TLV185x and TLV186x Family of 40 V, Nanopower Comparators
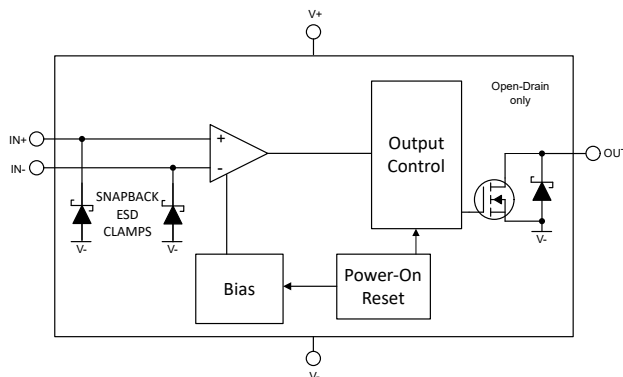
1 Features

- Low supply current: 440 nA per channel
- Wide supply range: 1.8 V to 40 V
- Over-the-rail inputs: common-mode range extends 40 V above (V-) independent of (V+)
- Fail-safe inputs: high impedance inputs with no supply
- Internal power-on-reset provides a known startup condition
- No phase reversal for overdriven inputs
- Reverse battery protection up to 40 V
- Push-pull output option (TLV185x)
- Open-drain output option (TLV186x)
- Temperature range: -40°C to +125°C

2 Applications

- Mobile phones & tablets
- Headsets/headphones & earbuds
- PC & notebooks
- Gas detector
- Smoke & heat detector
- Motion Detector
- Gas meter
- Servo drive position sensor

3 Description

The TLV185x and TLV186x are a family of nanopower, 40 Volt comparators with single, dual and quad channel options. The family offers fail-safe (FS) inputs with push-pull and open-drain output options. These features coupled with nanopower operation over the wide supply range of 1.8 V to 40 V make this family well-suited for house-keeping functions such as voltage and temperature monitoring in low-power, always-on systems.

All devices include a Power-On Reset (POR) feature that ensures the output is in a known state until the minimum supply voltage has been reached before the output responds to the inputs, thus preventing false outputs during system power-up and power-down.
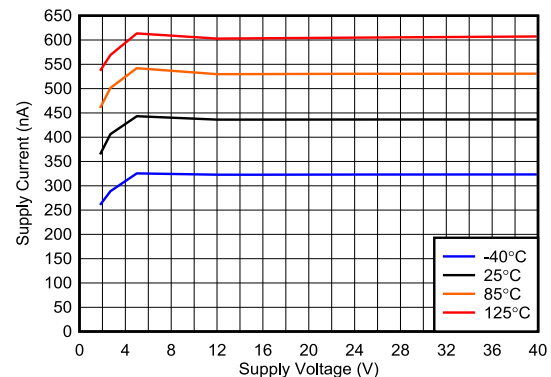
The inputs have over-the-rail capability where both inputs can exceed the supply voltage up to 40 V and still operate properly. This makes the comparators well suited for both high and low supply voltage systems without limiting the range of input voltages that can be compared. Likewise, the internal reverse battery protection feature prevents damage to the comparator in the event of improper battery installation to the supply pins.

The TLV185x comparators have a push-pull output stage where as the TLV186x comparators have an open-drain output stage, making it appropriate for level translation.

Device Information

PART NUMBER	PACKAGE [1]	BODY SIZE (NOM)
TLV1851 TLV1861	SOT-23 (5) (Preview) SOT-23 (5)	1.60 mm x 2.90 mm
TLV1852, TLV1862	SOIC (8) (Preview)	3.91 mm × 4.90 mm
	VSSOP (8) (Preview)	3.00 mm × 3.00 mm
	WSON (8) (Preview)	2.00 mm × 2.00 mm
	SOT-23 (8) (Preview)	1.60 mm × 2.90 mm
TLV1854, TLV1864	SOIC (14) (Preview)	3.91 mm x 8.65 mm
	TSSOP (14) (Preview)	4.40 mm × 5.00 mm
	SOT-23 (14) (Preview)	4.20 mm x 2.00 mm
	WQFN (16) (Preview)	3.00 mm × 3.00 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Block Diagram

Supply Current vs. Supply Voltage

Table of Contents

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
December 2022	*	Initial Release

Product Folder Links: *TLV1861*

5 Pin Configuration and Functions

Pin Configuration
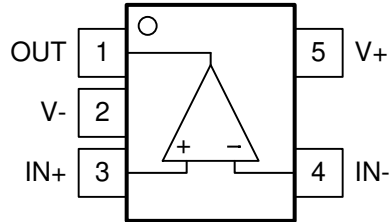
TLV1851, TLV1861 DBV Package,
SOT-23-5
Top View
(Standard "north west" pinout)

Pin Functions: TLV1851 and TLV1861

PIN		I/O	DESCRIPTION
NAME	NO.		
OUT	1	O	Output
V-	2	-	Negative Supply Voltage
IN+	3	I	Non-Inverting (+) Input
IN-	4	I	Inverting (-) Input
V+	5	-	Positive Supply Voltage

Product Folder Links: *TLV1861*

Pin Configurations: TLV1852 and TLV1862
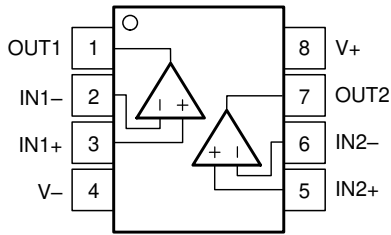
D, DGK, DDF Packages
8-Pin SOIC, VSSOP, SOT-23-8
Top View
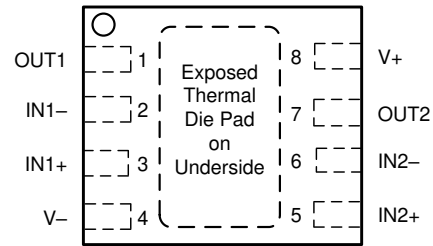
NOTE: Connect exposed thermal pad directly to V- pin.
DSG Package,
8-Pad WSON With Exposed Thermal Pad,
Top View

Pin Functions: TLV1852 and TLV1862

PIN		I/O	DESCRIPTION
NAME	NO.		
OUT1	1	O	Output pin of the comparator 1
IN1–	2	I	Inverting input pin of comparator 1
IN1+	3	I	Noninverting input pin of comparator 1
V-	4	—	Negative supply voltage
IN2+	5	I	Noninverting input pin of comparator 2
IN2–	6	I	Inverting input pin of comparator 2
OUT2	7	O	Output pin of the comparator 2
V+	8	—	Positive supply voltage
Thermal Pad	—	—	Connect directly to V- pin (DSG Package only)

Product Folder Links: *TLV1861*

Pin Configurations: TLV1854 and TLV1864

Not to scale

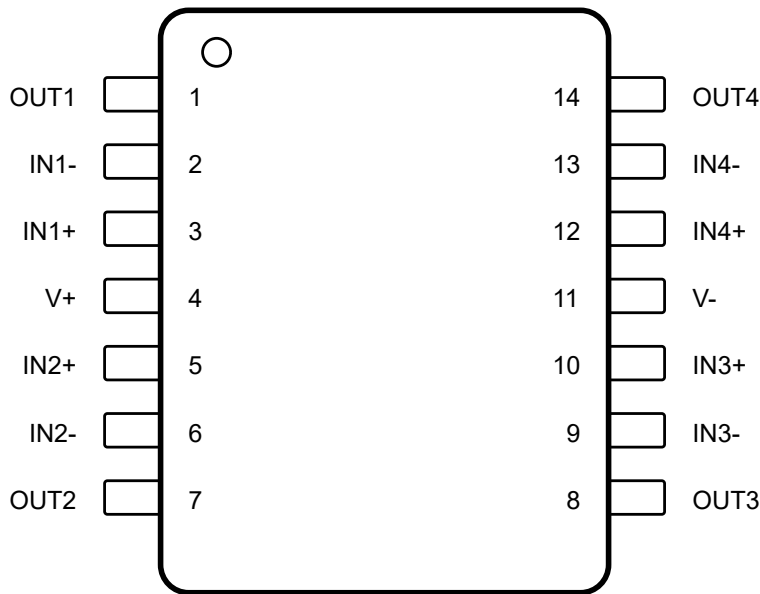**D, PW, DYY Package, 14-Pin SOIC, TSSOP, SOT-23,
Top View**

NOTE: Connect exposed thermal pad directly to V- pin.

**RTE Package, 16-Pad WQFN With Exposed
Thermal Pad, Top View**
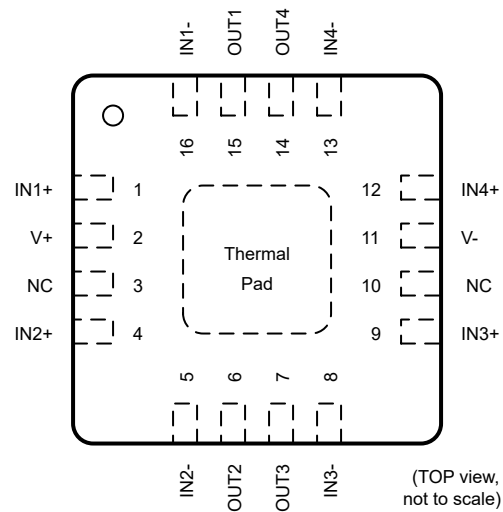
Pin Functions: TLV1854 and TLV1864

PIN			I/O	DESCRIPTION
NAME	**SOIC**	**WQFN**		
OUT1	1	15	O	Output pin of the comparator 1
IN1-	2	16	I	Negative input pin of the comparator 1
IN1+	3	1	I	Positive input pin of the comparator 1
V+	4	2	-	Positive supply voltage
IN2+	5	4	I	Positive input pin of the comparator 2
IN2-	6	5	I	Negative input pin of the comparator 2
OUT2	7	6	O	Output pin of the comparator 2
OUT3	8	7	O	Output pin of the comparator 3
IN3-	9	8	I	Negative input pin of the comparator 3
IN3+	10	9	I	Positive input pin of the comparator 3
V-	11	11	-	Negative supply voltage
IN4+	12	12	I	Positive input pin of the comparator 4
IN4-	13	13	I	Negative input pin of the comparator 4
OUT4	14	14	O	Output pin of the comparator 4
NC	—	3	—	No Internal Connection - Leave floating or GND
NC	—	10	—	No Internal Connection - Leave floating or GND
Thermal Pad	—	PAD	—	Connect directly to V- pin. (RTE Package only)

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[1]

	MIN	MAX	UNIT
Supply voltage: V_S = (V+) – (V–)		42	V
Differential Input Voltage, VID	–42	42	V
Input pins (IN+, IN–) from (V–)[2]	–0.3	42	V
Current into Input pins (IN+, IN–)[3]	–10	10	mA
Output (Open-drain version only) from (V–)[4]	–0.3	42	V
Output (OUT) (Push-Pull) from (V–)	–0.3	(V+) + 0.3	V
Output short circuit current[5]	-10	10	mA
Junction temperature, T_J		150	°C
Storage temperature, T_{stg}	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) Input terminals are diode-clamped to (V–). Inputs (IN+, IN–) can be greater than (V+) and OUT as long as it is within the –0.3 V to 42 V range

(3) Input terminals are diode-clamped to (V–). Input signals that swing more than 0.3 V below (V–) must be current-limited to 10 mA or less.

(4) Output (OUT) for open drain can be greater than (V+) and inputs (IN+, IN–) as long as it is within the –0.3 V to 42 V range

(5) Short-circuit to (V–) or (V+).

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±1500	V
		Charged-device model (CDM), per ANSI/ESDA/JEDEC JS-002[2]	±1500	

(1) JEDEC document JEP155 states that 500 V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250 V CDM allows safe manufacturing with a standard ESD control process.

6.3 Thermal Information

THERMAL METRIC[1]		TLV185x/6x					UNIT
		DBV (SOT-23)	D (SOIC)	DGK (VSSOP)	PW (TSSOP)	RTE (WQFN)	
		5 pin	8 pin	8 pin	14 pin	16 pin	
R_{qJA}	Junction-to-ambient thermal resistance	168.1					°C/W
$R_{qJC(top)}$	Junction-to-case (top) thermal resistance	68.1					°C/W
R_{qJB}	Junction-to-board thermal resistance	37.4					°C/W
y_{JT}	Junction-to-top characterization parameter	11.4					°C/W
y_{JB}	Junction-to-board characterization parameter	37.1					°C/W
$R_{qJC(bot)}$	Junction-to-case (bottom) thermal resistance						°C/W

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report.

6.4 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

	MIN	MAX	UNIT
Supply voltage: V_S = (V+) – (V–)	1.8	40	V
Input voltage range from (V–)	–0.1	40	V
Common-mode input voltage range from (V–)	0	40	V
Output voltage for open drain from (V–)	–0.1	40	V
Ambient temperature, T_A	–40	125	°C

6.5 Electrical Characteristics

For V_S = (V+) – (V–) = 12V, V_{CM} = V_S/2 at T_A = 25°C (Unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage		–4.7	±0.25	4.7	mV
V_{OS}	Input offset voltage	T_A = –40°C to +125°C	–5.5		5.5	mV
dV_{IO}/dT	Input offset voltage drift			3		µV/°C
V_{HYS}	Input hysteresis voltage		1	2.8	5	mV
$V_{CM\text{-}Range}$	Common-mode voltage range from (V–)	V_S = 1.8 V to 40 V T_A = –40°C to +125°C	0		40	V
POWER SUPPLY						
I_Q	Quiescent current per comparator (output high)	Open Drain Output option, no pull-up resistor		440	700	nA
I_Q	Quiescent current per comparator (output high)	Open Drain Output option, no pull-up resistor, T_A = –40 °C to 125°C			850	nA
V_{POR}		During power on, VS must exceed V_{POR} for t_{ON} before the output will reflect the input.		1.5		V
INPUT BIAS CURRENT						
I_B	Input bias current [1]			1	250	pA
		T_A = –40°C to +125°C			1500	pA
I_{OS}	Input offset current [1]			0.1	100	pA
		T_A = –40°C to +125°C			1000	pA
INPUT CAPACITANCE						
OUTPUT						
V_{OL}	Voltage swing from (V–)	I_{SINK} = 50 µA		20	200	mV
		I_{SINK} = 50 µA T_A = –40°C to +125°C			300	mV
I_{LKG}	Open-drain output leakage current	V_{ID} = +0.1 V, V_{PULLUP} = (V+)		0.3		pA

(1) This parameter is ensured by design and/or characterization and is not tested in production.

Product Folder Links: *TLV1861*

6.6 Switching Characteristics

For V_S = (V+) – (V–) = 12 V, V_{CM} = V_S / 2 at T_A = 25°C (Unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT						
T_{PD-HL}	Propagation delay time, high-to-low	V_{OD} = 10 mV, C_L = 25 pF, V_{STEP} = 100 mV		45		µs
		V_{OD} = 50mV, C_L = 25 pF, V_{STEP} = 100 mV		16		µs
		V_{OD} = 100mV, C_L = 25 pF, V_{STEP} = 200 mV		13		µs
T_{PD-LH}	Propagation delay time, low-to-high (Open-Drain output)	V_{OD} = 10 mV, C_L = 25 pF, R_P = 1 MΩ, V_{STEP} = 100 mV		57		µs
		V_{OD} = 50 mV, C_L = 25 pF, R_P = 1 MΩ, V_{STEP} = 100 mV		36		µs
		V_{OD} = 100 mV, C_L = 25 pF, R_P = 1 MΩ, V_{STEP} = 200 mV		35		µs
T_{FALL}	Output Fall Time, 80% to 20%	C_L = 25 pF		0.2		µs
POWER ON TIME						
T_{ON}	Power on-time			2		ms

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Product Folder Links: *TLV1861*

6.7 Typical Characteristics

At T_A = 25°C, V_S = 12 V, VCM = V_S/2 V, R_P = 1MΩ (Open Drain only), C_L = 25 pF, $V_{OVERDRIVE}$ = 100 mV unless otherwise noted.
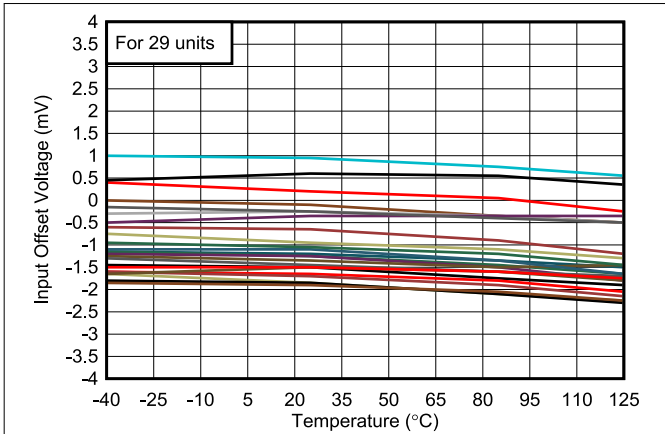

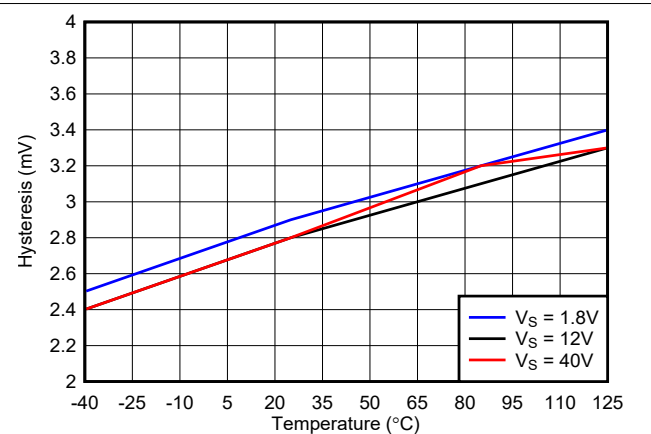Figure 6-1. Offset vs. Temperature
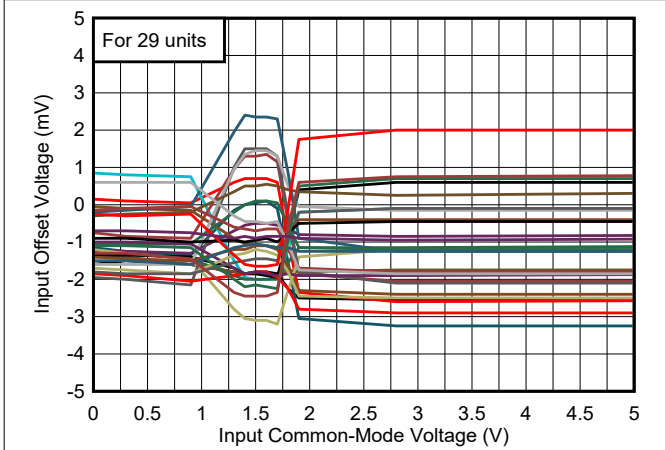

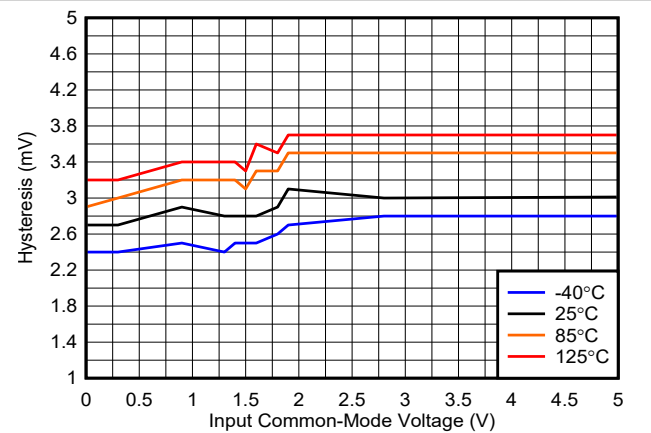Figure 6-2. Hysteresis vs. Temperature

Figure 6-3. Offset vs. Common-Mode, 1.8 V

Figure 6-4. Hysteresis vs. Common-Mode, 1.8 V

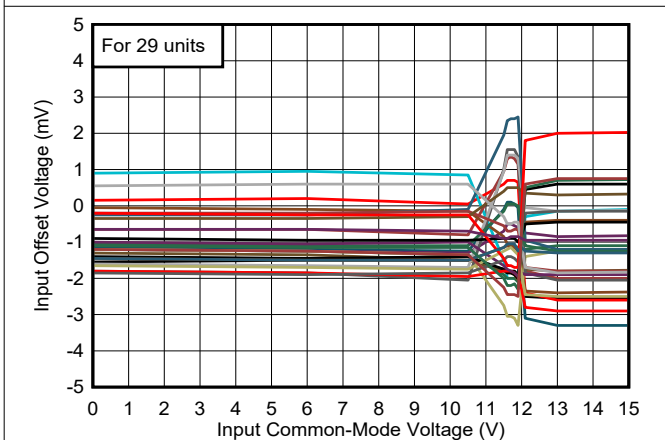Figure 6-5. Offset vs. Common-Mode, 12 V

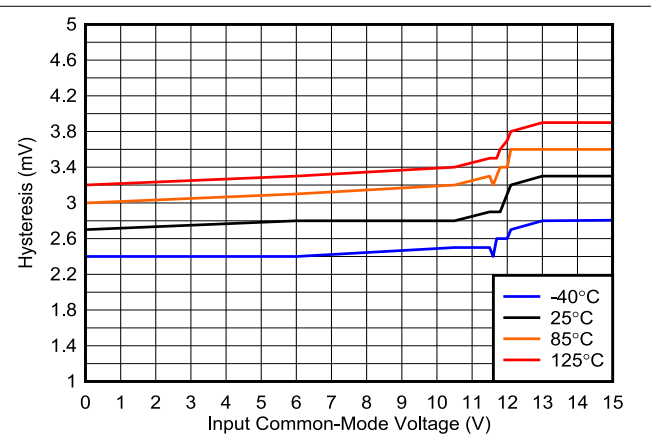Figure 6-6. Hysteresis vs. Common-Mode, 12 V

Product Folder Links: *TLV1861*

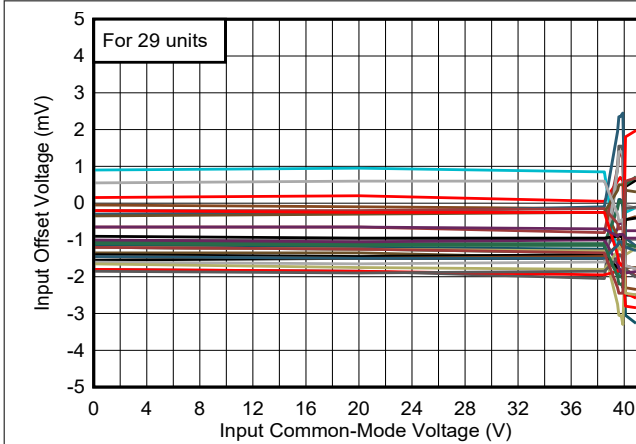## 6.7 Typical Characteristics (continued)

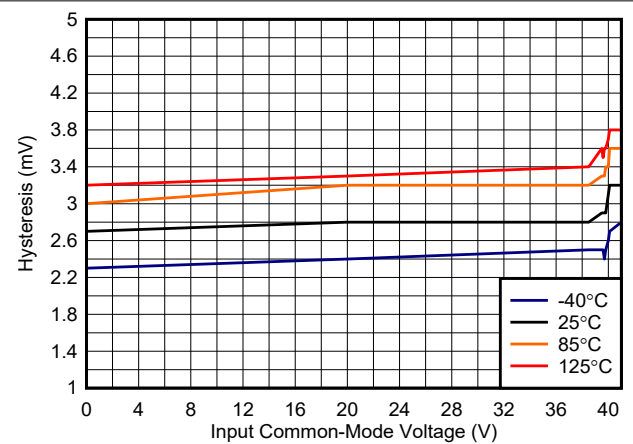**Figure 6-7. Offset vs. Common-Mode, 40 V**

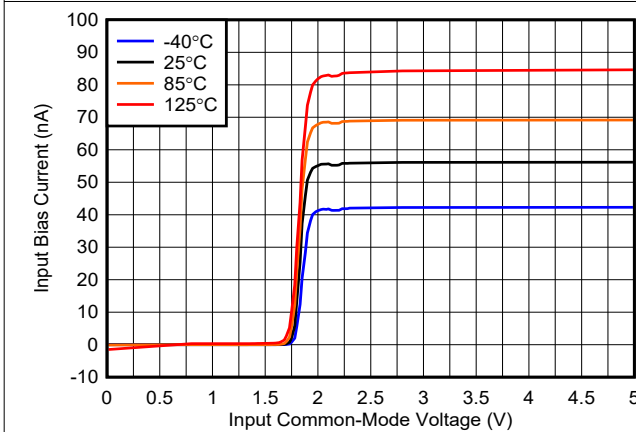**Figure 6-8. Hysteresis vs. Common-Mode, 40 V**

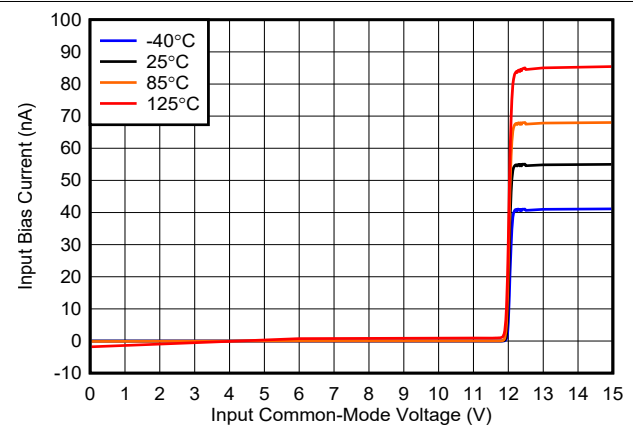**Figure 6-9. Bias Current vs. Common-Mode, 1.8 V**
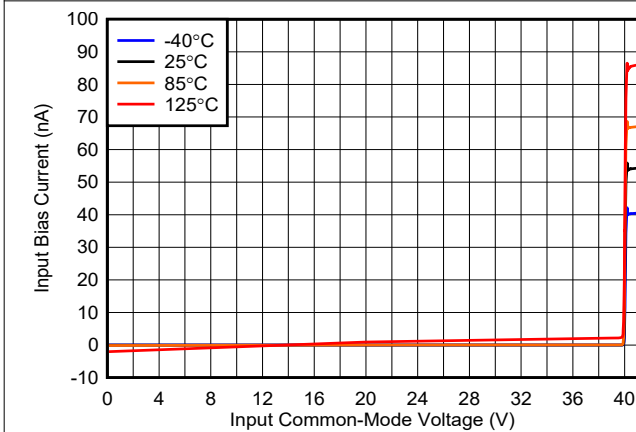

Figure 6-10. Bias Current vs. Common-Mode, 12 V
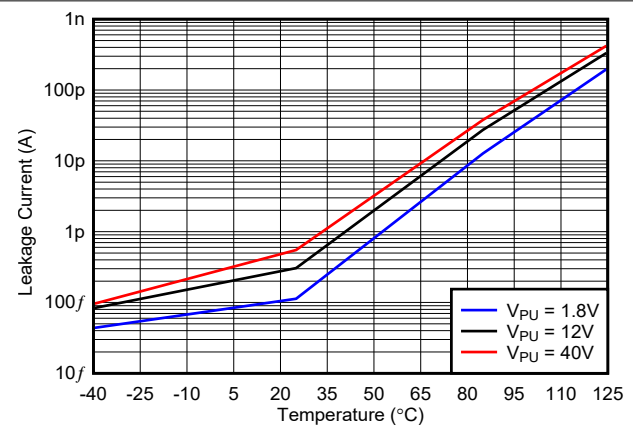

Figure 6-11. Bias Current vs. Common-Mode, 40 V

Figure 6-12. Leakage Current vs. Temperature (Open Drain only)

Product Folder Links: *TLV1861*

6.7 Typical Characteristics (continued)

Figure 6-13. Output Voltage vs. Output Sinking Current, 1.8 V
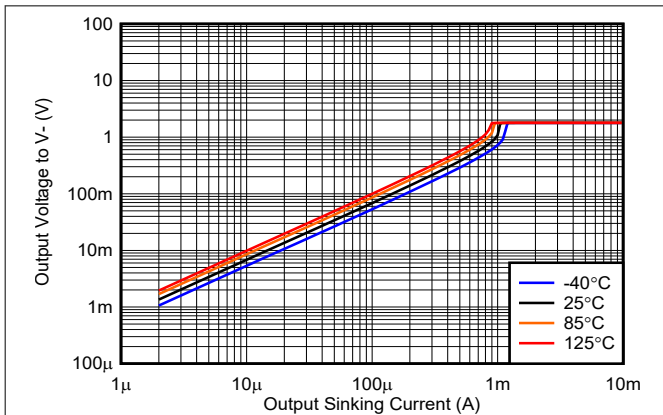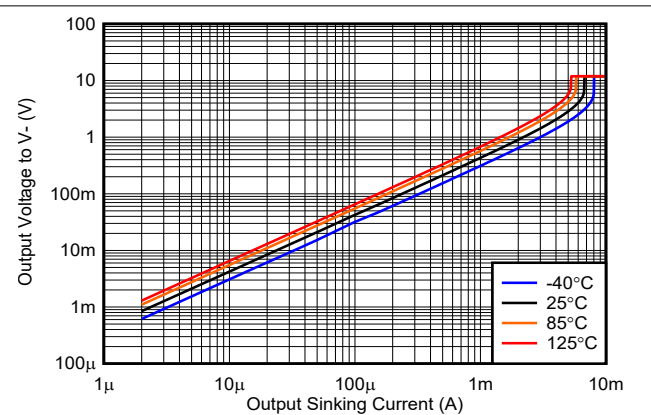

Figure 6-14. Output Voltage vs. Output Sinking Current, 12 V
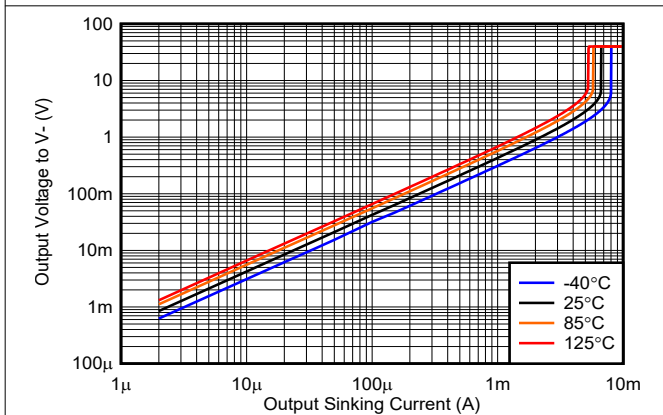
Figure 6-15. Output Voltage vs. Output Sinking Current, 40 V
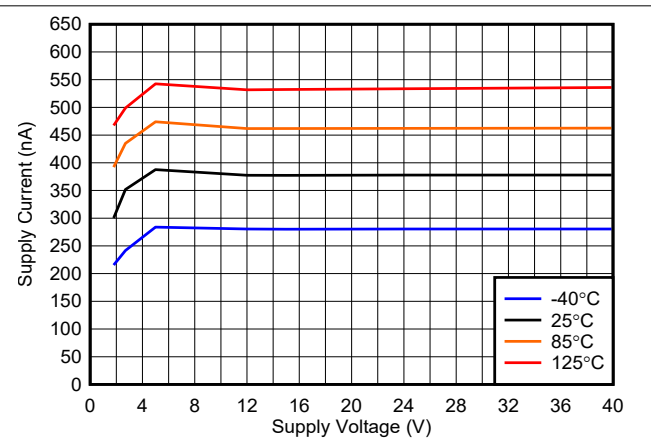
Figure 6-16. Supply Current vs. Supply Voltage (Output Low)
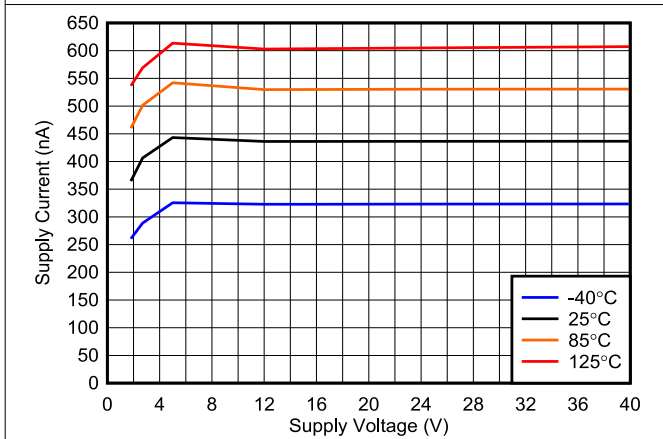
Figure 6-17. Supply Current vs. Supply Voltage (Output High)
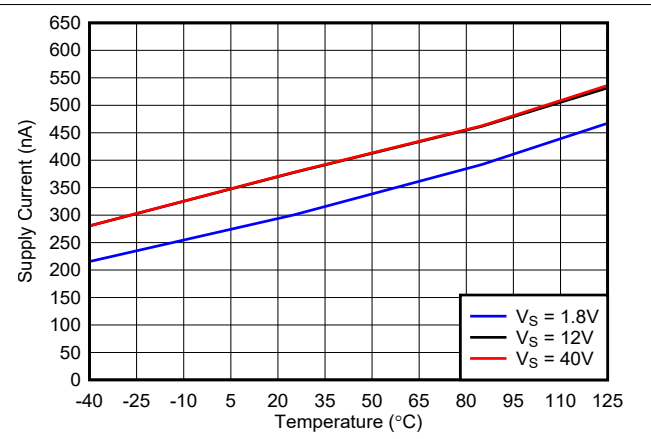
Figure 6-18. Supply Current vs. Temperature (Output Low)

Product Folder Links: *TLV1861*

6.7 Typical Characteristics (continued)
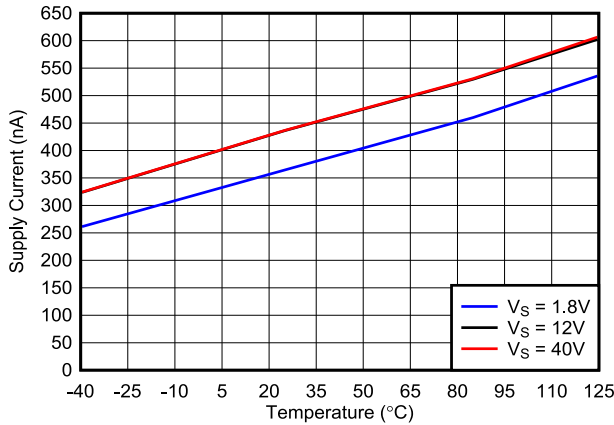
Figure 6-19. Supply Current vs. Temperature (Output High)
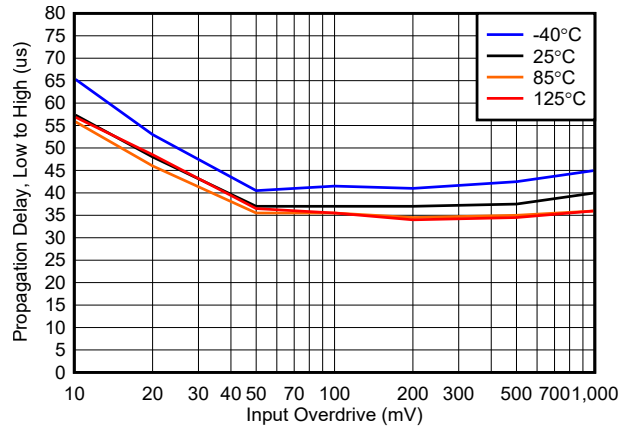
Figure 6-20. Propagation Delay, Low to High, 1.8 V, Open Drain output
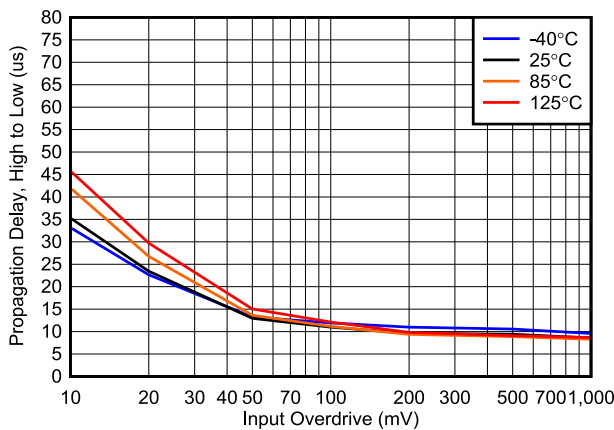
Figure 6-21. Propagation Delay, High to Low, 1.8 V
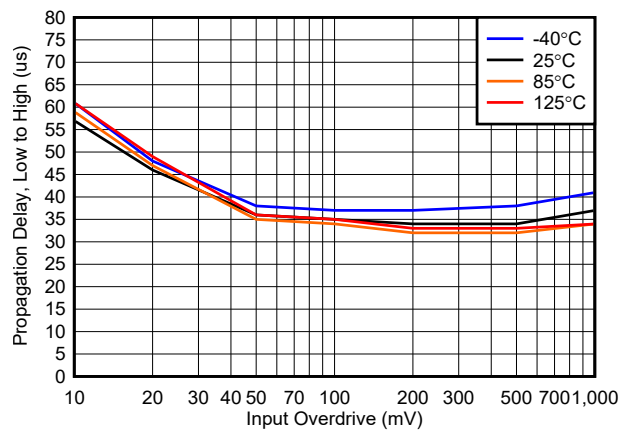
Figure 6-22. Propagation Delay, Low to High, 12 V, Open Drain output
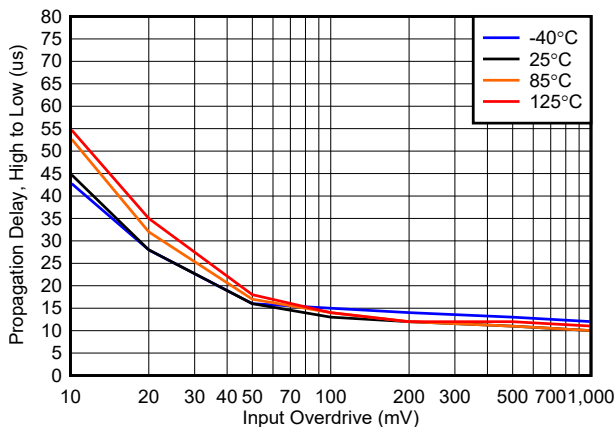
Figure 6-23. Propagation Delay, High to Low, 12 V
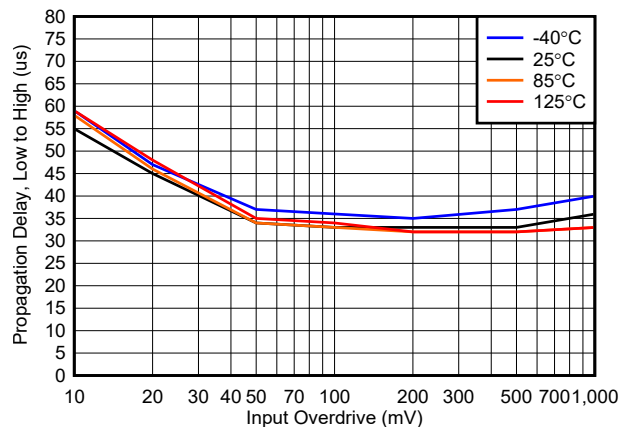
Figure 6-24. Propagation Delay, Low to High, 40 V, Open Drain output

Product Folder Links: *TLV1861*

6.7 Typical Characteristics (continued)
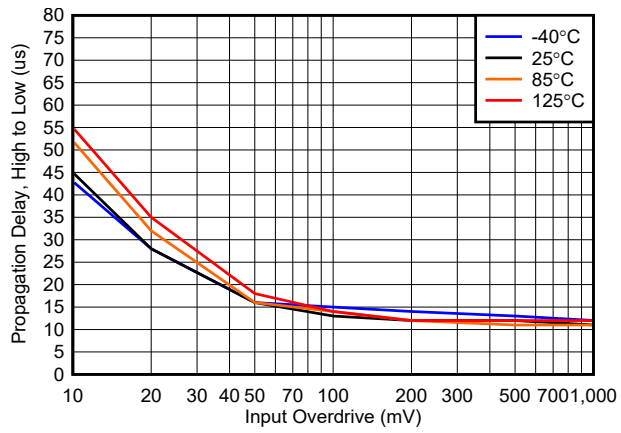
Figure 6-25. Propagation Delay, High to Low, 40 V

Product Folder Links: *TLV1861*

7 Detailed Description

7.1 Overview

The TLV185x and TLV186x devices are nanopower comparators with push-pull and open-drain output options. Operating down to 1.8 V while only consuming only 440 nA per channel, the TLV185x and TLV186x are well suited for voltage, current, and temperature sensing in low and high voltage low-power, always-on systems. An internal power-on reset circuit ensures that the output remains in a known state during power-up and power-down. Inputs have fail-safe inputs that can tolerate input transients without damage or false outputs.

7.2 Functional Block Diagrams
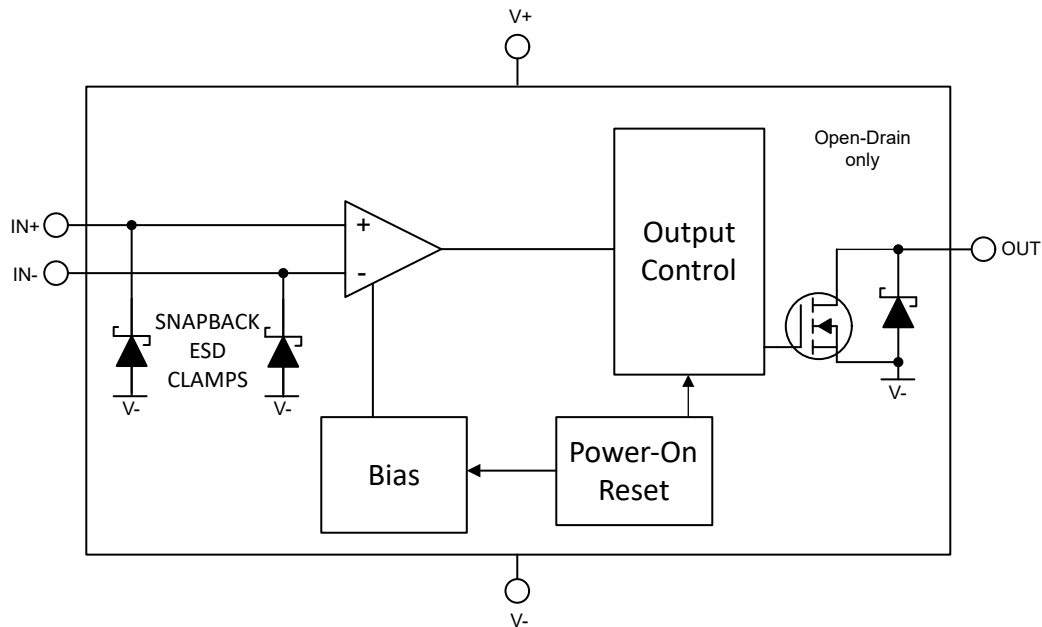
Figure 7-1. Block Diagram

7.3 Feature Description

The TLV185x (push-pull output) and TLV186x (open-drain output) devices are nano-power comparators that are capable of operating at high voltages. This family of comparators feature a fail safe input stage and over the rail operating condition mode capable of operating up to 40 V, independent of V+. The comparators also have an internal reverse battery protection feature and Power-On-Reset for known start-up conditions.

7.4 Device Functional Modes

7.4.1 Inputs

7.4.1.1 Operating Common-Mode Ranges

The TLV185x and TLV186x devices have two operating common-mode ranges: within-the-rail and over-the-rail.

Within-the-rail operation: IN+ and IN- are less than (V+)

When an input pin is operating less than (V+), there are two operating regions defined where input voltages can be compared: low common-mode and high-common mode. In low-common mode which extends typically from 0 V to (V+) - 1 V, the typical input bias current is less than 1 pA. In high common-mode which extends typically from (V+) - 1 V to (V+), the typical input bias current is less than 14 nA.

Over-the-rail operation: IN+ and/or IN- are greater than (V+)

The TLV185x and TLV186x devices have a distinctive input stage that allows the input common mode range to extend from 0 V to 40 V independent of the supply voltage. This feature means that operation at low supply

voltages does not limit the range of input voltages that can be compared. When an input pin is operating over-the-rail (above (V+)), the bias current increases to a typical value of 55 nA.

See Figure 6-9 to 6-11 in the Typical Characteristics section for input bias current vs. common-mode voltages.

7.4.1.2 Fail-Safe Inputs

A feature of the TLV185x and TLV186x family is that the inputs are fail safe up to 40 V, independent of (V+). The inputs are maintained as high input impedance and can be of any value between -0.1 V and 40 V, even while (V+) is unpowered or below the minimum supply voltage. This feature avoids power sequencing or transient issues since the inputs are not diode clamped to (V+).

7.4.1.3 Unused Inputs

If a channel is not to be used, DO NOT tie the inputs together. Due to the high equivalent bandwidth and low offset voltage, tying the inputs directly together can cause high frequency oscillations as the device triggers on it's own internal wideband noise. Instead, the inputs should be tied to any available voltage that resides within the specified input voltage range and provides a minimum of 50mV differential voltage. For example, one input can be grounded and the other input connected to a reference voltage, or even (V+).

7.4.2 Internal Hysteresis

The device hysteresis transfer curve is shown in Figure 7-2. This curve is a function of three components: V_{TH}, V_{OS}, and V_{HYST}:

- V_{TH} is the actual set voltage or threshold trip voltage.
- V_{OS} is the internal offset voltage between V_{IN+} and V_{IN-}. This voltage is added to V_{TH} to form the actual trip point at which the comparator must respond to change output states.
- V_{HYST} is the internal hysteresis (or trip window) that is designed to reduce comparator sensitivity to noise.

    (2.8 mV for the TLV185x/6x family)

$V_{TH} + V_{OS} - (V_{HYST} / 2)$ $V_{TH} + V_{OS}$ $V_{TH} + V_{OS} + (V_{HYST} / 2)$
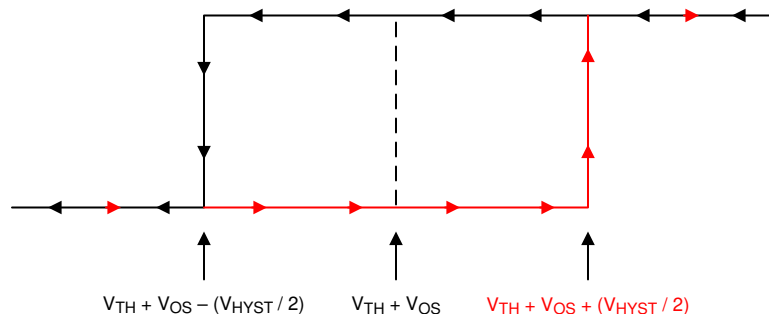
Figure 7-2. Hysteresis Transfer Curve

7.4.3 Outputs

7.4.3.1 TLV185x Push-Pull Output

The TLV185x features a push-pull output stage capable of both sinking and sourcing current. This allows driving loads such as LED's and MOSFET gates, as well as eliminating the need for a power-wasting external pull-up resistor. The push-pull output must never be connected to another output.

Directly shorting the output to the supply rails ((V+) when output "low" or (V-) when output "High") can result in thermal runaway and eventual device destruction at high (>12 V) supply voltages. If output shorts are possible, a series current limiting resistor is recommended to limit the power dissipation.

Unused push-pull outputs should be left floating, and never tied to a supply, ground, or another output.

7.4.3.2 TLV186x Open-Drain Output

The TLV186x features an open-drain (also commonly called open collector) sinking-only output stage enabling the output logic levels to be pulled up to an external voltage from 0 V up to 40 V, independent of the comparator supply voltage (V+). The open-drain output also allows logical OR'ing of multiple open drain outputs and logic

level translation. TI recommends setting the pull-up resistor current to less than 100 uA to optimize V_{OL} logic levels. Lower pull-up resistor values will help increase the rising edge risetime, but at the expense of increasing V_{OL} and higher power dissipation. The risetime will be dependent on the time constant of the total pull-up resistance and total load capacitance. Large value pull-up resistors (>1 MΩ) will create an exponential rising edge due to the output RC time constant and increase the risetime.

Directly shorting the output to (V+) can result in thermal runaway and eventual device destruction at high (>12 V) pull-up voltages. If output shorts are possible, a series current limitng resistor is recommended to limit the power dissipation.

Unused open drain outputs should be left floating, or can be tied to the (V-) pin if floating pins are not desired.

7.4.4 ESD Protection

7.4.4.1 Inputs

The fail-safe inputs incorporates internal ESD protection circuits on all pins. The fail-safe inputs have ESD protection from each pin to (V-) which allows these pins to exceed the supply voltage (V+) up to 40 V. If input voltages are to exceed 40 V, an external clamp would be required. Likewise, negative voltages on the inputs are ESD clamped to (V-) and should be limited to less than -0.1 V.

If the inputs are to be connected to a low impedance source, such as a power supply or buffered reference line, TI recommends adding a current-limiting resistor in series with the input to limit any transient currents should the clamps conduct. The current should be limited to 10 mA or less. This series resistance can be part of any resistive input dividers or networks.

7.4.4.2 Outputs

The TLV185x push-pull output protection also contains a conventional diode-type ESD clamps between the output and (V-), as the output should not exceed the supply rails.

The TLV186x open-drain output ESD protection also consists of a snapback ESD clamp between the output and (V-) to allow the output to be pulled above (V+) to a maximum of 40 V.

7.4.5 Power-On Reset (POR)

The TLV185x and TLV186x devices have an internal Power-on-Reset (POR) circuit for known start-up or power-down conditions. While the power supply (V+) is ramping up or ramping down, the POR circuitry will be activated for up to 2 ms after the V_{POR} of 1.5 V is crossed. When the supply voltage is equal to or greater than the minimum supply voltage, and after the delay period, the comparator output reflects the state of the differential input (V_{ID}).

For the TLV185x push-pull output devices, the output is held low during the POR period (t_{on}).

For the TLV186x open drain output devices, the POR circuit will keep the output high impedance (Hi-Z) during the POR period (t_{on}).
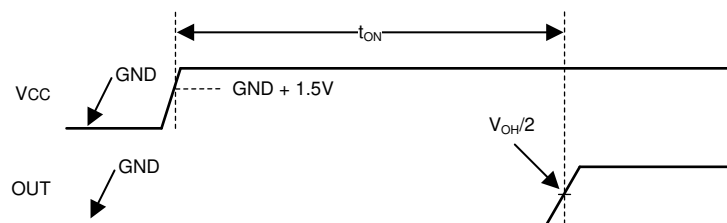
Figure 7-3. Power-On Reset Timing Diagram

Note that it the nature of an open collector output that the output will rise with the pull-up voltage during the POR period.

7.4.6 Reverse Battery Protection

The TLV185x and TLV186x devices have an internal reverse battery protection feature that prevents damage to the comparator in the event of improper battery installation to the supply pins. This protection feature works up to 40 V.

8 Application and Implementation

> **Note**
>
> Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

8.1.1 Basic Comparator Definitions

8.1.1.1 Operation

The basic comparator compares the input voltage (V_{IN}) on one input to a reference voltage (V_{REF}) on the other input. In the Figure 8-1 example below, if V_{IN} is less than V_{REF}, the output voltage (V_O) is logic low (V_{OL}). If V_{IN} is greater than V_{REF}, the output voltage (V_O) is at logic high (V_{OH}). Table 8-1 summarizes the output conditions. The output logic can be inverted by simply swapping the input pins.

Table 8-1. Output Conditions

Inputs Condition	Output
IN+ > IN-	HIGH (V_{OH})
IN+ = IN-	Indeterminate (chatters - see Hysteresis)
IN+ < IN-	LOW (V_{OL})

8.1.1.2 Propagation Delay

There is a delay between from when the input crosses the reference voltage and the output responds. This is called the Propagation Delay. Propagation delay can be different between high-to low and low-to-high input transitions. This is shown as t_{pLH} and t_{pHL} in Figure 8-1 and is measured from the mid-point of the input to the midpoint of the output.
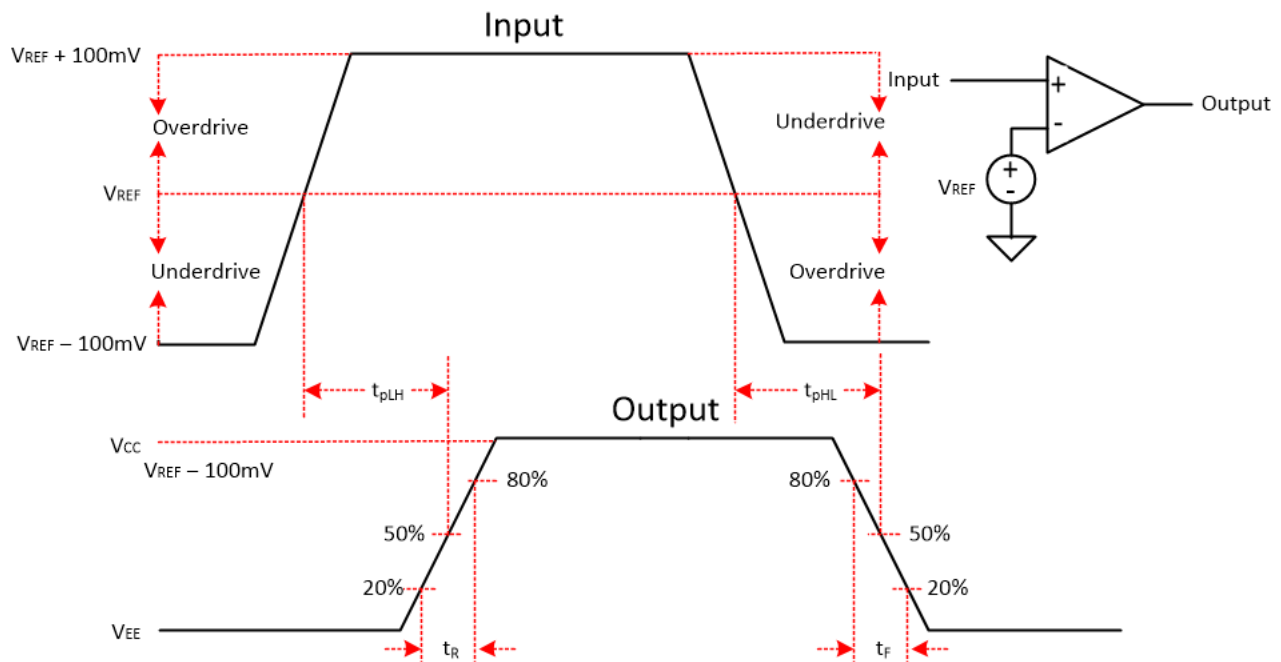

Figure 8-1. Comparator Timing Diagram

Product Folder Links: TLV1861

8.1.1.3 Overdrive Voltage

The overdrive voltage, V_{OD}, is the amount of input voltage beyond the reference voltage (and not the total input peak-to-peak voltage). The overdrive voltage is 100 mV as shown in the Figure 8-1 example. The overdrive voltage can influence the propagation delay (t_p). The smaller the overdrive voltage, the longer the propagation delay, particularly when <100mV. If the fastest speeds are desired, it is recommended to apply the highest amount of overdrive possible.

The risetime (t_r) and falltime (t_f) is the time from the 20% and 80% points of the output waveform.

8.1.2 Hysteresis

The basic comparator configuration may produce a noisy "chatter" output if the applied differential input voltage is near the comparator's offset voltage. This usually occurs when the input signal is moving very slowly across the switching threshold of the comparator. This problem can be prevented by adding external hysteresis to the comparator.

Since the TLV185x and TLV186x devices only have a minimal amount of internal hysteresis of 2.7 mV, external hysteresis can be applied in the form of a positive feedback loop that adjusts the trip point of the comparator depending on its current output state.

The hysteresis transfer curve is shown in Figure 8-2. This curve is a function of three components: V_{TH}, V_{OS}, and V_{HYST}:

- V_{TH} is the actual set voltage or threshold trip voltage.
- V_{OS} is the internal offset voltage between V_{IN+} and V_{IN-}. This voltage is added to V_{TH} to form the actual trip point at which the comparator must respond to change output states.
- V_{HYST} is the hysteresis (or trip window) that is designed to reduce comparator sensitivity to noise.
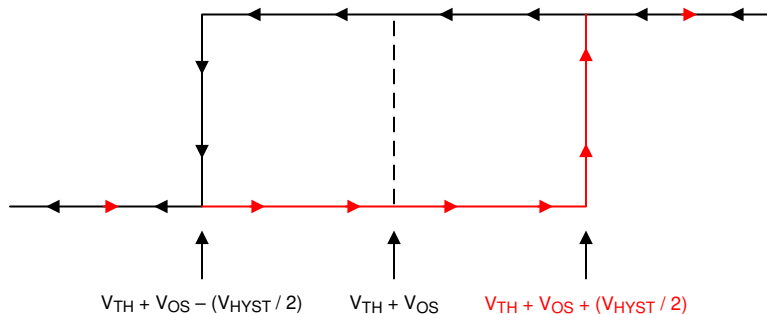
Figure 8-2. Hysteresis Transfer Curve

For more information, please see Application Note SBOA219 "Comparator with and without hysteresis circuit".

8.1.2.1 Inverting Comparator With Hysteresis

The inverting comparator with hysteresis requires a three-resistor network that is referenced to the comparator supply voltage (V_{CC}), as shown in Figure 8-3.
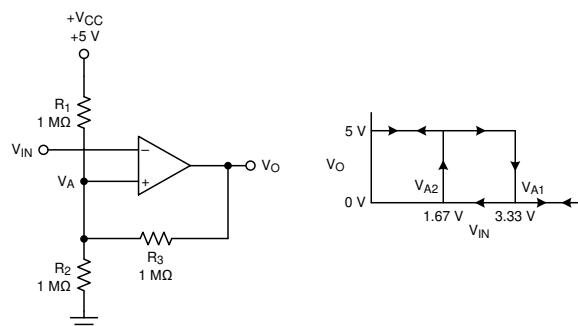

Figure 8-3. TLV185x in an Inverting Configuration With Hysteresis

The equivalent resistor networks when the output is high and low are shown in Figure 8-3.
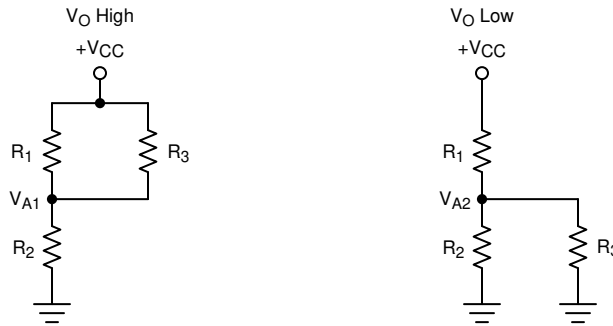

Figure 8-4. Inverting Configuration Resistor Equivalent Networks

When V_{IN} is less than V_A, the output voltage is high (for simplicity, assume V_O switches as high as V_{CC}). The three network resistors can be represented as R1 || R3 in series with R2, as shown in Figure 8-4.

Equation 1 below defines the high-to-low trip voltage (V_{A1}).

$$V_{A1} = V_{CC} \times \frac{R2}{(R1 \,||\, R3) + R2} \tag{1}$$

When V_{IN} is greater than V_A, the output voltage is low. In this case, the three network resistors can be presented as R2 || R3 in series with R1, as shown in Equation 2.

Use Equation 2 to define the low to high trip voltage (V_{A2}).

$$V_{A2} = V_{CC} \times \frac{R2 \,||\, R3}{R1 + (R2 \,||\, R3)} \tag{2}$$

Equation 3 defines the total hysteresis provided by the network.

$$\Delta V_A = V_{A1} - V_{A2} \tag{3}$$

8.1.2.2 Non-Inverting Comparator With Hysteresis

A non-inverting comparator with hysteresis requires a two-resistor network and a voltage reference (V_{REF}) at the inverting input, as shown in Figure 8-5,
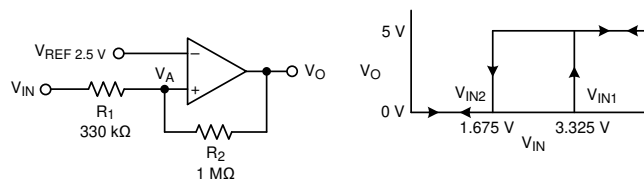

Figure 8-5. TLV185x in a Non-Inverting Configuration With Hysteresis

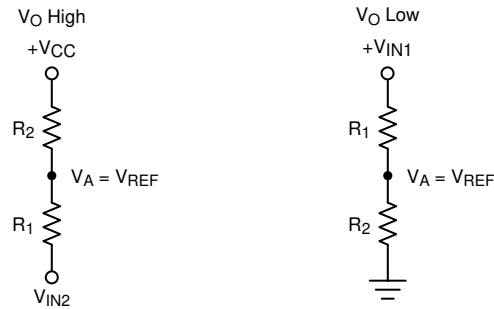The equivalent resistor networks when the output is high and low are shown in Figure 8-6.

Product Folder Links: *TLV1861*

Figure 8-6. Non-Inverting Configuration Resistor Networks

When V_{IN} is less than V_{REF}, the output is low. For the output to switch from low to high, V_{IN} must rise above the V_{IN1} threshold. Use Equation 4 to calculate V_{IN1}.

$$V_{IN1} = R1 \times \frac{V_{REF}}{R2} + V_{REF} \tag{4}$$

When V_{IN} is greater than V_{REF}, the output is high. For the comparator to switch back to a low state, V_{IN} must drop below V_{IN2}. Use Equation 5 to calculate V_{IN2}.

$$V_{IN2} = \frac{V_{REF}(R1 + R2) - V_{CC} \times R1}{R2} \tag{5}$$

The hysteresis of this circuit is the difference between V_{IN1} and V_{IN2}, as shown in Equation 6.

$$\Delta V_{IN} = V_{CC} \times \frac{R1}{R2} \tag{6}$$

For more information, please see Application Notes SNOA997 "Inverting comparator with hysteresis circuit" and SBOA313 "Non-Inverting Comparator With Hysteresis Circuit".

8.1.2.3 Inverting and Non-Inverting Hysteresis using Open-Drain Output

It is also possible to use an open drain output device, such as the TLV186x, but the output pull-up resistor must also be taken into account in the calculations. The pull-up resistor is seen in series with the feedback resistor when the output is high. Thus, the feedback resistor is actually seen as R2 + R_{PULLUP}. TI recommends that the pull-up resistor be at least 10 times less than the feedback resistor value.

8.2 Typical Applications

8.2.1 Window Comparator

Window comparators are commonly used to detect undervoltage and overvoltage conditions. Figure 8-7 shows a simple window comparator circuit. Window comparators require open drain outputs (TLV186x if the outputs are directly connected together.
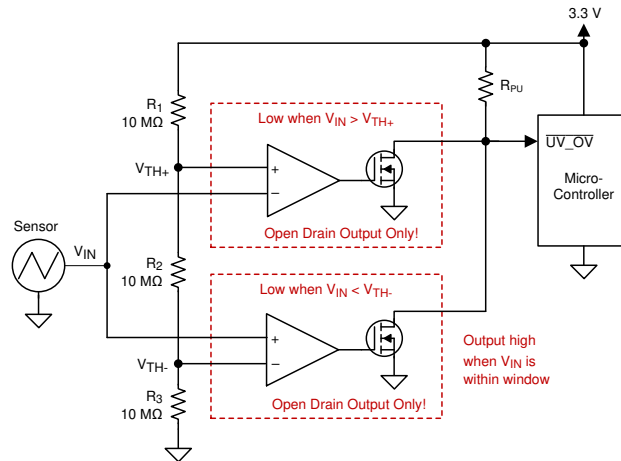
Figure 8-7. Window Comparator

8.2.1.1 Design Requirements

For this design, follow these design requirements:
- Alert (logic low output) when an input signal is less than 1.1 V
- Alert (logic low output) when an input signal is greater than 2.2 V
- Alert signal is active low
- Operate from a 3.3-V power supply

8.2.1.2 Detailed Design Procedure

Configure the circuit as shown in Figure 8-7. Connect V+ to a 3.3-V power supply and V_{EE} to ground. Make R1, R2 and R3 each 10-MΩ resistors. These three resistors are used to create the positive and negative thresholds for the window comparator (V_{TH+} and V_{TH-}).

With each resistor being equal, V_{TH+} is 2.2 V and V_{TH-} is 1.1 V. Large resistor values such as 10-MΩ are used to minimize power consumption. The resistor values may be recalculated to provide the desired trip point values.

The sensor output voltage is applied to the inverting and noninverting inputs of the two comparators. Using two open-drain output comparators allows the two comparator outputs to be Wire-OR'ed together.

The respective comparator outputs will be low when the sensor is less than 1.1 V or greater than 2.2 V. The respective comparator outputs will be high when the sensor is in the range of 1.1 V to 2.2 V (within the "window"), as shown in Figure 8-8.
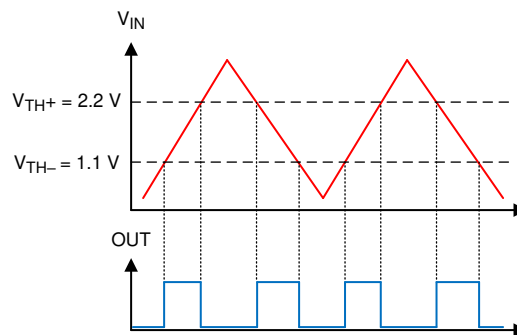
8.2.1.3 Application Curve

Figure 8-8. Window Comparator Results

For more information, please see Application note SBOA221 "Window comparator circuit".

8.3 Power Supply Recommendations

Due to the fast output edges, it is critical to have bypass capacitors on the supply pin to prevent supply ringing and false triggers and oscillations. Bypass the supply directly at *each* device with a low ESR 0.1 µF ceramic bypass capacitor directly between the (V+) pin and ground pins. Narrow peak currents will be drawn during the output transition time, particularly for the push-pull output device. These narrow pulses can cause un-bypassed supply lines and poor grounds to ring, possibly causing variation that can eat into the input voltage range and create an inaccurate comparison or even oscillations.

The device may be powered from both "split" supplies ((V+) &(V-)), or "single" supplies ((V+) and GND), with GND applied to the (V-) pin. Input signals must stay within the recommended input range for either type. Note that with a "split" supply the output will now swing "low" (V_{OL}) to (V-) potential and not GND.

Product Folder Links: *TLV1861*

9 Layout

9.1 Layout Guidelines

For accurate comparator applications it is important maintain a stable power supply with minimized noise and glitches. Output rise and fall times are in the tens of nanoseconds, and should be treated as high speed logic devices. The bypass capacitor should be as close to the supply pin as possible and connected to a solid ground plane, and preferably directly between the (V+) and GND pins.

Minimize coupling between outputs and inputs to prevent output oscillations. Do not run output and input traces in parallel unless there is a (V+) or GND trace between output to reduce coupling. When series resistance is added to inputs, place resistor close to the device. A low value (<100 ohms) resistor may also be added in series with the output to dampen any ringing or reflections on long, non-impedance controlled traces. For best edge shapes, controlled impedance traces with back-terminations should be used when routing long distances.
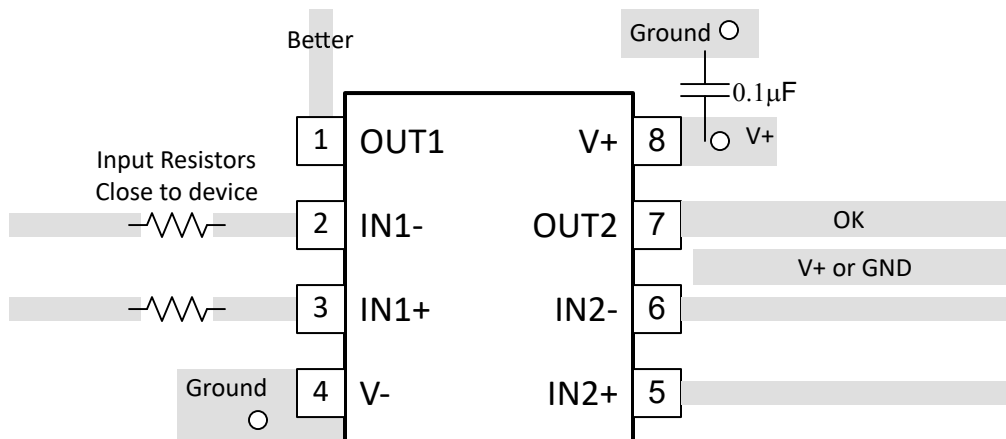
9.2 Layout Example

Figure 9-1. Dual Layout Example

Product Folder Links: *TLV1861*

10 Device and Documentation Support

10.1 Documentation Support

10.1.1 Related Documentation

Analog Engineers Circuit Cookbook: Amplifiers (See Comparators section) - SLYY137

Precision Design, Comparator with Hysteresis Reference Design— TIDU020

Window comparator circuit - SBOA221

Reference Design, Window Comparator Reference Design— TIPD178

Comparator with and without hysteresis circuit - SBOA219

Inverting comparator with hysteresis circuit - SNOA997

Non-Inverting Comparator With Hysteresis Circuit - SBOA313

A Quad of Independently Func Comparators - SNOA654

10.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

10.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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10.4 Trademarks

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10.5 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

10.6 Glossary

TI Glossary   This glossary lists and explains terms, acronyms, and definitions.

11 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TLV1861DBVR	ACTIVE	SOT-23	DBV	5	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1861	Samples

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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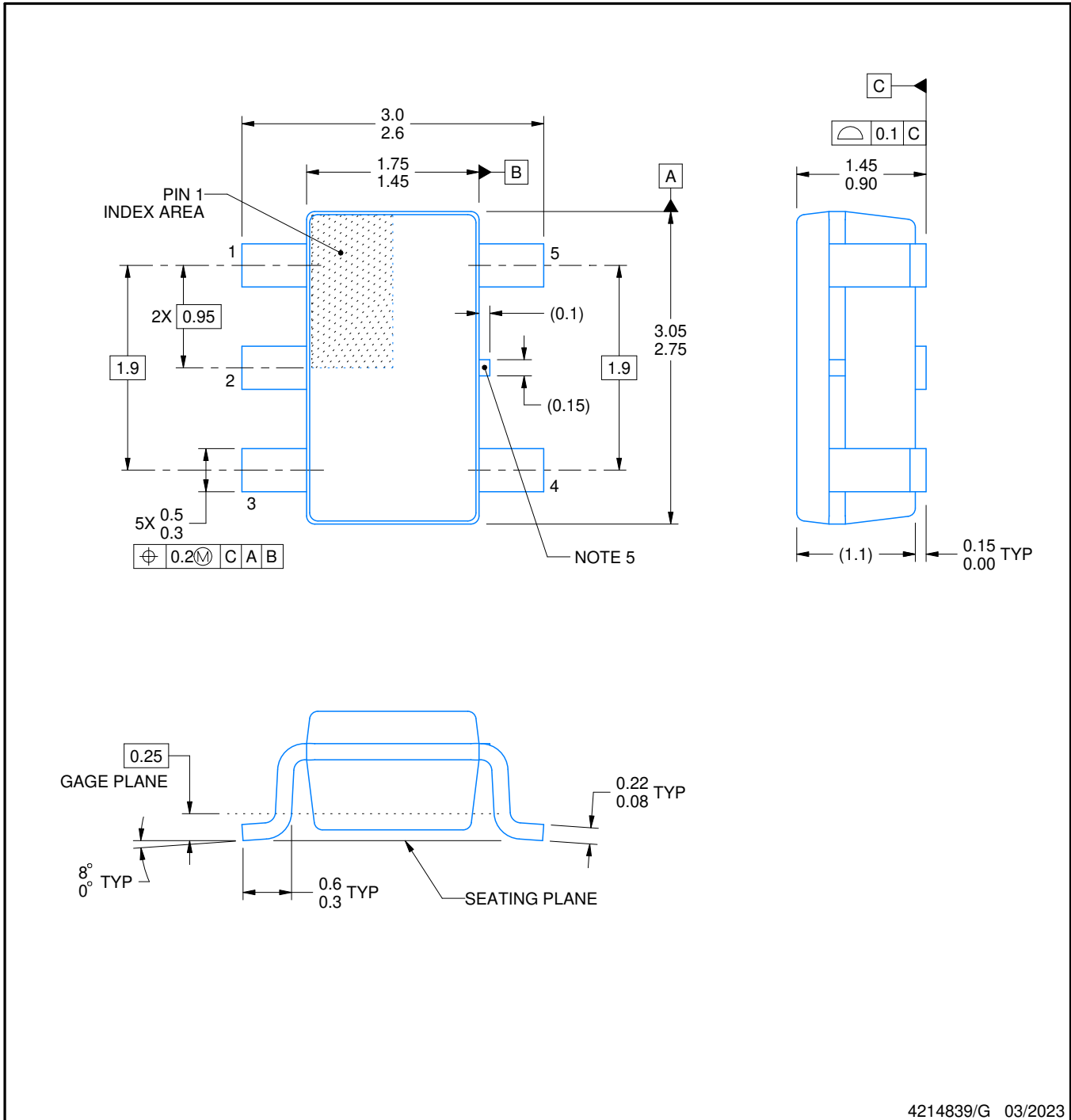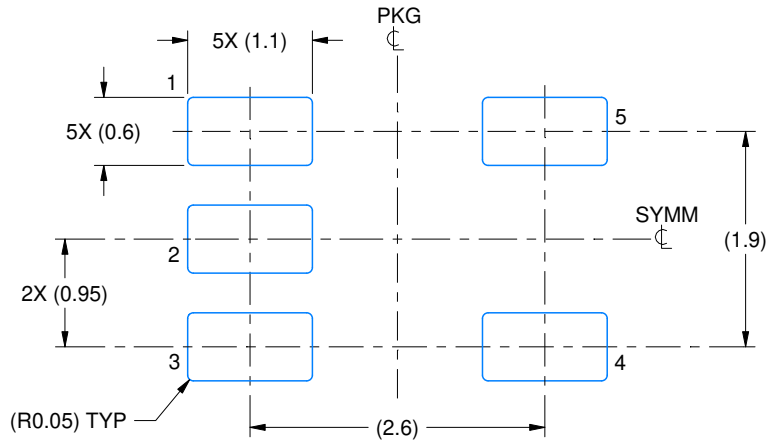
4214839/G   03/2023

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.

PKG
℄

5X (1.1)

1
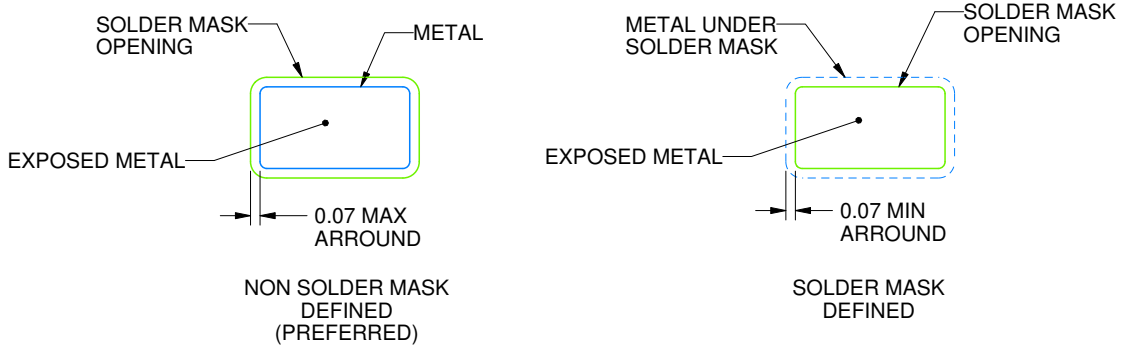
5X (0.6)

2

2X (0.95)

3

5

SYMM
℄

(1.9)

4

(2.6)

(R0.05) TYP

LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

SOLDER MASK
OPENING

METAL

EXPOSED METAL

0.07 MAX
ARROUND

**NON SOLDER MASK
DEFINED
(PREFERRED)**

METAL UNDER
SOLDER MASK

SOLDER MASK
OPENING

EXPOSED METAL

0.07 MIN
ARROUND

**SOLDER MASK
DEFINED**

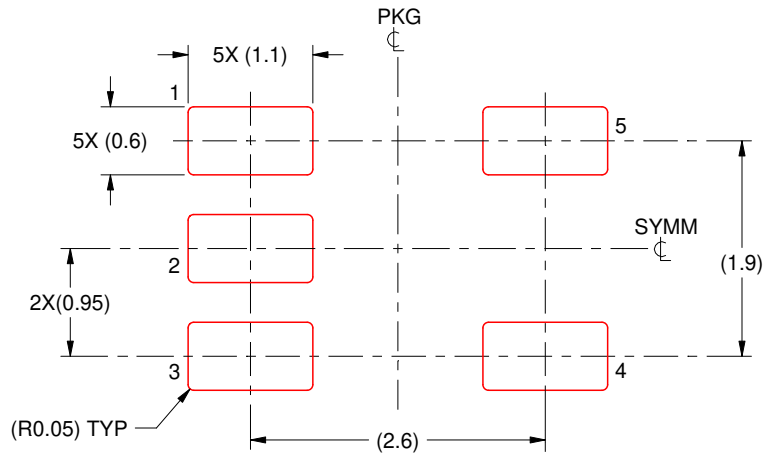**SOLDER MASK DETAILS**

4214839/G   03/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/G   03/2023

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate
   design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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