# High Slew Rate Rail-to-Rail Single Operational Amplifiers with OTP

## FEATURES

- Wide supply voltage range 6V ~ 18V
- Input range 500mV beyond the rails
- Unity-gain stable
- Rail-to-rail output swing
- High slew rate 40V/μs
- GBWP 20MHz
- 30MHz -3dB Bandwidth
- Ultra-small Package SOT-25、TSOT25、SOT-26、TSOT-26 and TSSOP-8

## APPLICATIONS

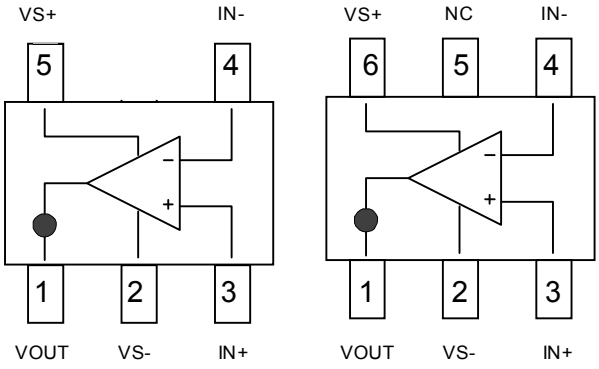
- TFT-LCD Reference Driver
- Touch-Screen Display
- Wireless LANs
- Personal Communication Devices
- Direct Access Arrangement
- Personal Digital Assistant (PDA)
- Active Filter
- Sampling ADC Amplifier
- ADC/DAC Buffer
- Electronic Notebook
- Office Automation
- Portable Electronics

## GENERAL DESCRIPTION

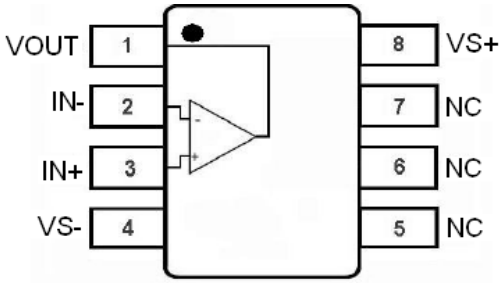
The EC5601 is a rail-to-rail one channel operational amplifier with wide supply range from 6V to 18V. It provides 0.5V beyond the supply rails of common mode input range and capability of rail-to-rail output swing as well. This enables the amplifier to offer maximum dynamic range at any supply voltage among many applications. A 20MHz gain bandwidth product allows EC5601 to perform more stable than other devices in Internet applications.

With features of 40V/μs high slew rate and 200ns of fast settling time, as well as 100mA (sink and source) of high output driving capability, the EC5601 is ideal for the requirements of flat panel Thin Film Transistor Liquid Crystal Displays (TFT-LCD) panel grayscale reference buffers application. Due to insensitive to power supply variation, EC5601 offers flexibility of use in multitude of applications such as battery power, portable devices and anywhere low power consumption is concerned. With standard operational amplifier pin assignment, the EC5601 is offered in a space saving 6-Pin SOT-26 package and specified over the -40℃ to +85℃ temperature range.

## PIN ASSIGNMENT




SOT25/TSOT25 SOT26/TSOT26




TSSOP-8

## Functional Pin Description

| Pin Name | Pin Function |
|---|---|
| VOUT | Operational Amplifier Output |
| VS- | IC GROUND or Negative power supply |
| IN+ | Operational Amplifier Non-Inverting Input |
| IN- | Operational Amplifier Inverting Input |
| VS+ | Supply Voltage VCC can range from 6V to 18V |

## ABSOLUTE MAXIMUM RATINGS (TA = 25 °C)

Values beyond absolute maximum ratings may cause permanent damage to the device. These are stress ratings only; functional device operation is not implied. Exposure to AMR conditions for extended periods may affect device reliability.

Supply Voltage between VS+ and VS- +18V
Input Voltage VS- -0.5V, VS+ +0.5V
Maximum Continuous Output Current 100mA

Storage Temperature -65°C to +150°C
Maximum Die Temperature +125°C
Operating Temperature -40°C to +85°C
Lead Temperature 260°C

**Important Note:**
**All parameters having Min/Max specifications are guaranteed. Typical values are for information purposes only. Unless otherwise noted, all tests are at the specified temperature and are pulsed tests, therefore: TJ = TC = TA**

## ELECTRICAL CHARACTERISTICS

**$V_{S+}$= +5V, $V_{S-}$ = -5V, $R_L$ = 10kΩ and $C_L$ = 10pF to 0V, $T_A$ = 25°C unless otherwise specified.**

| Parameter | Description | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Input Characteristics** | | | | | | |
| $V_{OS}$ | Input Offset Voltage | $V_{CM}$= 0V | | 2 | 12 | mV |
| $TCV_{OS}$ | Average Offset Voltage | [1] | | 5 | | µV/°C |
| $I_B$ | Input Bias Current | $V_{CM}$= 0V | | 2 | 50 | nA |
| $R_{IN}$ | Input Impedance | | | 1 | | GΩ |
| $C_{IN}$ | Input Capacitance | | | 1.35 | | pF |
| CMIR | Common-Mode Input | | -5.0 | | +5.5 | V |
| CMRR | Common-Mode Rejection Ratio | for VIN from -5.5V to 5.5V | 50 | 70 | | dB |
| $A_{VOL}$ | Open-Loop Gain | 0.5V ≦VOUT≦4.5V | 75 | 90 | | dB |
| Output Characteristics | | | | | | |
| $V_{OL}$ | Output Swing Low- | VS+=8V,VS-=-8V,$I_L$=-5mA | | -7.92 | -7.85 | V |
| $V_{OH}$ | Output Swing High | VS+=8V,VS-=-8V,$I_L$=5mA | 7.85 | 7.92 | | V |
| $I_{SC}$ | Short Circuit Current | (Note 1) | | ±350 | | mA |
| $I_{OUT}$ | Output Current | | | ±100 | | mA |
| $I_{peak}$ | $I_{peak}$ Current | VS+=14V, VS-=0V (Note 2) — Source Current: I load $V_{OUT}$ to GND | | 450 | | mA |
| | | VS+=14V, VS-=0V (Note 2) — Sink Current: I load $V_{OUT}$ to $V_{DD}$ | | | | |
| Power Supply Performance | | | | | | |
| PSRR | Power Supply Rejection Ratio | VS is moved from ±2.25V to ±7.75V | 60 | 80 | | dB |
| $I_S$ | Supply Current | No Load | | 3 | | mA |

## ELECTRICAL CHARACTERISTICS

**$V_{S+}$= +5V, $V_{S-}$ = -5V, $R_L$ = 10kΩ and $C_L$ = 10pF to 0V, $T_A$ = 25°C unless otherwise specified.**

| Parameter | Description | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Dynamic Performance** | | | | | | |
| SR | Slew Rate [2] | VS+=8V,VS-=-8V, -4.0V≦VOUT≦4.0V, 20% to 80% | 30 | 40 | | V/μs |
| $t_S$ | Settling to +0.1% (AV = +1) | (AV = +1), $V_O$=2V Step | | 500 | | Ns |
| BW | -3dB Bandwidth | $R_L$ = 10kΩ, $C_L$=10pF | | 30 | | MHz |
| GBWP | Gain-Bandwidth Product | $R_L$ = 10kΩ, CL=10pF | | 20 | | MHz |
| PM | Phase Margin | $R_L$ = 10kΩ, CL = 10 pF | | 50 | | Degree |
| CS | Channel Separation | f = 1 MHz | | 75 | | dB |
| **Temperature Performance** | | | | | | |
| Temp | Thermal Shutdown | | | 150 | | ℃ |
| 1. Measured over operating temperature range<br>2. Slew rate is measured on rising and falling edges | | | | | | |

**Note 1:** Short circuit current is tested with one output at a time.
**Note 2:** $I_{peak}$ current is for a 1μs pulsed current only , not to exceed thermal characteristics of package.

## TYPICAL PERFORMANCE CURVES

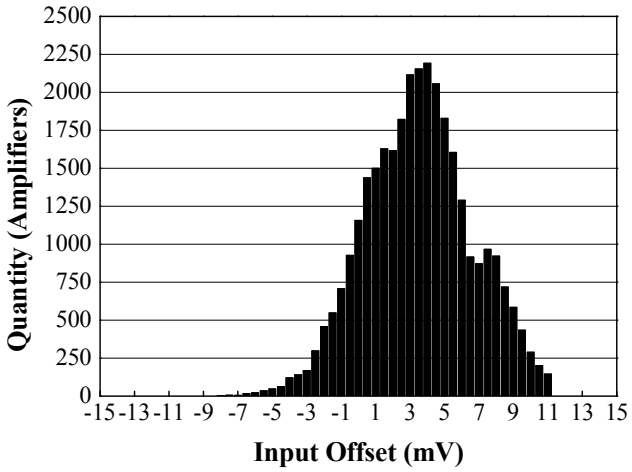



Figure (a) Input Offset Voltage Distribution

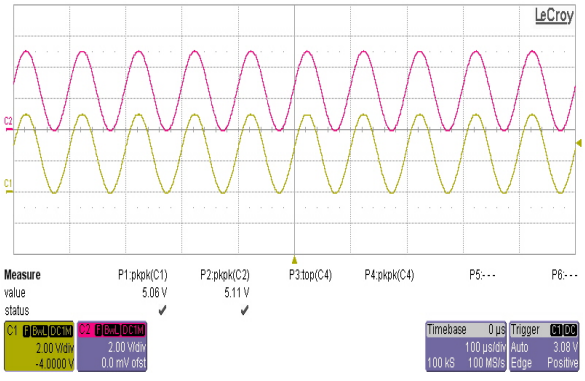



Figure (b) Rail to Rail Capability

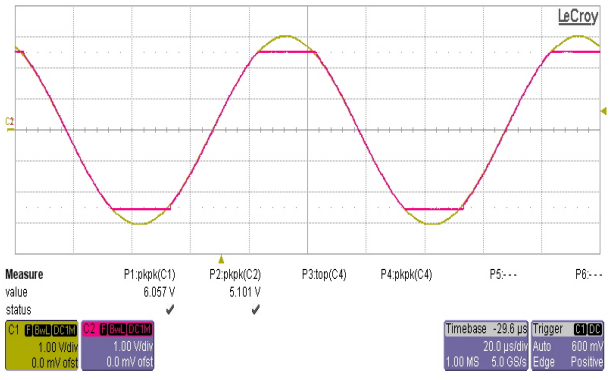



Figure (c) Input Beyond the Rails Signal

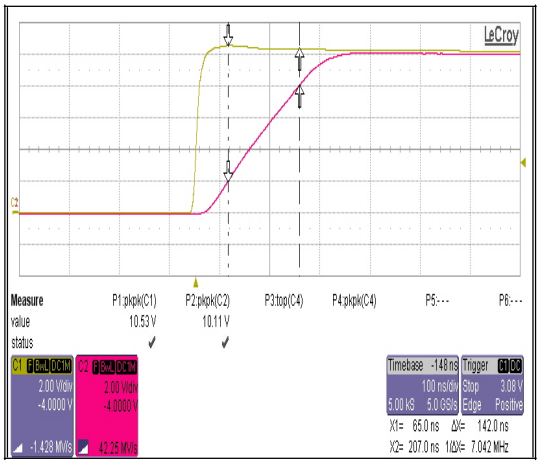



Figure (d) Large Signal Transient Response

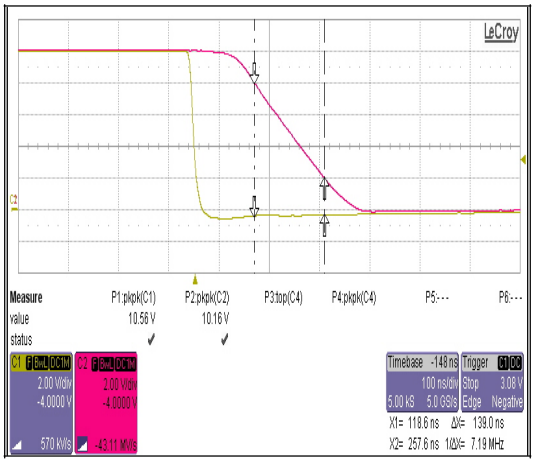



Figure (e) Large Signal Transient Response

# APPLICATIONS INFORMATION

## Product Description

The EC5601 rail-to-rail one channel amplifier is built on an advanced high voltage CMOS process. It's beyond rails input capability and full swing of output range makes itself an ideal amplifier for use in a wide range of general-purpose applications. The features of 40V/μs high slew rate, fast settling time, 30MHz of GBWP as well as high output driving capability have proven the EC5601 a good voltage reference buffer in TFT-LCD for grayscale reference applications. High phase margin and extremely low power consumption make the EC5601 ideal for connected in voltage follower mode for low power high drive applications.

## Supply Voltage, Input Range and Output Swing

The EC5601 can be operated with a single nominal wide supply voltage ranging from 6V to 18V with stable performance over operating temperature of -40°C to +85°C. With 500mV greater than rail-to-rail input common mode voltage range and 70dB of Common Mode Rejection Ratio, the EC5601 allows a wide range sensing among many applications without having any concerns over exceeding the range and no compromise in accuracy. The output swings of the EC5601 typically extend to within 80mV of positive and negative supply rails with load currents of 5mA. The output voltage swing can be even closer to the supply rails by merely decreasing the load current. Figure 1 shows the input and output waveforms for the device in the unity-gain configuration. The amplifier is operated under ±5V supply with a 10KΩ load connected to GND. The input is a 10Vp-p sinusoid. An Approximately 9.985 Vp-p of output voltage swing can be easily achieved.

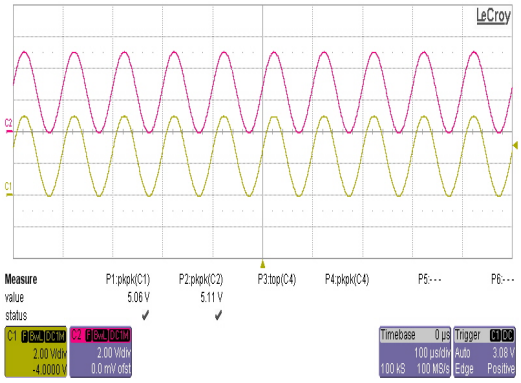



Figure 1. Operation with Rail-to-Rail Input and Output

## Output Short Circuit Current Limit

A +/-350mA short circuit current will be limited by the EC5601 if the output is directly shorted to the positive or the negative supply. For an indefinitely output short circuit, the power dissipation could easily increase such that the device may be damaged. The internal metal interconnections are well designed to prevent the output continuous current from exceeding +/-100mA such that the maximum reliability can be well maintained.

## Output Phase Reversal

The EC5601 is designed to prevent its output from being phase reversal as long as the input voltage is limited from VS- -0.5V to VS+ +0.5V. Figure 2 shows a photo of the device output with its input voltage driven beyond the supply rails. Although the phase of the device's output will not be reversed, the input's over-voltage should be avoided. An improper input voltage exceeds supply range by more than 0.6V may result in an over stress damage.

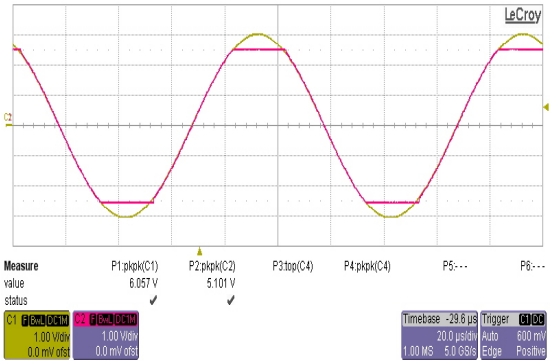



Figure 2. Operation with Beyond-the Rails Input

## Power Dissipation

The EC5601 is designed for maximum output current capability. Even though momentary output shorted to ground causes little damage to device.

For the high drive amplifier EC5601, it is possible to exceed the 'absolute-maximum junction temperature' under certain load current conditions. Therefore, it is important to calculate the maximum junction temperature for the application to determine if load conditions need to be modified for the amplifier to remain in the safe operating area. The maximum power dissipation allowed in a package is determined according to:

$$P_{Dmax} = \frac{T_{Jmax} - T_{Amax}}{\Theta_{JA}}$$

Where:

$T_{Jmax}$ = Maximum Junction Temperature

$T_{Amax}$ = Maximum Ambient Temperature

$\Theta_{JA}$ = Thermal Resistance of the Package

$P_{Dmax}$ = Maximum Power Dissipation in the Package.

The maximum power dissipation actually produced by an IC is the total quiescent supply current times the total power supply voltage, plus the power in the IC due to the loads, or:

$P_{Dmax} = \sum_i [VS * I_{Smax} + (VS+ - VO) * I_L]$

When sourcing, and

$P_{Dmax} = \sum_i [VS * I_{Smax} + (VO - VS-) * I_L]$

When sinking.

Where:

**i** = 1 to 1

**VS** = Total Supply Voltage

$I_{Smax}$ = Maximum Supply Current Per Amplifier

**VO** = Maximum Output Voltage of the Application

$I_L$ = Load current

$R_L$ = Load Resistance = $(VS+ - VO)/I_L = (VO - VS-)/ I_L$

A calculation for $R_L$ to prevent device from overheat can be easily solved by setting the two $P_{Dmax}$ equations equal to each other.

## Driving Capacitive Loads

The EC5601 is designed to drive a wide range of capacitive loads. In addition, the output current handling capability of the device allows for good slewing characteristics even with large capacitive loads. The combination of these features make the EC5601 ideally for applications such as TFT LCD panel grayscale reference voltage buffers, ADC input amplifiers, etc.

As load capacitance increases, however, the -3dB bandwidth of the device will decrease and the peaking increase. Depending on the application, it must be necessary to reduce peaking and to improve device stability. To improve device stability, a small value of series resistor (usually between 5Ω and 50Ω) must be placed in series with the output. The advantage is that it improves the settling and overshooting performance with very large capacitive loads. Figure 3. shows the typical application configuration.

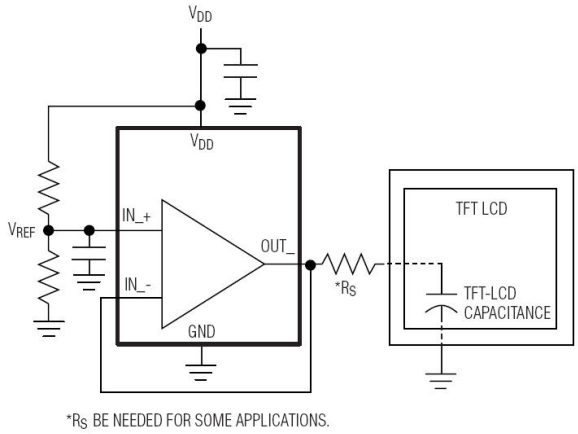



Figure 3. Typical Application Configuration.

## Power Supply Bypassing and Printed Circuit Board Layout

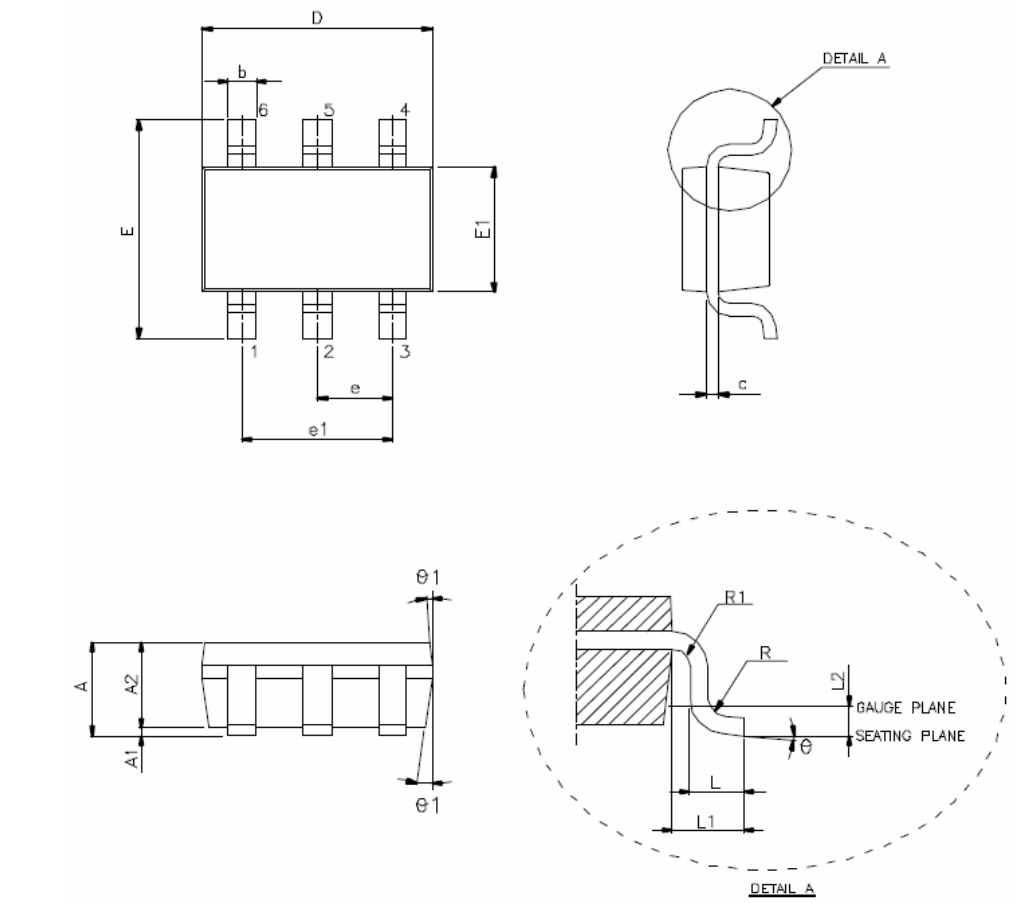
With high phase margin, the EC5601 performs stable gain at high frequency. Like any high-frequency device, good layout of the printed circuit board usually comes with optimum performance. Ground plane construction is highly recommended, lead lengths should be as short as possible and the power supply pins must be well bypassed to reduce the risk of oscillation. For normal single supply operation, where the $V_S$- pin is connected to ground, a 0.1 µF ceramic capacitor should be placed from $V_{S+}$ pin to $V_{S-}$ pin as a bypassing capacitor. A 4.7µF tantalum capacitor should then be connected in parallel, placed in the region of the amplifier. One 4.7µF capacitor may be used for multiple devices. This same capacitor combination should be placed at each supply pin to ground if split supplies are to be used.

## *ORDERING INFORMATION*

| PART NO | TOP MARK | PACKAGE TYPE |
|---|---|---|
| EC5601B2-G | EC5601<br>XXXXX | SOT-25 GREEN PACKAGE<br>"XXXX" is lot code |
| EC5601T2-G | EC5601<br>XXXXX | TSOT-25 GREEN PACKAGE<br>"XXXX" is lot code |
| EC5601B3-G | EC5601<br>XXXXX | SOT-26 GREEN PACKAGE<br>"XXXX" is lot code |
| EC5601T3-G | EC5601<br>XXXXX | TSOT-26 GREEN PACKAGE<br>"XXXX" is lot code |
| EC5601I-G | EC5601<br>XXXXX<br>YYWW | TSSOP-8 GREEN PACKAGE<br>"XXXX" is lot code<br>"YYWW" is date code |

## *OUTLINE DIMENSIONS* (Dimensions shown in millimeters)

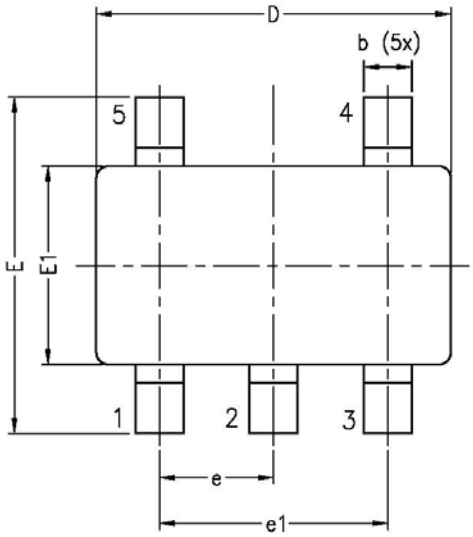
### SOT-26

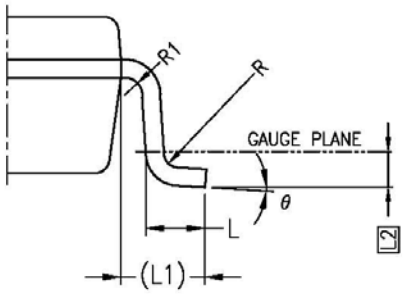



VARIATION(ALL DIMENSIONS SHOWN IN MM)

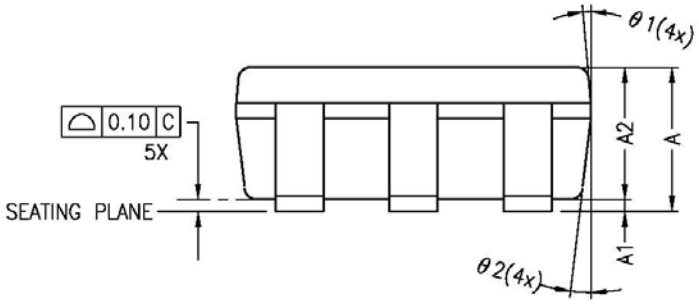
| SYMBOL | MIN. | NOM. | MAX. |
|---|---|---|---|
| A | – | – | 1.45 |
| A1 | – | – | 0.15 |
| A2 | 0.90 | 1.15 | 1.30 |
| b | 0.30 | – | 0.50 |
| c | 0.08 | – | 0.22 |
| D | | 2.90 BSC. | |
| E | | 2.80 BSC. | |
| E1 | | 1.60 BSC. | |
| e | | 0.95 BSC | |
| e1 | | 1.90 BSC. | |
| L | 0.30 | 0.45 | 0.60 |
| L1 | | 0.60 REF. | |
| L2 | | 0.25 BSC. | |
| R | 0.10 | – | – |
| R1 | 0.10 | – | 0.25 |
| θ | 0° | 4° | 8° |
| θ1 | 5° | 10° | 15° |

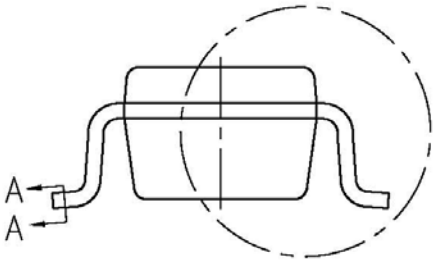
## SOT-25




VIEW B



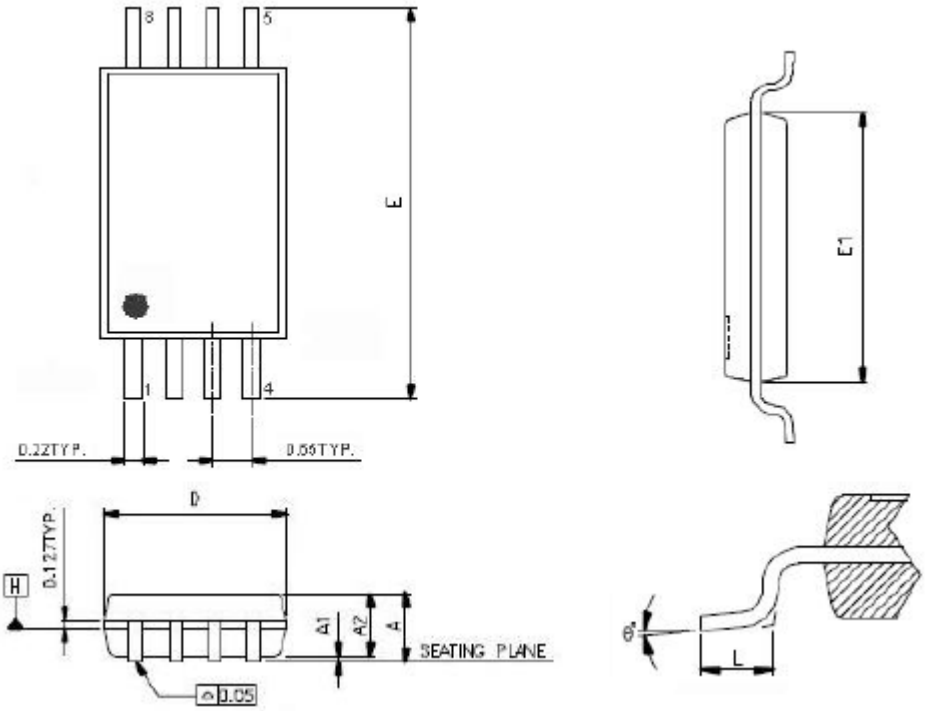




SEE VIEW B

VARIATION(ALL DIMENSIONS SHOWN IN MM)

| SYMBOL | MIN. | NOM. | MAX. |
|---|---|---|---|
| A | – | – | 1.45 |
| A1 | – | – | 0.15 |
| A2 | 0.90 | 1.15 | 1.30 |
| b | 0.30 | – | 0.50 |
| c | 0.08 | – | 0.22 |
| D | | 2.90 BSC. | |
| E | | 2.80 BSC. | |
| E1 | | 1.60 BSC. | |
| e | | 0.95 BSC | |
| e1 | | 1.90 BSC. | |
| L | 0.30 | 0.45 | 0.60 |
| L1 | | 0.60 REF. | |
| L2 | | 0.25 BSC. | |
| R | 0.10 | – | – |
| R1 | 0.10 | – | 0.25 |
| θ | 0° | 4° | 8° |
| θ1 | 5° | 10° | 15° |

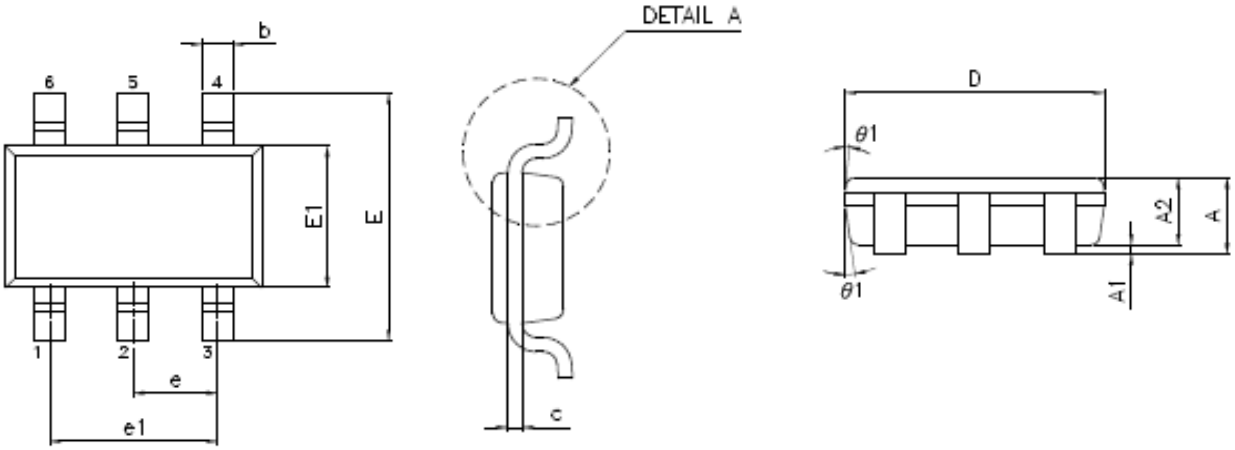
## TSSOP-8

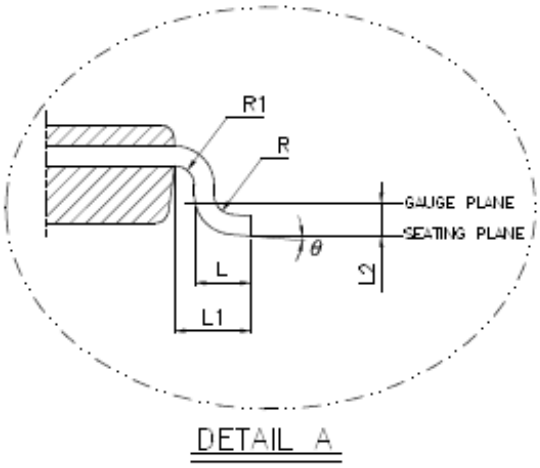



| SYMBOLS | MIN. | NOM. | MAX. |
|---|---|---|---|
| A | – | – | 1.20 |
| A1 | 0.05 | – | 0.15 |
| A2 | 0.96 | 1.01 | 1.06 |
| D | 2.90 | 3.00 | 3.10 |
| E | | 6.40 BSC | |
| E1 | 4.30 | 4.40 | 4.50 |
| L | 0.45 | 0.60 | 0.75 |
| θ° | 0 | – | 8 |

UNIT : MM

# TSOT-26



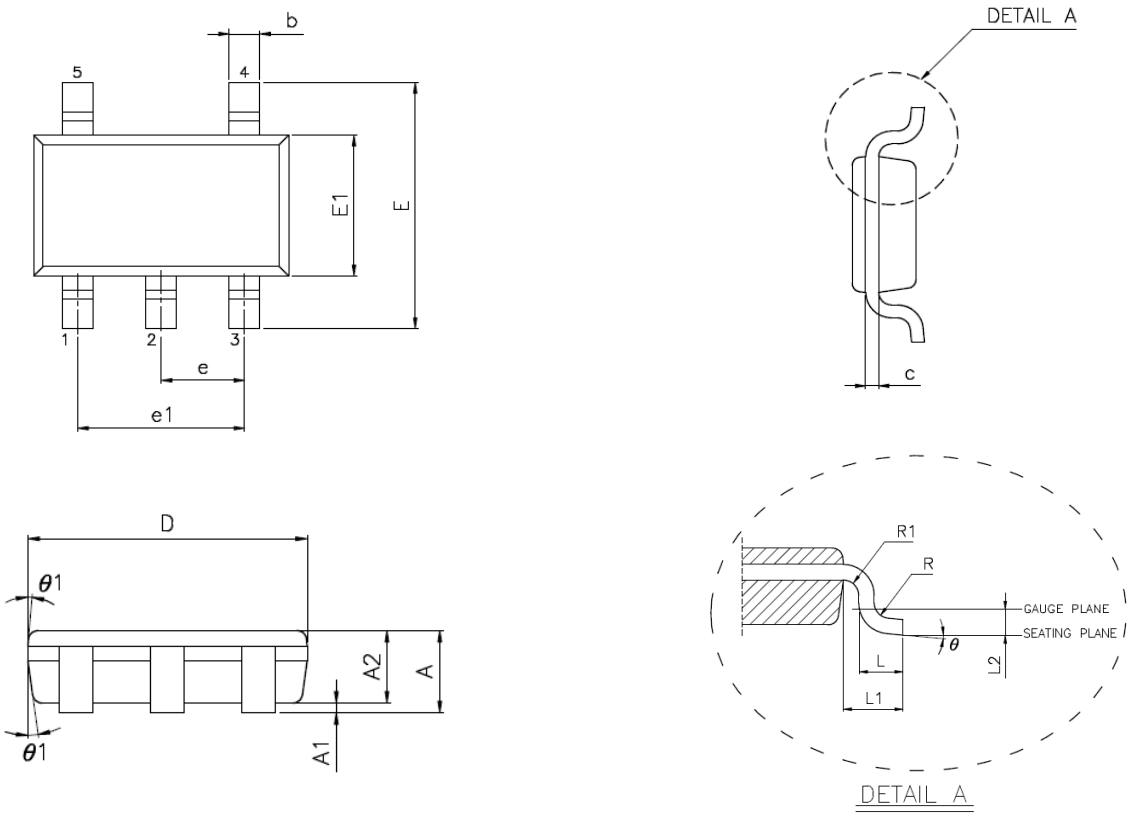




VARIATION(ALL DIMENSIONS SHOWN IN MM)

| SYMBOL | MIN. | NOM. | MAX. |
|---|---|---|---|
| A | 0.750 | — | 0.800 |
| A1 | 0.000 | — | 0.050 |
| A2 | 0.700 | 0.750 | 0.775 |
| b | 0.350 | — | 0.500 |
| c | 0.100 | — | 0.200 |
| D | 2.800 | 2.900 | 3.000 |
| E | 2.600 | 2.800 | 3.000 |
| E1 | 1.500 | 1.600 | 1.700 |
| e | 0.950 BSC | | |
| e1 | 1.900 BSC | | |
| L | 0.370 | 0.450 | 0.600 |
| L1 | 0.600 REF | | |
| L2 | 0.250 BSC | | |
| R | 0.100 | — | — |
| R1 | 0.100 | — | 0.250 |
| θ | 0° | 4° | 8° |
| θ1 | 4° | 10° | 12° |

NOTE :
1. JEDEC OUTLINE : N/A.

## TSOT-25




**VARIATION (ALL DIMENSIONS SHOWN IN MM)**

| SYMBOL | MIN. | NOM. | MAX. |
|---|---|---|---|
| A | 0.750 | - | 0.800 |
| A1 | 0.000 | - | 0.050 |
| A2 | 0.700 | 0.750 | 0.775 |
| b | 0.350 | - | 0.500 |
| c | 0.100 | - | 0.200 |
| D | 2.800 | 2.900 | 3.000 |
| E | 2.600 | 2.800 | 3.000 |
| E1 | 1.500 | 1.600 | 1.700 |
| e | 0.950 BSC | | |
| e1 | 1.900 BSC | | |
| L | 0.370 | 0.450 | 0.600 |
| L1 | 0.600 REF | | |
| L2 | 0.250 BSC | | |
| R | 0.100 | - | - |
| R1 | 0.100 | - | 0.250 |
| θ | 0° | 4° | 8° |
| θ1 | 4° | 10° | 12° |

NOTE：

1. JEDEC OUT LINE：N/A