

## Operational Amplifiers

# Low Noise Operational Amplifier

### LM4565xxx

#### General Description

The LM4565xxx are low noise operational amplifiers with high voltage gain and wide bandwidth. They have good performance of input referred noise voltage ( $5 \text{ nV}/\sqrt{\text{Hz}}$ ) and total harmonic distortion (0.0002%). These are suitable for audio applications and active filter.

#### Features

- High Voltage Gain
- High Slew Rate
- Low Input Referred Noise Voltage
- Low Total Harmonic Distortion
- Wide Gain Bandwidth

#### Application

- Audio Application
- Consumer Equipment
- Active Filter

#### Key Specifications

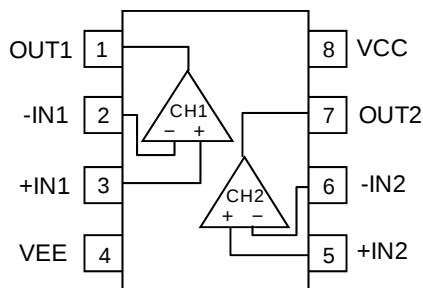
|                                           |                                            |
|-------------------------------------------|--------------------------------------------|
| ■ Operating Supply Voltage:               | $\pm 2\text{V}$ to $\pm 18\text{V}$        |
| ■ Temperature Range:                      | $-40^\circ\text{C}$ to $+85^\circ\text{C}$ |
| ■ Voltage Gain ( $R_L=2\text{k}\Omega$ ): | 100dB(Typ)                                 |
| ■ Slew Rate:                              | $5.0\text{V}/\mu\text{s}$ (Typ)            |
| ■ Gain Bandwidth:                         | 10MHz (Typ)                                |
| ■ Input Referred Noise Voltage:           | $5 \text{ nV}/\sqrt{\text{Hz}}$ (Typ)      |

#### Package

|           | W(Typ) xD(Typ) xH(Max)   |
|-----------|--------------------------|
| SOP-8     | 5.00mm x 6.20mm x 1.71mm |
| SOP-J8    | 4.90mm x 6.00mm x 1.65mm |
| SSOP-B8   | 3.00mm x 6.40mm x 1.35mm |
| TSSOP-B8  | 3.00mm x 6.40mm x 1.20mm |
| MSOP8     | 2.90mm x 4.00mm x 0.90mm |
| TSSOP-B8J | 3.00mm x 4.90mm x 1.10mm |

#### Pin Configuration

|           |             |
|-----------|-------------|
| LM4565F   | : SOP8      |
| LM4565FJ  | : SOP-J8    |
| LM4565FV  | : SSOP-B8   |
| LM4565FVT | : TSSOP-B8  |
| LM4565FVM | : MSOP8     |
| LM4565FVJ | : TSSOP-B8J |



| Pin No. | Pin Name |
|---------|----------|
| 1       | OUT1     |
| 2       | -IN1     |
| 3       | +IN1     |
| 4       | VEE      |
| 5       | +IN2     |
| 6       | -IN2     |
| 7       | OUT2     |
| 8       | VCC      |

Figure1. Pin Configuration

○Product structure : Silicon monolithic integrated circuit ○This product has no designed protection against radioactive rays.

## Ordering Information

|                         |  |  |  |  |                 |  |  |                                          |  |
|-------------------------|--|--|--|--|-----------------|--|--|------------------------------------------|--|
| L M 4 5 6 5 x x x - x x |  |  |  |  |                 |  |  |                                          |  |
| Part Number             |  |  |  |  | Package         |  |  | Packaging and forming specification      |  |
| LM4565xxx               |  |  |  |  | F : SOP8        |  |  | E2: Embossed tape and reel               |  |
|                         |  |  |  |  | FJ : SOP-J8     |  |  | (SOP8/SOP-J8/SSOP-B8/TSSOP-B8/TSSOP-B8J) |  |
|                         |  |  |  |  | FV : SSOP-B8    |  |  | TR: Embossed tape and reel               |  |
|                         |  |  |  |  | FVT : TSSOP-B8  |  |  | (MSOP8)                                  |  |
|                         |  |  |  |  | FVM : MSOP8     |  |  |                                          |  |
|                         |  |  |  |  | FVJ : TSSOP-B8J |  |  |                                          |  |

## Line-up

| T <sub>opr</sub> | Package   |              | Orderable Part Number |
|------------------|-----------|--------------|-----------------------|
| -40°C to +85°C   | SOP8      | Reel of 2500 | LM4565F-E2            |
|                  | SOP-J8    | Reel of 2500 | LM4565FJ-E2           |
|                  | SSOP-B8   | Reel of 2500 | LM4565FV-E2           |
|                  | TSSOP-B8  | Reel of 3000 | LM4565FVT-E2          |
|                  | MSOP8     | Reel of 3000 | LM4565FVM-TR          |
|                  | TSSOP-B8J | Reel of 2500 | LM4565FVJ-E2          |

Absolute Maximum Ratings (T<sub>A</sub>=25°C)

| Parameter                                      | Symbol                            | Rating                                            | Unit                       |
|------------------------------------------------|-----------------------------------|---------------------------------------------------|----------------------------|
| Supply Voltage                                 | V <sub>CC</sub> - V <sub>EE</sub> | +36                                               | V                          |
| Power Dissipation                              | P <sub>D</sub>                    | SOP8                                              | 0.68 <sup>(Note 1,5)</sup> |
|                                                |                                   | SOP-J8                                            | 0.67 <sup>(Note 2,5)</sup> |
|                                                |                                   | SSOP-B8                                           | 0.62 <sup>(Note 3,5)</sup> |
|                                                |                                   | TSSOP-B8                                          | 0.62 <sup>(Note 3,5)</sup> |
|                                                |                                   | MSOP8                                             | 0.58 <sup>(Note 4,5)</sup> |
|                                                |                                   | TSSOP-B8J                                         | 0.58 <sup>(Note 4,5)</sup> |
| Differential Input Voltage <sup>(Note 6)</sup> | V <sub>ID</sub>                   | +36                                               | V                          |
| Input Common-mode Voltage Range                | V <sub>ICM</sub>                  | (V <sub>EE</sub> - 0.3) to (V <sub>EE</sub> + 36) | V                          |
| Operating Voltage                              | V <sub>opr</sub>                  | ±2 to ±18                                         | V                          |
| Operating Temperature                          | T <sub>opr</sub>                  | - 40 to +85                                       | °C                         |
| Storage Temperature                            | T <sub>stg</sub>                  | - 55 to +150                                      | °C                         |
| Maximum Junction Temperature                   | T <sub>Jmax</sub>                 | +150                                              | °C                         |

(Note 1) When used at temperature above T<sub>A</sub>=25°C, reduce by 5.5mW/°C.(Note 2) When used at temperature above T<sub>A</sub>=25°C, reduce by 5.4mW/°C.(Note 3) When used at temperature above T<sub>A</sub>=25°C, reduce by 5.0mW/°C.(Note 4) When used at temperature above T<sub>A</sub>=25°C, reduce by 4.7mW/°C.

(Note 5) Mounted on a FR4 glass epoxy PCB(70mm×70mm×1.6mm).

(Note 6) The differential input voltage is the voltage difference between inverting input and non-inverting input.

Input terminal voltage is set to more than V<sub>EE</sub>.

**Caution:** Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.

**Electrical Characteristics:**

OLM4565xxx (Unless otherwise specified VCC = +15V, VEE = -15V)

| Parameter                                 | Symbol              | Temperature Range | Limit |        |     | Unit   | Conditions                                                                 |
|-------------------------------------------|---------------------|-------------------|-------|--------|-----|--------|----------------------------------------------------------------------------|
|                                           |                     |                   | Min   | Typ    | Max |        |                                                                            |
| Input Offset Voltage <sup>(Note 7)</sup>  | V <sub>IO</sub>     | 25°C              | -     | 0.5    | 1.5 | mV     | R <sub>S</sub> ≤10kΩ                                                       |
| Input Offset Current <sup>(Note 7)</sup>  | I <sub>IO</sub>     | 25°C              | -     | 2      | 50  | nA     | -                                                                          |
| Input Bias Current <sup>(Note 7)</sup>    | I <sub>B</sub>      | 25°C              | -     | 70     | 250 | nA     | -                                                                          |
| Supply Current <sup>(Note 8)</sup>        | I <sub>CC</sub>     | 25°C              | -     | 4.5    | 7   | mA     | R <sub>L</sub> =∞, All Op-Amps<br>+IN=0V                                   |
|                                           |                     | Full range        | -     | -      | 8.5 |        |                                                                            |
| Large Signal Voltage Gain                 | A <sub>V</sub>      | 25°C              | 86    | 100    | -   | dB     | R <sub>L</sub> ≥2kΩ, OUT=±10V                                              |
| Maximum Output Voltage                    | V <sub>OM</sub>     | 25°C              | ±12   | ±14    | -   | V      | R <sub>L</sub> ≥2kΩ                                                        |
|                                           |                     | 25°C              | ±11   | ±12.5  | -   | V      | I <sub>O</sub> =25mA                                                       |
| Input Common-mode Voltage Range           | V <sub>ICM</sub>    | 25°C              | ±12   | ±14    | -   | V      | -                                                                          |
| Output Source Current <sup>(Note 9)</sup> | I <sub>SOURCE</sub> | 25°C              | -     | 130    | -   | mA     | +IN=1V, -IN=0V<br>OUT=-15V<br>1CH is short circuit                         |
| Output Sink Current <sup>(Note 9)</sup>   | I <sub>SINK</sub>   | 25°C              | -     | 160    | -   | mA     | +IN=0V, -IN=1V<br>OUT=+15V<br>1CH is short circuit                         |
| Common-mode Rejection Ratio               | CMRR                | 25°C              | 80    | 100    | -   | dB     | R <sub>L</sub> ≤10kΩ                                                       |
| Power Supply Rejection Ratio              | PSRR                | 25°C              | 82    | 100    | -   | dB     | R <sub>L</sub> ≤10kΩ                                                       |
| Slew Rate                                 | SR                  | 25°C              | -     | 5      | -   | V/μs   | R <sub>L</sub> =2kΩ, C <sub>L</sub> =100pF                                 |
| Unity Gain Frequency                      | f <sub>T</sub>      | 25°C              | -     | 4      | -   | MHz    | R <sub>L</sub> =2kΩ                                                        |
| Gain Bandwidth                            | GBW                 | 25°C              | -     | 10     | -   | MHz    | R <sub>L</sub> =2kΩ, f=100kHz                                              |
| Phase Margin                              | θ                   | 25°C              | -     | 40     | -   | deg    | R <sub>L</sub> =2kΩ                                                        |
| Input Referred Noise Voltage              | V <sub>N</sub>      | 25°C              | -     | 0.6    | -   | μVrms  | A <sub>V</sub> =40dB<br>R <sub>S</sub> =100Ω<br>DIN-AUDIO                  |
|                                           |                     |                   | -     | 5      | -   | nV/√Hz | A <sub>V</sub> =40dB, V <sub>ICM</sub> =0V<br>R <sub>S</sub> =100Ω, f=1kHz |
| Total Harmonic Distortion + Noise         | THD+N               | 25°C              | -     | 0.0002 | -   | %      | A <sub>V</sub> =20dB, f=1kHz<br>OUT=5Vrms                                  |
| Channel Separation                        | CS                  | 25°C              | -     | 110    | -   | dB     | A <sub>V</sub> =40dB, f=1kHz<br>OUT=1Vrms                                  |

(Note 7) Absolute value.

(Note 8) Full range: T<sub>A</sub>=-40°C to +85°C

(Note 9) Please consider the power dissipation when selecting the output current.

When the output terminal is continuously shorted the output current reduces the internal temperature by flushing.

## Description of Electrical Characteristics

Described here are the terms of electric characteristics used in this datasheet. Items and symbols used are also shown. Note that item name, symbol and their meaning may differ from those on other manufacturer's document or general documents.

### 1. Absolute maximum ratings

Absolute maximum rating items indicate the condition which must not be exceeded. Application of voltage in excess of absolute maximum rating or use out of absolute maximum rated temperature environment may cause deterioration of characteristics.

- (1) Supply Voltage ( $V_{CC}/V_{EE}$ )  
Indicates the maximum voltage that can be applied between the positive power supply terminal and negative power supply terminal without deterioration or destruction of characteristics of internal circuit.
- (2) Differential Input Voltage ( $V_{ID}$ )  
Indicates the maximum voltage that can be applied between non-inverting and inverting terminals without damaging the IC.
- (3) Input Common-mode Voltage Range ( $V_{ICM}$ )  
Indicates the maximum voltage that can be applied to the non-inverting and inverting terminals without deterioration or destruction of electrical characteristics. Input common-mode voltage range of the maximum ratings does not assure normal operation of IC. For normal operation, use the IC within the input common-mode voltage range characteristics.
- (4) Power dissipation ( $P_D$ )  
Indicates the power that can be consumed by the IC when mounted on a specific board at the ambient temperature 25°C (normal temperature). As for package product,  $P_D$  is determined by the temperature that can be permitted by the IC in the package (maximum junction temperature) and the thermal resistance of the package.

### 2. Electrical characteristics item

- (1) Input Offset Voltage ( $V_{IO}$ )  
Indicates the voltage difference between non-inverting terminal and inverting terminals. It can be translated into the input voltage difference required for setting the output voltage at 0 V.
- (2) Input Offset Current ( $I_{IO}$ )  
Indicates the difference of input bias current between the non-inverting and inverting terminals.
- (3) Input Bias Current ( $I_B$ )  
Indicates the current that flows into or out of the input terminal. It is defined by the average of input bias currents at the non-inverting and inverting terminals.
- (4) Supply Current ( $I_{CC}$ )  
Indicates the current that flows within the IC under specified no-load conditions.
- (5) Large Signal Voltage Gain ( $A_V$ )  
Indicates the amplifying rate (gain) of output voltage against the voltage difference between non-inverting terminal and inverting terminal. It is normally the amplifying rate (gain) with reference to DC voltage.  
 $A_V = (\text{Output voltage}) / (\text{Differential Input voltage})$
- (6) Maximum Output Voltage ( $V_{OM}$ )  
Indicates the voltage range that the IC can output under specified load condition. It is typically divided into high-level output voltage and low-level output voltage. High-level output voltage indicates the upper limit of output voltage. Low-level output voltage indicates the lower limit.
- (7) Input Common-mode Voltage Range ( $V_{ICM}$ )  
Indicates the input voltage range where IC operates normally.
- (8) Output Source Current/ Output Sink Current ( $I_{SOURCE} / I_{SINK}$ )  
The maximum current that can be output from the IC under specific output conditions. The output source current indicates the current flowing out from the IC, and the output sink current indicates the current flowing into the IC.
- (9) Common-mode Rejection Ratio (CMRR)  
Indicates the ratio of fluctuation of input offset voltage when the input common-mode voltage is changed. It is normally the fluctuation of DC.  
 $CMRR = (\text{Change of Input common-mode voltage}) / (\text{Input offset fluctuation})$
- (10) Power Supply Rejection Ratio (PSRR)  
Indicates the ratio of fluctuation of input offset voltage when supply voltage is changed. It is normally the fluctuation of DC.  
 $PSRR = (\text{Change of power supply voltage}) / (\text{Input offset fluctuation})$
- (11) Slew Rate (SR)  
Indicates the ratio of the change in output voltage with time when a step input signal is applied.
- (12) Unity Gain Frequency ( $f_T$ )  
Indicates a frequency where the voltage gain of operational amplifier is 1.
- (13) Gain Bandwidth (GBW)  
Indicates to multiply by the frequency and the gain where the voltage gain decreases 6dB/octave.
- (14) Phase Margin ( $\theta$ )  
Indicates the margin of phase from 180 degree phase lag at unity gain frequency.
- (15) Input Referred Noise Voltage ( $V_N$ )  
Indicates a noise voltage generated inside the operational amplifier reflected back to an ideal voltage source connected in series with the input terminal.

- (16) Total Harmonic Distortion + Noise (THD+N)  
Indicates the fluctuation of input offset voltage or that of output voltage with reference to the change of output voltage of driven channel.
- (17) Channel Separation (CS)  
Indicates the fluctuation in the output voltage of the driven channel with reference to the change of output voltage of the channel which is not driven.

### Typical Performance Curves

#### OLM4565xxx

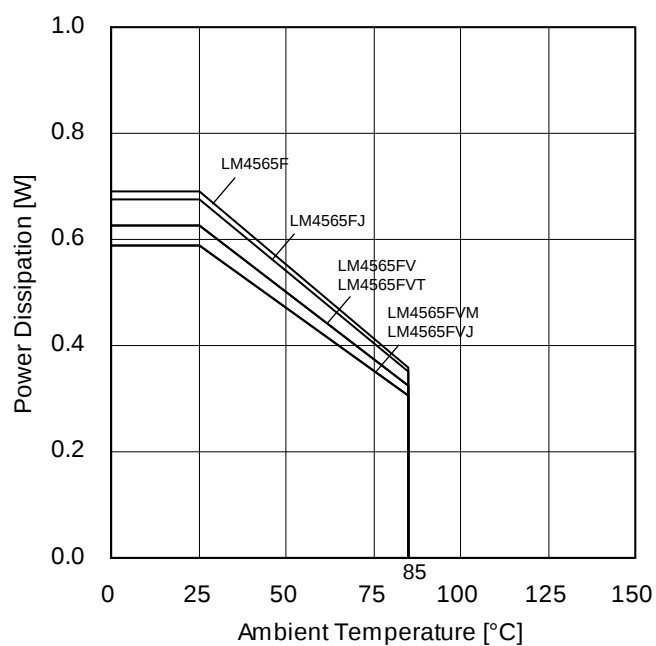


Figure 2.  
Power Dissipation vs Ambient Temperature  
(Derating Curve)

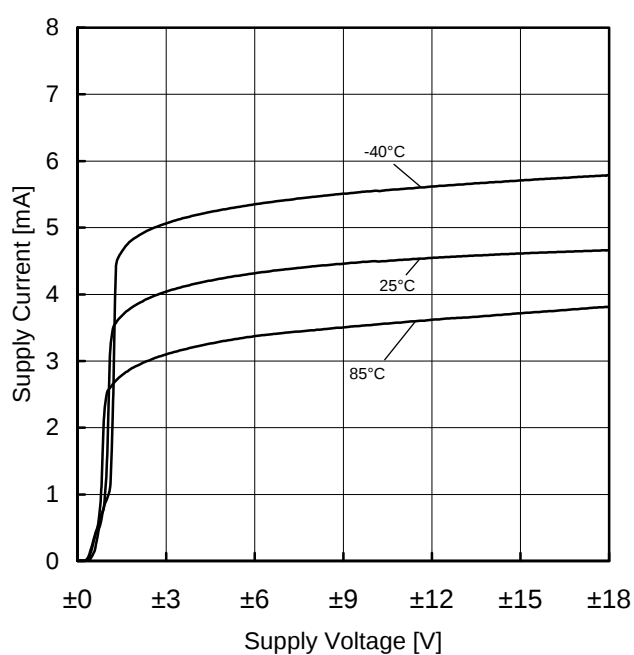


Figure 3.  
Supply Current vs Supply Voltage

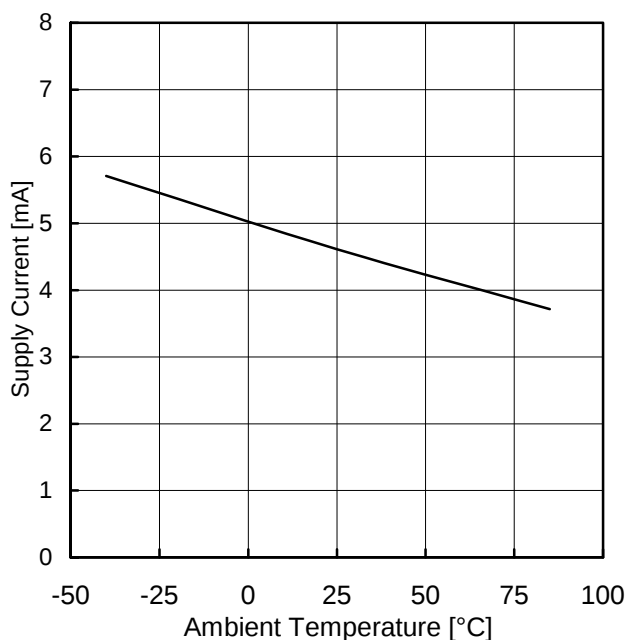


Figure 4.  
Supply Current vs Ambient Temperature  
(VCC/VEE=±15V)

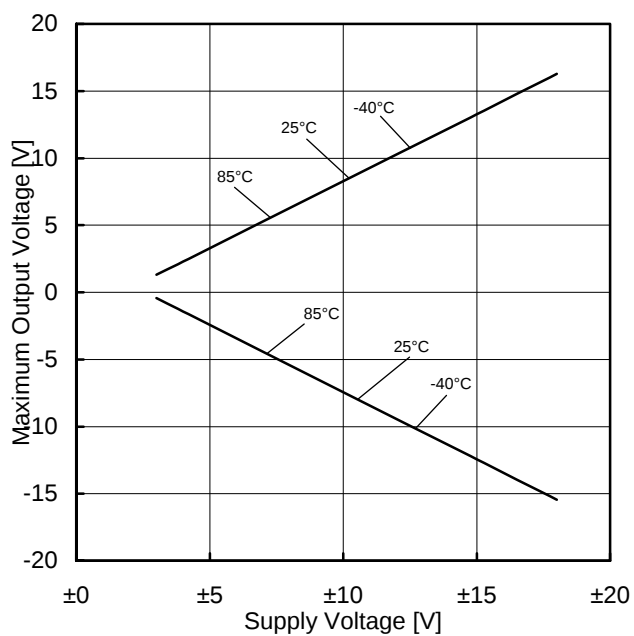


Figure 5.  
Maximum Output Voltage vs Supply Voltage  
( $R_L=2k\Omega$ ,  $T_A=25^\circ\text{C}$ )

(\*)The above characteristics are measurements of typical sample, they are not guaranteed.

# Typical Performance Curves (Reference data) – continued

## OLM4565xxx

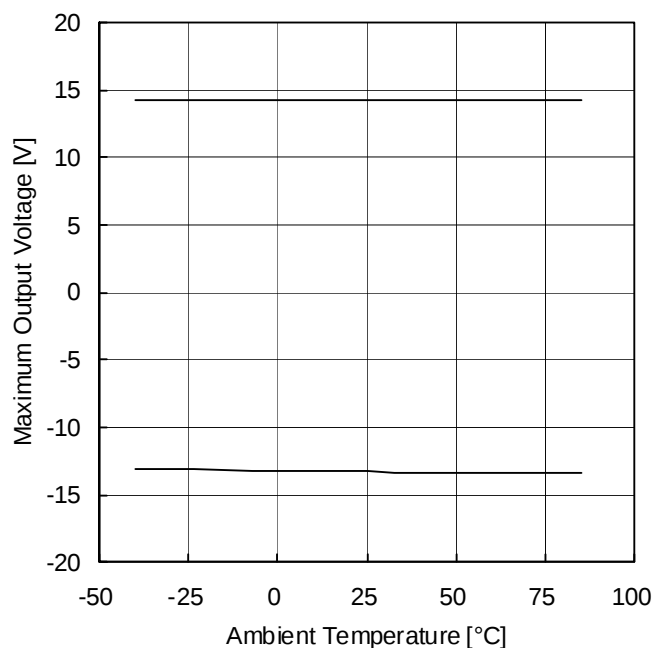


Figure 6.  
Maximum Output Voltage vs Ambient Temperature  
( $V_{CC}/V_{EE}=\pm 15V$ ,  $R_L=2K\Omega$ )

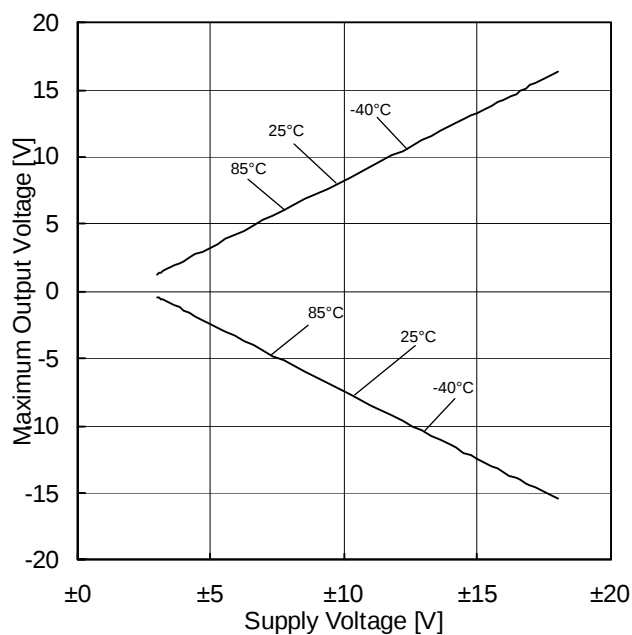


Figure 7.  
Maximum Output Voltage vs Supply Voltage  
( $I_O=25mA$ ,  $T_A=25^\circ C$ )

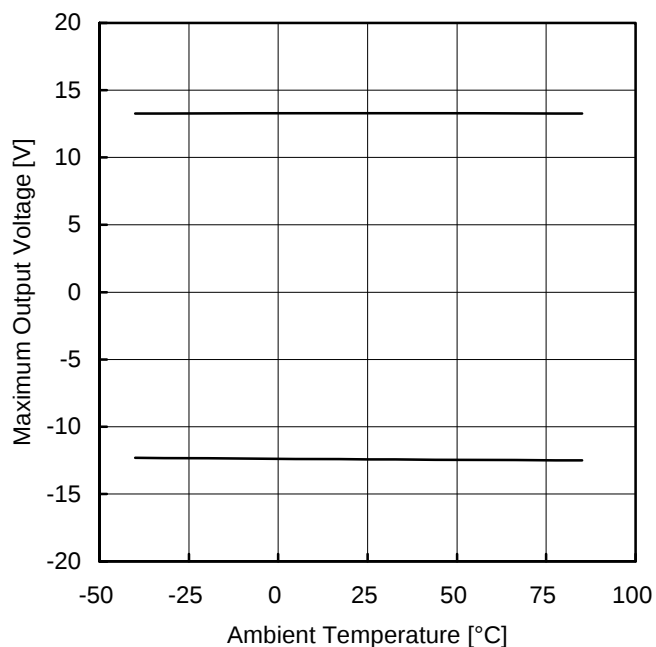


Figure 8.  
Maximum Output Voltage vs Ambient Temperature  
( $V_{CC}/V_{EE}=\pm 15V$ ,  $I_O=25mA$ )

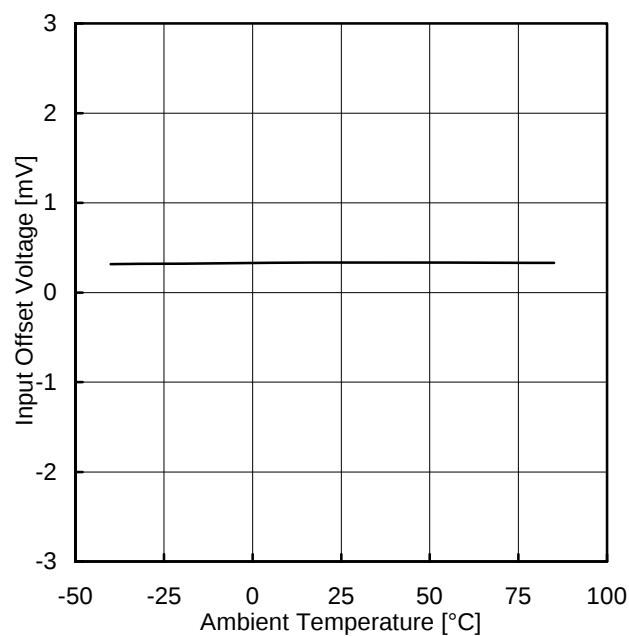


Figure 9.  
Input Offset Voltage vs Ambient Temperature  
( $V_{CC}/V_{EE}=\pm 15V$ )

(\*)The above characteristics are measurements of typical sample, they are not guaranteed.

# Typical Performance Curves (Reference data) – continued

## OLM4565xxx

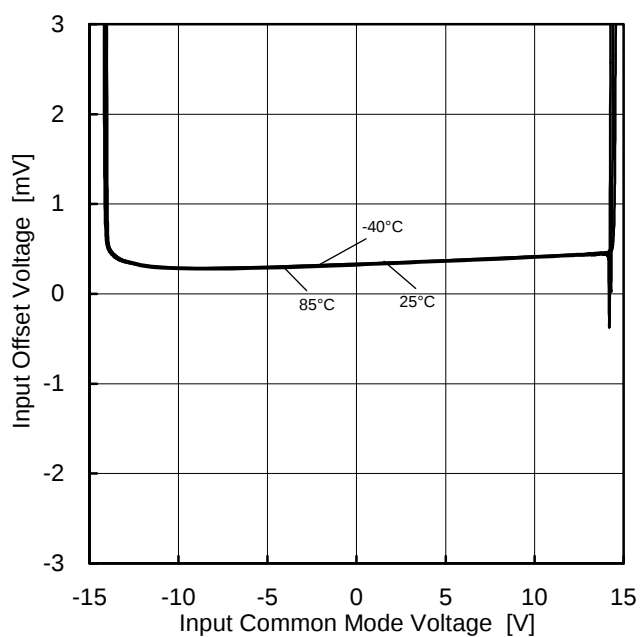


Figure 10.  
Input Offset Voltage vs Input Common mode Voltage  
(VCC/VEE=±15V)

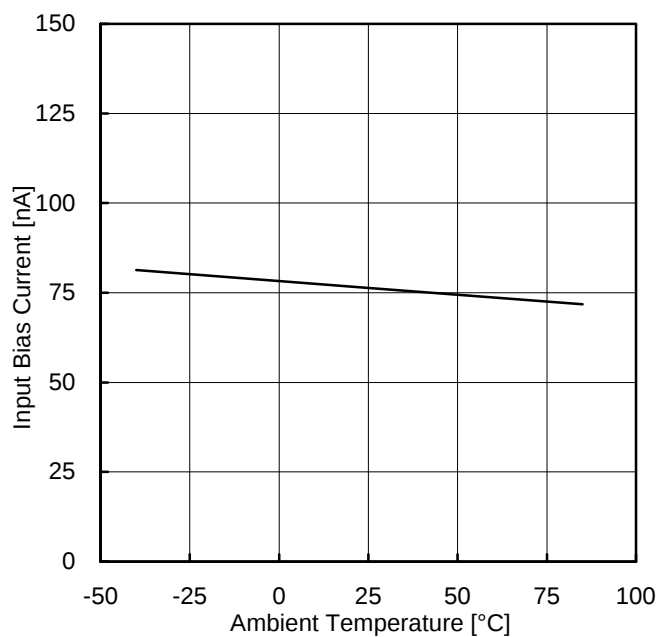


Figure 11.  
Input Bias Current vs Ambient Temperature  
(VCC/VEE=±15V)

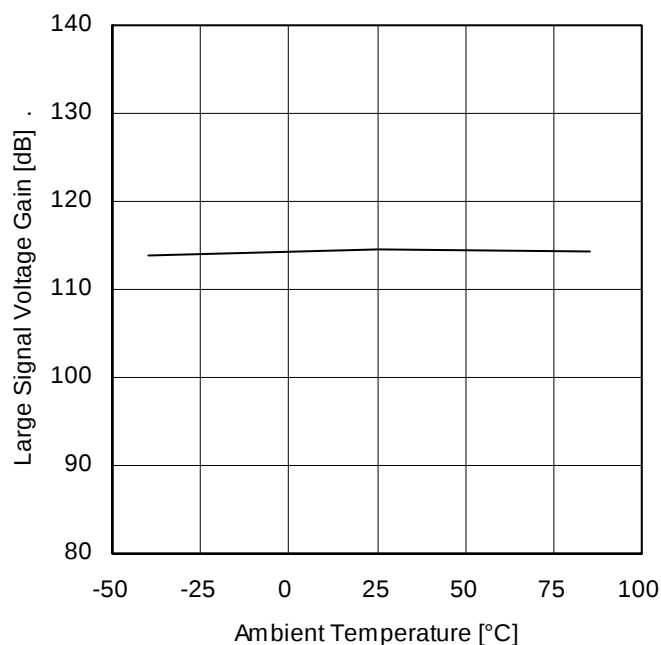


Figure 12.  
Large Signal Voltage Gain vs Ambient Temperature  
(VCC/VEE=±15V, R<sub>L</sub>=2kΩ)

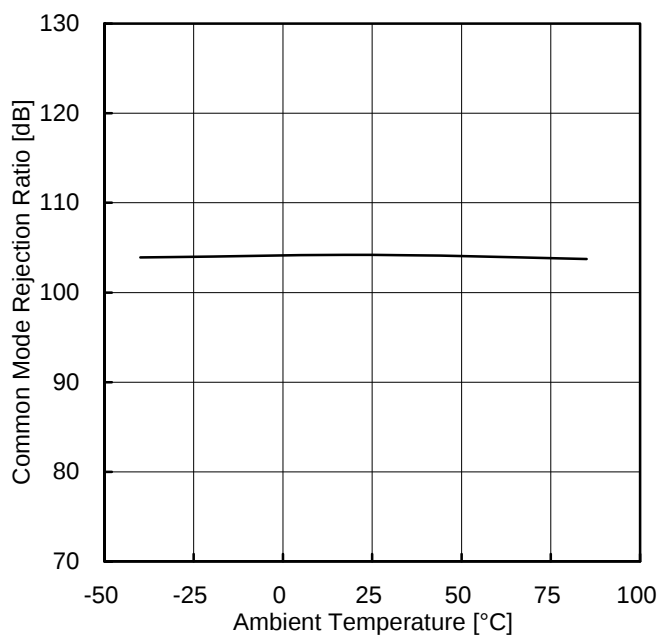


Figure 13.  
Common Mode Rejection Ratio vs Ambient Temperature  
(VCC/VEE=±15V)

(\*)The above characteristics are measurements of typical sample, they are not guaranteed.

# Typical Performance Curves (Reference data) - continued

## OLM4565xxx

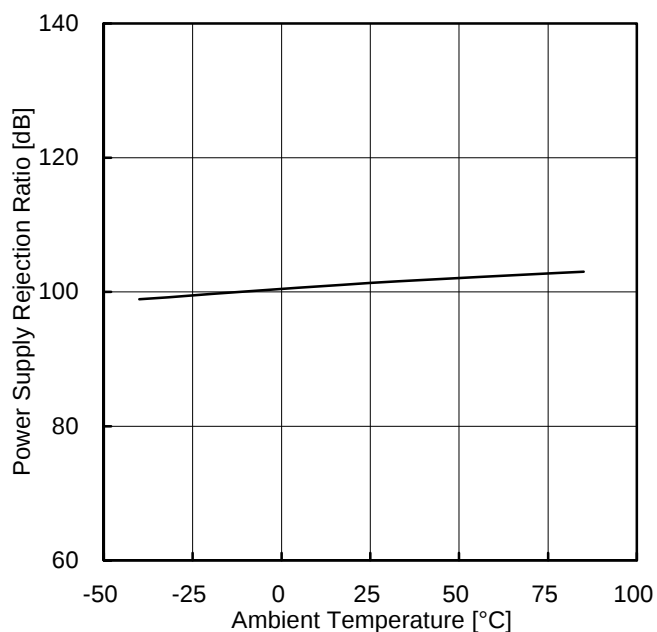


Figure 14.  
Power Supply Rejection Ratio vs Ambient Temperature

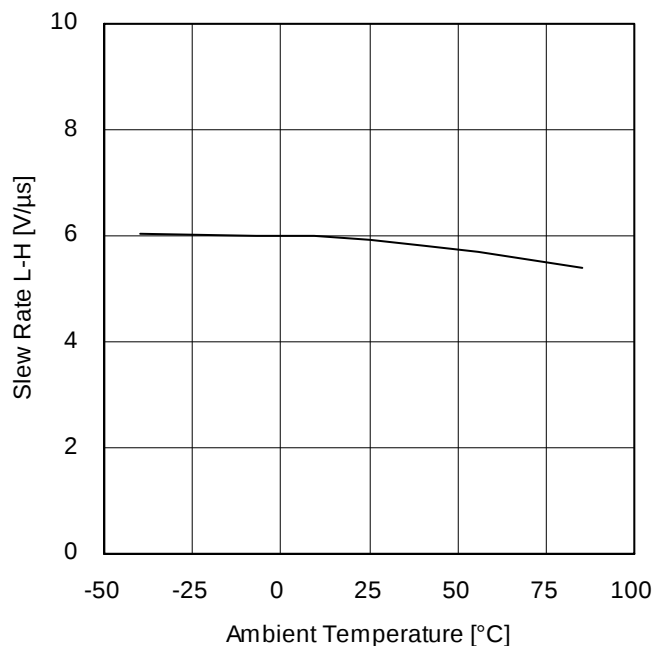


Figure 15.  
Slew Rate L-H vs Ambient Temperature  
(VCC/VEE=±15V, R<sub>L</sub>=2kΩ, C<sub>L</sub>=100pF)

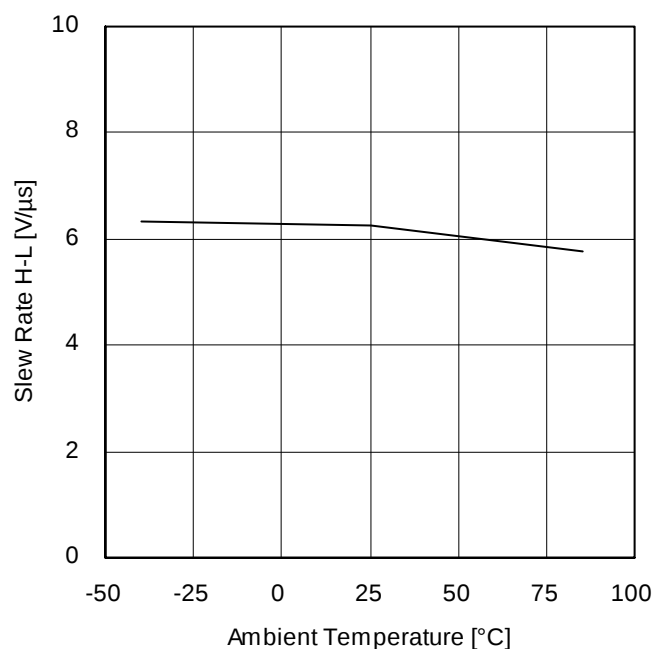


Figure 16.  
Slew Rate H-L vs Ambient Temperature  
(VCC/VEE=±15V, R<sub>L</sub>=2kΩ, C<sub>L</sub>=100pF)

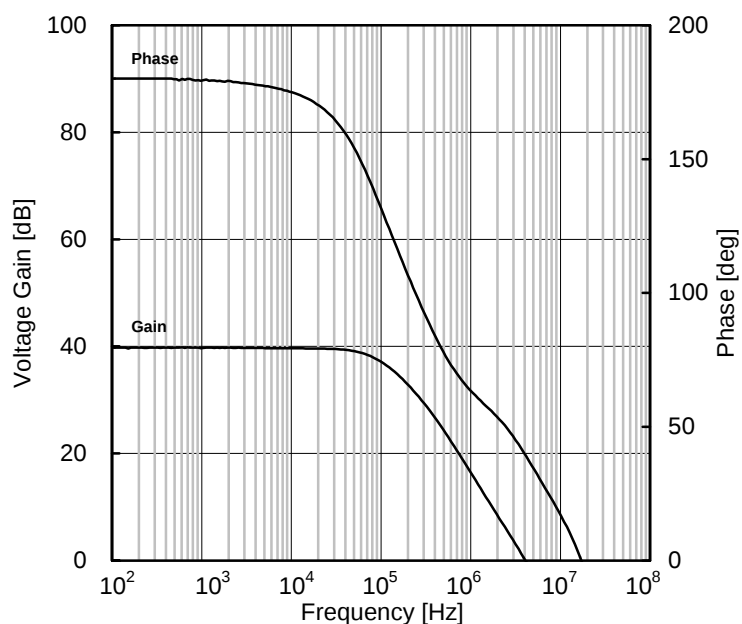


Figure 17.  
Voltage Gain • Phase vs Frequency  
(VCC/VEE=±15V, R<sub>L</sub>=2kΩ)

(\*)The above characteristics are measurements of typical sample, they are not guaranteed.

# Typical Performance Curves (Reference data) - continued

## OLM4565xxx

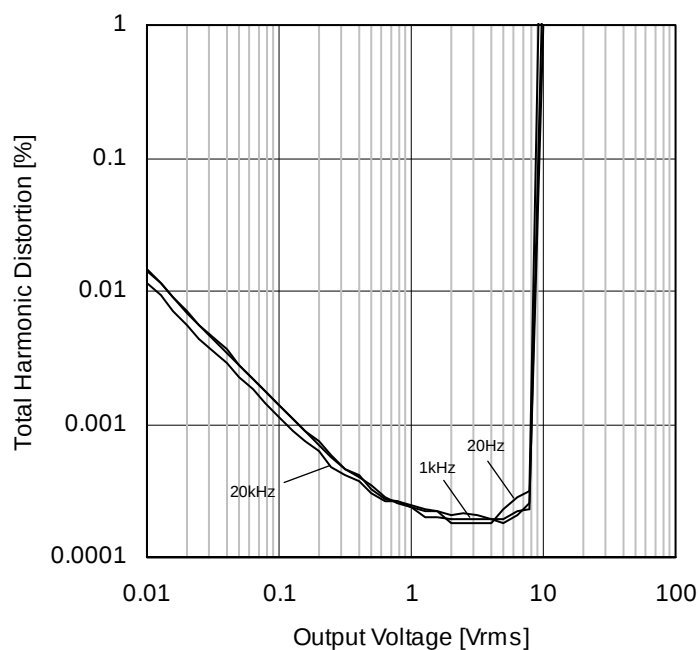


Figure 18.  
Total Harmonic Distortion vs Output Voltage  
(VCC/VEE=±15V,  $R_L=2k\Omega$ ,  $f=1kHz$ )

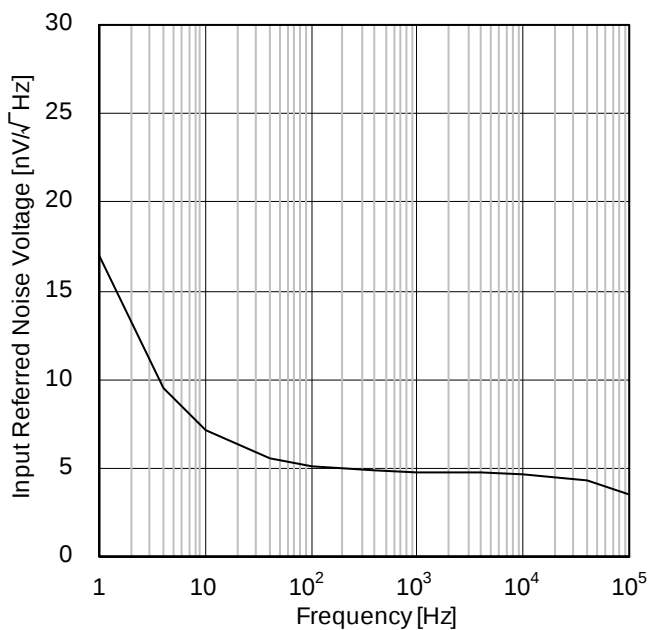


Figure 19.  
Input Referred Noise Voltage vs Frequency  
(VCC/VEE=±15V,  $T_A=25^\circ C$ ,  $A_v=40dB$ )

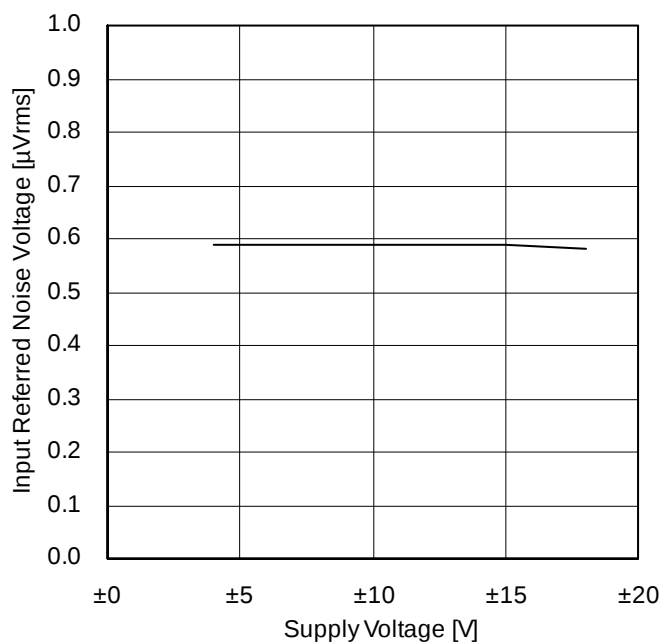


Figure 20.  
Input Referred Noise Voltage vs Supply Voltage  
( $T_A=25^\circ C$ , DIN-AUDIO)

(\*)The above characteristics are measurements of typical sample, they are not guaranteed.

Application Information  
NULL method condition for Test Circuit 1

| VCC, VEE, E <sub>K</sub> , V <sub>ICM</sub> Unit:V               |                 |    |    |     |     |     |                |                  |             |
|------------------------------------------------------------------|-----------------|----|----|-----|-----|-----|----------------|------------------|-------------|
| Parameter                                                        | V <sub>F</sub>  | S1 | S2 | S3  | VCC | VEE | E <sub>K</sub> | V <sub>ICM</sub> | Calculation |
| Input Offset Voltage                                             | V <sub>F1</sub> | ON | ON | OFF | 15  | -15 | 0              | 0                | 1           |
| Large Signal Voltage Gain                                        | V <sub>F2</sub> | ON | ON | ON  | 15  | -15 | -10            | 0                | 2           |
|                                                                  | V <sub>F3</sub> |    |    |     |     |     | 10             |                  |             |
| Common Mode Rejection Ratio<br>(Input Common-mode Voltage Range) | V <sub>F4</sub> | ON | ON | OFF | 15  | -15 | 0              | -10              | 3           |
|                                                                  | V <sub>F5</sub> |    |    |     |     |     | 0              | 10               |             |
| Power Supply Rejection Ratio                                     | V <sub>F6</sub> | ON | ON | OFF | 4   | -4  | 0              | 0                | 4           |
|                                                                  | V <sub>F7</sub> |    |    |     | 18  | -18 |                |                  |             |

— Calculation —

1. Input Offset Voltage (V<sub>IO</sub>)

$$V_{IO} = \frac{|V_{F1}|}{1+R_F/R_S} \text{ [V]}$$
2. Large Signal Voltage Gain (A<sub>V</sub>)

$$A_V = 20\text{Log} \frac{\Delta E_K \times (1+R_F/R_S)}{|V_{F2}-V_{F3}|} \text{ [dB]}$$
3. Common-mode Rejection Ratio (CMRR)

$$\text{CMRR} = 20\text{Log} \frac{\Delta V_{ICM} \times (1+R_F/R_S)}{|V_{F4} - V_{F5}|} \text{ [dB]}$$
4. Power Supply Rejection Ratio (PSRR)

$$\text{PSRR} = 20\text{Log} \frac{\Delta V_{CC} \times (1+R_F/R_S)}{|V_{F6} - V_{F7}|} \text{ [dB]}$$

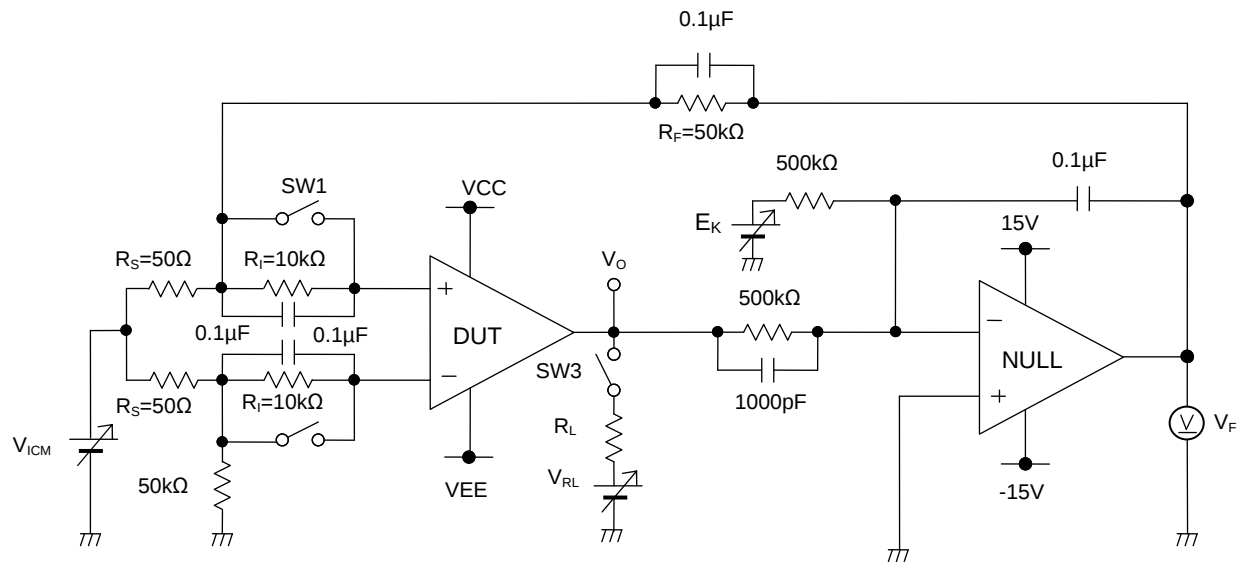


Figure21. Test Circuit 1

Switch Condition for Test Circuit 2

| SW No.                                | SW1 | SW2 | SW3 | SW4 | SW5 | SW6 | SW7 | SW8 | SW9 | SW10 | SW11 | SW12 |
|---------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|
| Supply Current                        | OFF | OFF | ON  | OFF | ON  | OFF | OFF | OFF | OFF | OFF  | OFF  | OFF  |
| Maximum Output Voltage $R_L=2k\Omega$ | OFF | ON  | OFF | OFF | ON  | OFF | OFF | ON  | OFF | OFF  | ON   | OFF  |
| Slew Rate                             | OFF | OFF | ON  | OFF | OFF | OFF | ON  | OFF | ON  | OFF  | OFF  | ON   |
| Maximum Frequency                     | ON  | OFF | OFF | ON  | ON  | OFF | OFF | OFF | ON  | OFF  | OFF  | ON   |

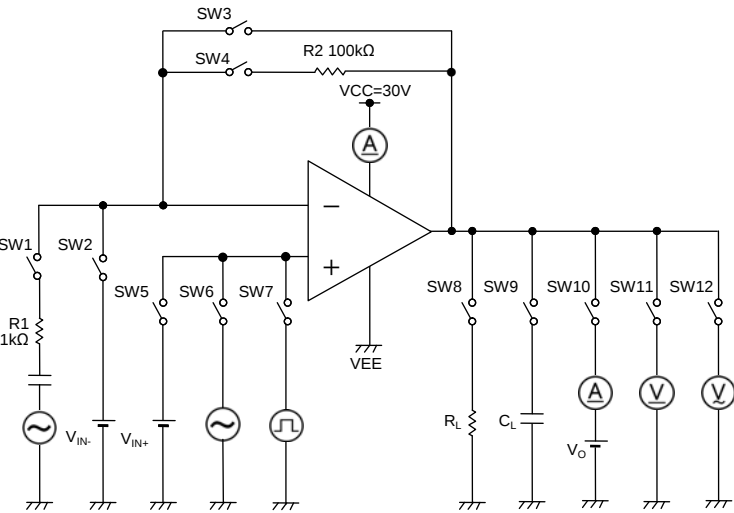


Figure 22. Test Circuit2

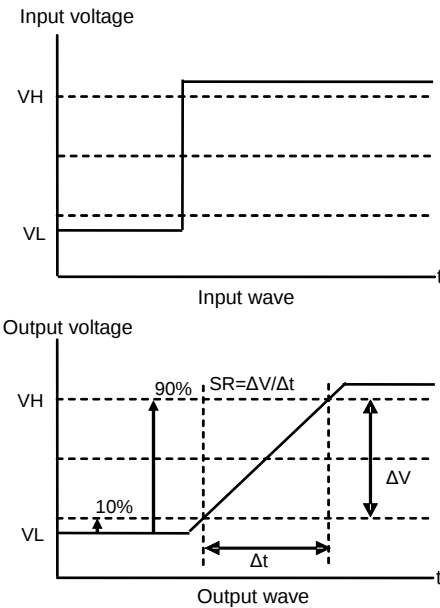


Figure 23. Slew Rate Input Output Wave

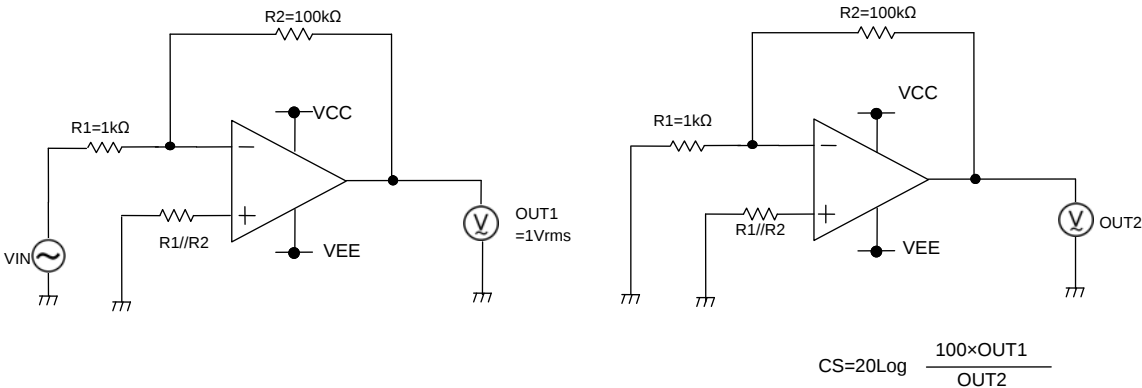


Figure 24. Test Circuit 3 (Channel Separation)

**Application Example**

## ○Voltage Follower

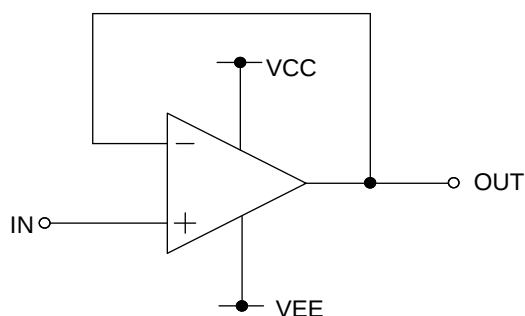


Figure 25. Voltage Follower

Voltage gain is 0dB.

Using this circuit, the output voltage (OUT) is controlled to be equal to the input voltage (IN). This circuit also stabilizes OUT due to high input impedance and low output impedance. Computation for OUT is shown below.

$$OUT = IN$$

## ○Inverting Amplifier

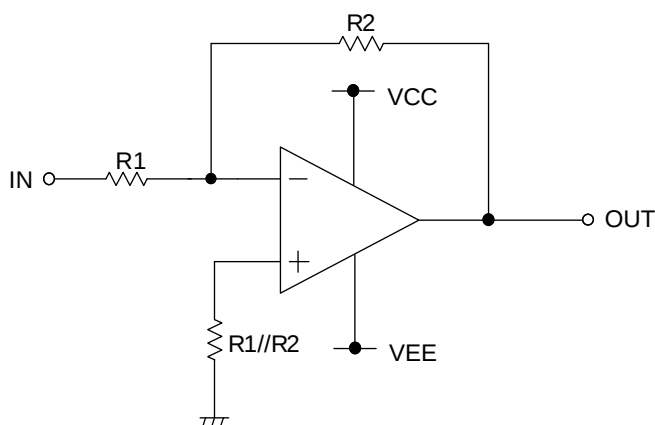


Figure 26. Inverting Amplifier Circuit

For inverting amplifier, IN is amplified by a voltage gain decided by the ratio of R1 and R2. The out-of-phase output voltage is shown in the next expression.

$$OUT = -(R2/R1) \cdot IN$$

This circuit has input impedance equal to R1.

## ○Non-inverting amplifier

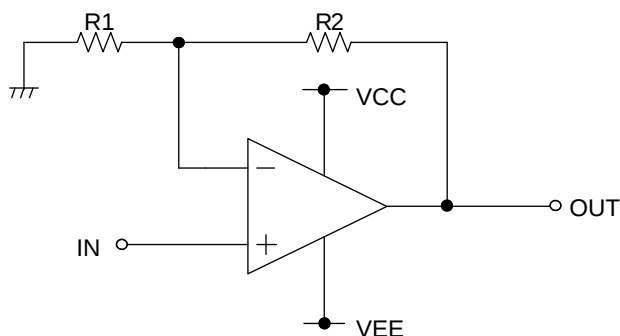


Figure 27. Non-inverting Amplifier Circuit

For non-inverting amplifier, IN is amplified by a voltage gain decided by the ratio of R1 and R2. OUT is in-phase with Vin and is shown in the next expression.

$$OUT = (1 + R2/R1) \cdot IN$$

Effectively, this circuit has high input impedance since its input side is the same as that of the operational amplifier.

## Power Dissipation

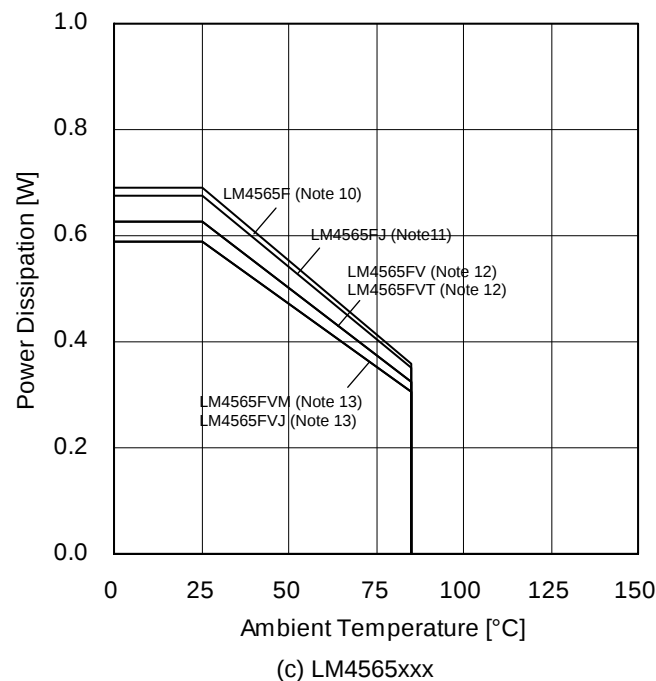
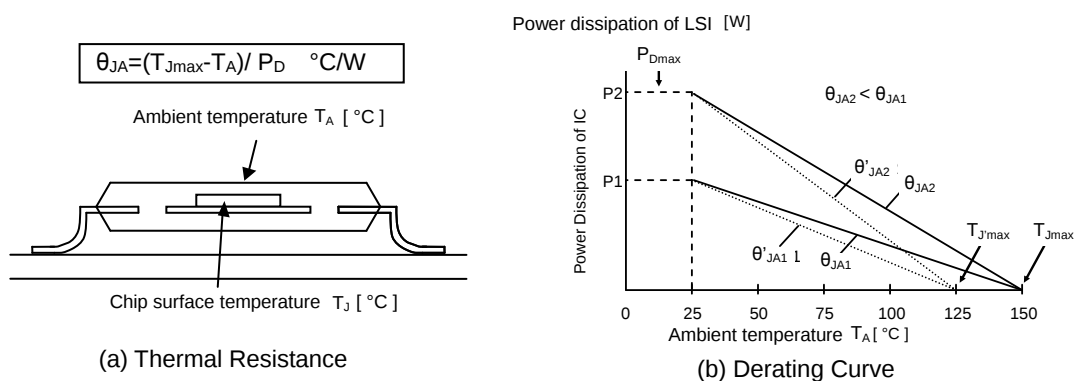
Power dissipation (total loss) indicates the power that the IC can consume at  $T_A=25^{\circ}\text{C}$  (normal temperature). As the IC consumes power, it heats up, causing its temperature to be higher than the ambient temperature. The allowable temperature that the IC can accept is limited. This depends on the circuit configuration, manufacturing process, and consumable power.

Power dissipation is determined by the allowable temperature within the IC (maximum junction temperature) and the thermal resistance of the package used (heat dissipation capability). Maximum junction temperature is typically equal to the maximum storage temperature. The heat generated through the consumption of power by the IC radiates from the mold resin or lead frame of the package. Thermal resistance, represented by the symbol  $\theta_{JA}$   $^{\circ}\text{C/W}$ , indicates this heat dissipation capability. Similarly, the temperature of an IC inside its package can be estimated by thermal resistance.

Figure 28(a) shows the model of the thermal resistance of the package. The equation below shows how to compute for the Thermal resistance ( $\theta_{JA}$ ), given the ambient temperature ( $T_A$ ), maximum junction temperature ( $T_{Jmax}$ ), and power dissipation ( $P_D$ ).

$$\theta_{JA} = (T_{Jmax} - T_A) / P_D \quad ^{\circ}\text{C/W} \quad \dots \dots (I)$$

The derating curve in Figure 28(b) indicates the power that the IC can consume with reference to ambient temperature. Power consumption of the IC begins to attenuate at certain temperatures. This gradient is determined by Thermal resistance ( $\theta_{JA}$ ), which depends on the chip size, power consumption, package, ambient temperature, package condition, wind velocity, etc. This may also vary even when the same of package is used. Thermal reduction curve indicates a reference value measured at a specified condition. Figure 28(c) shows an example of the derating curve for LM4565xxx.



| (Note 10) | (Note 11) | (Note 12) | (Note 13) | Unit  |
|-----------|-----------|-----------|-----------|-------|
| 5.5       | 5.4       | 5.0       | 4.7       | mW/°C |

When using the unit above  $T_A=25^{\circ}\text{C}$ , subtract the value above per  $^{\circ}\text{C}$ . Permissible dissipation is the value when FR4 glass epoxy board 70mm×70mm×1.6mm (copper foil area below 3%) is mounted

Figure 28. Thermal Resistance and Derating Curve

**Operational Notes****1. Reverse Connection of Power Supply**

Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

**2. Power Supply Lines**

Design the PCB layout pattern to provide low impedance supply lines. Separate the ground and supply lines of the digital and analog blocks to prevent noise in the ground and supply lines of the digital block from affecting the analog block. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

**3. Ground Voltage**

Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition.

**4. Ground Wiring Pattern**

When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

**5. Thermal Consideration**

Should by any chance the power dissipation rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. The absolute maximum rating of the  $P_D$  stated in this specification is when the IC is mounted on a 70mm x 70mm x 1.6mm glass epoxy board. In case of exceeding this absolute maximum rating, increase the board size and copper area to prevent exceeding the  $P_D$  rating.

**6. Recommended Operating Conditions**

These conditions represent a range within which the expected characteristics of the IC can be approximately obtained. The electrical characteristics are guaranteed under the conditions of each parameter.

**7. Inrush Current**

When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

**8. Operation Under Strong Electromagnetic Field**

Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

**9. Testing on Application Boards**

When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

**10. Inter-pin Short and Mounting Errors**

Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

## Operational Notes – continued

**11. Regarding the Input Pin of the IC**

This monolithic IC contains P+ isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example (refer to figure below):

When  $GND > Pin A$  and  $GND > Pin B$ , the P-N junction operates as a parasitic diode.

When  $GND > Pin B$ , the P-N junction operates as a parasitic transistor.

Parasitic diodes inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

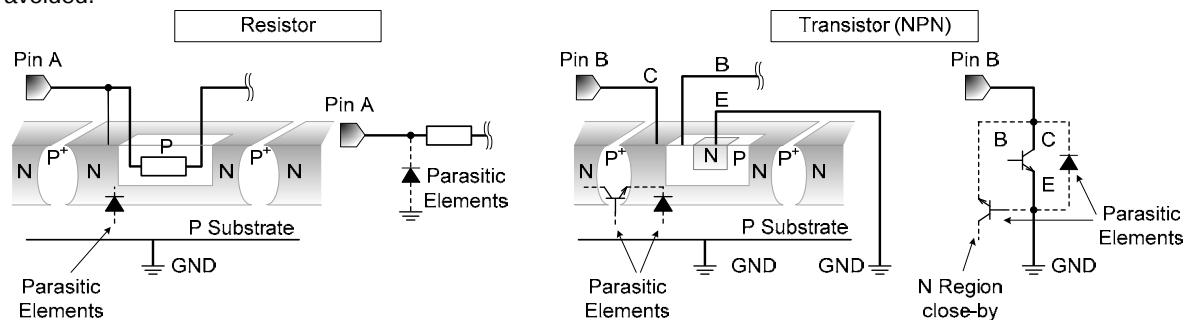


Figure 29. Example of monolithic IC structure

**12. Unused Circuits**

It is recommended to apply the connection (see Figure 30.) and set the non-inverting input terminal at a potential within the Input Common-mode Voltage Range ( $V_{ICM}$ ) for any unused circuit.

**13. Input Voltage**

Applying  $VEE + 36V$  to the input terminal is possible without causing deterioration of the electrical characteristics or destruction, regardless of the supply voltage. However, this does not ensure normal circuit operation. Please note that the circuit operates normally only when the input voltage is within the common mode input voltage range of the electric characteristics.

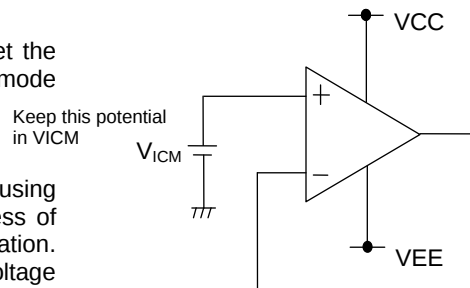


Figure 30. Example of Application Circuit for Unused Op-amp

**14. Power Supply(single/dual)**

The operational amplifier operates when the voltage supplied is between VCC and VEE. Therefore, the single supply operational amplifier can be used as dual supply operational amplifier as well.

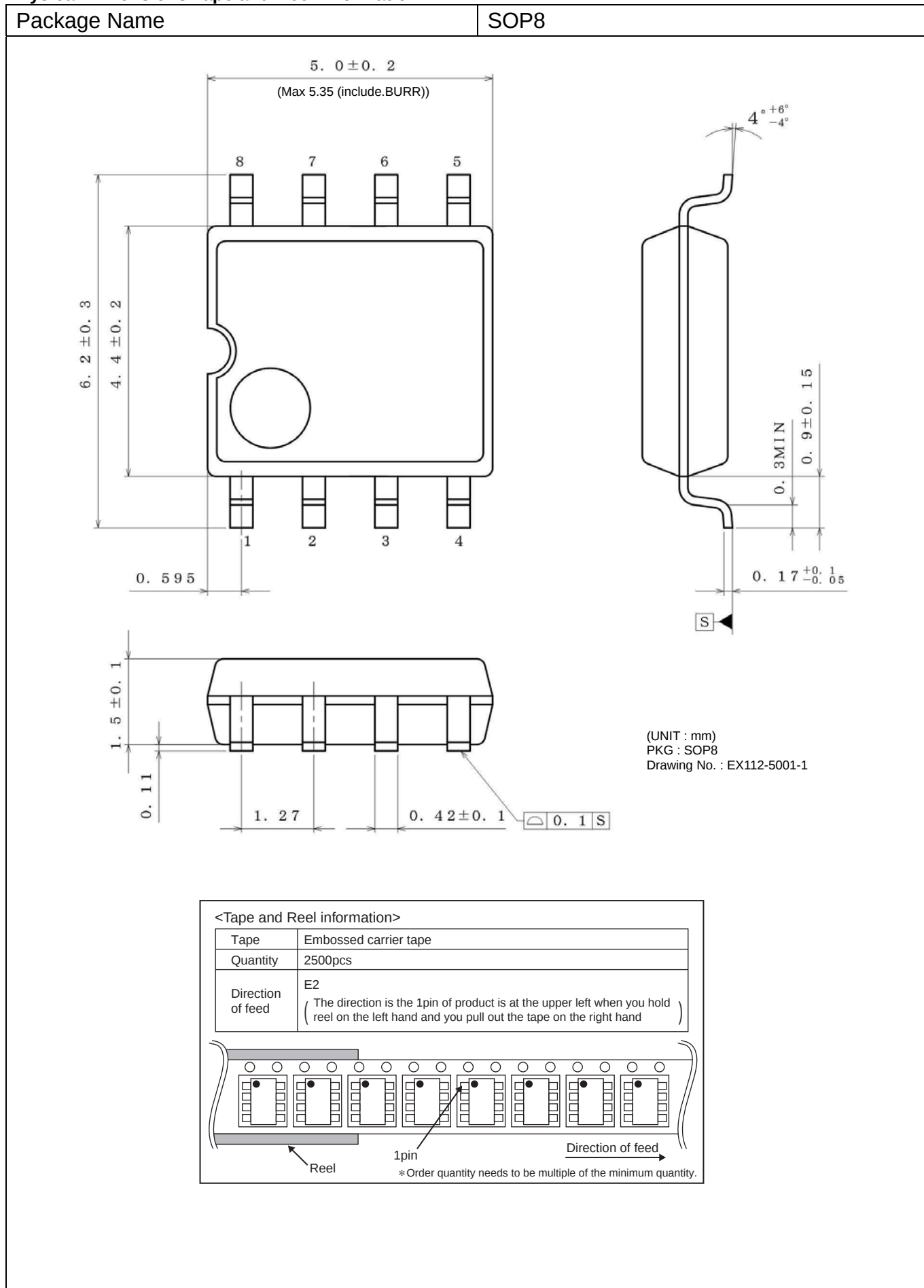
**15. IC Handling**

When pressure is applied to the IC through warp on the printed circuit board, the characteristics may fluctuate due to the piezo effect. Be careful with the warp on the printed circuit board.

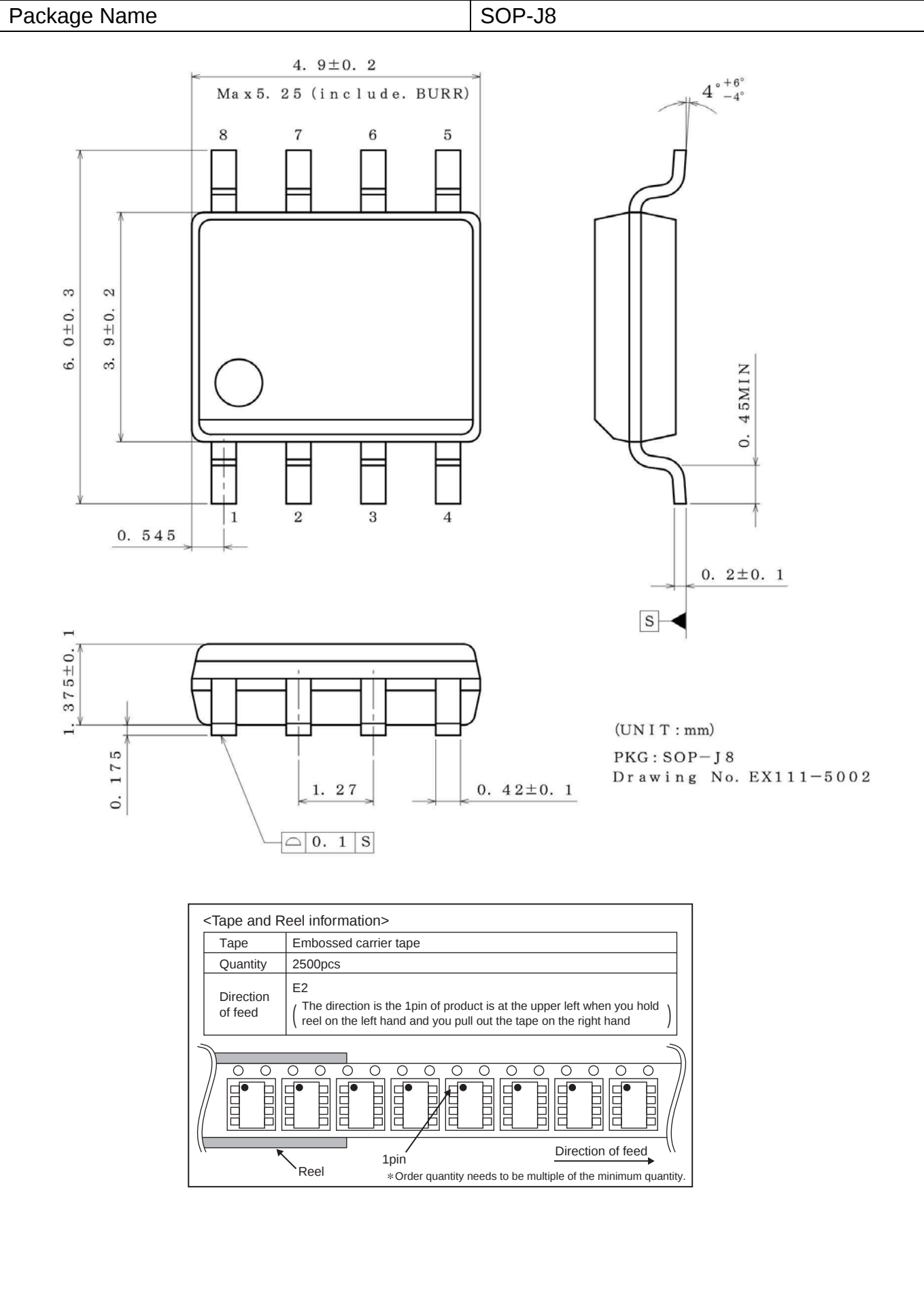
**16. The IC Destruction Caused by Capacitive Load**

The IC may be damaged when VCC terminal and VEE terminal is shorted with the charged output terminal capacitor. When IC is used as an operational amplifier or as an application circuit where oscillation is not activated by an output capacitor, output capacitor must be kept below  $0.1\mu F$  in order to prevent the damage mentioned above.

## Physical Dimensions Tape and Reel Information

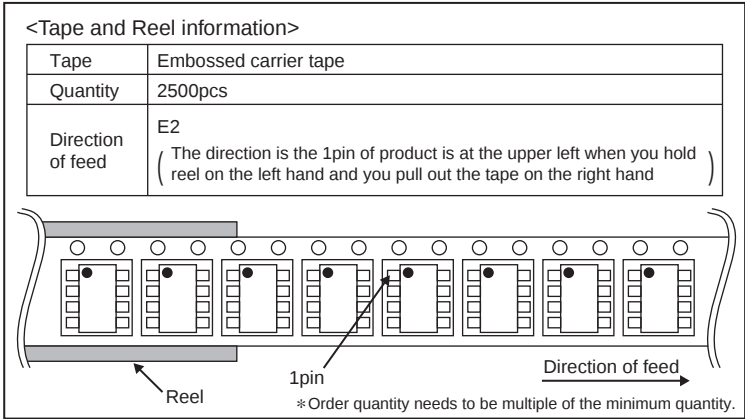
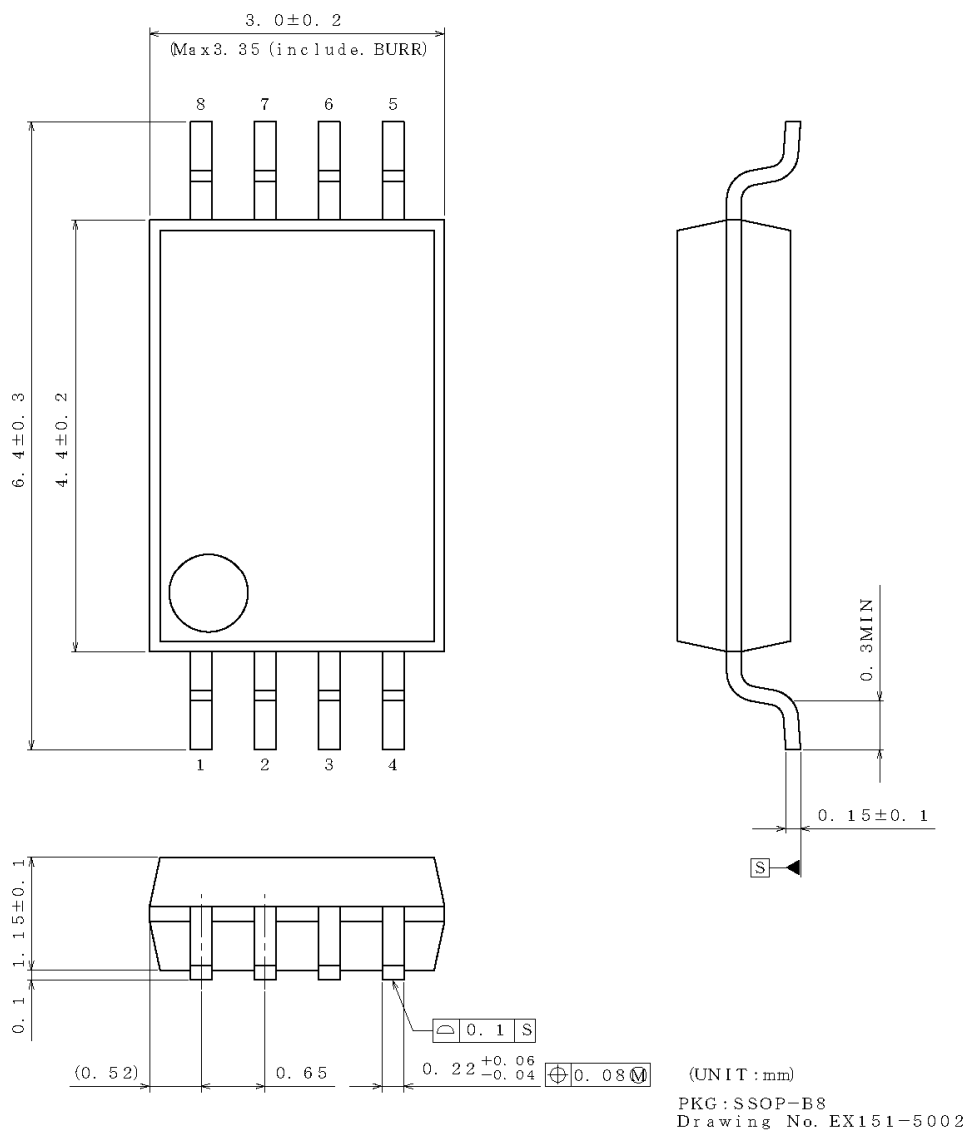


Physical Dimension Tape and Reel Information - continued

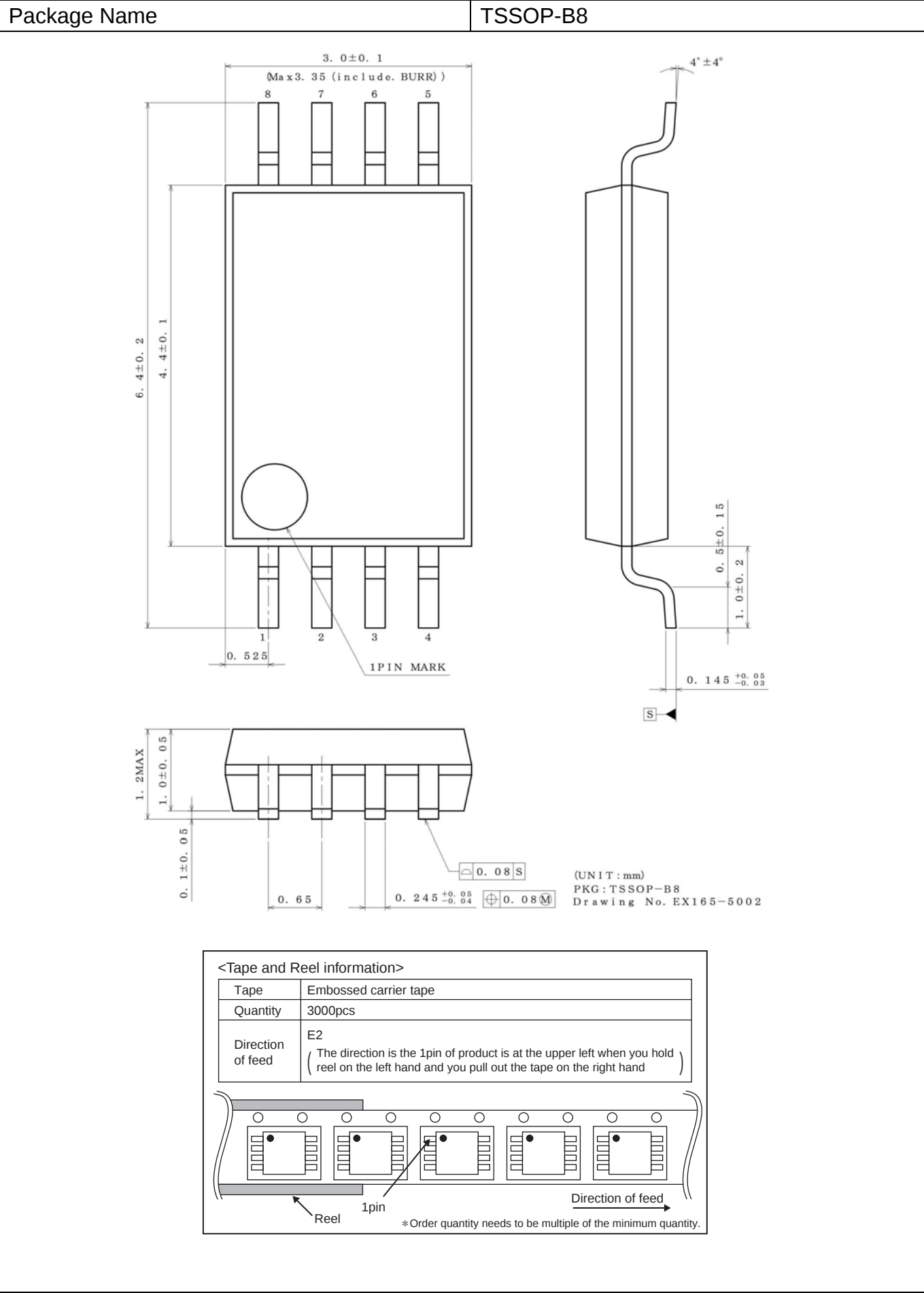


Physical Dimension Tape and Reel Information - continued

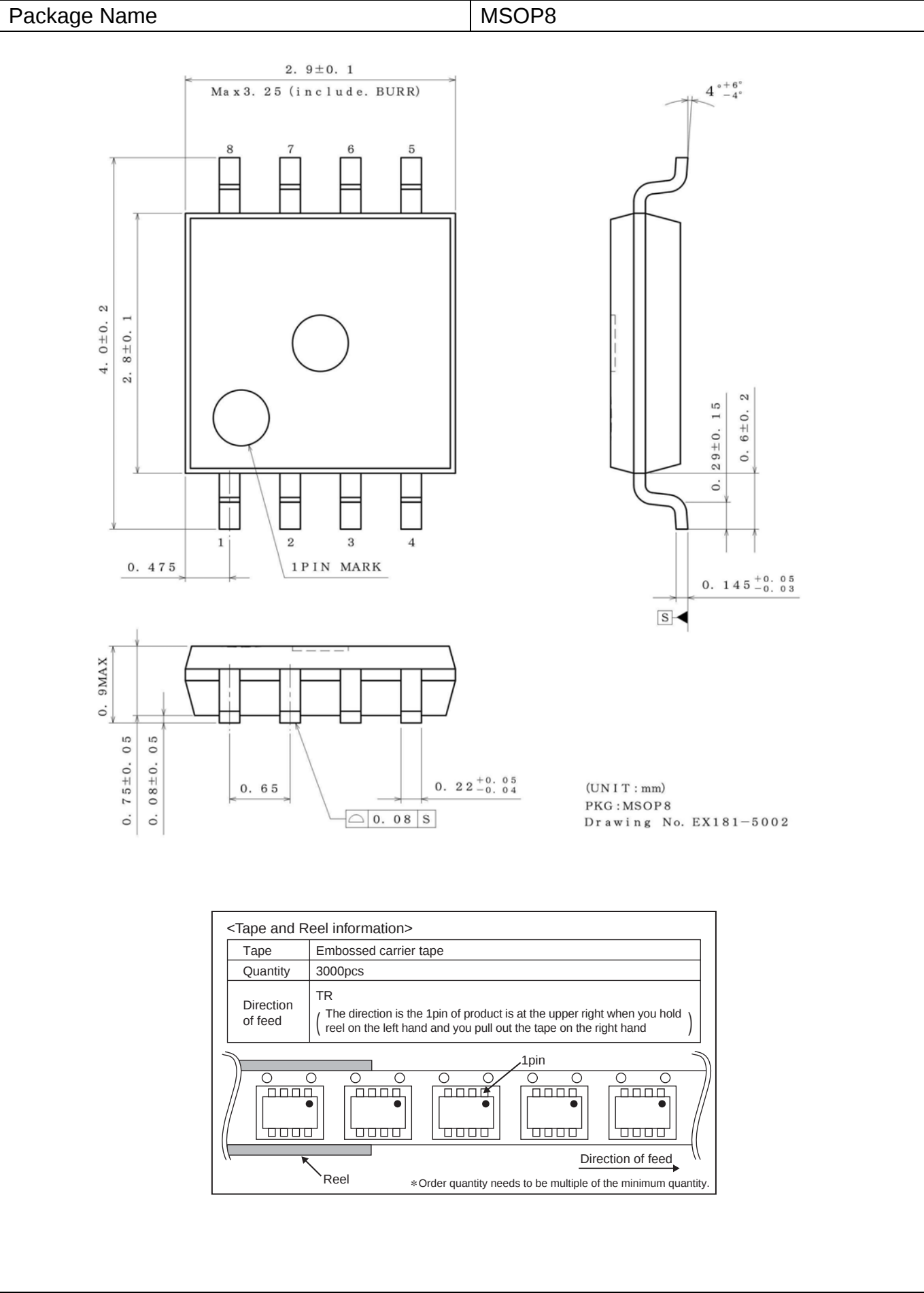
|              |         |
|--------------|---------|
| Package Name | SSOP-B8 |
|--------------|---------|



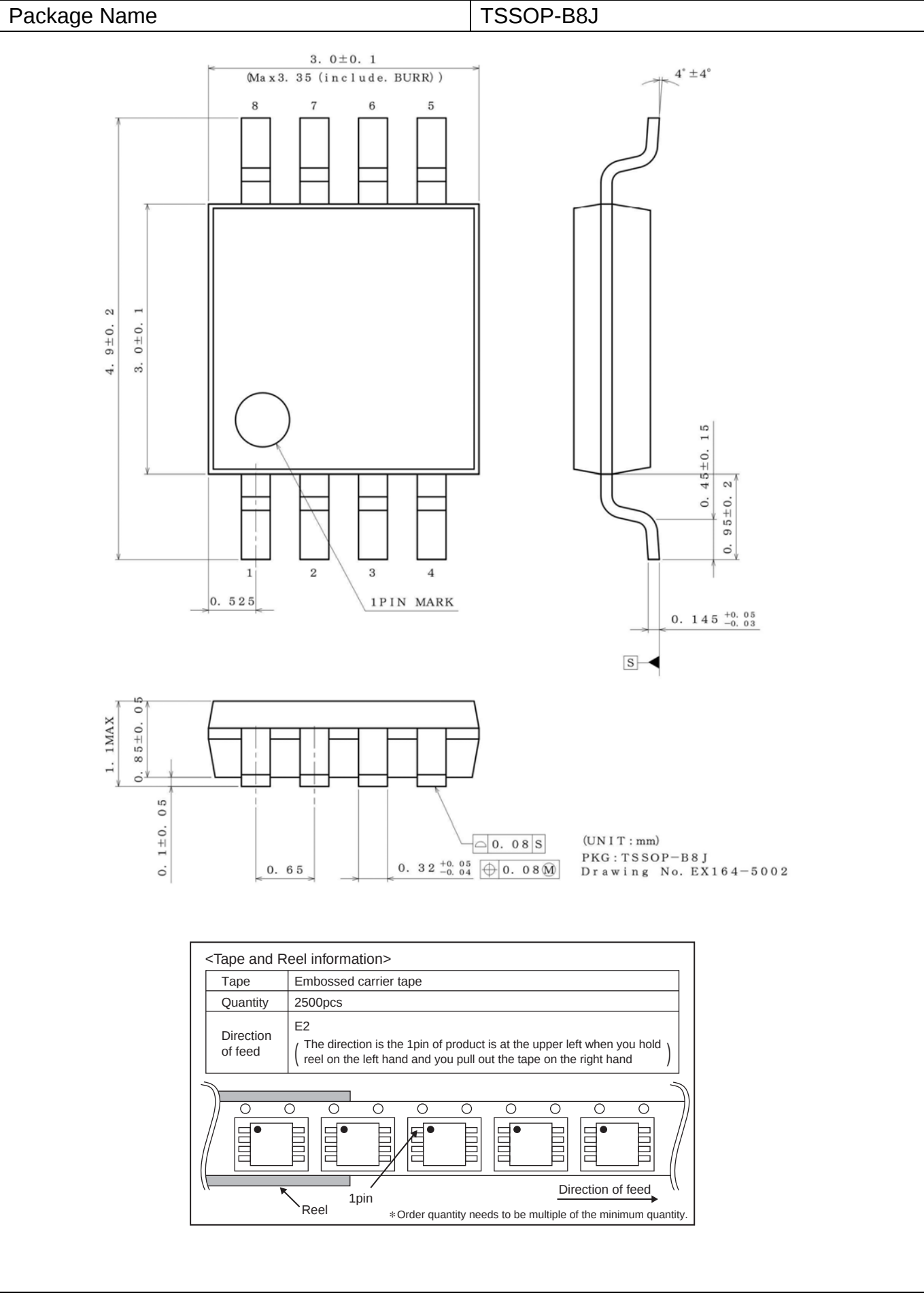
Physical Dimension Tape and Reel Information - continued



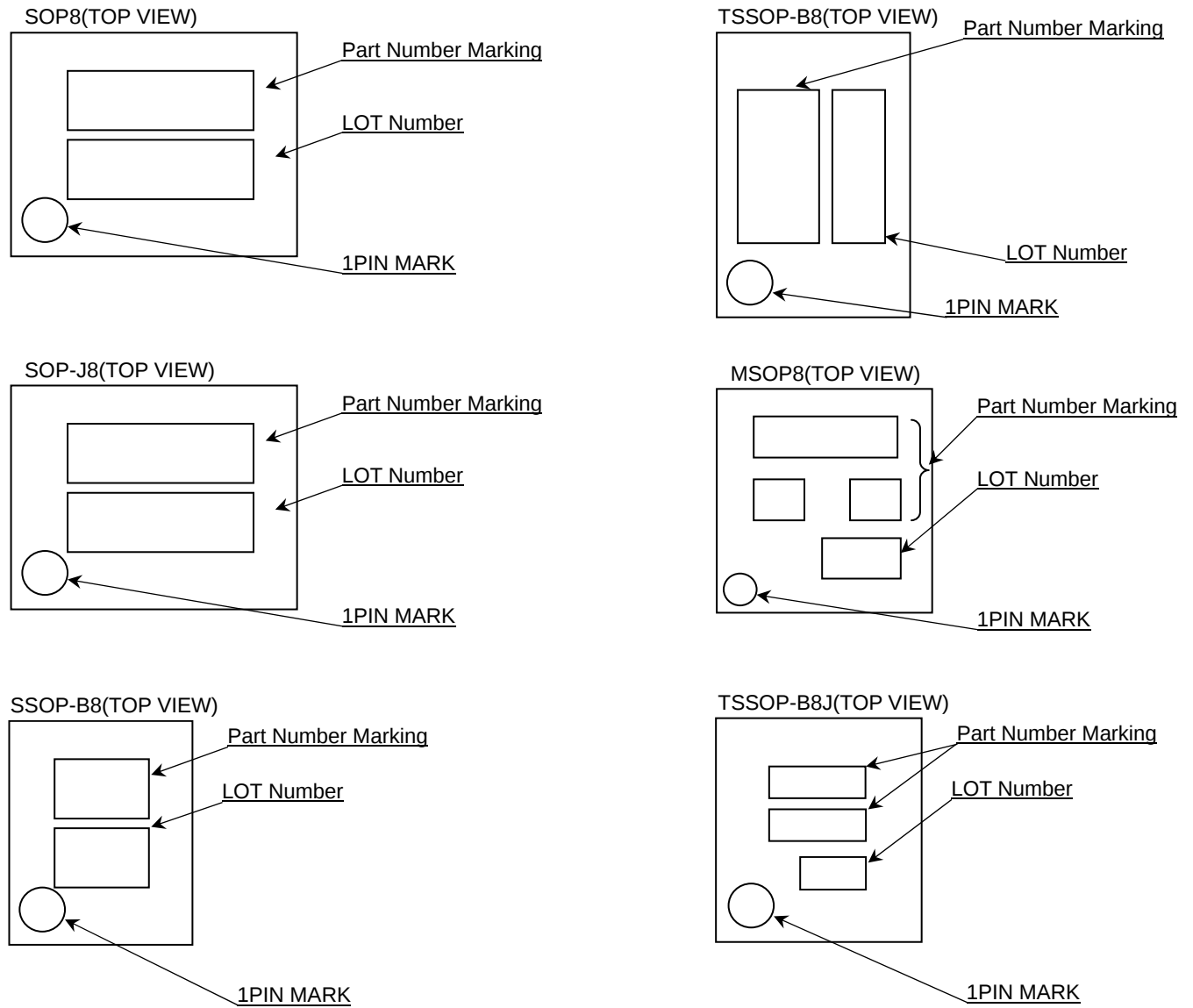
Physical Dimension Tape and Reel Information - continued



Physical Dimension Tape and Reel Information - continued



Marking Diagram

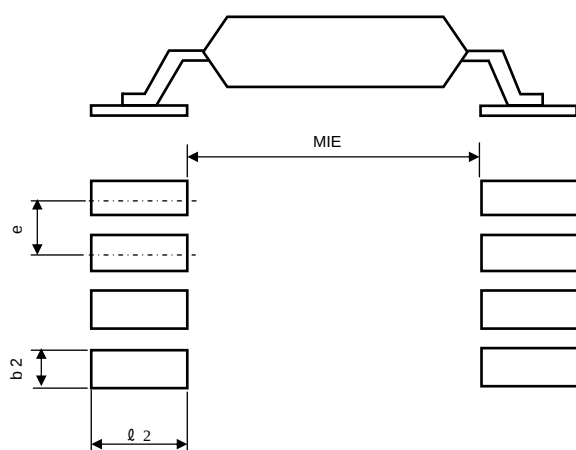


| Product Name |     | Package Type | Marking |
|--------------|-----|--------------|---------|
| LM4565       | F   | SOP8         | 4565    |
|              | FJ  | SOP-J8       | L4565   |
|              | FV  | SSOP-B8      | 4565    |
|              | FVT | TSSOP-B8     | L4565   |
|              | FVM | MSOP8        | L4565   |
|              | FVJ | TSSOP-B8J    | L4565   |

## Land Pattern Data

All dimensions in mm

| PKG       | Land pitch<br>e | Land space<br>MIE | Land length<br>$\geq l_2$ | Land width<br>b2 |
|-----------|-----------------|-------------------|---------------------------|------------------|
| SOP8      | 1.27            | 4.60              | 1.10                      | 0.76             |
| SOP-J8    | 1.27            | 3.90              | 1.35                      | 0.76             |
| SSOP-B8   | 0.65            | 4.60              | 1.20                      | 0.35             |
| TSSOP-B8  | 0.65            | 4.60              | 1.20                      | 0.35             |
| MSOP8     | 0.65            | 2.62              | 0.99                      | 0.35             |
| TSSOP-B8J | 0.65            | 3.20              | 1.15                      | 0.35             |



## Revision History

| Date        | Revision | Changes                                                   |
|-------------|----------|-----------------------------------------------------------|
| 30.Nov.2012 | 001      | New Release                                               |
| 2.Sep.2013  | 002      | Added LM4565FV, LM4565FJ, LM4565FVT, LM4565FVM, LM4565FVJ |
| 15.Apr.2014 | 003      | The Operating Supply Voltage Range is changed.            |

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|-----------|-----------|------------|-----------|
| CLASS III | CLASS III | CLASS II b | CLASS III |
| CLASS IV  |           | CLASS III  |           |

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