# DATA SHEET

# SA58603
## High precision operational amplifier, comparator, and voltage reference

Product data
Supersedes data of 2002 Nov 13

2003 Nov 10

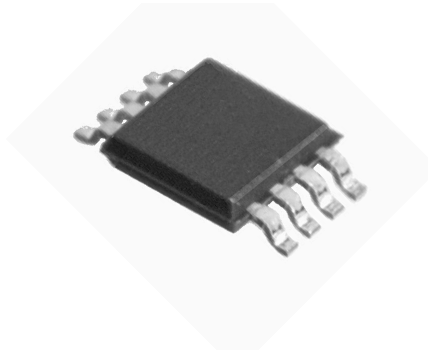
Philips
Semiconductors

PHILIPS

# High precision operational amplifier, comparator, and voltage reference

# SA58603

## GENERAL DESCRIPTION



The SA58603 is comprised of a low voltage, high precision dual operational amplifier, a comparator, and a reference voltage source. The input offset voltage is typically 100 µV with a very low temperature drift of ±1 µV/°C. The SA58603 supply current is typically 100 µA per amplifier and it operates from 1.8 V to 6 V single supply.

Having single power supply capability, low current consumption, low offset voltage, low input offset current and low input bias current, the SA58603 is ideal for battery-powered applications and amplification of very small signals. It is excellent for precision amplifiers in gas burners and gas pilot water heaters which use thermal couple heat sensors.

## FEATURES

### General

- Functionality to 1.8 V typical
- Low supply current: 100 µA per amplifier (typical)

### Amplifier section

- Very low input offset voltage: 100 µV (typical)
- Very low input offset drift: ±1 µV/°C (typical)
- Low input offset current: 1 nA (typical)
- Input bias current: 50 nA (typical)
- Open loop gain: 100 dB (typical)
- Common mode input includes ground

### Comparator section

- Input offset voltage: ±1.0 mV (typical)
- Low input offset voltage voltage drift (–40 to +85 °C): ±10 µV (typical)
- Input bias current: 25 nA (typical)
- Output sink current: 5 mA (minimum)

### Reference voltage section

- Reference voltage: 1.27 V ±50 mV
- Reference voltage temperature characteristics: ±100 ppm/°C (typical)
- Output current: 0.3 mA (minimum)

## APPLICATIONS

- Gas burners
- Gas water heaters
- Tankless gas water heaters

## SIMPLIFIED DEVICE DIAGRAM

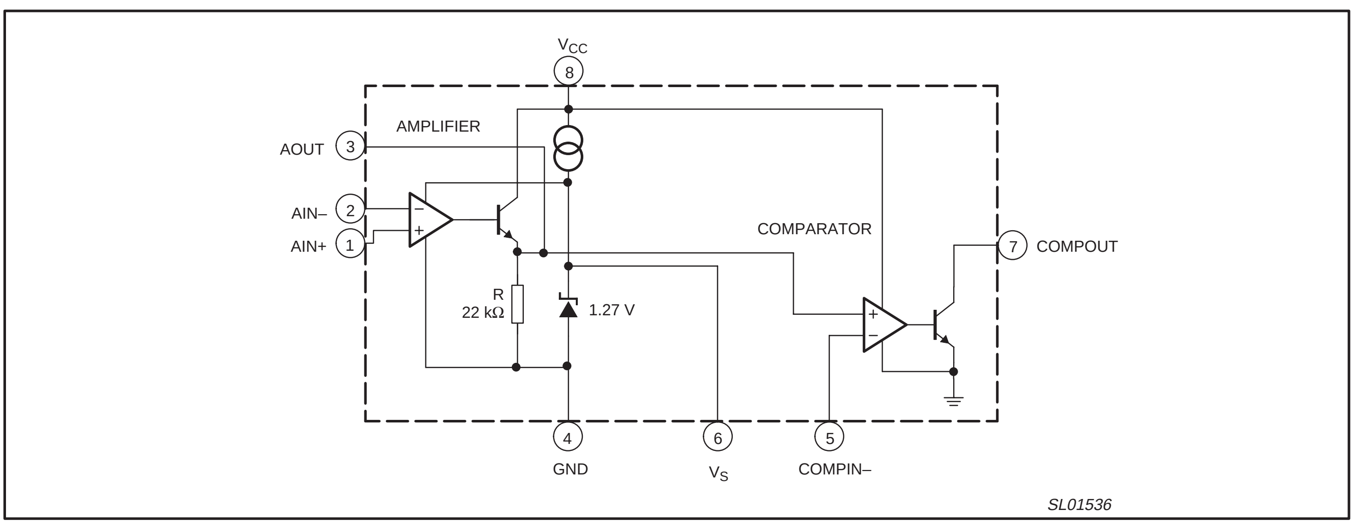



**Figure 1. Simplified device diagram.**

## ORDERING INFORMATION

| TYPE NUMBER | PACKAGE | | | TEMPERATURE RANGE |
|---|---|---|---|---|
| | NAME | DESCRIPTION | VERSION | |
| SA58603D | SO8 | plastic small outline package; 8 leads; body width 3.9 mm | SOP005 | –40 to +85 °C |

## PIN CONFIGURATION

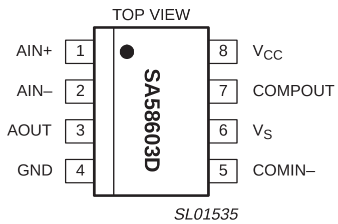
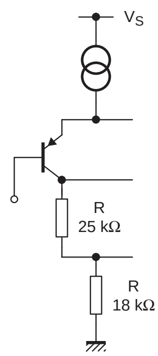
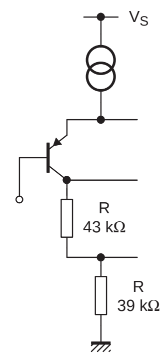
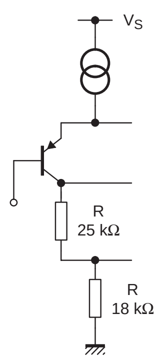
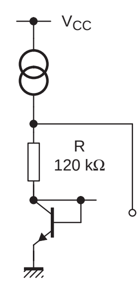
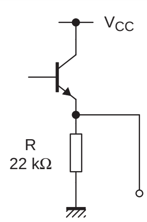
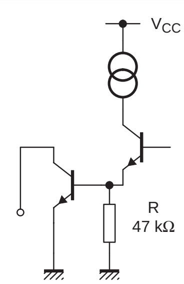



**Figure 2. Pin configuration.**

## PIN DESCRIPTION

| PIN | SYMBOL | DESCRIPTION |
|---|---|---|
| 1 | AIN+ | Non-inverting input of Op Amp. This is a PNP amplifier with the reference voltage as its supply voltage. |
| 2 | AIN– | Inverting input of Op Amp. This is a PNP amplifier with the reference voltage as its supply voltage. |
| 3 | AOUT | Output of Op Amp. This is a NPN emitter follower output with a 22 kΩ internal on-chip pull-down resistor. Its supply voltage is $V_{CC}$. |
| 4 | GND | Ground. |
| 5 | COMPIN– | Inverting input of Comparator. This is a PNP amplifier with $V_{CC}$ as its positive supply voltage. |
| 6 | $V_S$ | Reference voltage output. The output reference is typically 1.27 V. The output reference is derived from the series combination of a NPN transistor (configured as a diode with the base shorted to the collector) and a 120 kΩ resistor. |
| 7 | COMPOUT | Output of Comparator. It is an open collector output stage which requires an external pull-up resistor. |
| 8 | $V_{CC}$ | Positive supply. Its operating range is 1.8 to 6.0 V. |

## EQUIVALENT CIRCUITS

<table>
<tr><th>PIN NUMBER</th><th>PIN NAME</th><th>INTERNAL EQUIVALENT CIRCUIT</th><th>PIN NUMBER</th><th>PIN NAME</th><th>INTERNAL EQUIVALENT CIRCUIT</th></tr>
<tr><td>1</td><td>AIN+</td><td>
</td><td>5</td><td>COMPIN–</td><td>
</td></tr>
<tr><td>2</td><td>AIN–</td><td>
</td><td>6</td><td>$V_S$</td><td>
</td></tr>
<tr><td>3</td><td>AOUT</td><td>
</td><td>7</td><td>COMPOUT</td><td>
</td></tr>
<tr><td>4</td><td>GND</td><td></td><td>8</td><td>$V_{CC}$</td><td></td></tr>
</table>

## MAXIMUM RATINGS

| SYMBOL | PARAMETER | MIN. | MAX. | UNIT |
|---|---|---|---|---|
| $V_{CC}$ | Single supply voltage | –0.3 | +10 | V |
| $V_{IN}$ | Input voltage | –0.3 | +10 | V |
| $T_{stg}$ | Storage temperature | –40 | +125 | °C |
| $T_{amb}$ | Operating temperature | –40 | +85 | °C |
| P | Power dissipation | – | 300 | mW |

## ELECTRICAL CHARACTERISTICS

$V_{CC}$ = 3.0 V, $V_{IN}$ = 0 V, and $T_{amb}$ = 25 °C, unless otherwise specified.

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|---|---|---|---|---|---|---|
| $I_{CC}$ | Supply current | | – | 0.1 | 0.15 | mA |
| $I_{OVS}$ | Reference voltage output current | | 0.3 | – | – | mA |
| $V_S$ | Reference voltage | | 1.22 | 1.27 | 1.32 | V |
| $\Delta V_S$ | Reference voltage temperature drift | | – | ±100 | – | ppm/°C |
| PSRR | Power supply rejection ratio | f = 100 Hz | 50 | 60 | – | dB |
| $V_{CC}$ | Power supply voltage operating range | | 1.8 | 3.0 | 6.0 | V |
| **Amplifier section (note 1)** | | | | | | |
| $V_{INA}$ | Input voltage range | | –0.2 | – | 0.3 | V |
| $V_{IOA}$ | Input offset voltage | | – | ±0.1 | ±0.35 | mV |
| $\Delta V_{IO}/\Delta T$ | Input offset voltage temperature drift | $T_{amb}$ = –20 to +75 °C | – | ±1 | ±3 | µV/°C |
| $I_{IOA}$ | Input offset current | | – | 1 | 10 | nA |
| $I_{i(bias)A}$ | Input bias current | | – | 50 | 150 | nA |
| $G_{v(ol)A}$ | Open-loop voltage gain | | 80 | 100 | – | dB |
| $I_{OA}$ | Output current | $V_{IN}$ = 10 mV; $V_O$ = 0.5 V | 0.5 | – | – | mA |
| $V_{OA}$ | Output voltage swing | $V_{IN}$ = –5 to +25 mV; $R_L$ = 10 kΩ | 0.01 | – | $V_{CC}$ – 1.0 | V |
| **Comparator section (note 2)** | | | | | | |
| $V_{IOC}$ | Input offset voltage | $V_{IN}$ = –5 mV | – | ±1.0 | ±3.5 | mV |
| $\Delta V_{IOC}/\Delta T$ | Input offset voltage temperature drift | $V_{IN}$ = –5 mV | – | ±10 | ±30 | µV/°C |
| $I_{i(bias)C}$ | Input bias current | $V_{IN}$ = –5 mV | – | 25 | 75 | nA |
| $I_{O(sink)}$ | Output sink current | $V_{IN}$ = 10 mV; $V_O$ = 0.4 V | 5 | – | – | mA |
| $I_{LO}$ | Output leakage current | $V_O$ = $V_{CC}$ + 1 V | – | – | 0.2 | µA |
| $V_{SAT}$ | Output saturation voltage | $V_{IN}$ = 10 mV; $I_{O(sink)}$ = 5 mA | – | 200 | 400 | mV |

**NOTES:**
1. Amplifier output is emitter follower with an on-chip 22 kΩ pull-down resistor.
2. Comparator output is open collector; it requires an external pull-up resistor. See application section on how to determine this resistor.

## TYPICAL CHARACTERIZATION CURVES

$T_{amb}$ = 25 °C, $V_{CC}$ = 3 V, $V_{IN}$ = 0 V, unless otherwise specified.

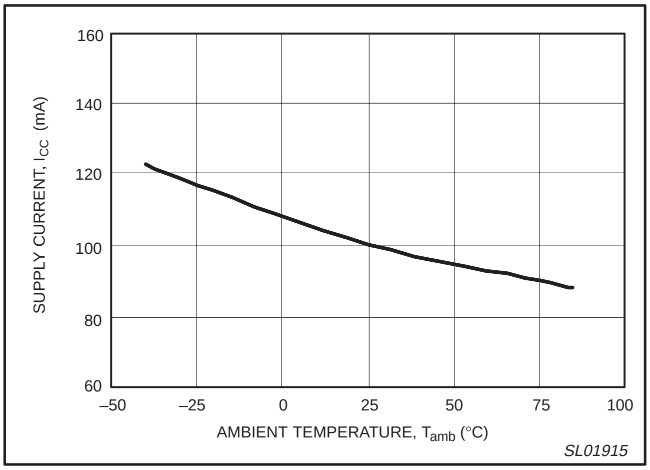



**Figure 3. Supply current versus ambient temperature.**

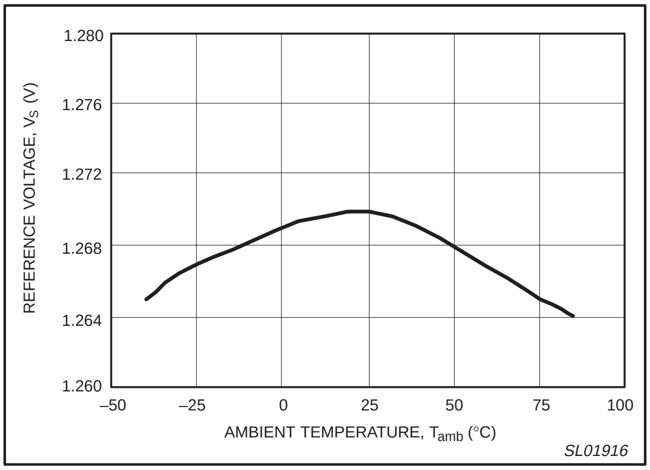



**Figure 4. Reference voltage versus ambient temperature.**

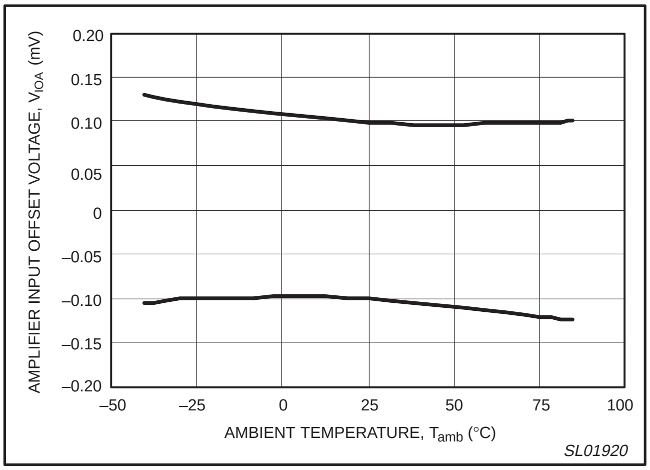



**Figure 5. Amplifier input offset voltage versus ambient temperature.**

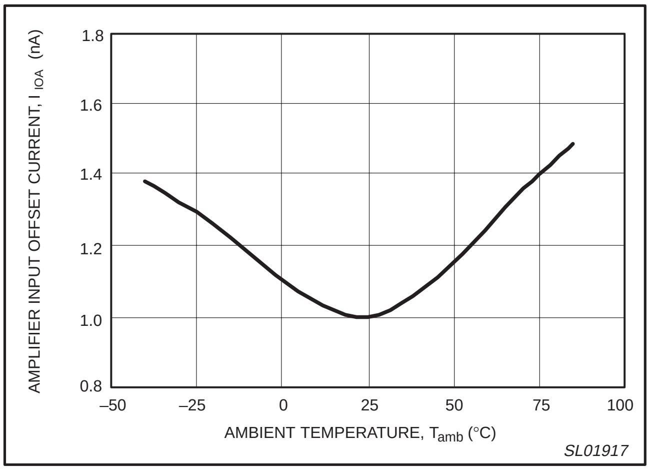



**Figure 6. Amplifier input offset current versus ambient temperature.**

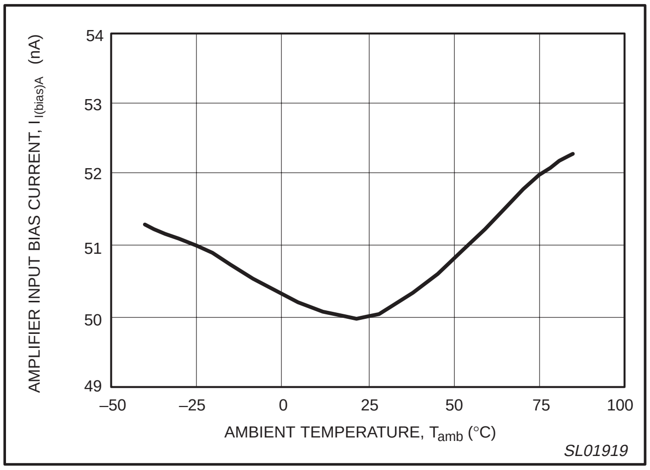



**Figure 7. Amplifier input bias current versus ambient temperature.**

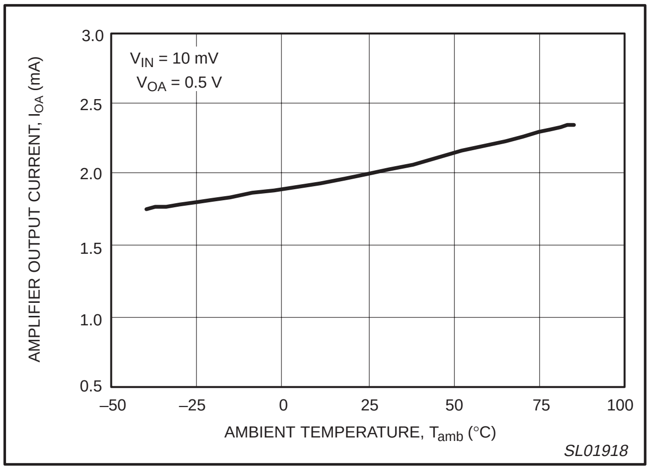



**Figure 8. Amplifier output current versus ambient temperature.**

## TYPICAL CHARACTERIZATION CURVES *(continued)*

$T_{amb}$ = 25 °C, $V_{CC}$ = 3 V, $V_{IN}$ = 0 V, unless otherwise specified.

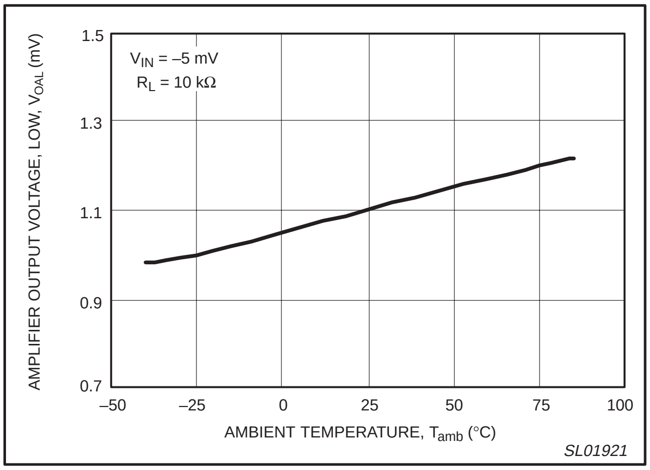



**Figure 9. Amplifier output voltage, LOW versus ambient temperature.**

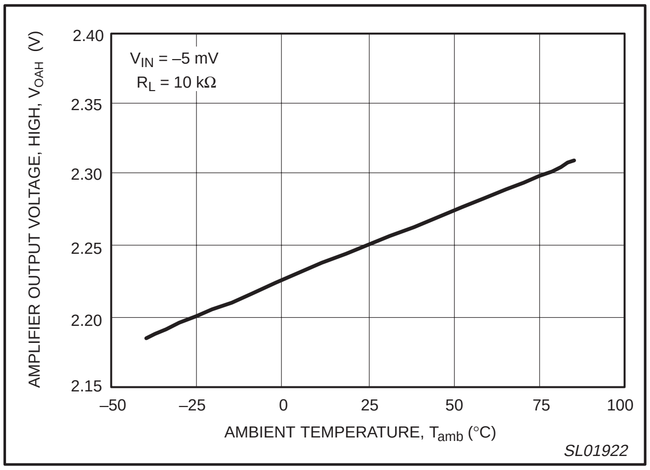



**Figure 10. Amplifier output voltage, HIGH versus ambient temperature.**

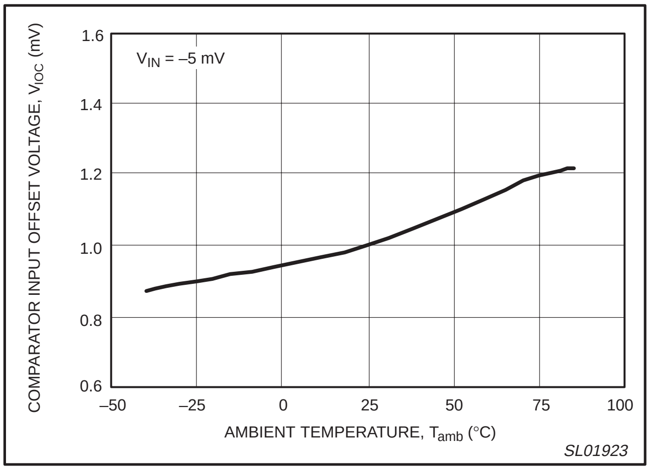



**Figure 11. Comparator input offset voltage versus ambient temperature.**

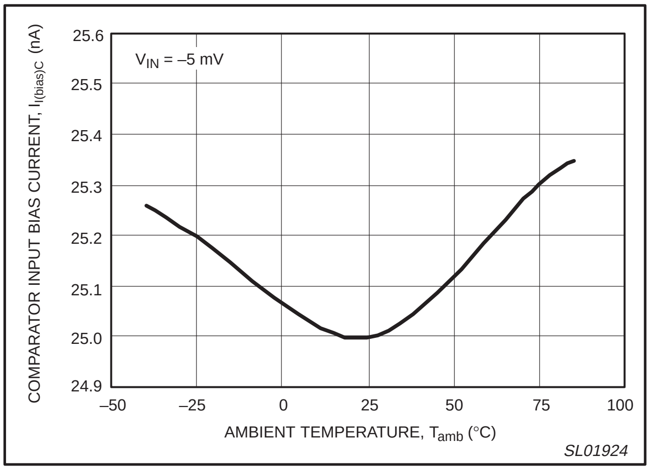



**Figure 12. Comparator bias current versus ambient temperature.**

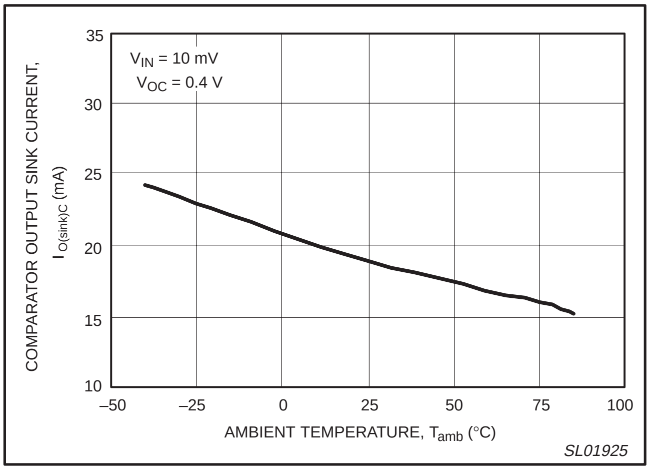



**Figure 13. Comparator output sink current versus ambient temperature.**

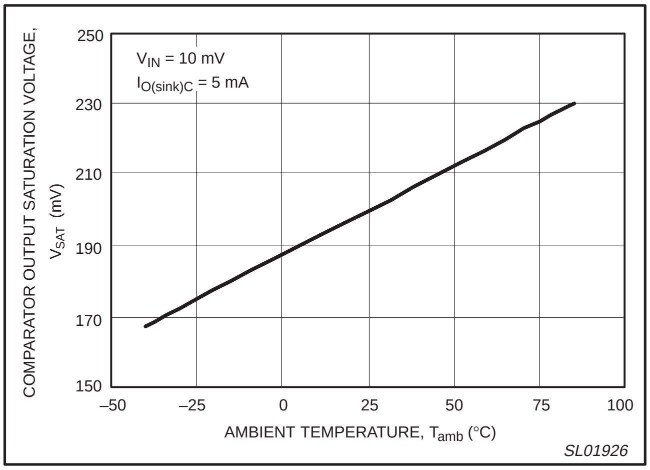



**Figure 14. Comparator output saturation voltage versus ambient temperature.**

## TYPICAL CHARACTERIZATION CURVES *(continued)*

$T_{amb}$ = 25 °C, $V_{CC}$ = 3 V, $V_{IN}$ = 0 V, unless otherwise specified.

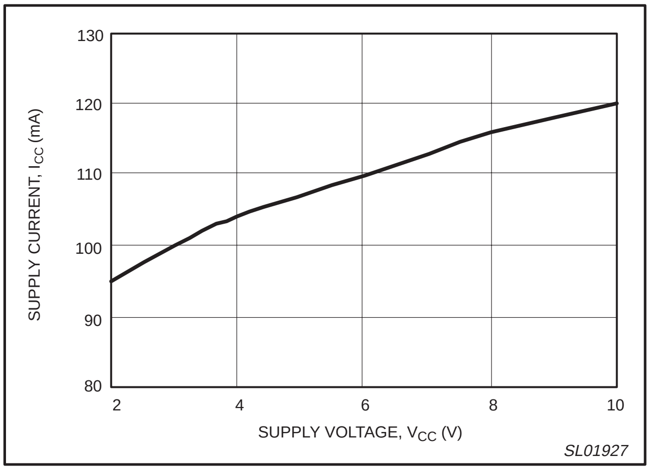



**Figure 15. Supply current versus supply voltage.**

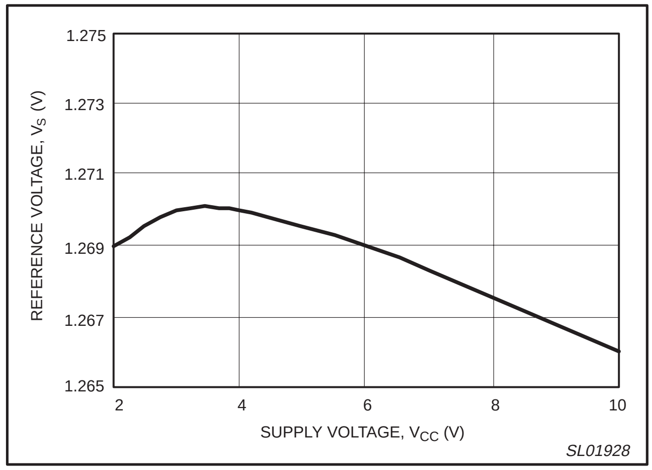



**Figure 16. Reference voltage versus supply voltage.**

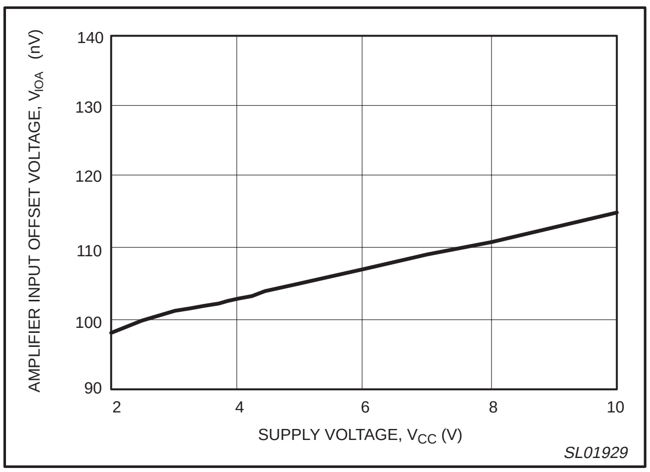



**Figure 17. Amplifier input offset voltage versus supply voltage.**

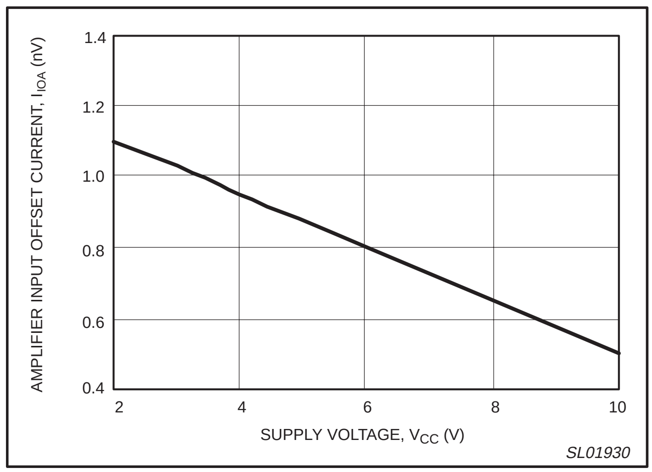



**Figure 18. Amplifier input offset current versus supply voltage.**

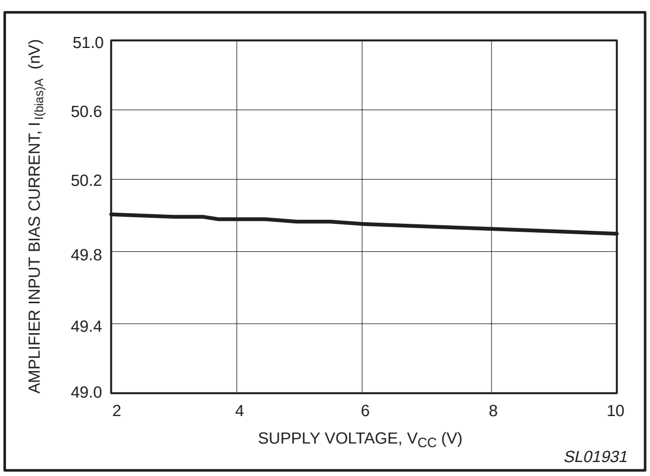



**Figure 19. Amplifier input bias current versus supply voltage.**

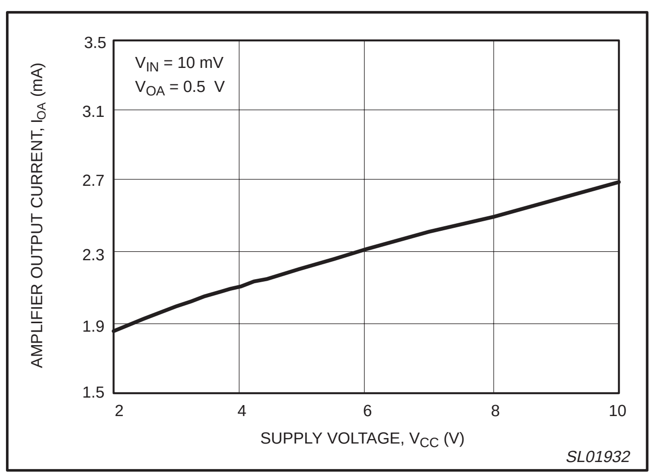



**Figure 20. Amplifier output current versus supply voltage.**

## TYPICAL CHARACTERIZATION CURVES *(continued)*

$T_{amb}$ = 25 °C, $V_{CC}$ = 3 V, $V_{IN}$ = 0 V, unless otherwise specified.

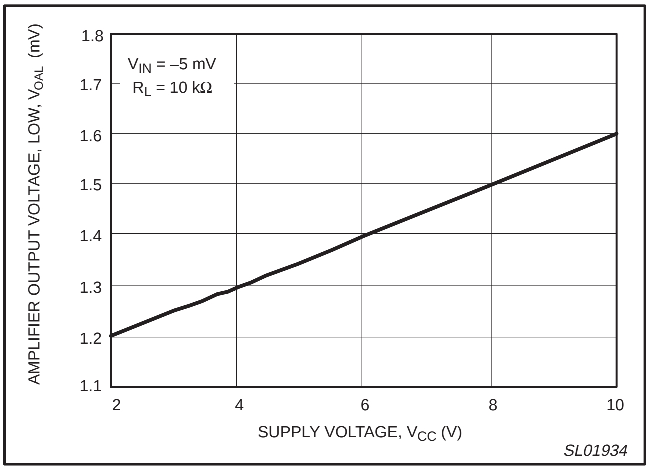



**Figure 21. Amplifier output voltage, LOW versus supply voltage.**

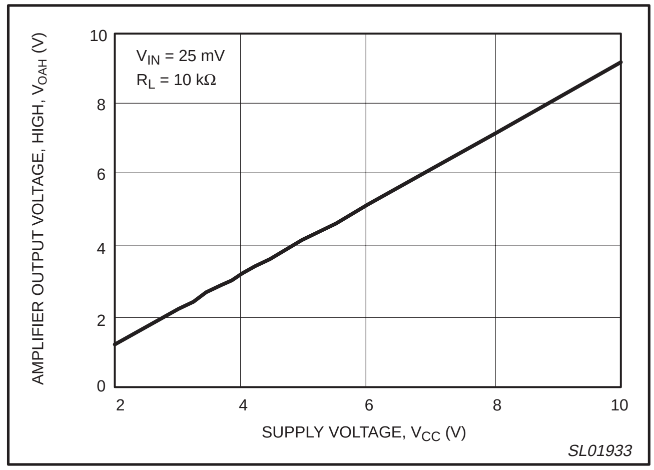



**Figure 22. Amplifier output voltage, HIGH versus supply voltage.**

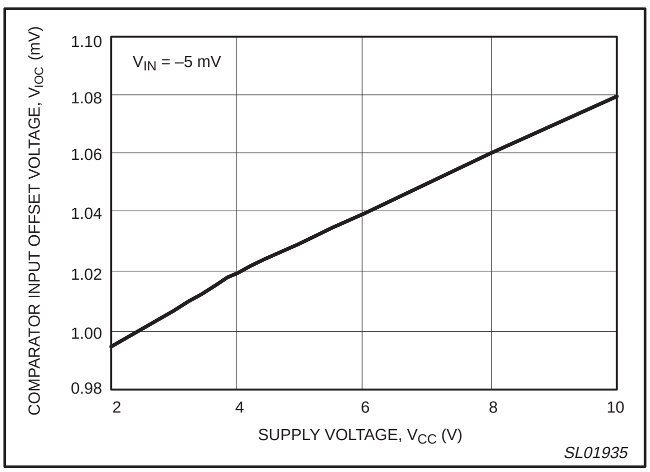



**Figure 23. Comparator input offset voltage versus supply voltage.**

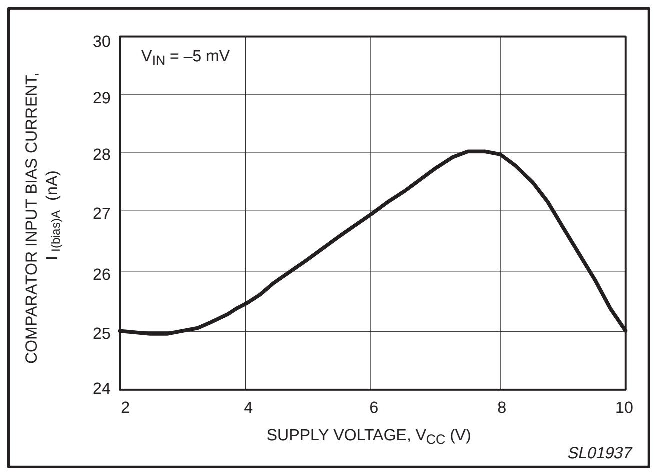



**Figure 24. Comparator bias current versus supply voltage.**

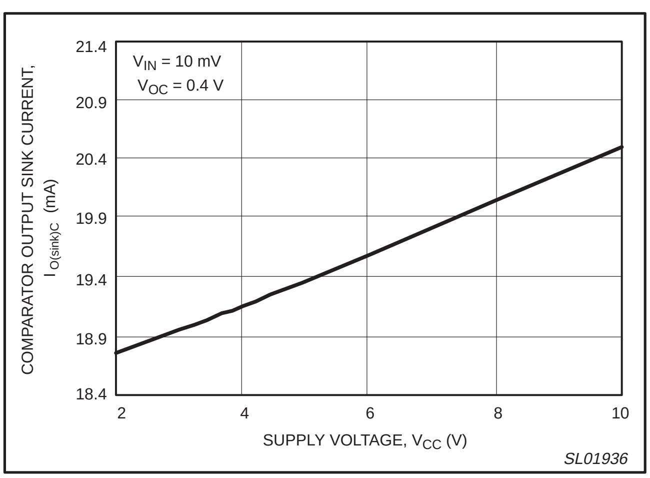



**Figure 25. Comparator output sink current versus supply voltage.**

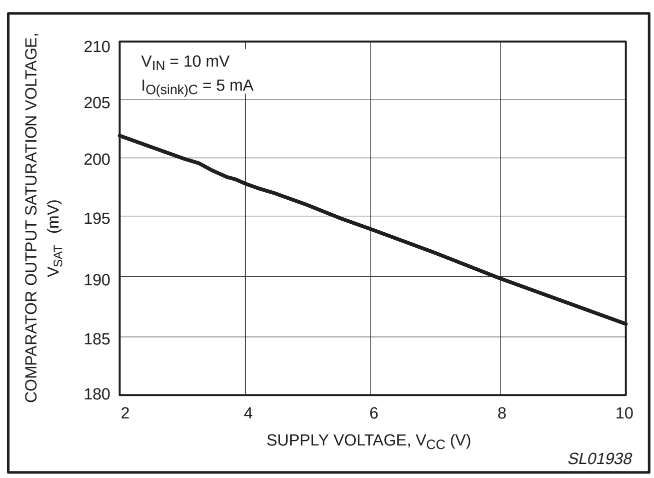



**Figure 26. Comparator output saturation voltage versus supply voltage.**

## TYPICAL CHARACTERIZATION CURVES *(continued)*

$T_{amb}$ = 25 °C, $V_{CC}$ = 3 V, $V_{IN}$ = 0 V, unless otherwise specified.

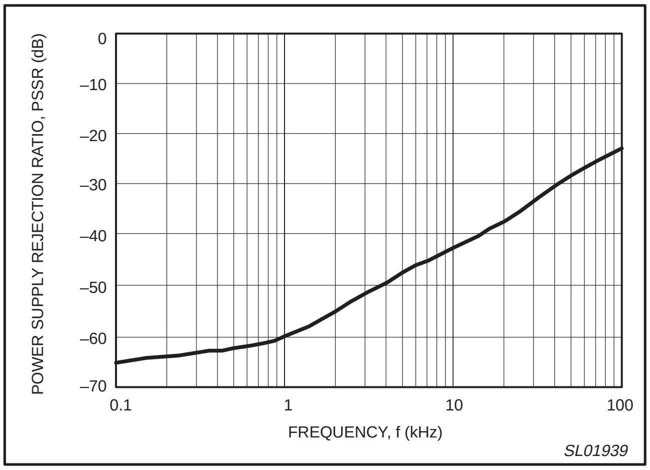



**Figure 27. Power supply rejection ratio versus frequency.**

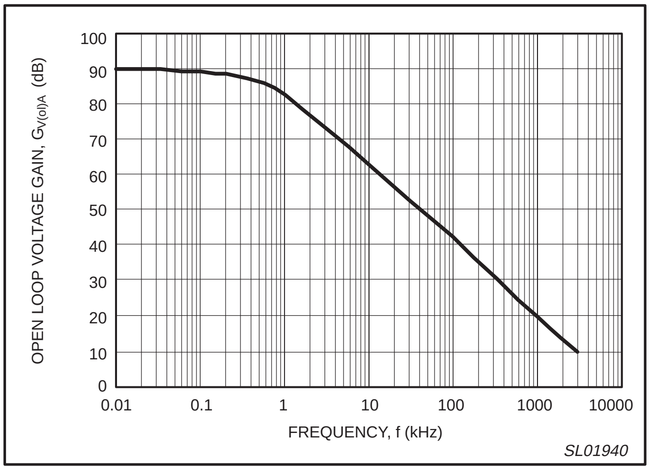



**Figure 28. Amplifier open loop gain versus frequency.**

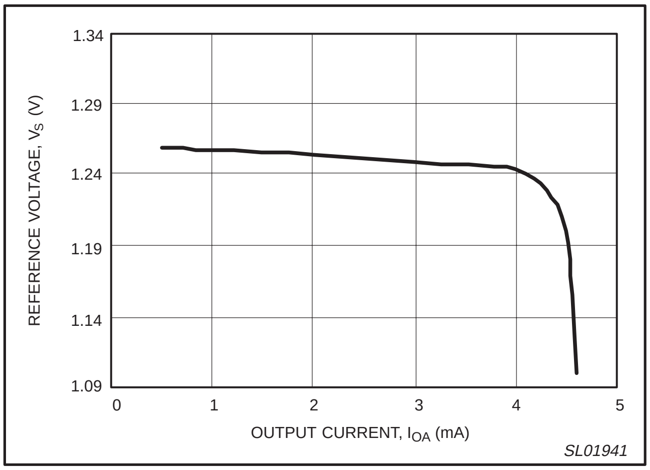



**Figure 29. Reference voltage versus output current.**

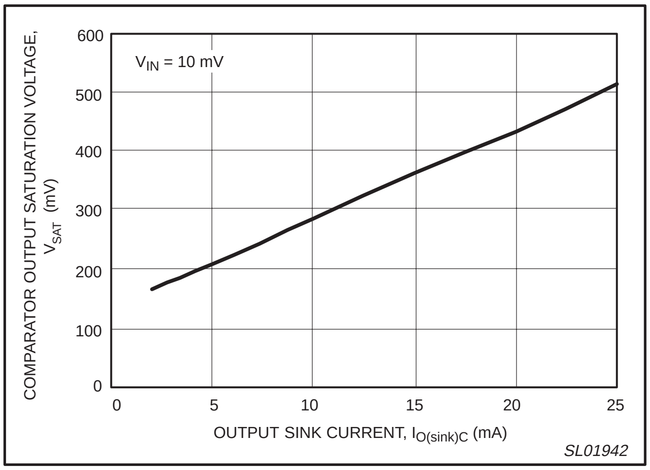



**Figure 30. Comparator output saturation voltage versus sink current.**

## APPLICATION INFORMATION

### Typical gas pilot detection circuit

Figure 31 shows a typical application of the SA58603 in which the input amplifier is driven by a thermocouple heated by the pilot flame in a water heater or gas burner. The circuit comparator may be programmed to detect when the pilot is out. The IC is operated from a single voltage supply making it capable of battery backup with loss of AC power. It may be operated from a one-cell Lithium battery or two alkaline cells. 10 nF bypass capacitors are placed from $V_{CC}$ and reference voltage output (pin 6) to ground to filter power supply noise and interference from external noise sources.

### Selecting external components

**Gain**

Recommended amplifier gain is 40 dB. The gain is is set by the combination of R1, R2, and R3 as shown in the following equations:

$$Av = \frac{(R3 + R2)}{R3}\text{; Av (dB) = 20 log (Av); R3 = R1 } \| \text{ R2}$$

For a gain of 40 dB, Av = 100 V/V;

if R2 = 1 kΩ, then 99*R3 = 1 kΩ; R3 = 10.1 Ω.

$$R3 = \frac{R1 \times R2}{(R1 + R2)}\text{; } R3 \times R1 + R3 \times R2 = R1 \times R2\text{:}$$

$$R3 \times R2 = R1\,(R2 - R3)$$

$$\text{Thus } R1 = \frac{R3 \times R2}{(R2 - R3)} = 10.2\Omega$$

**Comparator output pull-up resistor**

The comparator output pull-up resistor is determined by the following formula:

$$R = \frac{\left(V_{CC} - V_{SAT(max)}\right)}{I_{O(sink)(min)}}$$

where $V_{SAT(max)}$ = 400 mV, and $I_{O(sink)(min)}$ = 5 mA.

**Comparator threshold voltage**

The comparator threshold voltage is determined by R4 and R5. They form a voltage divider from the reference voltage output ($V_S$, Pin 6) to ground. In the application example, $V_{COMP}$, the comparator input (COMPIN–, Pin 5) is connected to the junction of R4 and R5. The input level is calculated by following relationship:

$$V_{COMP} = 1.27V \times \frac{R5}{(R4 + R5)}$$

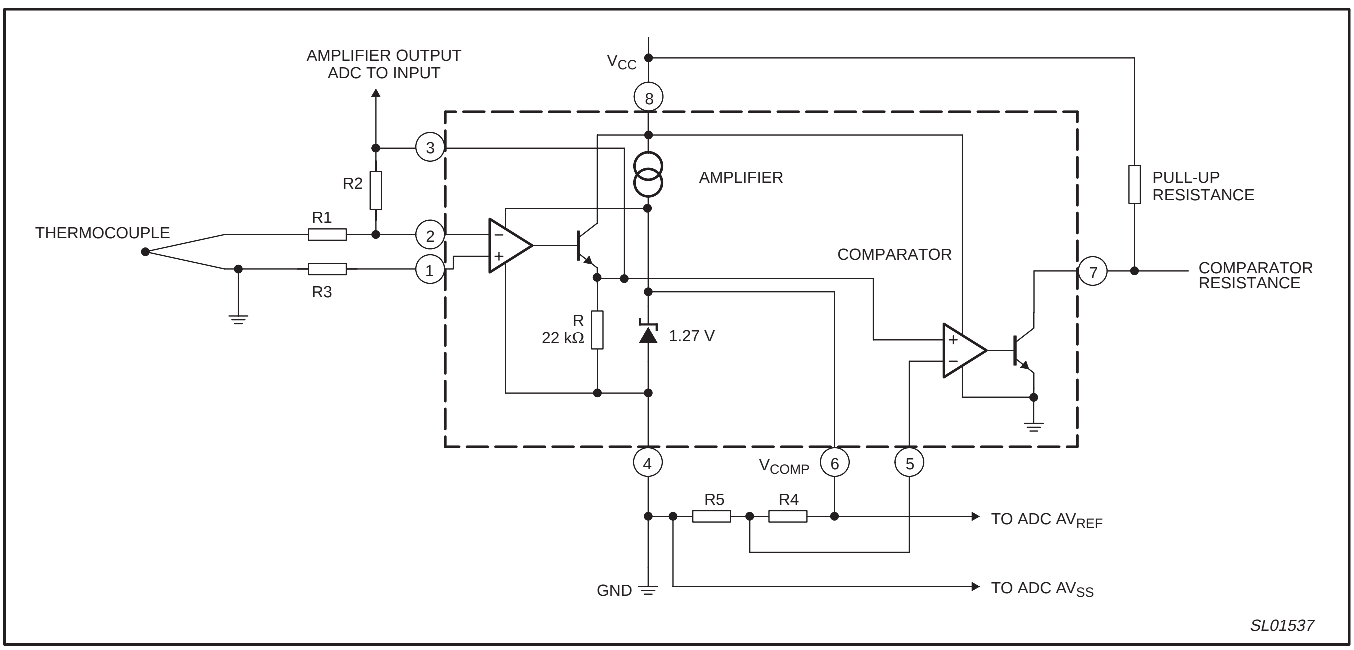



**Figure 31. Typical flame detection circuit.**

## PACKING METHOD

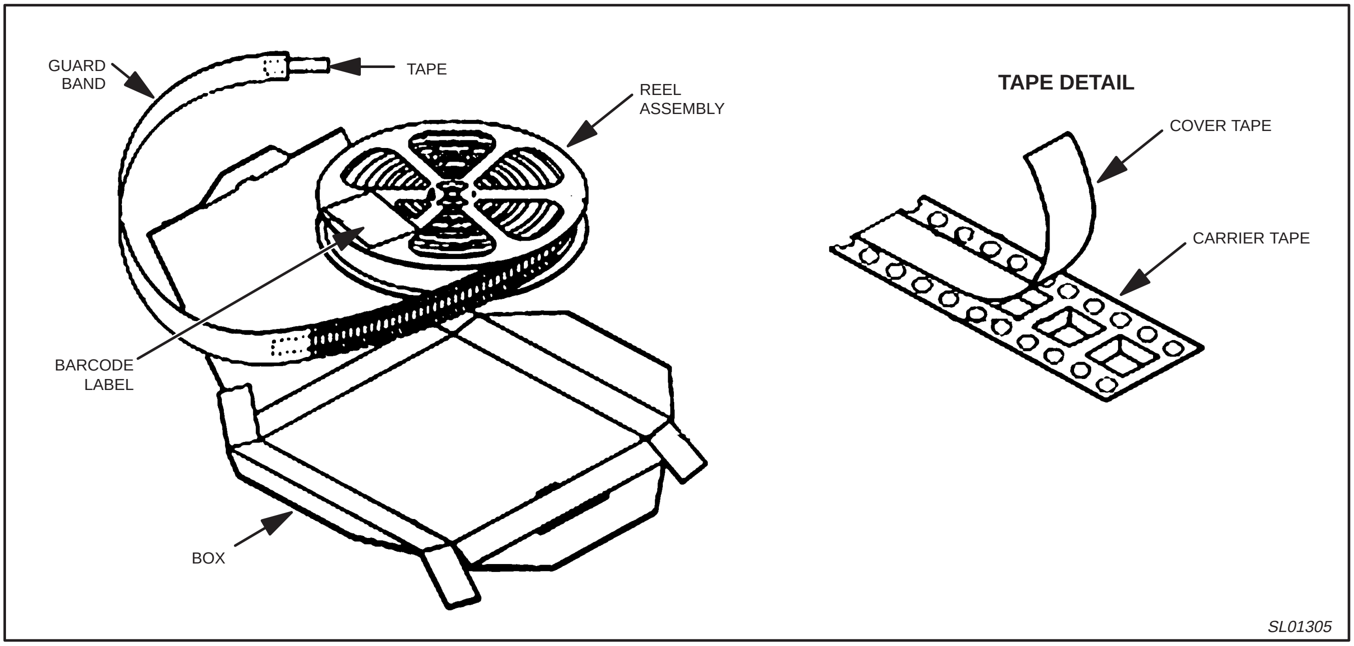
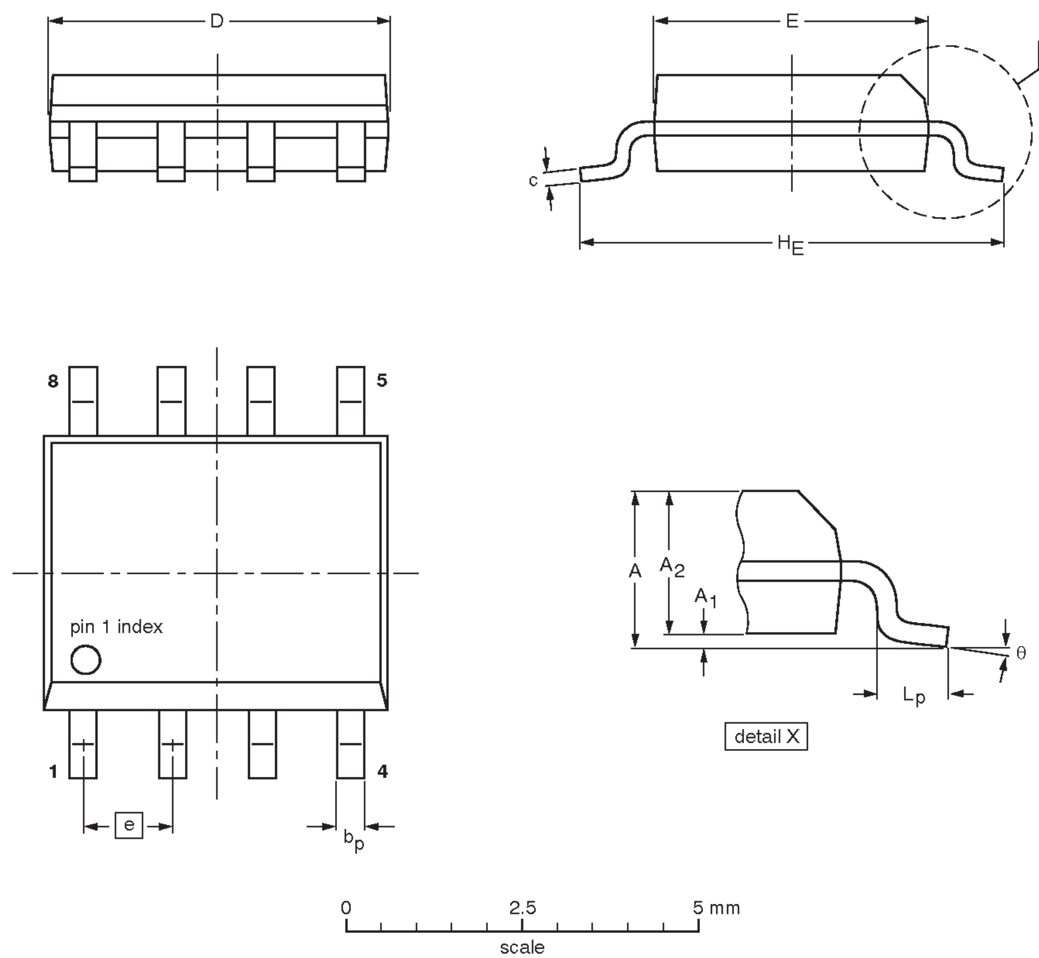



**Figure 32. Tape and reel packing method.**

## SO8: plastic small outline package; 8 leads; body width 3.9 mm SOP005




**DIMENSIONS (inch dimensions are derived from the original mm dimensions)**

| UNIT | A max. | $A_1$ | $A_2$ | $b_p$ | c | $D^{(1)}$ | $E^{(2)}$ | e | $H_E$ | $L_p$ | θ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | 1.73 | 0.25<br>0.10 | 1.45<br>1.25 | 0.51<br>0.33 | 0.25<br>0.19 | 4.95<br>4.80 | 4.0<br>3.8 | 1.27 | 6.2<br>5.8 | 1.27<br>0.38 | 8°<br>0° |
| inches | 0.068 | 0.010<br>0.004 | 0.057<br>0.049 | 0.013<br>0.020 | 0.0100<br>0.0075 | 0.20<br>0.19 | 0.16<br>0.15 | 0.050 | 0.244<br>0.228 | 0.050<br>0.015 | |

**Notes**

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

| OUTLINE VERSION | REFERENCES | | | | EUROPEAN PROJECTION | ISSUE DATE |
|---|---|---|---|---|---|---|
| | IEC | JEDEC | JEITA | | | |
| SOP005 | 076E03 | MS-012 | | | | 03-10-07 |

## REVISION HISTORY

| Rev | Date | Description |
|---|---|---|
| _3 | 20031110 | **Product data (9397 750 12287). ECN 853–2289 30322 of 09 September 2003.** **Supersedes data of 2002 Nov 13 (9397 750 10671).** Modifications: • Change package outline version to SOP005 in Ordering information table and Package outline sections. |
| _2 | 20021113 | **Product data (9397 750 10671). ECN 853–2289 29151 of 05 November 2002.** **Supersedes data of 2001 Oct 03 (9397 750 08955).** |
| _1 | 20011003 | **Product data (9397 750 08955). ECN 853–2289 27197 of 03 October 2001.** |

# High precision operational amplifier, comparator, and voltage reference

SA58603

## Data sheet status

| Level | Data sheet status [1] | Product status [2] [3] | Definitions |
|---|---|---|---|
| I | Objective data | Development | This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice. |
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[2] The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL http://www.semiconductors.philips.com.

[3] For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

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