

## Linear Building Block – Low Power Comparator with Op Amp and Voltage Reference

### Features

- Combines Low-Power Op Amp, Comparator and Voltage Reference in a Single Package
- Optimized for Single Supply Operation
- Small Packages: 8-Pin MSOP, 8-Pin SOIC, 8-Pin PDIP
- Ultra Low Input Bias Current: Less than 100pA
- Low Quiescent Current: 12 $\mu$ A (Typ.)
- Rail-to-Rail Inputs and Outputs
- Operates Down to  $V_{DD} = 1.8V$ , Min

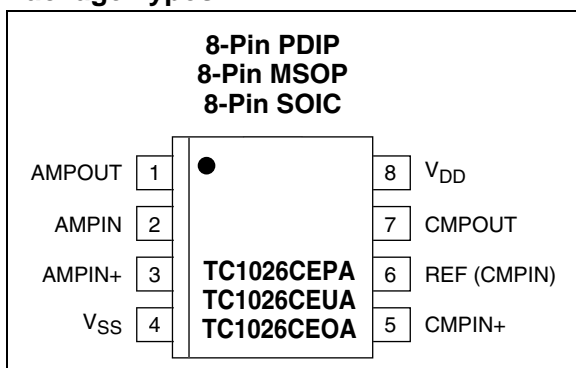
### Applications

- Power Management Circuits
- Battery Operated Equipment
- Consumer Products

### Device Selection Table

| Part Number | Package    | Temperature Range |
|-------------|------------|-------------------|
| TC1026CEPA  | 8-Pin PDIP | -40°C to +85°C    |
| TC1026CEUA  | 8-Pin MSOP | -40°C to +85°C    |
| TC1026CEOA  | 8-Pin SOIC | -40°C to +85°C    |

### Package Types



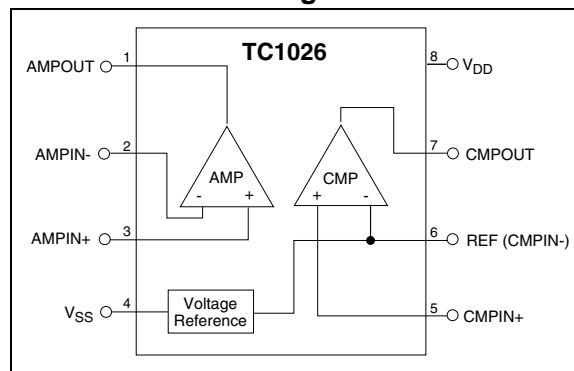
### General Description

The TC1026 is a mixed-function device combining a general-purpose op amp, comparator and voltage reference in a single 8-pin package. This increased integration allows the user to replace two or three packages, which saves space, lowers supply current and increases system performance.

Both the op amp and comparator have rail-to-rail inputs and outputs which allows operation from low supply voltages with large input and output swings. The TC1026 is optimized for low voltage ( $V_{DD} = 1.8V$ ), low supply current (12 $\mu$ A typ) operation.

Packaged in a space-saving 8-Pin MSOP, the TC1026 consumes half the board area of an 8-Pin SOIC and is ideal for applications requiring high integration, small size and low power. It is also available in 8-Pin SOIC and 8-Pin PDIP packages.

### Functional Block Diagram



# TC1026

## 1.0 ELECTRICAL CHARACTERISTICS

### ABSOLUTE MAXIMUM RATINGS\*

|                                   |  |
|-----------------------------------|--|
| Supply Voltage .....              | 6.0V                                       |
| Package Power Dissipation:        |  |
| 8-Pin PDIP .....                  | 730 mW                                     |
| 8-Pin SOIC .....                  | 470 mW                                     |
| 8-Pin MSOP .....                  | 320 mW                                     |
| Voltage on Any Pin .....          | ( $V_{SS} - 0.3V$ ) to ( $V_{DD} + 0.3V$ ) |
| Junction Temperature .....        | +150°C                                     |
| Operating Temperature Range ..... | -40°C to +85°C                             |
| Storage Temperature Range .....   | -55°C to +150°C                            |

\*Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operation sections of the specifications is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

### TC1026 ELECTRICAL SPECIFICATIONS

| Electrical Characteristics: Typical values apply at 25°C and $V_{DD} = 3.0V$ ; $T_A = -40^\circ$ to +85°C, and $V_{DD} = 1.8V$ to 5.5V, unless otherwise specified. |                              |                 |                        |                        |                  |   |
|---|------------------------------|-----------------|------------------------|------------------------|------------------|---|
| Symbol  | Parameter                    | Min             | Typ                    | Max                    | Units            | Test Conditions   |
| $V_{DD}$  | Supply Voltage               | 1.8             | —                      | 5.5                    | V                |   |
| $I_Q$   | Supply Current               | —               | 12                     | 18                     | $\mu A$          | All outputs unloaded  |
| <b>Op Amp</b>   |                              |                 |                        |                        |                  |   |
| $A_{VOL}$   | Large Signal Voltage Gain    | —               | 100                    | —                      | V/mV             | $R_L = 10k\Omega$ , $V_{DD} = 5V$   |
| $V_{ICMR}$  | Common Mode Input Range      | $V_{SS} - 0.2$  | —                      | $V_{DD} + 0.2$         | V                |   |
| $V_{OS}$  | Input Offset Voltage         |                 | $\pm 100$<br>$\pm 0.3$ | $\pm 500$<br>$\pm 1.5$ | $\mu V$<br>mV    | $V_{DD} = 3V$ , $V_{CM} = 1.5V$ , $T_A = 25^\circ C$<br>$T_A = -40^\circ C$ to $85^\circ C$         |
| $I_B$   | Input Bias Current           | -100            | 50                     | 100                    | pA               | $T_A = 25^\circ C$ , $V_{CM} = V_{DD}$ to $V_{SS}$  |
| $V_{OS (DRIFT)}$  | Input Offset Voltage Drift   | —               | $\pm 4$                | —                      | $\mu V/^\circ C$ | $V_{DD} = 3V$ , $V_{CM} = 1.5V$   |
| GBWP  | Gain-Bandwidth Product       | —               | 90                     | —                      | kHz              | $V_{DD} = 1.8V$ to $5.5V$ ;<br>$V_O = V_{DD}$ to $V_{SS}$   |
| SR  | Slew Rate                    | —               | 35                     | —                      | mV/ $\mu sec$    | $C_L = 100pF$<br>$R_L = 1M\Omega$ to GND<br>Gain = 1<br>$V_{IN} = V_{SS}$ to $V_{DD}$               |
| $V_{OUT}$   | Output Signal Swing          | $V_{SS} + 0.05$ | —                      | $V_{DD} - 0.05$        | V                | $R_L = 10k\Omega$   |
| CMRR  | Common Mode Rejection Ratio  | 66              | —                      | —                      | dB               | $T_A = 25^\circ C$ , $V_{DD} = 5V$<br>$V_{CM} = V_{DD}$ to $V_{SS}$                                 |
| PSRR  | Power Supply Rejection Ratio | 80              | —                      | —                      | dB               | $T_A = 25^\circ C$ , $V_{CM} = V_{SS}$<br>$V_{DD} = 1.8V$ to $5V$                                   |
| $I_{SRC}$   | Output Source Current        | 3               | —                      | —                      | mA               | $V_{IN+} = V_{DD}$ , $V_{IN-} = V_{SS}$<br>Output Shorted to $V_{SS}$<br>$V_{DD} = 1.8V$ , Gain = 1 |
| $I_{SINK}$  | Output Slnk Current          | —               | 125                    | —                      | nV/Hz            | $IN+ = V_{SS}$ , $IN- = V_{DD}$<br>Output Shorted to $V_{DD}$<br>$V_{DD} = 1.8V$ , Gain = 1         |
| $E_n$   | Input Noise Voltage          | —               | 10                     | —                      | $\mu V_{pp}$     | 0.1Hz to 10Hz   |
| $e_n$   | Input Noise Voltage Density  | —               | 125                    | —                      | nV/ $\sqrt{Hz}$  | 1kHz  |
| <b>Comparator</b>   |                              |                 |                        |                        |                  |   |
| $V_{IR}$  | Input Voltage Range          | $V_{SS} - 0.2$  | —                      | $V_{DD} + 0.2$         | V                |   |
| $V_{OS}$  | Input Offset Voltage         | -5<br>-5        | —<br>—                 | +5<br>+5               | mV               | $V_{DD} = 3V$ , $T_A = 25^\circ C$<br>$T_A = -40^\circ C$ to $85^\circ C$                           |
| $I_B$   | Input Bias Current           | —               | —                      | $\pm 100$              | pA               | $T_A = 25^\circ C$ , $IN+ = V_{DD}$ to $V_{SS}$   |
| $V_{OH}$  | Output High Voltage          | $V_{DD} - 0.3$  | —                      | —                      | V                | $R_L = 10k\Omega$ to $V_{SS}$   |
| $V_{OL}$  | Output Low Voltage           | —               | —                      | 0.3                    | V                | $R_L = 10k\Omega$ to $V_{DD}$   |

## TC1026 ELECTRICAL SPECIFICATIONS (CONTINUED)

| <b>Electrical Characteristics:</b> Typical values apply at 25°C and $V_{DD} = 3.0V$ ; $T_A = -40^\circ$ to $+85^\circ C$ , and $V_{DD} = 1.8V$ to $5.5V$ , unless otherwise specified. |                              |       |       |       |           |   |
|--|------------------------------|-------|-------|-------|-----------|---|
| Symbol   | Parameter                    | Min   | Typ   | Max   | Units     | Test Conditions   |
| PSRR   | Power Supply Rejection Ratio | 60    | —     | —     | dB        | $T_A = 25^\circ C$<br>$V_{DD} = 1.8V$ to $5V$                   |
| $I_{SRC}$  | Output Source Current        | 1     | —     | —     | mA        | $IN+ = V_{DD}$<br>Output Shorted to $V_{SS}$<br>$V_{DD} = 1.8V$ |
| $I_{SINK}$   | Output Sink Current          | 2     | —     | —     | mA        | $IN+ = V_{SS}$<br>Output Shorted to $V_{DD}$<br>$V_{DD} = 1.8V$ |
| $t_{PD1}$  | Response Time                | —     | 4     | —     | $\mu sec$ | 100mV Overdrive, $C_L = 100pF$                                  |
| $t_{PD2}$  | Response Time                | —     | 6     | —     | $\mu sec$ | 10mV Overdrive, $C_L = 100pF$                                   |
| <b>Voltage Reference</b>   |                              |       |       |       |           |   |
| $V_{REF}$  | Reference Voltage            | 1.176 | 1.200 | 1.221 | V         |   |
| $I_{REF(SOURCE)}$  | Source Current               | 50    | —     | —     | $\mu A$   |   |
| $I_{REF(SINK)}$  | Sink Current                 | 50    | —     | —     | $\mu A$   |   |
| $C_{L(REF)}$   | Load Capacitance             | —     | —     | 100   | pF        |   |

# TC1026

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## 2.0 PIN DESCRIPTION

The description of the pins are listed in Table 2-1.

**TABLE 2-1: PIN FUNCTION TABLE**

| Pin No.<br>(8-Pin PDIP)<br>(8-Pin MSOP)<br>(8-Pin SOIC) | Symbol          | Description  |
|---|-----------------|--|
| 1   | AMPOUT          | Op amp output.   |
| 2   | AMPIN-          | Inverting op amp input.  |
| 3   | AMPIN+          | Non-inverting op amp input.                                      |
| 4   | V <sub>SS</sub> | Negative power supply.   |
| 5   | CMPIN+          | Non-inverting comparator input.                                  |
| 6   | REF(CMPIN)      | Inverting comparator input and voltage reference output voltage. |
| 7   | CMPOUT          | Comparator output.   |
| 8   | V <sub>DD</sub> | Positive power supply.   |

## 3.0 DETAILED DESCRIPTION

The TC1026 is one of a series of very low power, linear building block products targeted at low voltage, single supply applications. The TC1026 minimum operating voltage is 1.8V, and typical supply current is only 12 $\mu$ A. It combines a comparator, an op amp and a voltage reference in a single package.

### 3.1 Comparator

The TC1026 contains one comparator. The comparator's input range extends beyond both supply voltages by 200mV and the outputs will swing to within several millivolts of the supplies depending on the load current being driven. The inverting input is internally connected to the output of the reference.

The comparator exhibits propagation delay and supply current which are largely independent of supply voltage. The low input bias current and offset voltage make it suitable for high impedance precision applications.

### 3.2 Operational Amplifier

The TC1026 contains one rail-to-rail op amp. The amplifier's input range extends beyond both supplies by 200mV and the outputs will swing to within several millivolts of the supplies depending on the load current being driven.

The amplifier design is such that large signal gain, slew rate and bandwidth are largely independent of supply voltage. The low input bias current and offset voltage of the TC1026 make it suitable for precision applications.

### 3.3 Voltage Reference

A 2.0% tolerance, internally biased, 1.20V bandgap voltage reference is included in the TC1026. It has a push-pull output capable of sourcing and sinking at least 50 $\mu$ A.

## 4.0 TYPICAL APPLICATIONS

The TC1026 lends itself to a wide variety of applications, particularly in battery powered systems. It typically finds application in power management, processor supervisory and interface circuitry.

### 4.1 External Hysteresis (Comparator)

Hysteresis can be set externally with three resistors using positive feedback techniques (see Figure 4-1). The design procedure for setting external comparator hysteresis is as follows:

1. Choose the feedback resistor  $R_C$ . Since the input bias current of the comparator is at most 100pA, the current through  $R_C$  can be set to 100nA (i.e., 1000 times the input bias current) and retain excellent accuracy. The current through  $R_C$  at the comparator's trip point is  $V_R / R_C$  where  $V_R$  is a stable reference voltage.
2. Determine the hysteresis voltage ( $V_{HY}$ ) between the upper and lower thresholds.
3. Calculate  $R_A$  as follows:

#### EQUATION 4-1:

$$R_A = R_C \left( \frac{V_{HY}}{V_{DD}} \right)$$

4. Choose the rising threshold voltage for  $V_{SRC}$  ( $V_{THR}$ ).
5. Calculate  $R_B$  as follows:

#### EQUATION 4-2:

$$R_B = \frac{1}{\left[ \left( \frac{V_{THR}}{V_R \times R_A} \right) - \frac{1}{R_A} - \frac{1}{R_C} \right]}$$

6. Verify the threshold voltages with these formulas:

$V_{SRC}$  rising:

#### EQUATION 4-3:

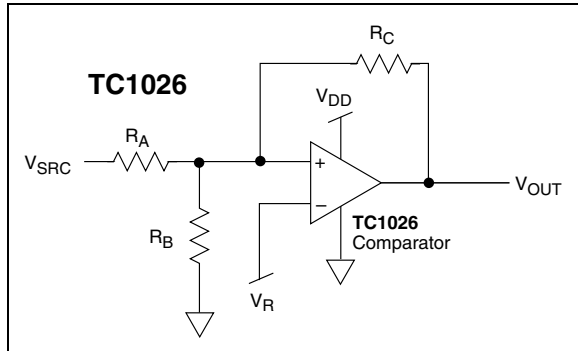
$$V_{THR} = (V_R)(R_A) \left[ \left( \frac{1}{R_A} \right) + \left( \frac{1}{R_B} \right) + \left( \frac{1}{R_C} \right) \right]$$

$V_{SRC}$  falling:

#### EQUATION 4-4:

$$V_{THF} = V_{THR} - \left[ \left( \frac{R_A \times V_{DD}}{R_C} \right) \right]$$

**FIGURE 4-1: COMPARATOR EXTERNAL HYSTERESIS CONFIGURATION**



## 4.2 Precision Battery Monitor

Figure 4-2 is a precision battery low/battery dead monitoring circuit. Typically, the battery low output warns the user that a battery dead condition is imminent. Battery dead typically initiates a forced shutdown to prevent operation at low internal supply voltages (which can cause unstable system operation).

The circuit of Figure 4-2 uses two TC1026 devices and only six external resistors. AMP 1 is a simple buffer while CMPTR1 and CMPTR2 provide precision voltage detection using  $V_R$  as a reference. Resistors R2 and R4 set the detection threshold for BATT LOW while resistors R1 and R3 set the detection threshold for BATT FAIL. The component values shown assert BATT LOW at 2.2V (typical) and BATT FAIL at 2.0V (typical). Total current consumed by this circuit is typically 28 $\mu$ A at 3V. Resistors R5 and R6 provide hysteresis for comparators CMPTR1 and CMPTR2, respectively.

## 4.3 Voice Band Receive Filter

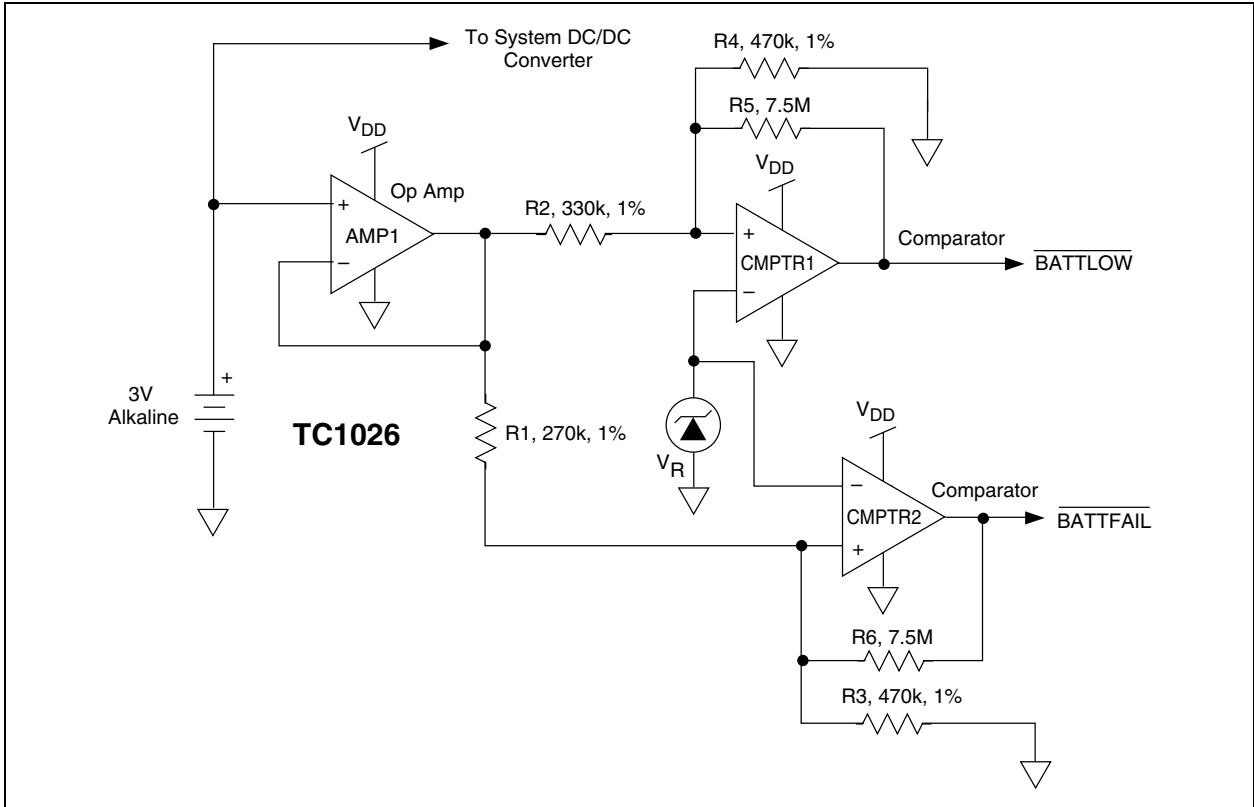
The majority of spectral energy for human voices is in a 2.7kHz frequency band from 300Hz to 3kHz. To properly recover a voice signal in applications such as radios, cellular phones and voice pagers, a low-power bandpass filter that is matched to the human voice spectrum can be implemented using Microchip's CMOS op amps. Figure 4-3 shows a unity-gain multipole Butterworth filter with ripple less than 0.15dB in the human voice band. The lower 3dB cut-off frequency is 70Hz (single-order response), while the upper cut-off frequency is 3.5kHz (fourth-order response).

## 4.4 Supervisory Audio Tone (SAT) Filter for Cellular

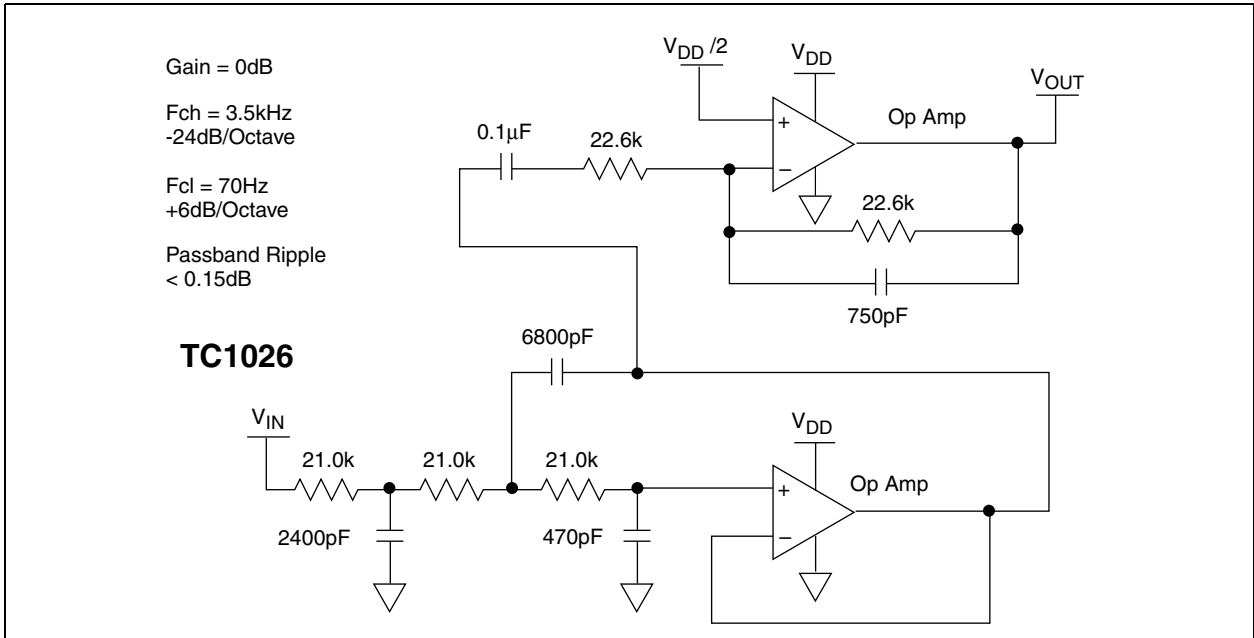
Supervisory Audio Tones (SAT) provide a reliable transmission path between cellular subscriber units and base stations. The SAT tone functions much like the current/voltage used in land line telephone systems to indicate that a phone is off the hook. The SAT tone may be one of three frequencies: 5970, 6000 or 6030Hz. A loss of SAT implies that channel conditions are impaired, and if SAT is interrupted for more than 5 seconds, a cellular call is terminated.

Figure 4-4 shows a high Q (30) first order SAT detection bandpass filter using Microchip's CMOS op amp architecture. This circuit nulls all frequencies except the three SAT tones of interest.

**FIGURE 4-2: PRECISION BATTERY MONITOR**

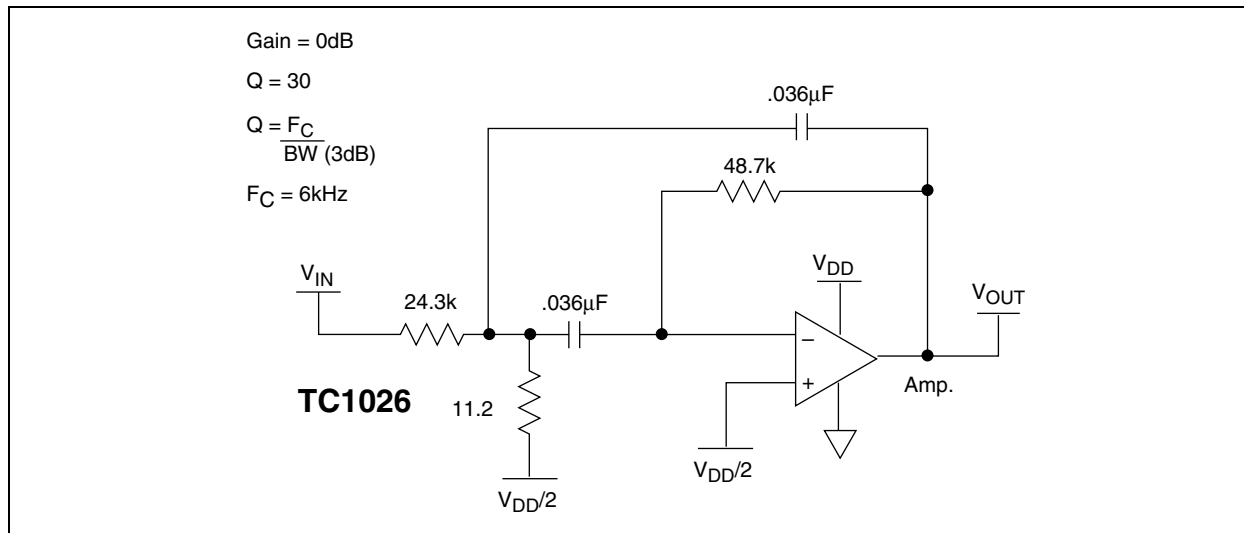


**FIGURE 4-3: MULTI-POLE BUTTERWORTH VOICE BAND RECEIVE FILTER**



# TC1026

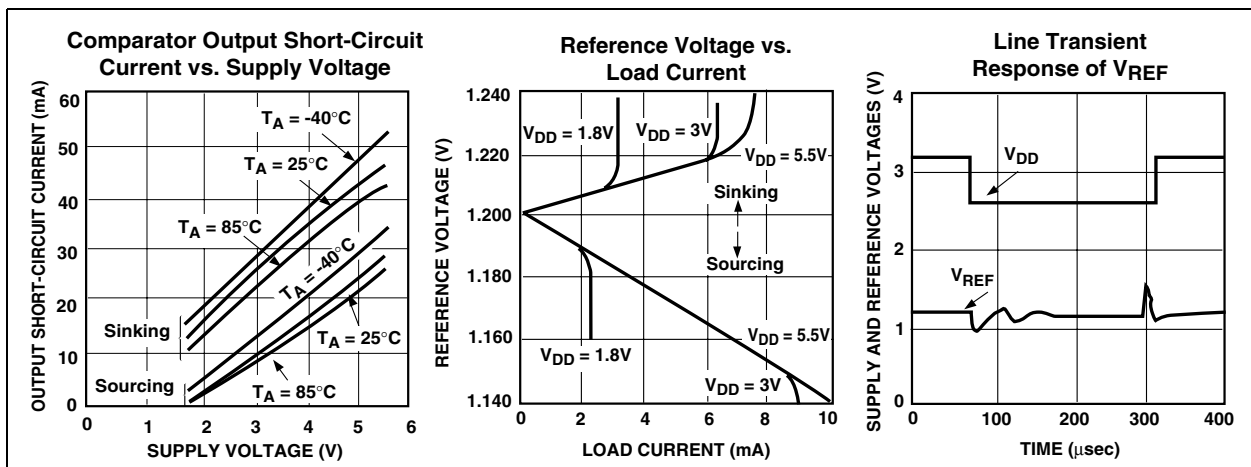
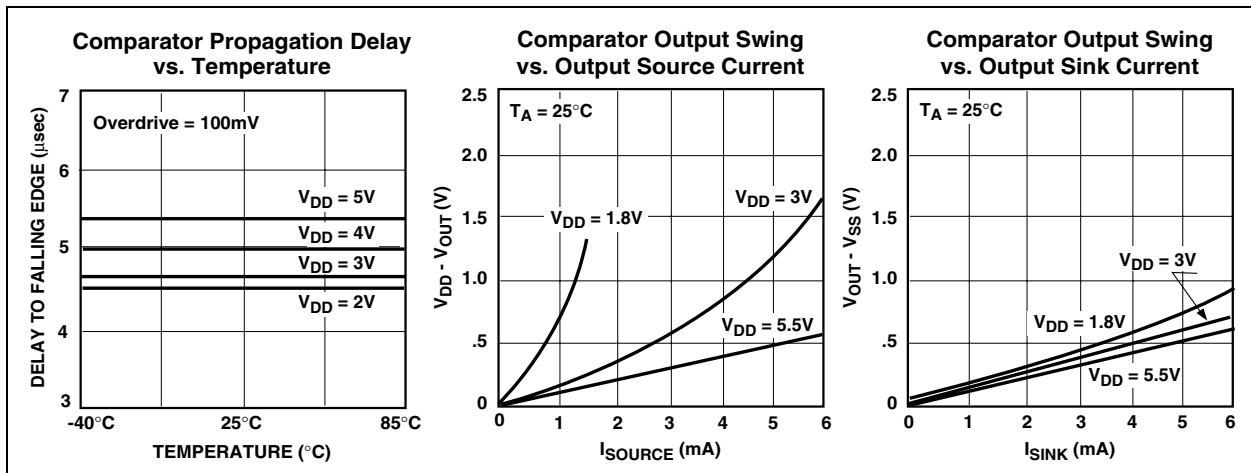
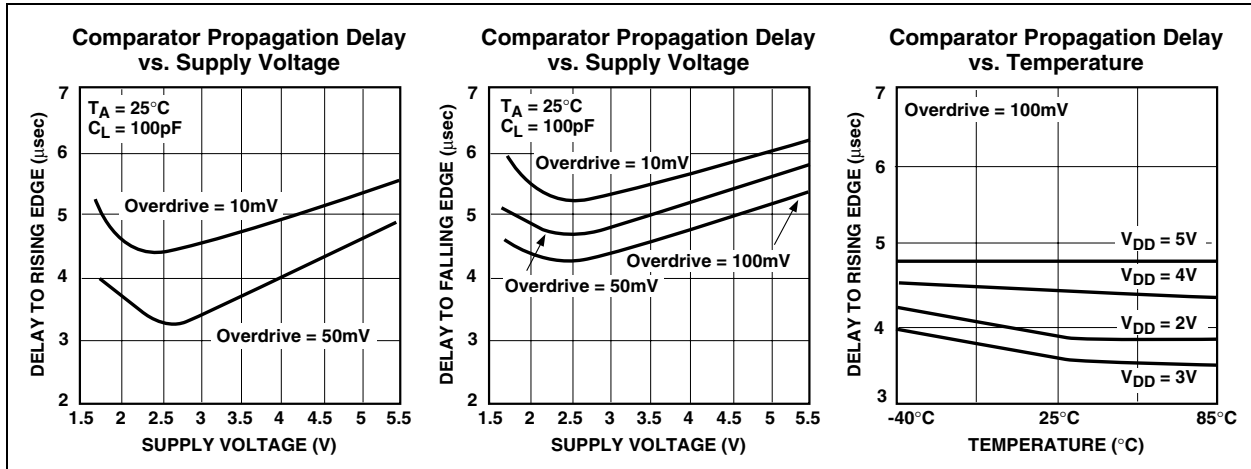
FIGURE 4-4: SECOND ORDER SAT BANDPASS FILTER



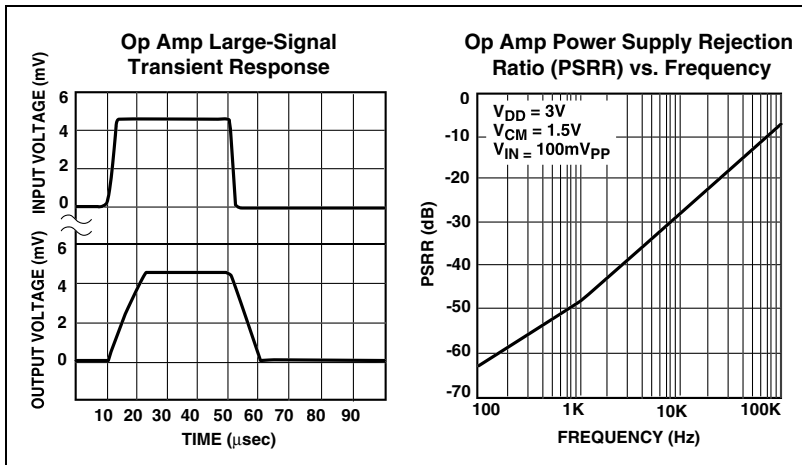
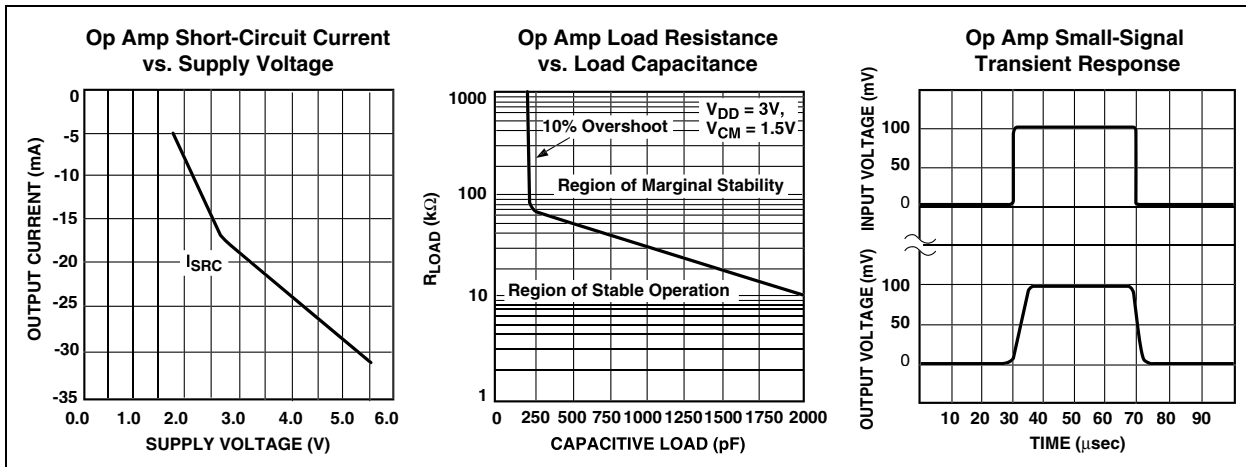
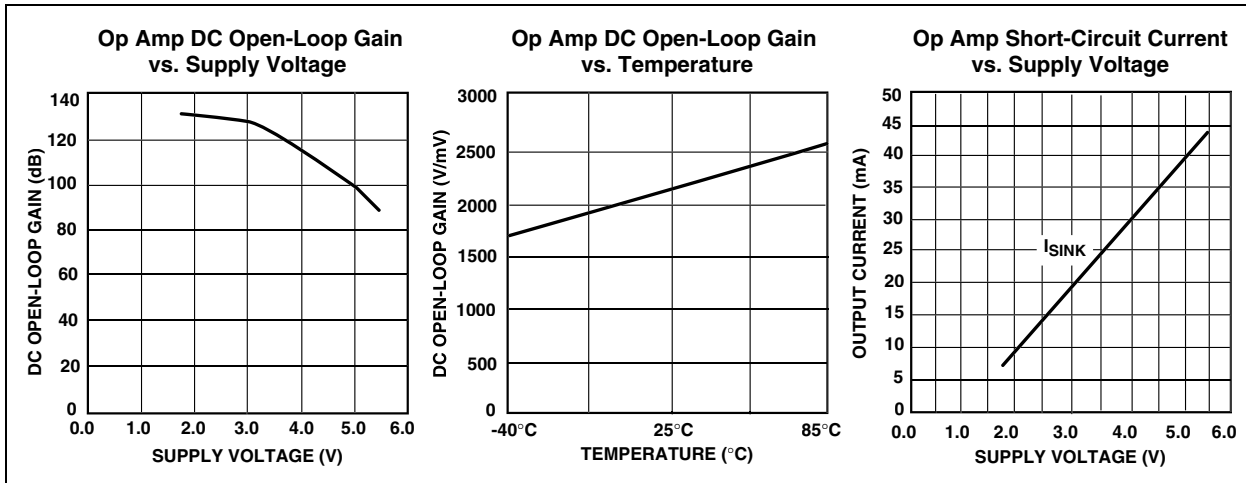


## 5.0 TYPICAL CHARACTERISTICS

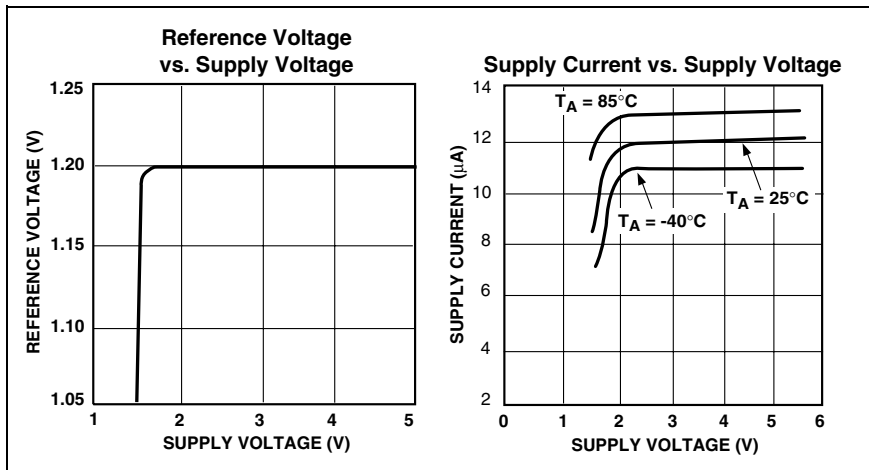
**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.



## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)



## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)



# TC1026

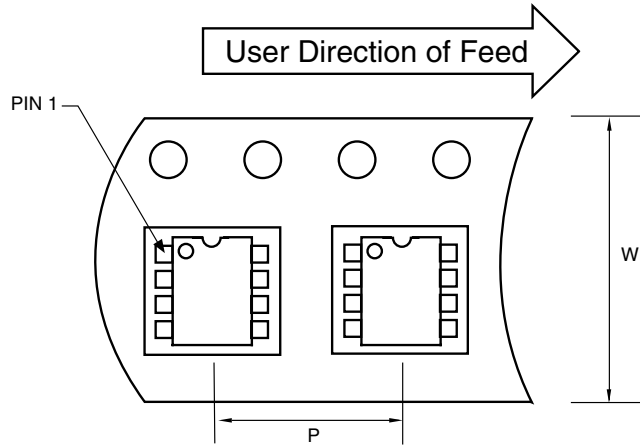
## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

Package marking data not available at this time.

### 6.2 Taping Form

#### Component Taping Orientation for 8-Pin MSOP Devices

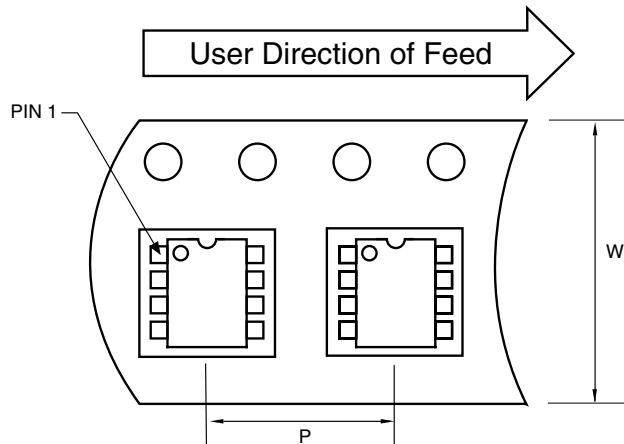


Standard Reel Component Orientation  
for TR Suffix Device

#### Carrier Tape, Number of Components Per Reel and Reel Size

| Package    | Carrier Width (W) | Pitch (P) | Part Per Full Reel | Reel Size |
|------------|-------------------|-----------|--------------------|-----------|
| 8-Pin MSOP | 12 mm             | 8 mm      | 2500               | 13 in     |

#### Component Taping Orientation for 8-Pin SOIC (Narrow) Devices



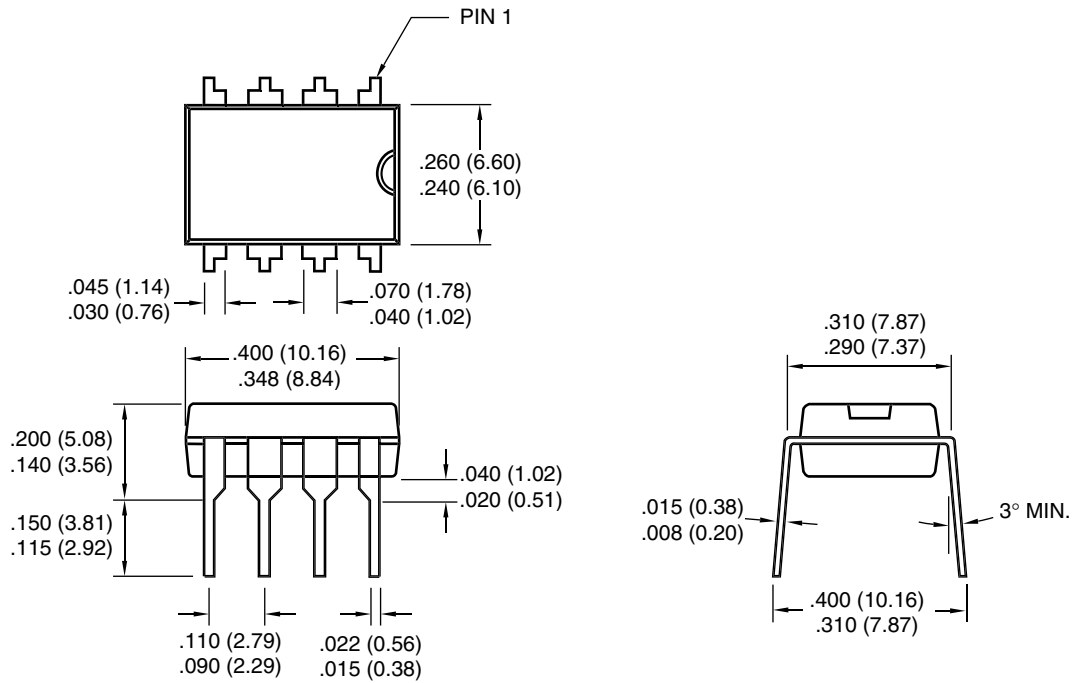
Standard Reel Component Orientation  
for TR Suffix Device

#### Carrier Tape, Number of Components Per Reel and Reel Size

| Package        | Carrier Width (W) | Pitch (P) | Part Per Full Reel | Reel Size |
|----------------|-------------------|-----------|--------------------|-----------|
| 8-Pin SOIC (N) | 12 mm             | 8 mm      | 2500               | 13 in     |

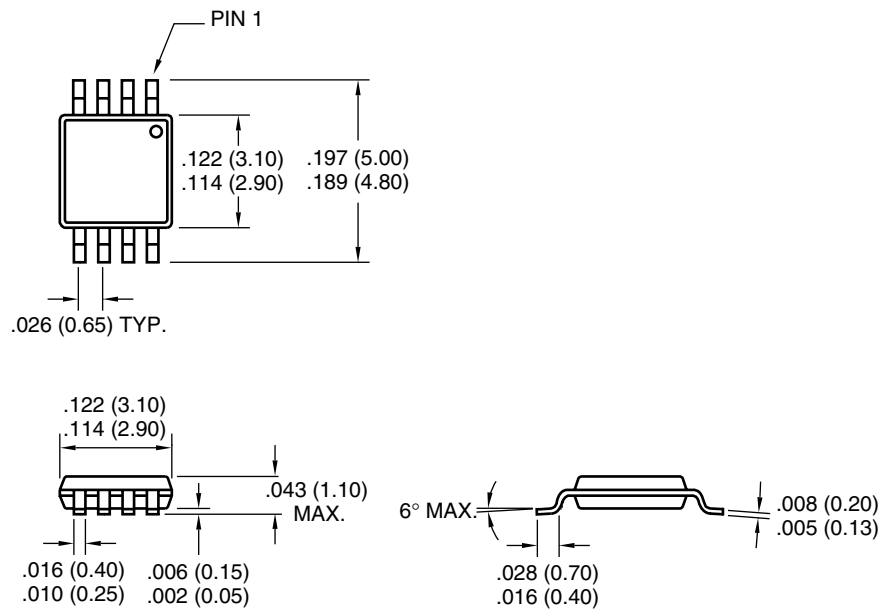
## 6.3 Package Dimensions

### 8-Pin Plastic DIP



Dimensions: inches (mm)

### 8-Pin MSOP

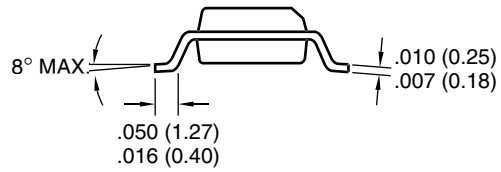
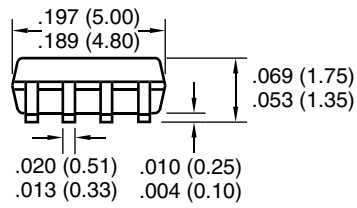
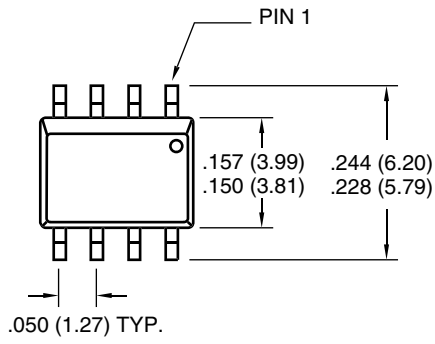


Dimensions: inches (mm)

# TC1026

## 6.3 Package Dimensions (Continued)

### 8-Pin SOIC



Dimensions: inches (mm)

## **Sales and Support**

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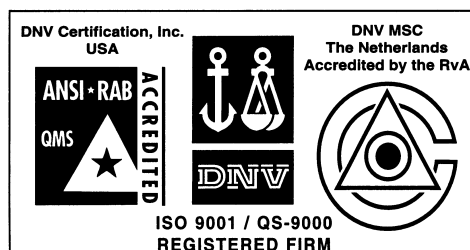
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