AS1976, AS1977

Ultra-Low Current, 1.8V Comparators

Data Sheet

1 General Description

The AS1976/AS1977 are very low-current comparators that can operate beyond the rail voltages and are guaranteed to operate down to 1.8V

Low input bias current, current-limiting output circuitry, and ultra-small packaging make these comparators ideal for low-power 2-cell applications including power-management and power-monitoring systems.

The comparators are available as the standard products listed in Table 1.

Table 1. Standard Products

Model	Output Type	Current
AS1976	Push/Pull	200nA
AS1977	Open-Drain	200nA

The AS1976 push/pull output can sink or source current.

The AS1977 open-drain output can be pulled beyond VCC to a maximum of 6V > VEE. This open-drain model is ideal for use as a logic-level translator or bipolar-to-unipolar converter.

Large internal output drivers provide rail-to-rail output swings with loads up to 8mA. Both devices feature built-in battery power-management and power-monitoring circuitry.

The AS1976/AS1977 are available in a 5-pin SOT23 package.

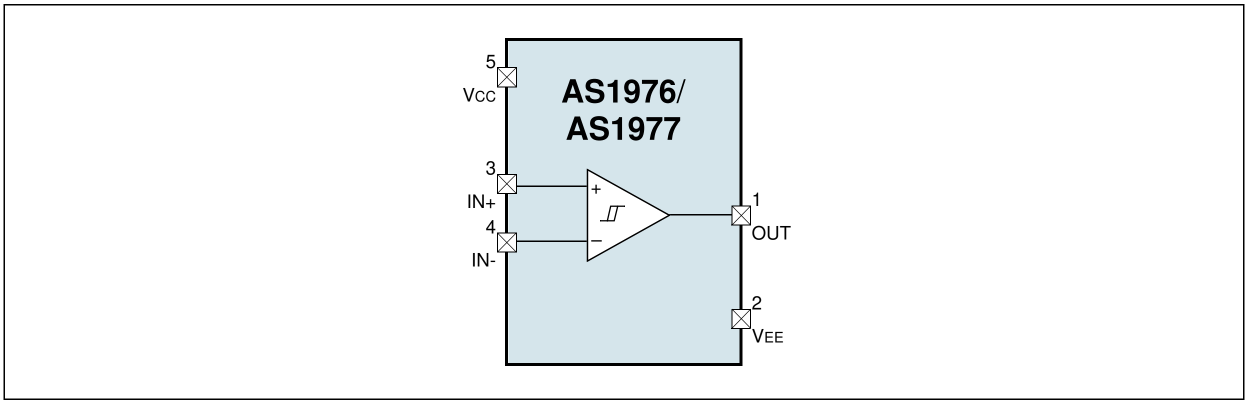
2 Key Features

- CMOS Push/Pull Output Sinks and Sources 8mA (AS1976)
- CMOS Open-Drain Output Voltage Extends Beyond VCC (AS1977)
- Ultra-Low Supply Current: 200nA
- Internal Hysteresis: 3mV
- 3V-to5V Logiv-Level Translation
- Guaranteed to Operate Down to +1.8V
- Input Voltage Range Operates 200mV Beyond the Rails
- Crowbar Current-Free Switching
- No Phase Reversal for Overdriven Inputs
- 5-pin SOT23 Package

3 Applications

The devices are ideal for battery monitoring/management, mobile communication devices, laptops and PDAs, ultra-low-power systems, threshold detectors/discriminators, telemetry and remote systems, medical instruments, or any other space-limited application with low power-consumption requirements.

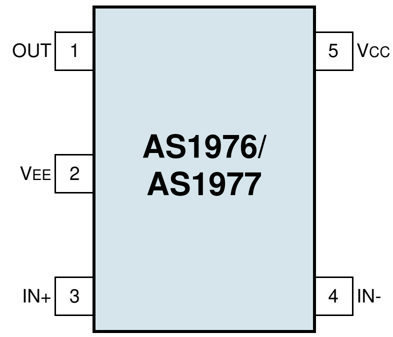
Figure 1. Block Diagram



4 Pinout

Pin Assignments

Figure 2. Pin Assignments (Top View)



Pin Descriptions

Table 2. Pin Descriptions

Pin Number	Pin Name	Description
1	OUT	**Comparator Output**
2	V_{EE}	**Negative Supply Voltage**
3	IN+	**Comparator Non-Inverting Input**
4	IN-	**Comparator Inverting Input**
5	V_{CC}	**Positive Supply Voltage**

5 Absolute Maximum Ratings

Stresses beyond those listed in Table 3 may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in Section 6 Electrical Characteristics on page 4 is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 3. Absolute Maximum Ratings

Parameter	Min	Max	Units	Comments
Supply Voltage V_{CC} to V_{EE}		+7	V	
Voltage Inputs IN+, IN-	V_{EE} - 0.3	V_{CC} + 0.3	V	
Output Voltage AS1976, AS1978	V_{EE} - 0.3	V_{CC} + 0.3	V	
Output Current	-50	+50	mA	
Output Short-Circuit Duration		10	s	
Continuous Power Dissipation		571	mW	Derate at 7.31mW/ºC above +70ºC
Operating Temperature Range	-40	+85	ºC	
Storage Temperature Range	-65	+150	ºC	
Package Body Temperature		+260	ºC	The reflow peak soldering temperature (body temperature) specified is in accordance with *IPC/JEDEC J-STD-020C "Moisture/Reflow Sensitivity Classification for Non-Hermetic Solid State Surface Mount Devices".* The lead finish for Pb-free leaded packages is matte tin (100% Sn).

6 Electrical Characteristics

V_{CC} = +5V, V_{EE} = 0, V_{CM} = 0, T_{AMB} = -40 to +85ºC (unless otherwise specified). Typ values are at T_{AMB} = +25ºC.

Table 4. AS1976/AS1977 Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{CC}	Supply Voltage Range	Inferred from the PSRR test	1.8		5.5	V
I_{CC}	Supply Current	V_{CC} = 1.8V		0.2		µA
		V_{CC} = 5V, T_{AMB} = +25ºC		0.21	0.5	
		V_{CC} = 5V, T_{AMB} = T_{MIN} to T_{MAX}			0.9	
V_{CM}	Input Common-Mode Voltage Range	Inferred from CMRR test	V_{EE} - 0.2		V_{CC} + 0.2	V
V_{OS}	Input Offset Voltage	-0.2V ≤ V_{CM} ≤ (V_{CC} + 0.2V), T_{AMB} = +25ºC [1]		1	5	mV
		-0.2V ≤ V_{CM} ≤ (V_{CC} + 0.2V), T_{AMB} = T_{MIN} to T_{MAX}			10	
V_{HB}	Input-Referred Hysteresis	-0.2V ≤ V_{CM} ≤ (V_{CC} + 0.2V) [2]		3		mV
I_B	Input Bias Current [3]	T_{AMB} = +25ºC		0.15	1	nA
		T_{AMB} = T_{MIN} to T_{MAX}			2	
I_{OS}	Input Offset Current			10		pA
PSRR	Power-Supply Rejection Ratio	V_{CC} = 1.8 to 5.5V, T_{AMB} = +25ºC		0.05	1	mV/V
CMRR	Common-Mode Rejection Ratio	(V_{EE} - 0.2V) ≤ V_{CM} ≤ (V_{CC} + 0.2V), T_{AMB} = +25ºC		0.2	3	mV/V
V_{CC} - V_{OH}	Output Voltage Swing High	T_{AMB} = +25ºC, AS1976 only V_{CC} = 5.5V, I_{SINK} = 8mA		220	500	mV
		T_{AMB} = T_{MIN} to T_{MAX}, AS1976 only V_{CC} = 5.5V, I_{SINK} = 8mA			650	
		T_{AMB} = +25ºC AS1976 only V_{CC} = 1.8V, I_{SOURCE} = 1mA		80	200	
		T_{AMB} = T_{MIN} to T_{MAX}, AS1976 only V_{CC} = 1.8V, I_{SOURCE} = 1mA			300	
V_{OL}	Output Voltage Swing Low	T_{AMB} = +25ºC, AS1976 only V_{CC} = 5.5V, I_{SINK} = 8mA		220	500	mV
		T_{AMB} = T_{MIN} to T_{MAX}, AS1976 only V_{CC} = 5.5V, I_{SINK} = 8mA			650	
		T_{AMB} = +25ºC, V_{CC} = 1.8V, I_{SOURCE} = 1mA		70	200	
		T_{AMB} = T_{MIN} to T_{MAX}, V_{CC} = 1.8V, I_{SOURCE} = 1mA			300	
I_{LEAK}	Output Leakage Current	AS1977 only, V_{OUT} = 5.5V		0.001	1	µA
I_{SC}	Output Short-Circuit Current	Sourcing, V_{OUT} = V_{EE}, V_{CC} = 5.5V		50		mA
		Sourcing, V_{OUT} = V_{EE}, V_{CC} = 1.8V		6		
		Sinking, V_{OUT} = V_{CC}, V_{CC} = 5.5V		70		
		Sinking, V_{OUT} = V_{CC}, V_{CC} = 1.8V		5		
t_{PD-}	High-to-Low Propagation Delay [4]	V_{CC} = 1.8V		10		µs
		V_{CC} = 5.5V		12		

Table 4. AS1976/AS1977 Electrical Characteristics (Continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{PD+}	Low-to-High Propagation Delay [4]	AS1976 only, V_{CC} = 1.8V		13		µs
		AS1976 only, V_{CC} = 5.5V		15		
		AS1977 only, V_{CC} = 1.8V, R_{PULUP} = 100kΩ		16		
		AS1977 only, V_{CC} = 3.6V, R_{PULUP} = 100kΩ		18		
t_{RISE}	Rise Time	AS1976 only, C_{LOAD} = 15pF		10		ns
t_{FALL}	Fall Time	C_{LOAD} = 15pF		10		ns
t_{ON}	Power-Up Time			100		ns

1. V_{OS} is defined as the center of the hysteresis band at the input.
2. The hysteresis-related trip points are defined as the edges of the hysteresis band, measured with respect to the center of the band (i.e., V_{OS}) (see Figure 26 on page 11).
3. Guaranteed by design.
4. Specified with an input overdrive voltage ($V_{OVERDRIVE}$) = 100mV, and load capacitance (C_{LOAD}) = 15pF. $V_{OVERDRIVE}$ is defined above and beyond the offset voltage and hysteresis of the comparator input. A reference voltage error should also be added.

7 Typical Operating Characteristics

Figure 3. ICC vs. VCC and Temperature

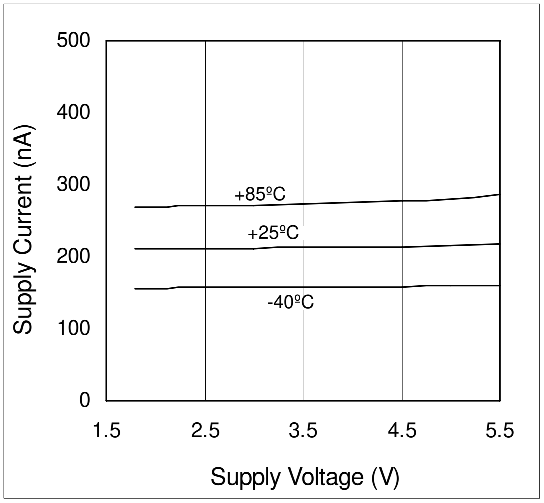


Figure 4. ICC vs. Temperature

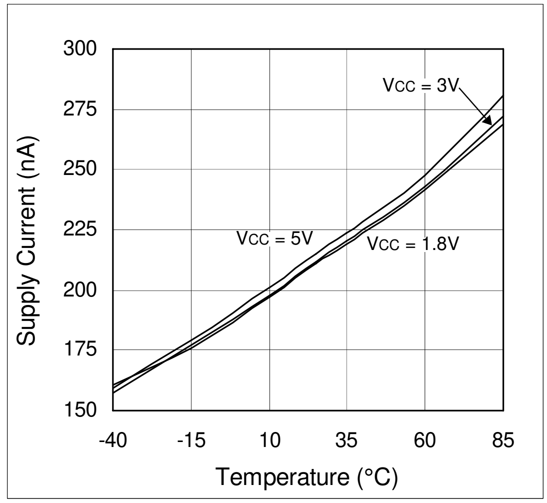


Figure 5. ICC vs. Output Transition Frequency

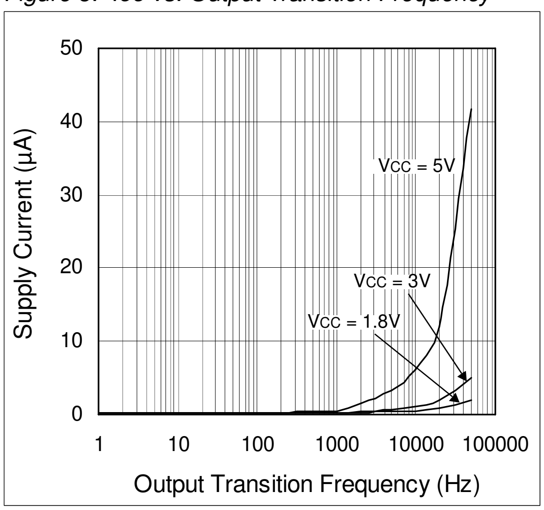


Figure 6. VOL vs. ISINK

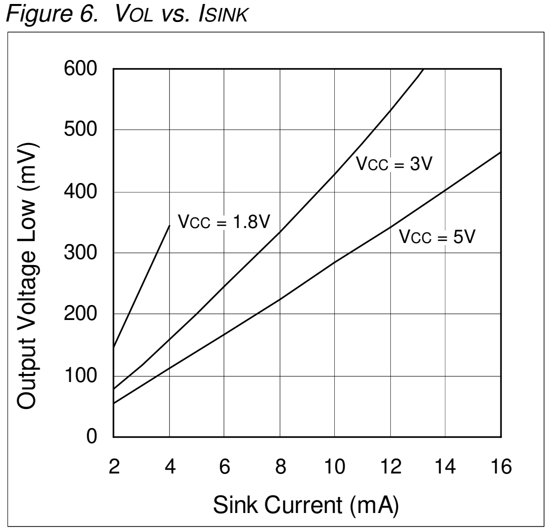


Figure 7. VOL vs. ISINK and Temperature

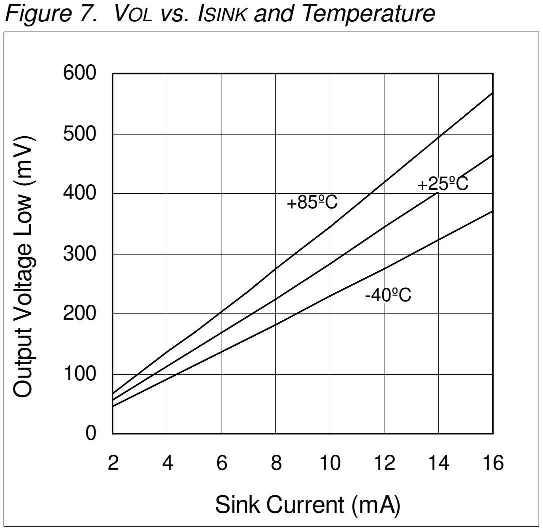


Figure 8. VOH vs. ISOURCE

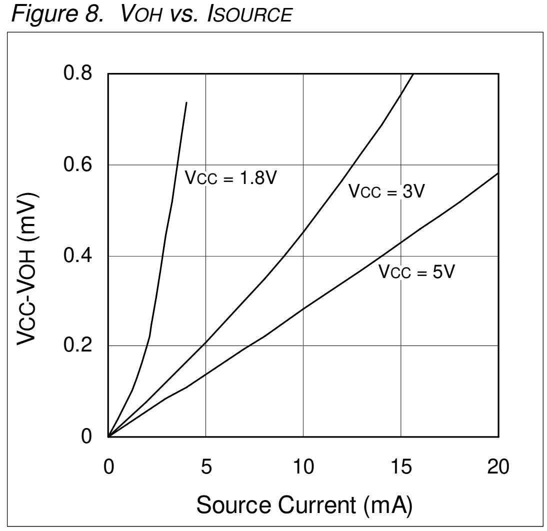


Figure 9. VOH vs. ISOURCE and Temperature

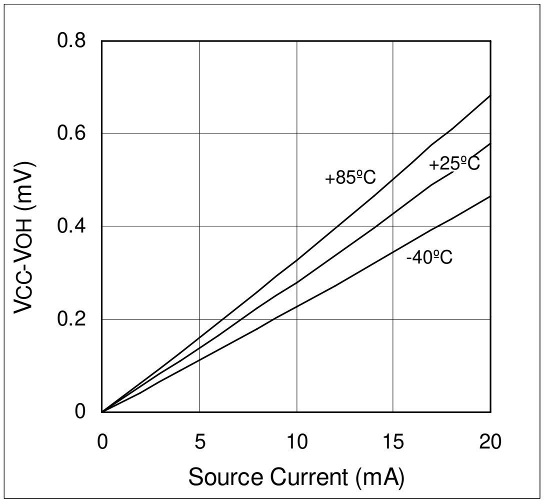


Figure 10. Short Circuit Sink Current vs. Temperature

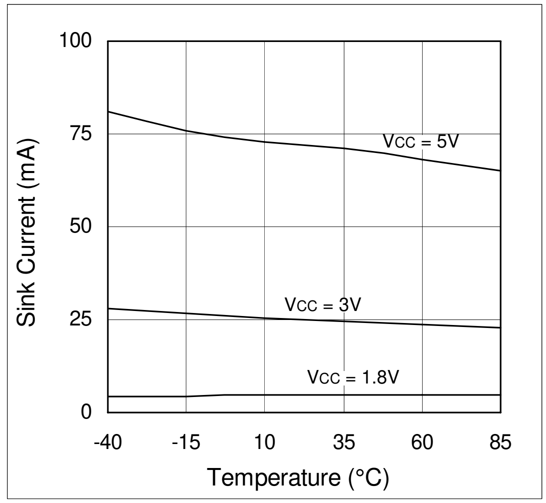


Figure 11. Short Circuit Source Current vs. Temperature

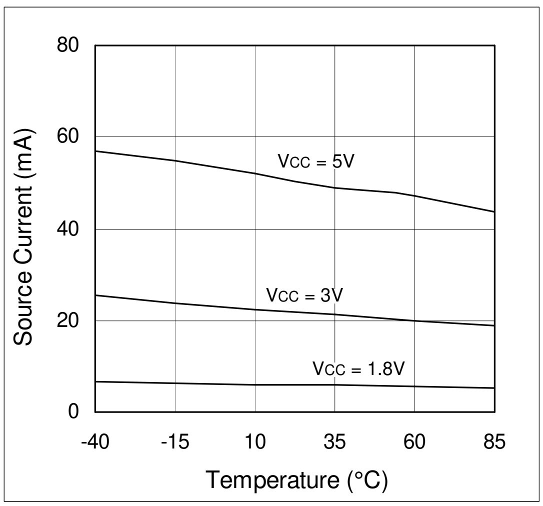


Figure 12. tPD+ vs. Temperature

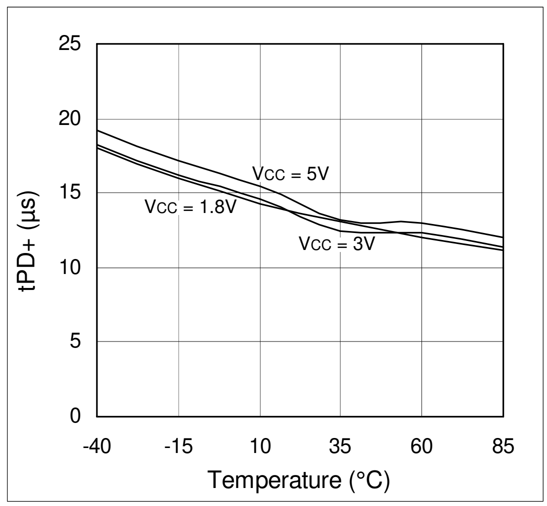


Figure 13. tPD- vs. Temperature

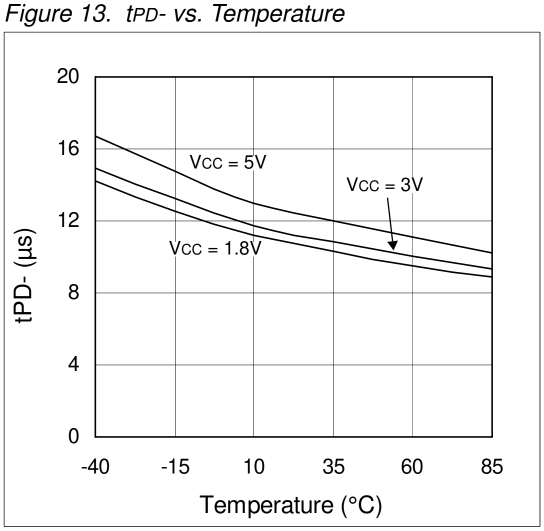


Figure 14. tPD- vs. Capacitive Load

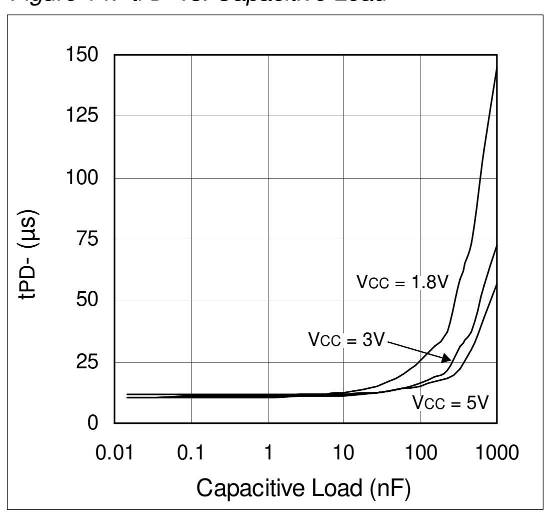


Figure 15. tPD+ vs. Capacitive Load

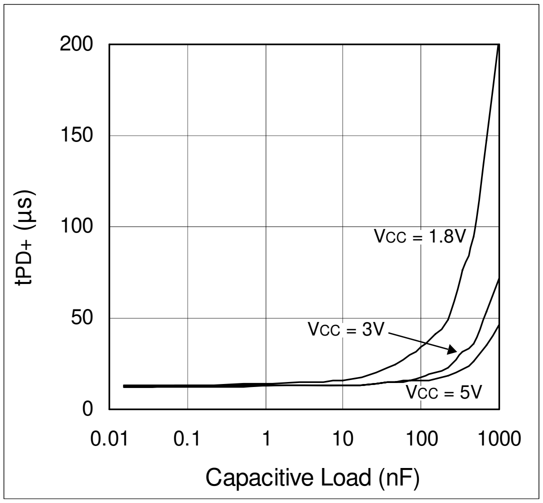


Figure 16. tPD+ 5V

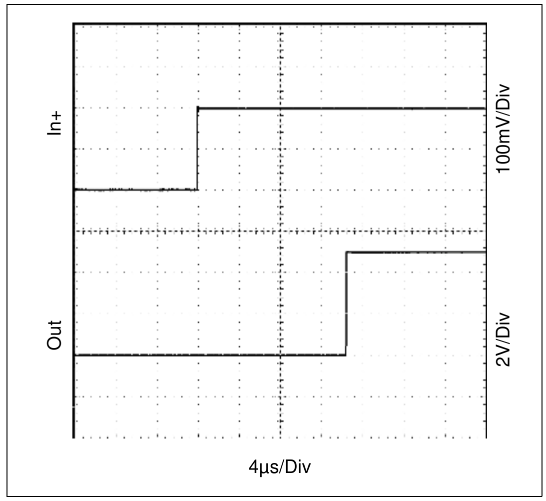


Figure 17. tPD- 5V

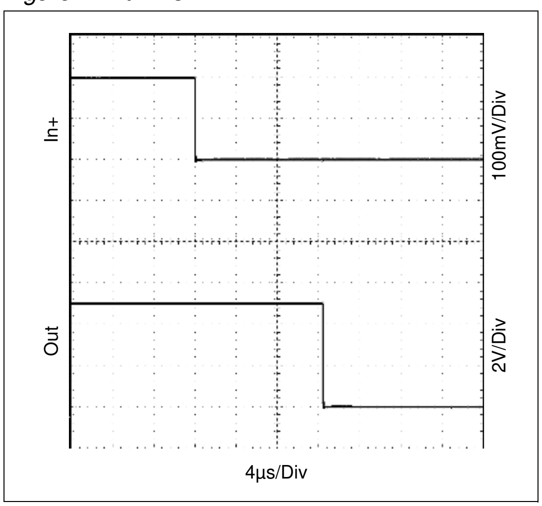


Figure 18. tPD+ 3V

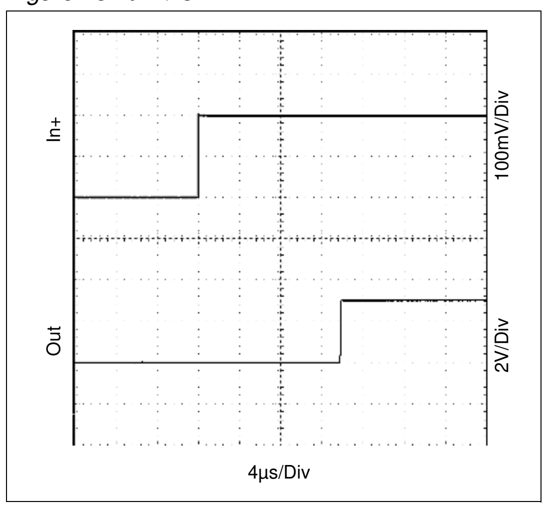


Figure 19. tPD- 3V

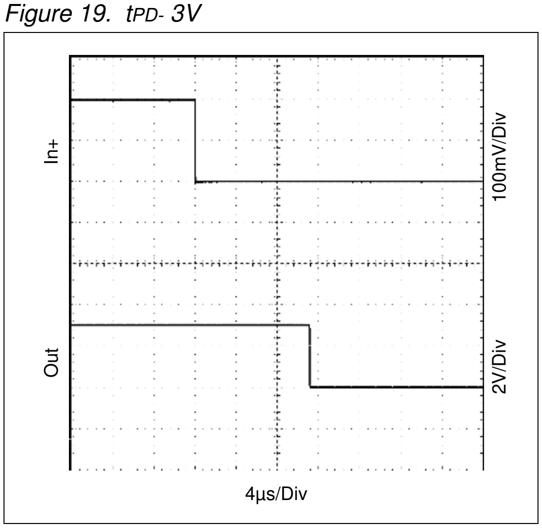


Figure 20. tPD+ 1.8V

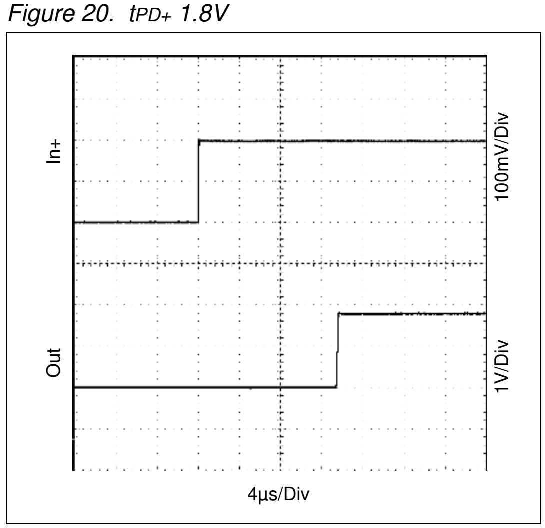


Figure 21. tPD- 1.8V

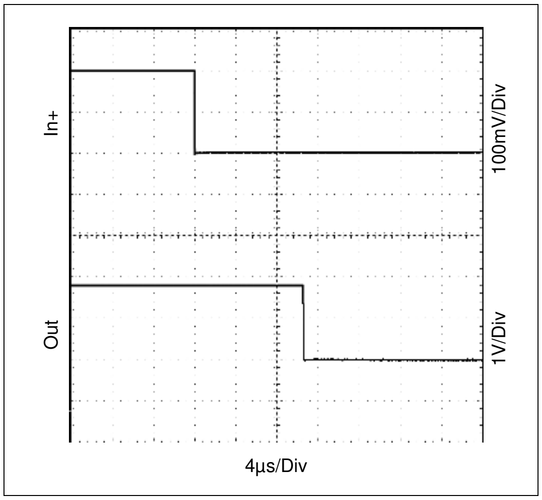


Figure 22. 10kHz Response @ 1.8V

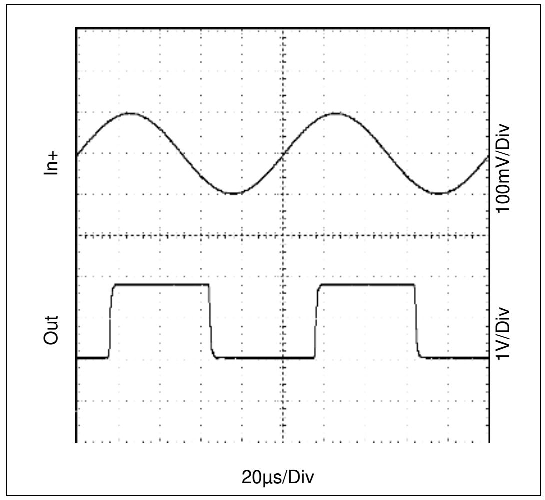


Figure 23. 1kHz Response @ 5V

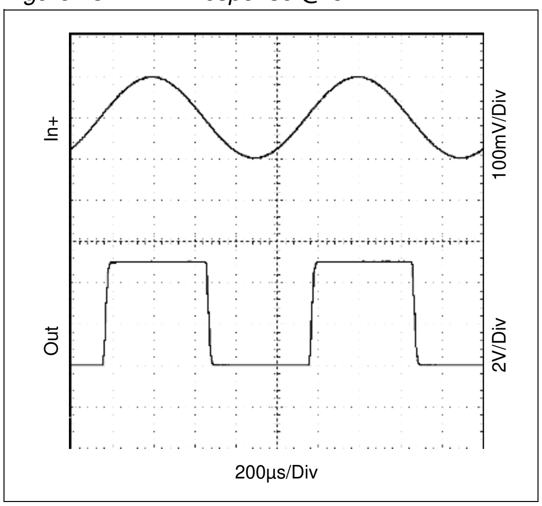
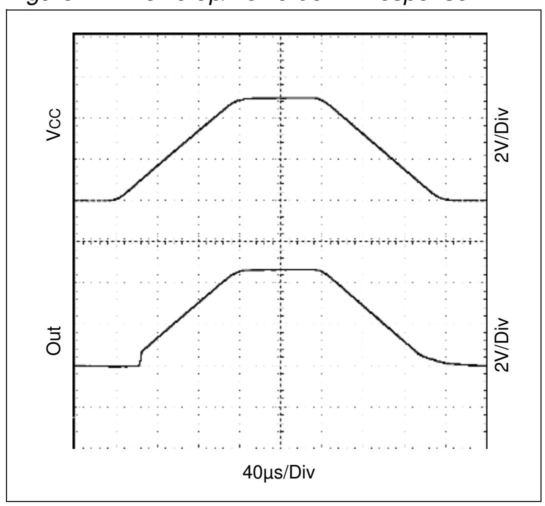


Figure 24. Powerup/Powerdown Response



8 Detailed Description

The AS1976/AS1977 are ultra low-current comparators and are guaranteed to operate with voltages as low as +1.8V. The common-mode input voltage range extends 200mV beyond the rail voltages, and internal hysteresis ensures clean output switching, even with slow input signals.

The AS1976 push/pull output stage sinks and sources-current. The AS1977 open-drain output stage can be pulled beyond V_{CC} to an absolute maximum of 3.6V > V_{EE}. The AS1979/AS1977 are perfect for implementing wired-OR output logic functions.

For all comparators, large internal output drivers allow rail-to-rail output swings with loads of up to 8mA. The output stage design minimizes supply-current surges during switching, eliminating most power supply transients.

Input Stage

The input common-mode voltage range extends from (V_{EE} - 0.2V) to (V_{CC} + 0.2V), and the comparators can operate at any differential input voltage within this range. The comparators have very low input bias current (±0.15nA, typ) if the input voltage is within the common-mode voltage range.

Inputs are protected from over-voltage conditions by internal ESD protection diodes connected to the supply rails. As the input voltage exceeds the supply rails, these ESD protection diodes are forward biased and begin to conduct.

Output Stage

The break-before-make output stage is capable of rail-to-rail operation with loads up to 8mA. Many comparators consume orders of magnitude more current during switching than during steady-state operation.

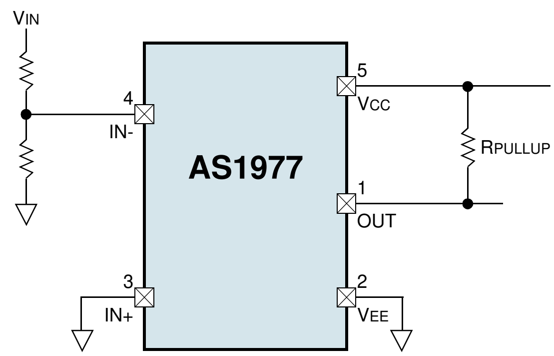
Even at loads of up to 8mA, changes in supply-current during an output transition are extremely small (see Figure 5 on page 6). As shown in Figure 5, the minimal supply current increases as the output switching frequency approaches 1kHz. This characteristic reduces the need for power-supply filter capacitors to reduce transients created by comparator switching currents.

Because of the unique design of its output stage, the AS1976/AS1977 can dramatically increase battery life, even in high-speed applications.

9 Application Information

The AS1976/AS1977 comparators are perfect for use with all 2-cell battery-powered applications. Figure 25 shows a typical application for the AS1977.

Figure 25. AS1977 Typical Application Circuit



Internal Hysteresis

The comparators were designed with 3mV of internal hysteresis to neutralize the effects of parasitic feedback, i.e., to prevent unwanted rapid changes between the two output states.

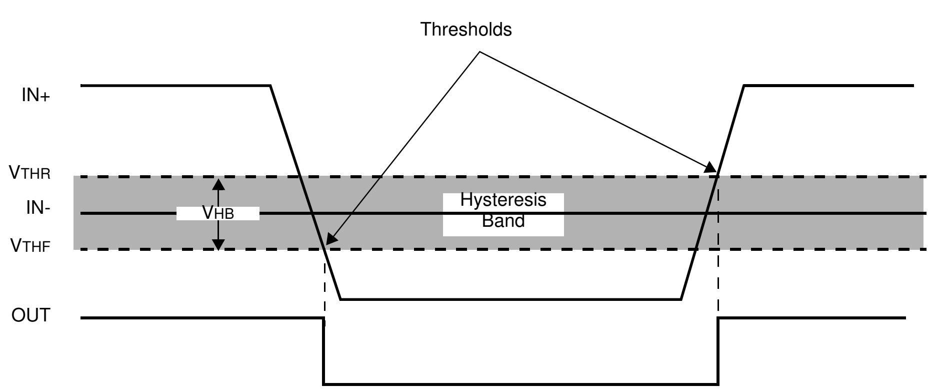
The internal hysteresis in the AS1976/AS1977 creates two trip points:

- Rising Input Voltage (V_{THR}) – The comparator switches its output from low to high as V_{IN} rises above this trip point.
- Falling Input Voltage (V_{THF}) – The comparator switches its output from high to low as V_{IN} falls below this trip point.

The area between the trip points is the hysteresis band (V_{HB}) (see Figure 26). When the AS1976/AS1977 input voltages are equivalent, the hysteresis effectively causes one input to move quickly past the other, thus taking the input out of the region where oscillation occurs. In Figure 26 IN- has a fixed voltage applied and IN+ is varied.

Note: If the inputs are reversed the output will be inverted.

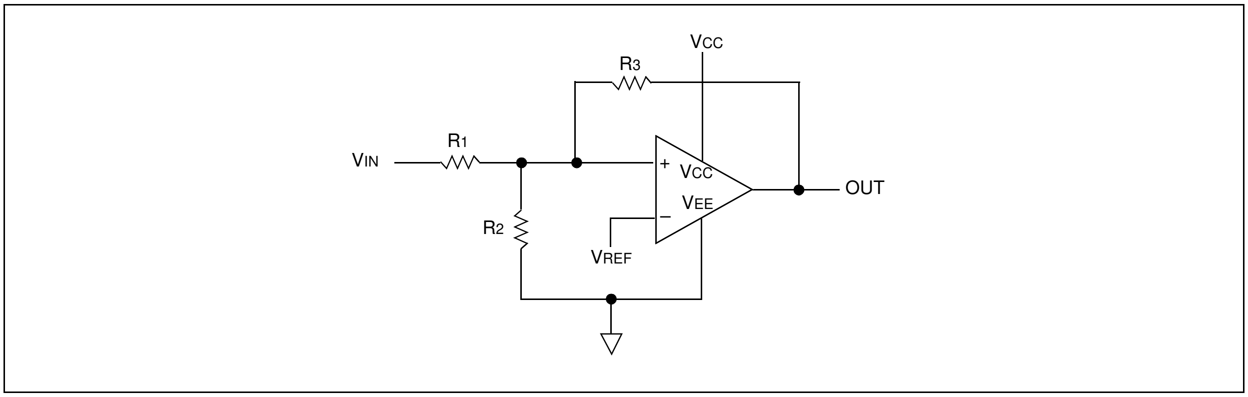
Figure 26. Threshold Hysteresis Band



Additional Hysteresis (AS1976)

Additional hysteresis can be added to the AS1976 and AS1978 with three resistors and positive feedback (see Figure 27), however, this positive feedback method slows hysteresis response time.

Figure 27. AS1976 Additional Hysteresis



Resistor Selection Example

For the circuit shown in Figure 27, use the following steps to calculate values for R_1, R_2, and R_3.

1. First select the value for R_3. Leakage current at IN is less than 2nA, thus the current through R_3 should be at least 0.2µA to minimize errors due to leakage current. The current through R_3 at the trip point is:

   $$(V_{REF} - V_{OUT})/R_3 \quad \text{(EQ 1)}$$

   Taking into consideration the two possible output states, solving for R_3 yields two formulas:

   $$R_3 = V_{REF}/I_{R3} \quad \text{(EQ 2)}$$

   $$R_3 = (V_{CC} - V_{REF})/I_{R3} \quad \text{(EQ 3)}$$

   Use the smaller of the two resulting values for R_3. For example, for V_{REF} = 1.245V, V_{CC} = 3.3V, and I_{R3} = 1µA, the two resistor values are 1.2MΩ and 2.0MΩ, therefore choose a 1.2MΩ standard resistor for R_3.

2. Choose the required hysteresis band (V_{HB}). For this example, choose 33mV.
3. Calculate R_1 as:

   $$R_1 = R_3(V_{HB}/V_{CC}) \quad \text{(EQ 4)}$$

   Substituting the R_1 and V_{HB} example values gives:

   $$R_1 = 1.2M\Omega(50mV/3.3V) = 12k\Omega$$

4. Choose the trip point for V_{IN} rising (V_{THR}) such that $V_{THR} > V_{REF}(R_1 + R_3)/R_3$. For this example, choose 3V.
5. Calculate R_2 as:

   $$R_2 = 1/[V_{THR}/(V_{REF} \times R_1) - (1/R_1) - (1/R_3)] \quad \text{(EQ 5)}$$

   Substituting the R_1 and R_3 example values gives:

   $$R_2 = 1/[3.0V/(1.2V \times 12k\Omega) - (1/12k\Omega) - (1/1.2M\Omega)] = 8.05k\Omega$$

   In this example, a standard 8.2kΩ resistor should be used for R_2.

6. Verify the trip voltages and hysteresis as:

   $$V_{THR} = V_{REF} \times R_1[(1/R_1) + (1/R_2) + (1/R_3)] \quad \text{(EQ 6)}$$

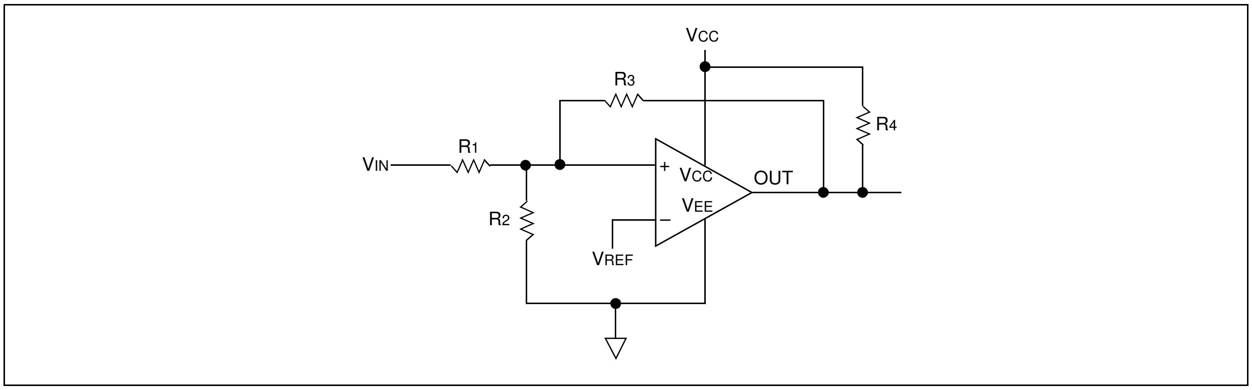
   $$V_{THF} = V_{THR} - (R_1 \times V_{CC}/R_3) \quad \text{(EQ 7)}$$

   $$Hysteresis = V_{THR} - V_{THF} \quad \text{(EQ 8)}$$

Additional Hysteresis (AS1977)

Additional hysteresis can be added to the AS1977 and AS1979 with 4 resistors and positive feedback (see Figure 28).

Figure 28. AS1977 Additional Hysteresis



Resistor Selection Example

For the circuit shown in Figure 28, use the following steps to calculate values for R_1, R_2, R_3, and R_4.

1. Select R3 according to one of these formulas:

$$R_3 = V_{REF}/1\mu A \quad \text{(EQ 9)}$$

$$R_3 = (V_{CC} - V_{REF})/1\mu A - R_4 \quad \text{(EQ 10)}$$

   Use the smaller of the two resulting resistor values for R_3.

2. Choose the hysteresis band required (V_{HB}).
3. Calculate R_1 as:

$$R_1 = (R_3 + R_4)(V_{HB}/VCC) \quad \text{(EQ 11)}$$

4. Choose the trip point for V_{IN} rising (V_{THR}).
5. Calculate R_2 as:

$$R_2 = 1/[V_{THR}/(V_{REF} \times R_1) - (1/R_1) - 1/R_3] \quad \text{(EQ 12)}$$

6. Verify the trip voltages and hysteresis as:

$$V_{IN} \text{ rising: } V_{THR} = V_{REF}[R_1(1/R_1 + 1/R_2 + 1/R_3)] \quad \text{(EQ 13)}$$

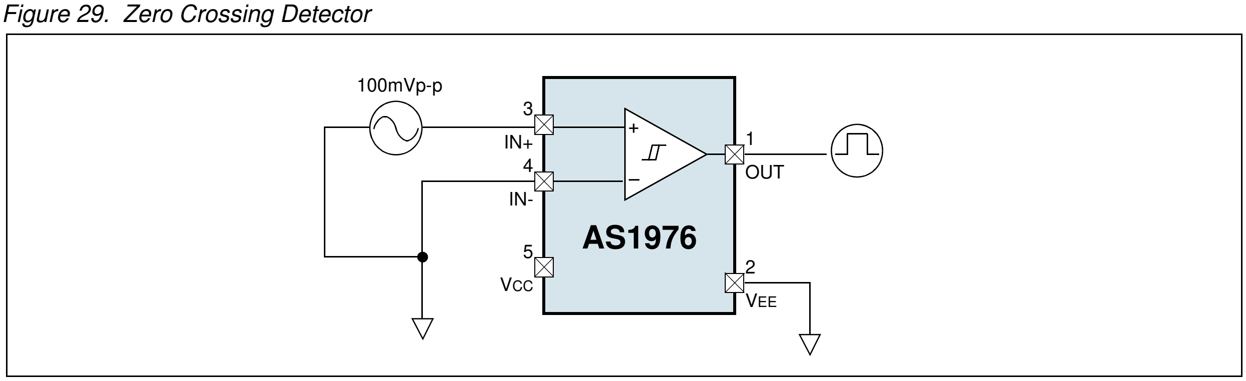
$$V_{IN} \text{ falling: } V_{THF} = V_{REF}[R_1(1/R_1 + 1/R_2 + 1/(R_3+R_4))] - [1/(R_3+R_4)]V_{CC} \quad \text{(EQ 14)}$$

$$\text{Hysteresis} = V_{THR} - V_{THF} \quad \text{(EQ 15)}$$

Zero-Crossing Detector

Figure 29 shows the AS1976 in a zero-crossing detector circuit. The inverting input (IN-) is connected to ground, and the non-inverting input (IN+) is connected to a 100mVp-p signal source. When the signal at IN- crosses 0V, the signal at OUT changes states.

Figure 29. Zero Crossing Detector



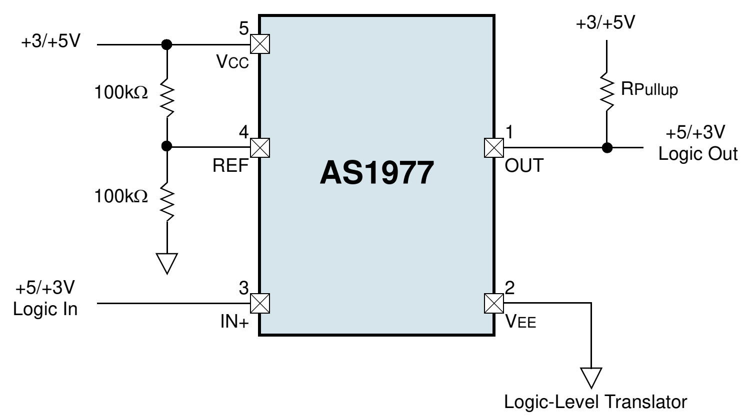
Logic-Level Translation

The AS1977 can be used as a 5V-to-3V logic translator. Figure 30 shows an application that converts 5V- to 3V-logic levels, and provides the full 5V logic-swing without creating overvoltage on the 3V logic inputs.

Note: When the comparator is powered by a 5V supply, R_{PULUP} for the open-drain output should be connected to the +3V supply voltage.

For 3V-to-5V logic-level translations, connect the +3V supply voltage to V_{CC} and the +5V supply voltage to R_{PULUP}.

Figure 30. AS1977 Logic-Level Translation Circuit



Layout Considerations

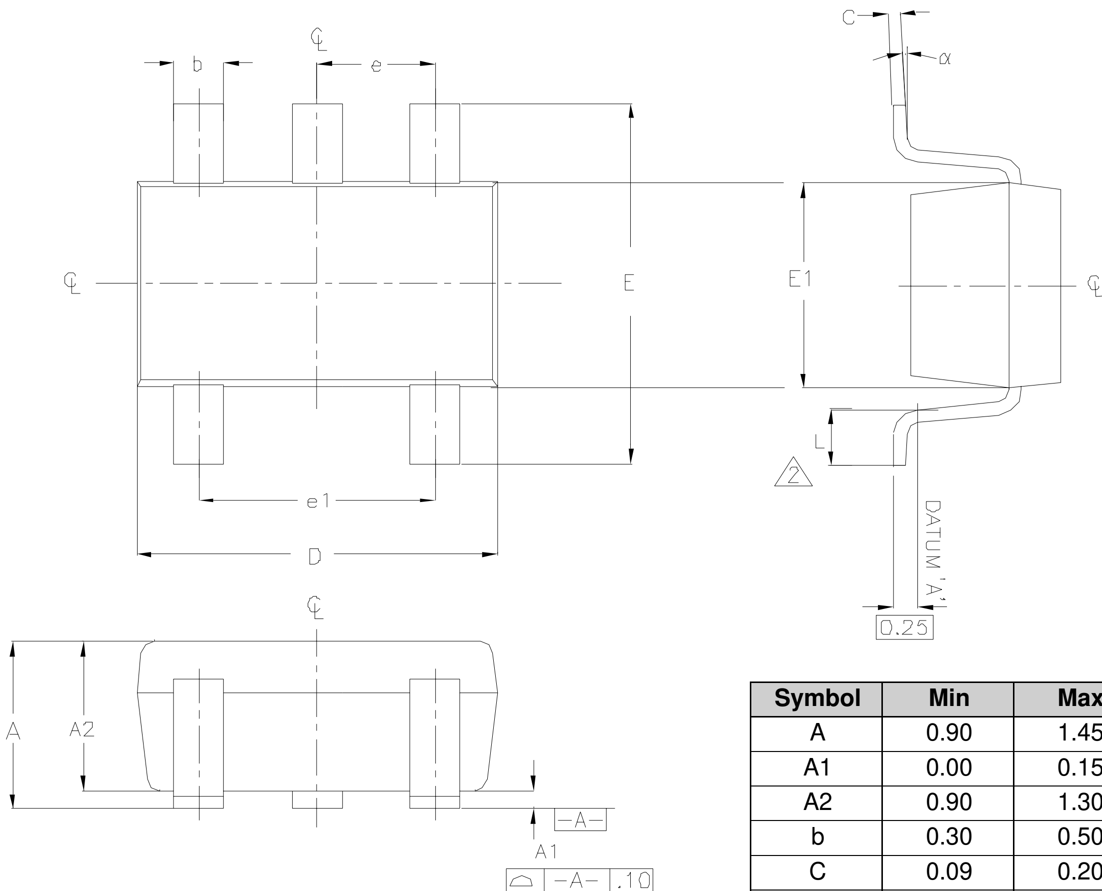
The AS1976/AS1977 requires proper layout and design techniques for optimum performance.

- Power-supply bypass capacitors are not typically required, although 100nF bypass capacitors should be placed close to the AS1976/AS1977 supply pins when supply impedance is high, leads are long, or for excessive noise on the supply lines.
- Minimize signal trace lengths to reduce stray capacitance.
- A ground plane should be used.
- Surface-mount components should be used whenever practical.

10 Package Drawings and Markings

The AS1976/AS1977 are available in a 5-pin SOT23 package.

Figure 31. 5-pin SOT23 Package



Symbol	Min	Max
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
b	0.30	0.50
C	0.09	0.20
D	2.80	3.05
E	2.60	3.00
E1	1.50	1.75
L	0.30	0.55
e	0.95 REF	
e1	1.90 REF	
α	0º	8º

Notes:

1. Controlling dimension is millimeters.
2. Foot length measured at intercept point between datum A and lead surface.
3. Package outline exclusive of mold flash and metal burr.
4. Package outline inclusive of solder plating.
5. Meets *JEDEC MO178*.

11 Ordering Information

The devices are available as the standard products shown in Table 5.

Table 5. Ordering Information

Type	Marking	Description	Output Type	Delivery Form	Package
AS1976	ASI9	Ultra-Low Current 1.8V Comparator	Push/Pull	Tube	5-pin SOT23
AS1976-T	ASI9	Ultra-Low Current 1.8V Comparator	Push/Pull	Tape and Reel	5-pin SOT23
AS1977	ASJA	Ultra-Low Current 1.8V Comparator	Open-Drain	Tube	5-pin SOT23
AS1977-T	ASJA	Ultra-Low Current 1.8V Comparator	Open-Drain	Tape and Reel	5-pin SOT23

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