Signal input pin <sup>(2)</sup>     | -10        | 10        | mA   |
|             | Signal output pin <sup>(3)</sup>    | -55        | 55        | mA   |
|             | Output short-circuit <sup>(4)</sup> | Continuous |           |      |
| Temperature | Operating range, $T_A$              | -40        | 85        | °C   |
|             | Junction, $T_J$                     |            | 150       |      |
|             | Storage, $T_{stg}$                  | -55        | 150       |      |

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

(2) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.5V beyond the supply rails should be current-limited to 10mA or less.

(3) Output terminals are diode-clamped to the power-supply rails. Output signals that can swing more than 0.5V beyond the supply rails should be current-limited to  $\pm 55$ mA or less.

(4) Short-circuit to ground, one amplifier per package.

### ESD Ratings

|             |                         |                        | VALUE | UNIT |
|-------------|-------------------------|------------------------|-------|------|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM) | 3000  | V    |
|             |                         | Machine Model (MM)     | 200   |      |

### Recommended Operating Conditions

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

|                                      |               | MIN       | NOM | MAX      | UNIT |
|--------------------------------------|---------------|-----------|-----|----------|------|
| Supply voltage , $V_s= (V+) - (V- )$ | Single-supply | 3         |     | 36       | V    |
|                                      | Dual-supply   | $\pm 1.5$ |     | $\pm 18$ |      |

### Thermal Information:

| THERMAL METRIC <sup>(1)</sup> |  | LM321   | LM358  | LM324       |          | UNIT |
|-------------------------------|--|---------|--------|-------------|----------|------|
|                               |  | 5PINS   | 8PINS  | 14PINS      |          |      |
|                               |  | SOT23-5 | SOIC-8 | SOIC-14     | TSSOP-14 |      |
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 273.8   | 124.7  | <b>83.8</b> | 120.8    | °C/W |
| $R_{\theta JC(top)}$          | Junction-to-case(top) thermal resistance     | 126.8   | 66.9   | 70.7        | 34.3     | °C/W |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 85.9    | 67.9   | 59.5        | 62.8     | °C/W |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 10.9    | 19.2   | 11.6        | 1        | °C/W |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 84.9    | 67.2   | 37.7        | 56.5     | °C/W |
| $R_{\theta JC(bot)}$          | Junction-to-case(bottom) thermal resistance  | N/A     | N/A    | N/A         | N/A      | °C/W |

**PACKAGE/ORDERING INFORMATION**

| Orderable Device | Package Type   | Pin | Channel | Op Temp(°C) | Device Marking | Package Qty        |
|------------------|----------------|-----|---------|-------------|----------------|--------------------|
| LM321BXF         | SOT23-5        | 5   | 1       | -40°C~85°C  | LM321B         | Tape and Reel,3000 |
| LM358XK          | SOIC-8(SOP8)   | 8   | 1       | -40°C~85°C  | LM358          | Tape and Reel,2500 |
| LM324XP          | SOIC-14(SOP14) | 14  | 4       | -40°C~85°C  | LM324          | Tape and Reel,2500 |
| LM324XQ          | TSSOP-14       | 14  | 4       | -40°C~85°C  | LM324          | Tape and Reel,3000 |

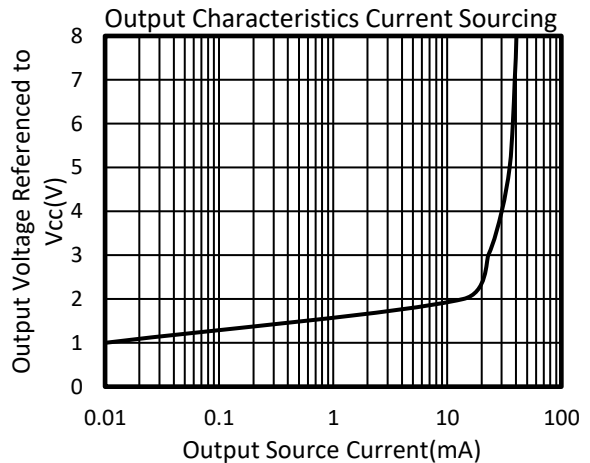
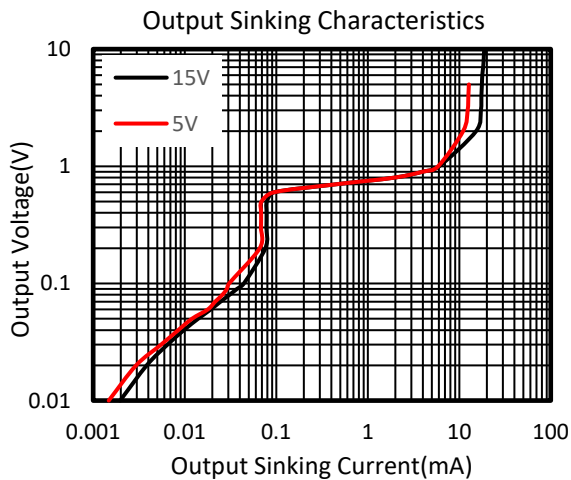
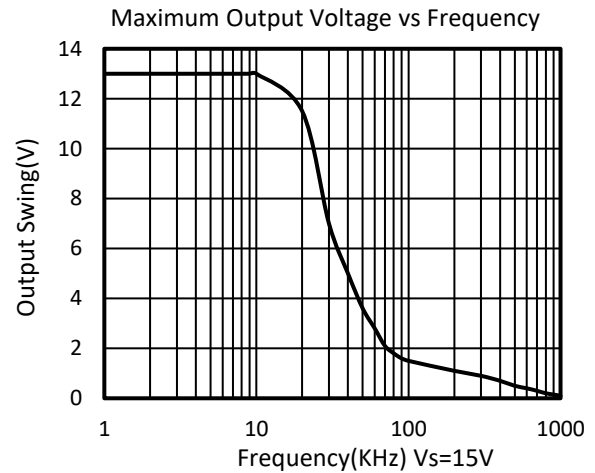
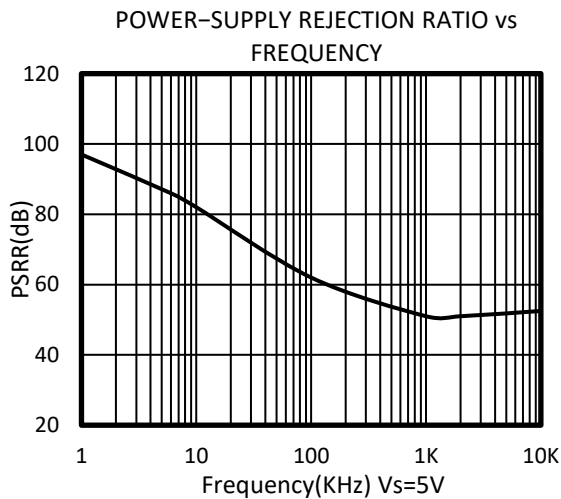
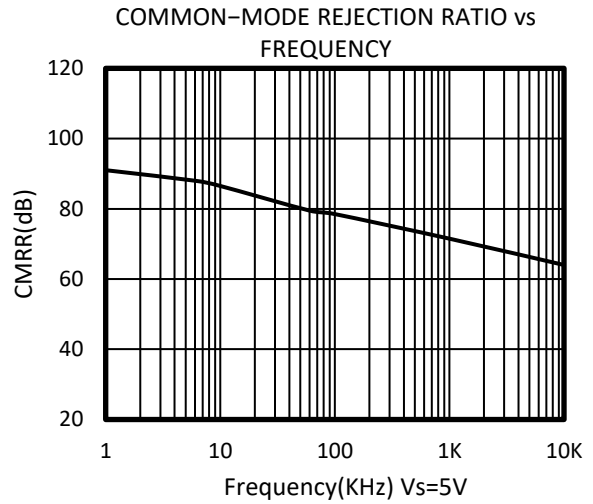
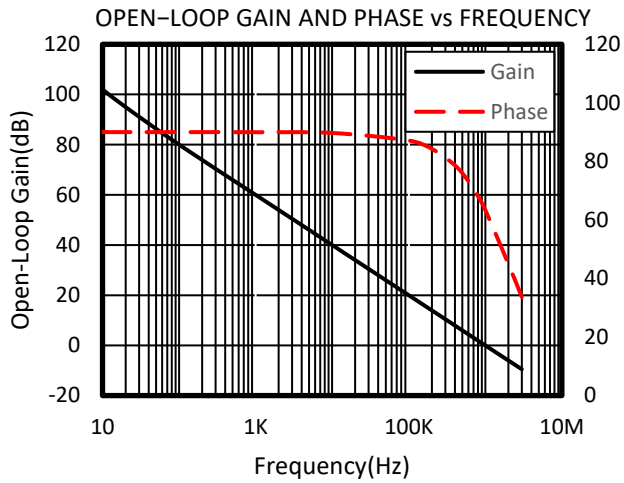
**ELECTRICAL CHARACTERISTICS**

 (At  $T_A = +25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $R_L = 10\text{k}\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.)

| PARAMETER                 | CONDITIONS                         | $T_J$  | LM358                                     |     |         | UNITS                |                        |
|---------------------------|------------------------------------|--|---|-----|---------|----------------------|------------------------|
|                           |                                    |  | MIN                                       | TYP | MAX     |                      |                        |
| <b>POWER SUPPLY</b>       |                                    |  |   |     |         |                      |                        |
| $V_S$                     | Operating Voltage Range            | $25^\circ\text{C}$   | 3   |     | 36      | V                    |                        |
| $I_Q$                     | Quiescent Current/Amplifier        | $V_S = 5\text{V}$ , $I_O = 0\text{mA}$   |   | 420 |         | uA                   |                        |
|                           |                                    | $V_S = 30\text{V}$ , $I_O = 0\text{mA}$  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ | 650 |         |                      |                        |
| PSRR                      | Power-Supply Rejection Ratio       | $V_S = 5\text{V}$ to $30\text{V}$  | $25^\circ\text{C}$                        | 70  | 100     | dB                   |                        |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ | 60  |         |                      |                        |
| <b>INPUT</b>              |                                    |  |   |     |         |                      |                        |
| $V_{OS}$                  | Input Offset Voltage               | $V_{CM} = V_S/2$   | $25^\circ\text{C}$                        | -5  | $\pm 2$ | 5                    | mV                     |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ |     |         | 7                    |                        |
| $V_{OS}$ Tc               | Input Offset Voltage Average Drift | $-40^\circ\text{C}$ to $85^\circ\text{C}$  |   |     | 7       | uV/ $^\circ\text{C}$ |                        |
| $I_B$                     | Input Bias Current                 | $V_{CM} = 0\text{V}$   | $25^\circ\text{C}$                        |     | 20      | 150                  | nA                     |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ |     |         | 200                  |                        |
| $I_{OS}$                  | Input Offset Current               | $V_{CM} = 0\text{V}$   | $25^\circ\text{C}$                        |     | 5       | 30                   | nA                     |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ |     |         | 100                  |                        |
| $V_{CM}$                  | Common-Mode Voltage Range          | $V_S = 30\text{V}$   | $25^\circ\text{C}$                        | 0   |         | $V_{CC} - 1.5$       | V                      |
| CMRR                      | Common-Mode Rejection Ratio        | $V_S = 5\text{V}$ , $V_{CM} = 0\text{V}$ to $(V_{CC} - 1.5)\text{V}$                   | $25^\circ\text{C}$                        | 60  | 80      |                      | dB                     |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ | 60  |         |                      |                        |
| <b>OUTPUT</b>             |                                    |  |   |     |         |                      |                        |
| $A_{OL}$                  | Open-Loop Voltage Gain             | $V_S = 15\text{V}$ , $R_L = 2\text{k}\Omega$ , $V_O = 1\text{V}$ to $11\text{V}$       | $25^\circ\text{C}$                        | 85  | 100     |                      | dB                     |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ | 80  |         |                      |                        |
|                           |                                    |  | $25^\circ\text{C}$                        | 83  | 96      |                      |                        |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ | 78  |         |                      |                        |
| $V_{OH}$                  | Output Swing From Rail             | $V_S = 30\text{V}$ , $R_L = 2\text{k}\Omega$   | $25^\circ\text{C}$                        | 26  |         |                      | V                      |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ | 26  |         |                      |                        |
|                           |                                    |  | $25^\circ\text{C}$                        | 27  | 28      |                      |                        |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ | 27  |         |                      |                        |
| $V_{OL}$                  |                                    | $V_S = 5\text{V}$ , $R_L = 10\text{k}\Omega$   | $25^\circ\text{C}$                        |     | 0.5     | 10                   | mV                     |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ |     |         | 20                   |                        |
| $I_{SOURCE}$              | Output current                     | $V_S = 15\text{V}$ , $V_{IN+} = 1\text{V}$ , $V_{IN-} = 0\text{V}$ , $V_O = 2\text{V}$ | $25^\circ\text{C}$                        | 20  | 40      |                      | mA                     |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ | 20  |         |                      |                        |
| $I_{SINK}$                |                                    | $V_S = 15\text{V}$ , $V_{IN-} = 1\text{V}$ , $V_{IN+} = 0\text{V}$ , $V_O = 2\text{V}$ | $25^\circ\text{C}$                        | 10  | 15      |                      | mA                     |
|                           |                                    |  | $-40^\circ\text{C}$ to $85^\circ\text{C}$ | 5   |         |                      |                        |
| $I_{SC}$                  | Short-circuit current              | $V_S = 15\text{V}$ , $V_O = 0\text{V}$   | $25^\circ\text{C}$                        |     | 40      | 60                   | mA                     |
|                           |                                    |  |   |     |         |                      |                        |
| <b>FREQUENCY RESPONSE</b> |                                    |  |   |     |         |                      |                        |
| SR                        | Slew Rate                          | $G = +1$ , $C_L = 100\text{pF}$  | $25^\circ\text{C}$                        |     | 0.35    |                      | V/us                   |
| GBP                       | Gain-Bandwidth Product             |  | $25^\circ\text{C}$                        |     | 1.1     |                      | MHz                    |
| PM                        | Phase Margin                       |  | $25^\circ\text{C}$                        |     | 56      |                      | $^\circ$               |
| $t_S$                     | Setting Time, 0.1%                 | $V_S = 5\text{V}$ , $G = +1$ , $C_L = 100\text{pF}$ , Step = 2V                        | $25^\circ\text{C}$                        |     | 22      |                      | us                     |
| $t_{OR}$                  | Overload Recovery Time             | $V_{IN-} \text{Gain} \geq V_S$ , $G = -100$  | $25^\circ\text{C}$                        |     | 10      |                      | us                     |
| <b>NOISE</b>              |                                    |  |   |     |         |                      |                        |
| $E_n$                     | Input Voltage Noise                | $f = 0.1\text{Hz}$ to $10\text{Hz}$ , $V_S = 5\text{V}$                                | $25^\circ\text{C}$                        |     | 0.9     |                      | uVpp                   |
| $e_n$                     | Input Voltage Noise Density        | $f = 1\text{KHz}$  | $25^\circ\text{C}$                        |     | 40      |                      | nV/ $\sqrt{\text{Hz}}$ |

### TYPICAL CHARACTERISTICS

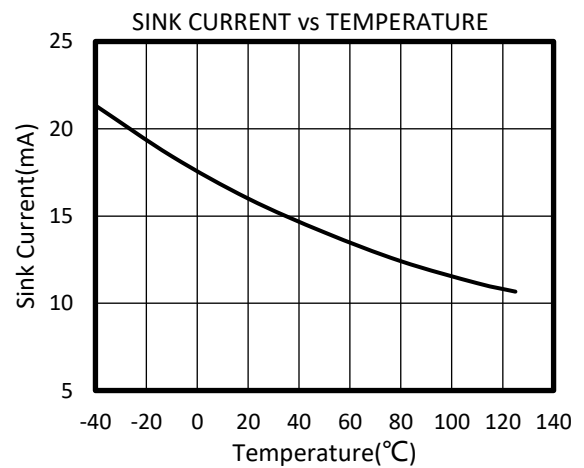
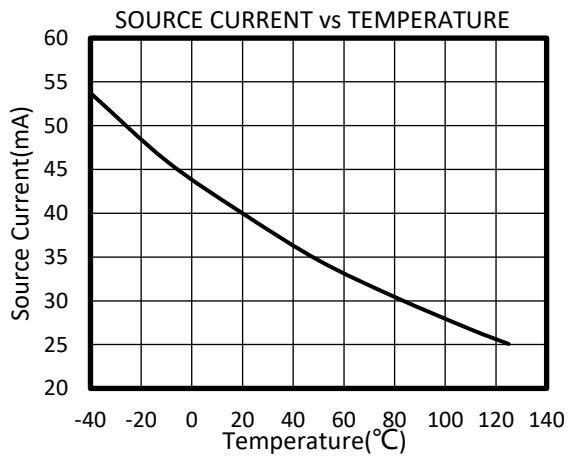
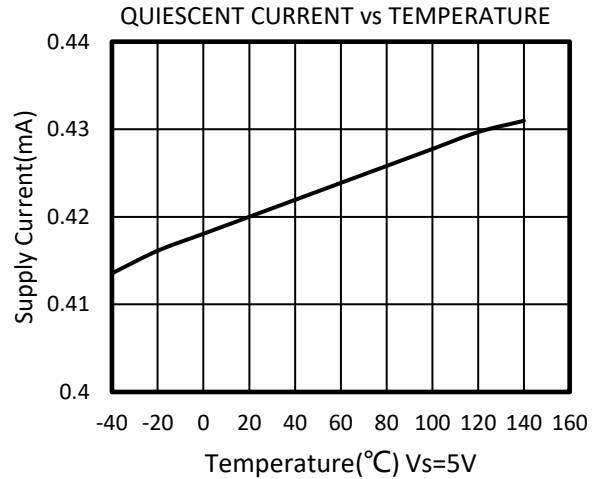
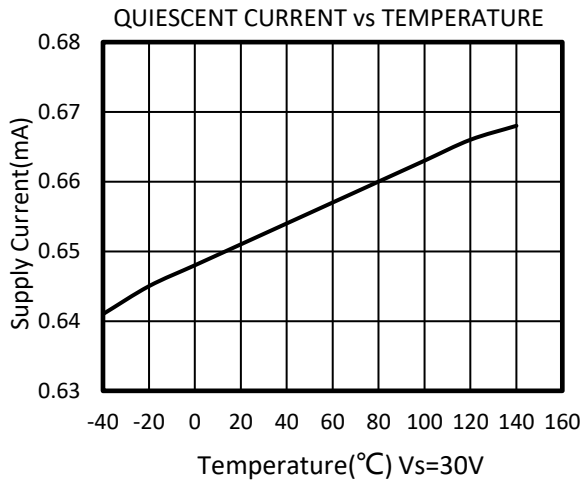
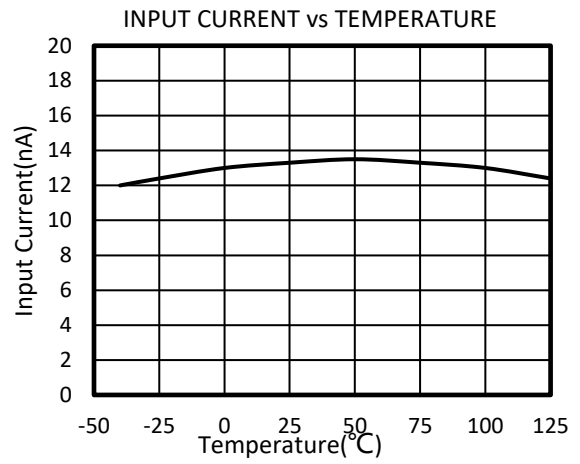
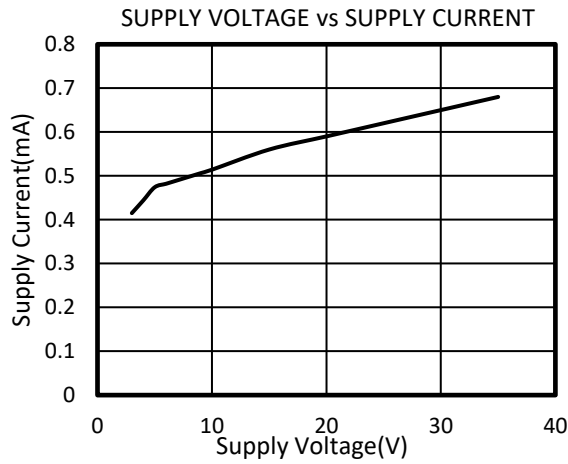
At  $T_A = +25^\circ\text{C}$ ,  $V_S = 36\text{ V}$  ( $\pm 18\text{ V}$ ),  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ ,  $V_{OUT} = V_S/2$ , unless otherwise noted.





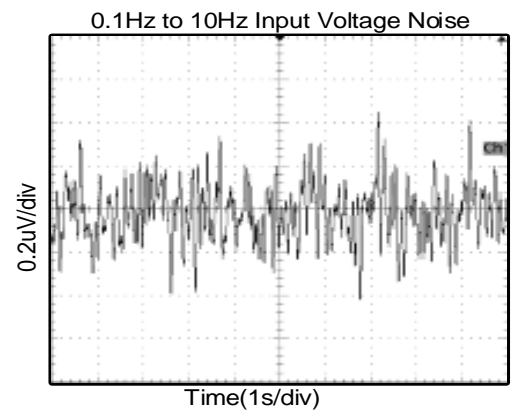
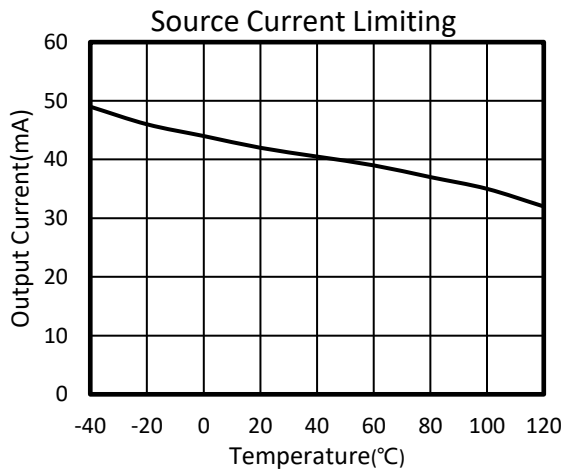
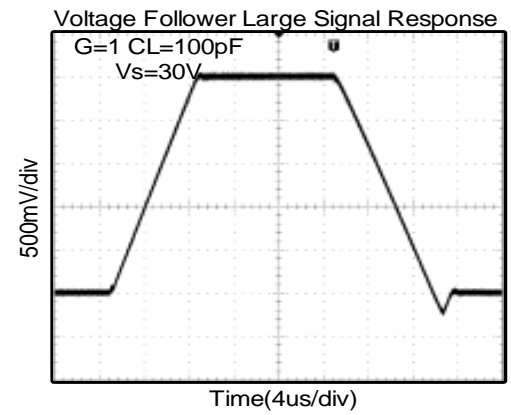
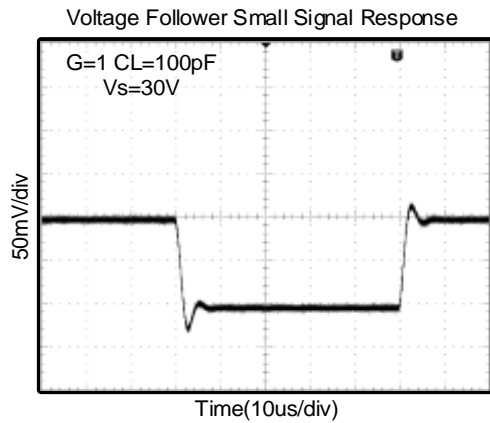
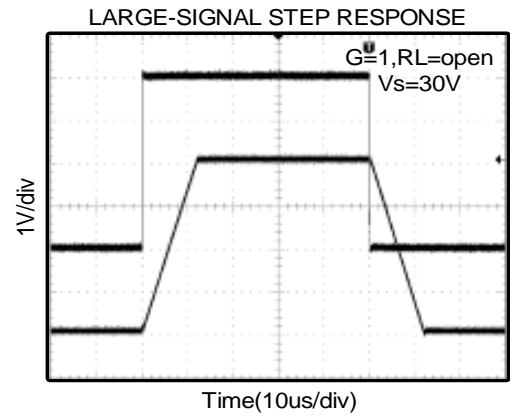
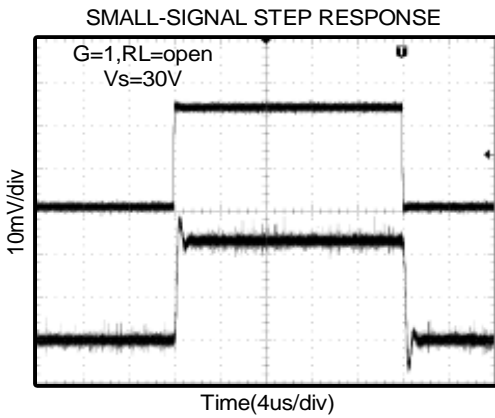
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## LAYOUT

### Layout Guidelines

Attention to good layout practices is always recommended. Keep traces short. When possible, use a PCB ground plane with surface-mount components placed as close to the device pins as possible. Place a 0.1uF capacitor closely across the supply pins.

These guidelines should be applied throughout the analog circuit to improve performance and provide benefits such as reducing the EMI susceptibility.

### Layout Example

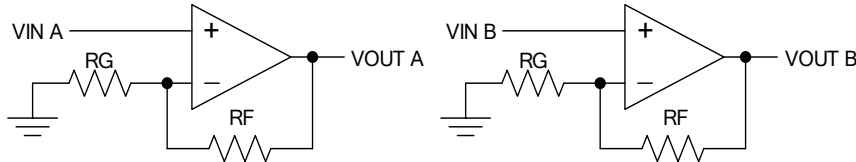


Figure 1. Schematic Representation

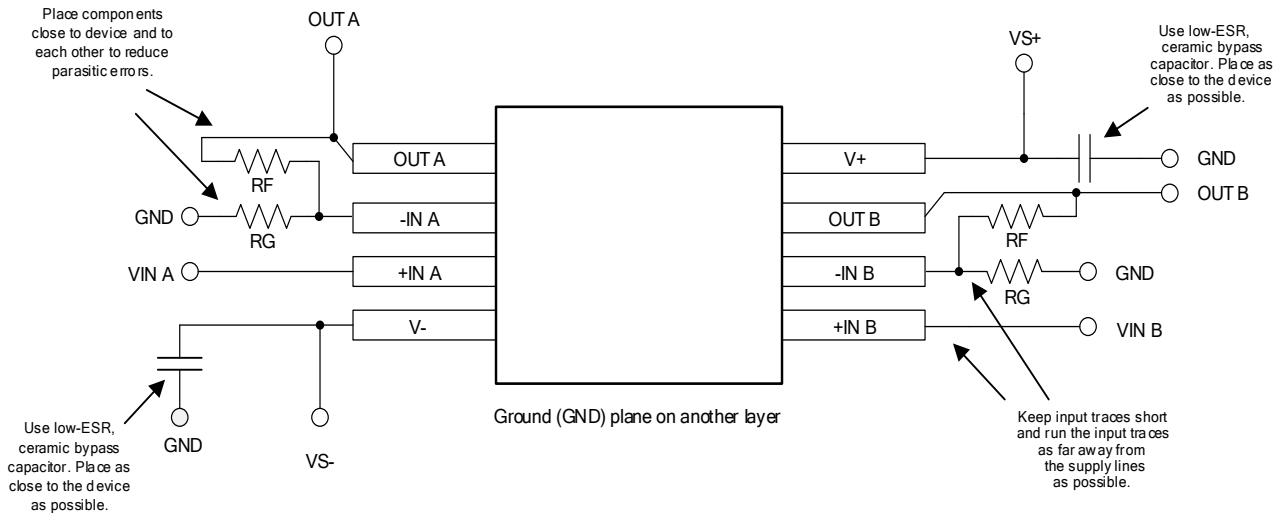
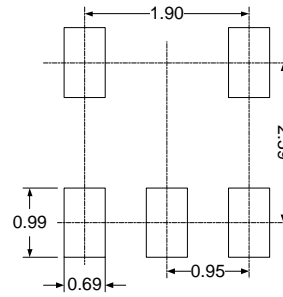
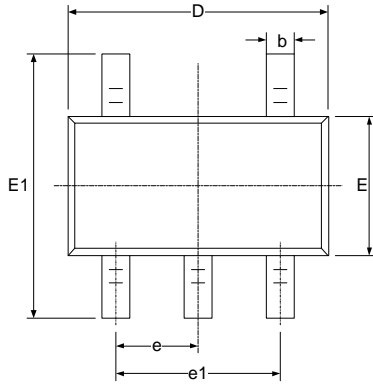


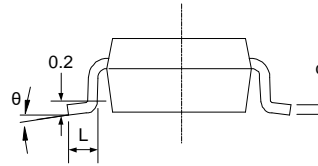
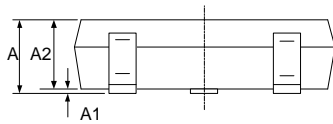
Figure 2. Layout Example

# PACKAGE OUTLINE DIMENSIONS

## SOT23-5

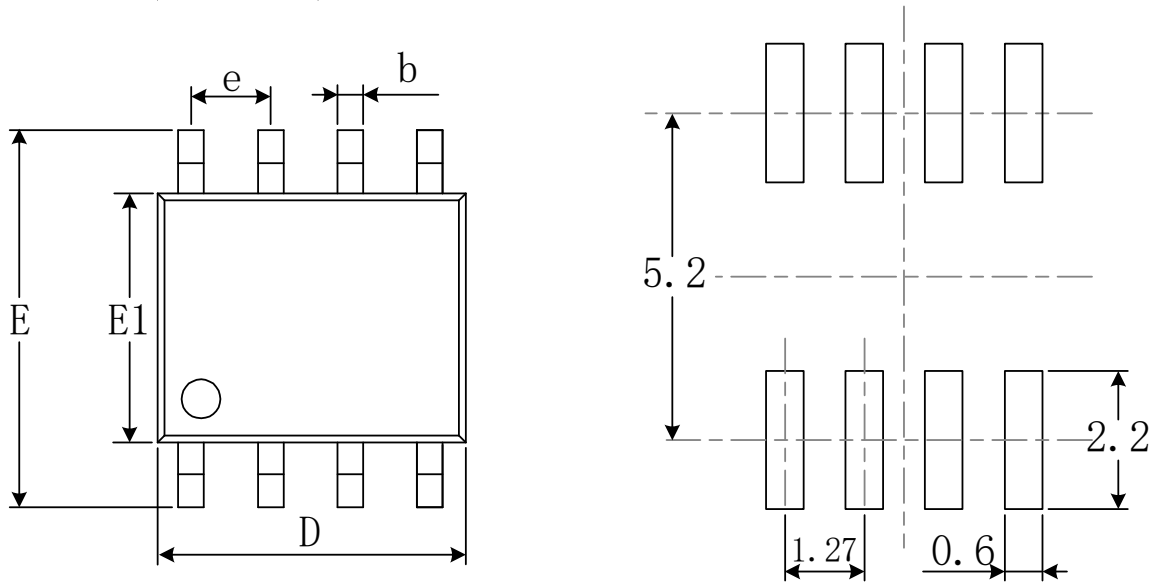


**RECOMMENDED LAND PATTERN (Unit: mm)**

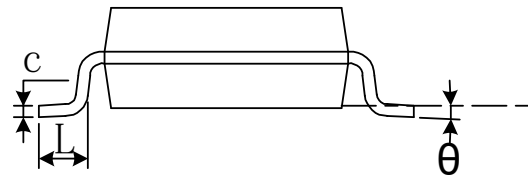
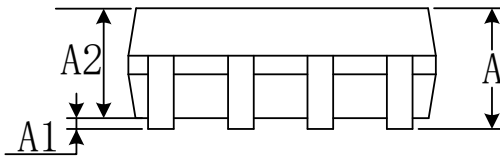


| Symbol   | Dimensions In Millimeters |       | Dimensions In Inches |       |
|----------|---------------------------|-------|----------------------|-------|
|          | Min                       | Max   | Min                  | Max   |
| A        | 1.050                     | 1.250 | 0.041                | 0.049 |
| A1       | 0.000                     | 0.100 | 0.000                | 0.004 |
| A2       | 1.050                     | 1.150 | 0.041                | 0.045 |
| b        | 0.300                     | 0.500 | 0.012                | 0.020 |
| c        | 0.100                     | 0.200 | 0.004                | 0.008 |
| D        | 2.820                     | 3.020 | 0.111                | 0.119 |
| E        | 1.500                     | 1.700 | 0.059                | 0.067 |
| E1       | 2.650                     | 2.950 | 0.104                | 0.116 |
| e        | 0.950(BSC)                |       | 0.037(BSC)           |       |
| e1       | 1.800                     | 2.000 | 0.071                | 0.079 |
| L        | 0.300                     | 0.600 | 0.012                | 0.024 |
| $\theta$ | 0°                        | 8°    | 0°                   | 8°    |

# SOIC-8(SOP8)

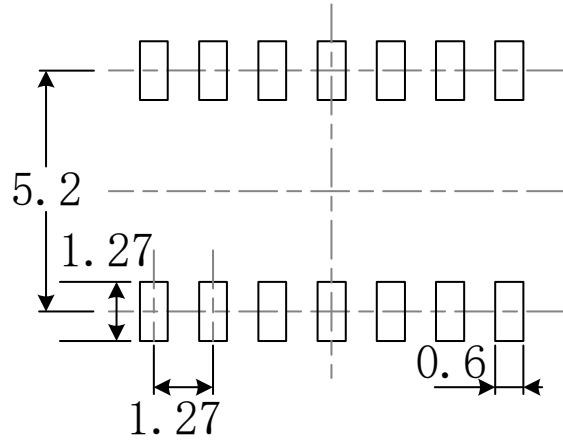
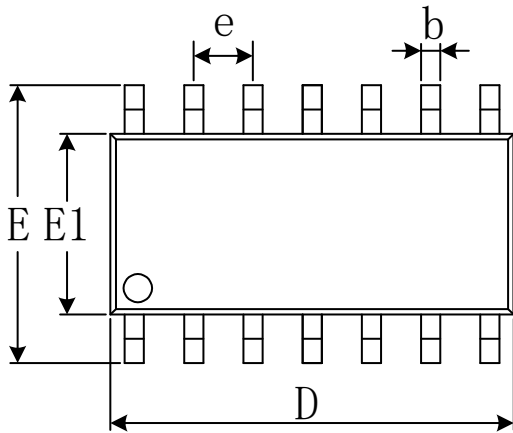


RECOMMENDED LAND PATTERN (Unit: mm)

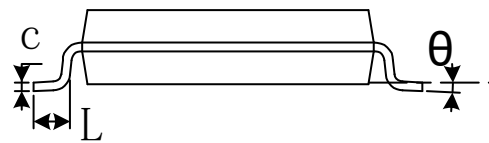
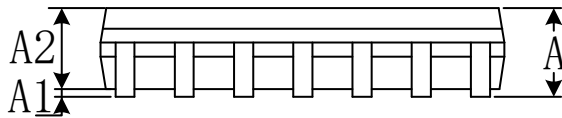


| Symbol | Dimensions In Millimeters |       | Dimensions In Inches |       |
|--------|---------------------------|-------|----------------------|-------|
|        | Min                       | Max   | Min                  | Max   |
| A      | 1.350                     | 1.750 | 0.053                | 0.069 |
| A1     | 0.100                     | 0.250 | 0.004                | 0.010 |
| A2     | 1.350                     | 1.550 | 0.053                | 0.061 |
| b      | 0.330                     | 0.510 | 0.013                | 0.020 |
| c      | 0.170                     | 0.250 | 0.007                | 0.010 |
| D      | 4.800                     | 5.000 | 0.189                | 0.197 |
| e      | 1.270(BSC)                |       | 0.050(BSC)           |       |
| E      | 5.800                     | 6.200 | 0.228                | 0.244 |
| E1     | 3.800                     | 4.000 | 0.150                | 0.157 |
| L      | 0.400                     | 1.270 | 0.016                | 0.050 |
| θ      | 0°                        | 8°    | 0°                   | 8°    |

# SOIC-14(SOP14)

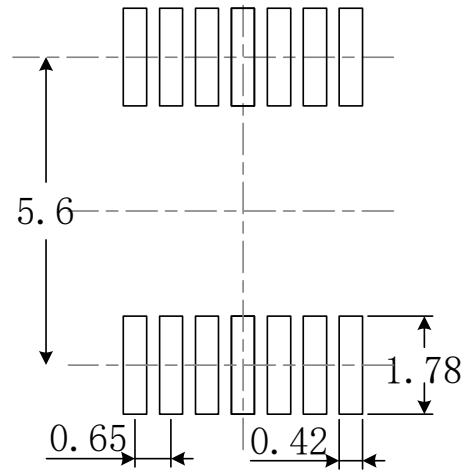
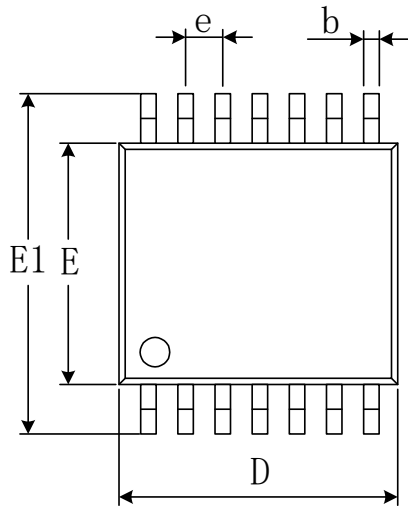
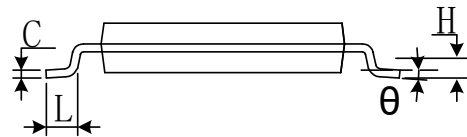
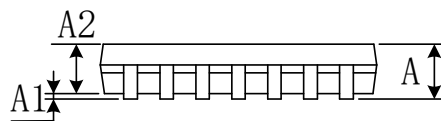


RECOMMENDED LAND PATTERN (Unit: mm)



| Symbol   | Dimensions In Millimeters |       | Dimensions In Inches |       |
|----------|---------------------------|-------|----------------------|-------|
|          | Min                       | Max   | Min                  | Max   |
| A        | 1.350                     | 1.750 | 0.053                | 0.069 |
| A1       | 0.100                     | 0.250 | 0.004                | 0.010 |
| A2       | 1.350                     | 1.550 | 0.053                | 0.061 |
| b        | 0.310                     | 0.510 | 0.012                | 0.020 |
| c        | 0.100                     | 0.250 | 0.004                | 0.010 |
| D        | 8.450                     | 8.850 | 0.333                | 0.348 |
| e        | 1.270(BSC)                |       | 0.050(BSC)           |       |
| E        | 5.800                     | 6.200 | 0.228                | 0.244 |
| E1       | 3.800                     | 4.000 | 0.150                | 0.157 |
| L        | 0.400                     | 1.270 | 0.016                | 0.050 |
| $\theta$ | 0°                        | 8°    | 0°                   | 8°    |

# TSSOP-14


**RECOMMENDED LAND PATTERN** (Unit: mm)


| Symbol   | Dimensions In Millimeters |       | Dimensions In Inches |       |
|----------|---------------------------|-------|----------------------|-------|
|          | Min                       | Max   | Min                  | Max   |
| A        |                           | 1.200 |                      | 0.047 |
| A1       | 0.050                     | 0.150 | 0.002                | 0.006 |
| A2       | 0.800                     | 1.050 | 0.031                | 0.041 |
| b        | 0.190                     | 0.300 | 0.007                | 0.012 |
| c        | 0.090                     | 0.200 | 0.004                | 0.008 |
| D        | 4.860                     | 5.100 | 0.191                | 0.201 |
| E        | 4.300                     | 4.500 | 0.169                | 0.177 |
| E1       | 6.250                     | 6.550 | 0.246                | 0.258 |
| e        | 0.650(BSC)                |       | 0.026(BSC)           |       |
| L        | 0.500                     | 0.700 | 0.020                | 0.028 |
| H        | 0.25(TYP)                 |       | 0.01(TYP)            |       |
| $\theta$ | 1°                        | 7°    | 1°                   | 7°    |