TLV1812-EP and TLV1822-EP Enhanced Product 40V Rail-to-Rail Input Comparators with Push-Pull and Open-Drain Outputs

1 Features

- VID: V62/24628-01XE (TLV1812-EP)
- VID: V62/24628-02XE (TLV1822-EP)
- Supports Defense and Aerospace Applications
  - Controlled baseline
  - One fabrication site
  - One assembly/test site
  - Extended product life cycle
  - Product traceability
- Extended temperature range: –55°C to +125°C
- Wide supply range: 2.4V to 40V
- Rail-to-rail input
- Power-On Reset (POR) for known start-up
- Low input offset voltage: 500µV
- 420ns typical propagation delay
- Low quiescent current: 5µA per channel
- Low input bias current: 150fA
- Push-pull output option (TLV1812-EP)
- Open-drain output option (TLV1822-EP)

2 Applications

- Airborne BMS
- Airborne Radar
- Aircraft Cockpit Display

3 Description

The TLV1812-EP and TLV1822-EP are 40V dual channel comparators with multiple output options. The family offers rail to-rail inputs with push-pull or open-drain output options. These devices also haves an excellent speed-to-power combination with a propagation delay of 420ns with a full supply voltage range of 2.4V to 40V and a quiescent supply current of only 5µA per channel.

All devices include a Power-On Reset (POR) feature. This makes sure 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 powerdown.

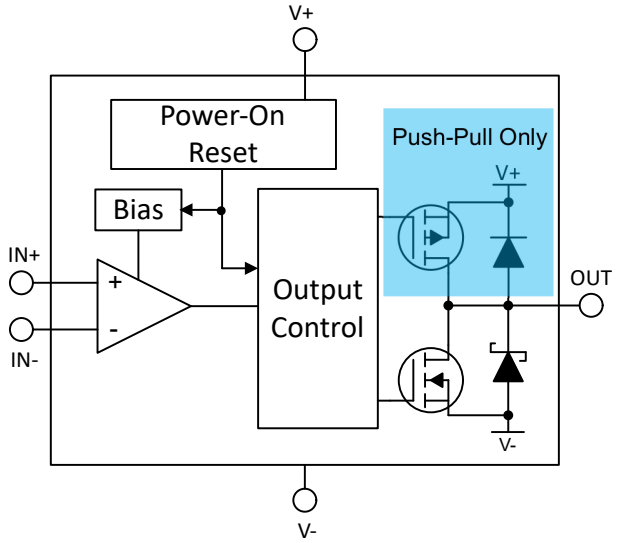
The TLV1812-EP device has a push-pull output stage capable of sinking and sourcing milliamps of current when controlling an LED or driving a capacitive load such as a MOSFET gate. The TLV1822-EP device has an open-drain output stage that can be pulled up to 40V independent of comparator supply voltage.

These comparators are available in the SOT23-8 packages and are specified for the extended temperature range of –55°C to +125°C.

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
TLV1812-EP TLV1822-EP	DDF (SOT-23, 8)	2.9mm × 2.8mm

(1) For all available packages, see Section 10.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



TLV18x2-EP Block Diagram

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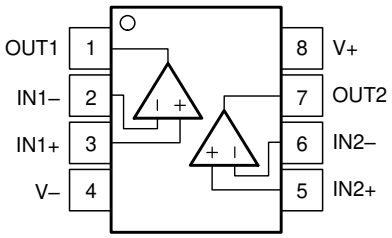
Pin Configuration and Functions



DDF Package
8-Pin SOT23-8
Top View

Table 4-1. Pin Functions: TLV1812-EP and TLV1822-EP

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 (low) supply
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

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4 Specifications

4.1 Absolute Maximum Ratings

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

	MIN	MAX	UNIT
Supply voltage: V_S = (V+) – (V–)	–0.3	42	V
Input pins (IN+, IN–) from (V–) (2)	–0.3	(V+) + 0.3	V
Current into Input pins (IN+, IN–)	–10	10	mA
Output (OUT) voltage (Open-Drain) from (V–)(3)	–0.3	42	V
Output (OUT) voltage (Push-Pull) from (V–)	–0.3	(V+) + 0.3	V
Output (OUT) current (4) (5) (6)	-10	10	mA
Junction temperature, T_J		150	°C
Storage temperature, T_{stg}	–65	150	°C

(1) Operation outside the Absolute Maximum Ratings can cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
(2) Input terminals are diode-clamped to (V–). Input signals that can swing more than 0.3V beyond the supply rails must be current-limited to 10mA or less.
(3) Output (OUT) for open drain can be greater than (V+) and inputs (IN+, IN–) as long as within the –0.3V to 42V range
(4) The output is diode-clamped to (V-) for both output options, and diode clamped to (V+) for the push-pull output option. The open drain version does not have a clamp to V+. Please see the *Outputs* and *ESD Protection* section of the *Application Information* Section for more information.
(5) Output sinking and sourcing current is internally limited to <35mA when operating within the Absolute Maximum output voltage limits. The Absolute Maximum Output Current limit specified here is the maximum current through the clamp structure when exceeding the supply voltage below (V-) for both output options, or above (V+) for the push-pull option.
(6) Short-circuit from output to (V–) or (V+). Continuous output short circuits at elevated supply voltages can result in excessive heating and exceeding the maximum allowed junction temperature, leading to eventual device destruction.

4.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±500	

(1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

4.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
Supply voltage: V_S = (V+) – (V–)		2.4	40	V
Input voltage range from (V–)		–0.2	(V+) + 0.2	V
Output voltage range from (V–)	Open Drain	–0.2	40	V
Output voltage range from (V–)	Push Pull	–0.2	(V+) + 0.2	V
Ambient temperature, T_A	Ambient temperature, T_A	–55	125	°C

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4.4 Thermal Information

THERMAL METRIC[1]		TLV18x2-EP DDF (SOT-23) 8 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	170.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	90.3	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	88.1	°C/W
ψ_{JT}	Junction-to-top characterization parameter	7.5	°C/W
ψ_{JB}	Junction-to-board characterization parameter	87.6	°C/W
$R_{\theta JC(bot)}$	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 report.

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4.5 Electrical Characteristics

For V_S (Total Supply Voltage) = (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		–3	±0.5	3	mV
V_{OS}	Input offset voltage	T_A = –55°C to +125°C	–4		4	mV
dV_{IO}/dT	Input offset voltage drift	T_A = –55°C to +125°C		±1.2		µV/°C
CMRR	Common mode rejection ratio	V_S = (V–) to (V+), Rail to Rail		90		dB
PSRR	Power supply rejection ratio	V_S = 2.4V to 40V, V_{CM} = (V–)		100		dB
POWER SUPPLY						
I_Q	Quiescent current per comparator, No Load	Output Low, T_A = 25°C		6	7.5	µA
		No Load, Output Low T_A = –55°C to +125°C			8.5	µA
		Output High, T_A = 25°C		7	9	µA
		No Load, Output High T_A = –55°C to +125°C			10	µA
V_{POR}	Power On Reset Voltage			1.7		V
INPUT BIAS CURRENT						
I_B	Input bias current			150		fA
I_B	Input bias current	T_A = –55°C to +125°C	–1.2		1.2	nA
I_{OS}	Input offset current			10		fA
INPUT CAPACITANCE						
C_{ID}	Input Capacitance, Differential			2		pF
C_{IC}	Input Capacitance, Common Mode			8		pF
INPUT COMMON MODE RANGE						
$V_{CM\text{-}Range}$	Common-mode voltage range	V_S = 2.4V to 40V T_A = –55°C to +125°C	(V–) – 0.2		(V+) + 0.2	V
OUTPUT						
V_{OL}	Voltage swing from (V–)	I_{SINK} = 4mA T_A = –55°C to +125°C			250	mV
V_{OH}	Voltage swing from (V+) (for Push-Pull only)	I_{SOURCE} = 4mA T_A = –55°C to +125°C			250	mV
I_{LKG}	Open-drain output leakage current	V_{ID} = +0.1V, V_{PULLUP} = (V+) T_A = –55°C to +125°C		0.1	20	nA
I_{OL}	Short-circuit current	Sinking	15	30		mA
I_{OH}	Short-circuit current	Sourcing (for Push-Pull only)	15	30		mA

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4.6 Switching Characteristics

For V_S (Total Supply Voltage) = (V+) – (V–) = 12V, 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} = 10mV, C_L = 50pF		900		ns
T_{PD-HL}	Propagation delay time, high-to-low	V_{OD} = 100mV, C_L = 50pF		450		ns
T_{PD-LH}	Propagation delay time, low-to-high, push-pull output	V_{OD} = 10mV, C_L = 50pF		900		ns
T_{PD-LH}	Propagation delay time, low-to-high, push-pull output	V_{OD} = 100mV, C_L = 50pF		420		ns
T_{RISE}	Output Rise Time, 20% to 80%, push-pull output	C_L = 50pF		15		ns
T_{FALL}	Output Fall Time, 80% to 20%	C_L = 50pF		15		ns
F_{TOGGLE}	Toggle Frequency	V_{ID} = 100mV, C_L = 50pF		500		kHz
POWER ON TIME						
P_{ON}	Power on-time			200		µs

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5 Typical Characteristics

T_A = 25°C, V_S = 12V, R_{PULLUP} = 2.5k, C_L = 20pF, V_{CM} = 0V, $V_{UNDERDRIVE}$ = 100mV, $V_{OVERDRIVE}$ = 100mV unless otherwise noted.

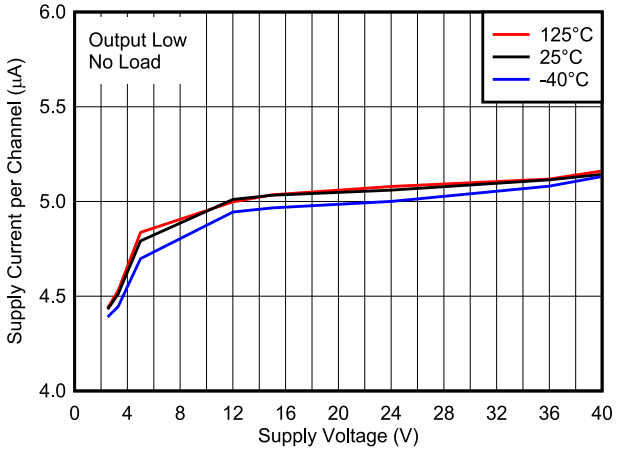

Figure 5-1. Supply Current per Channel vs. Supply Voltage, Output Low

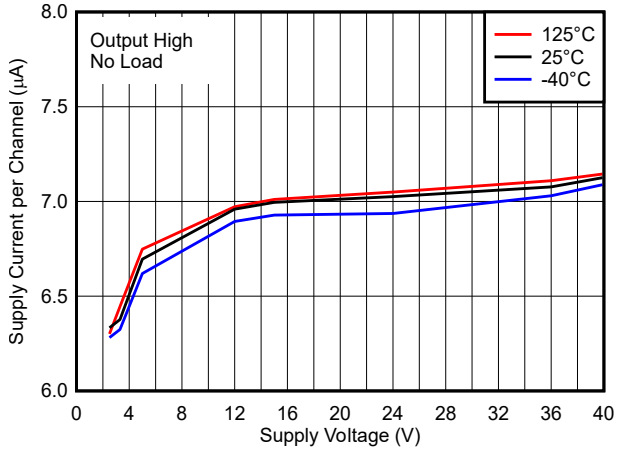

Figure 5-2. Supply Current per Channel vs. Supply Voltage, Output High

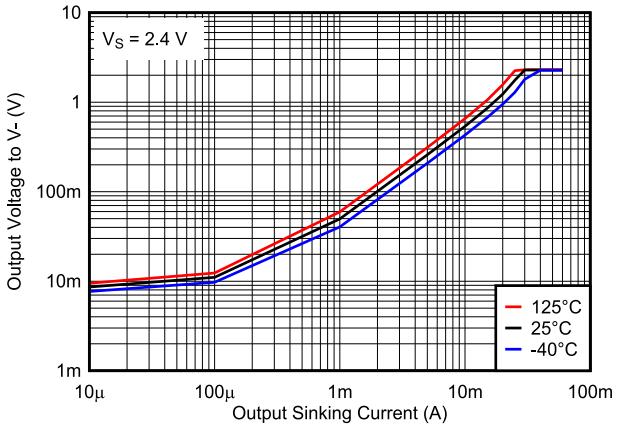

Figure 5-3. Output Voltage vs. Output Sinking Current, 2.4V

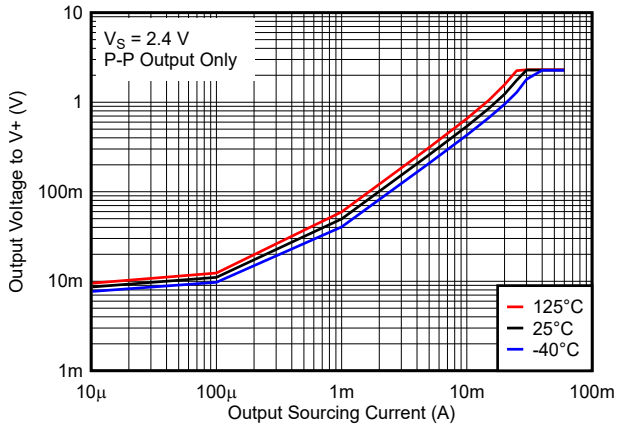

Figure 5-4. Output Voltage vs. Output Sourcing Current, 2.4V

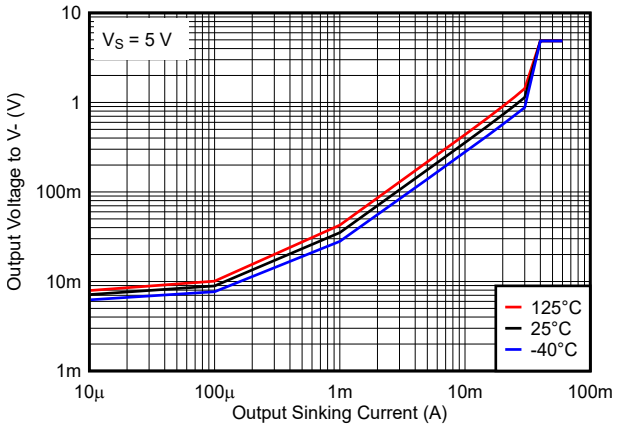

Figure 5-5. Output Voltage vs. Output Sinking Current, 5V

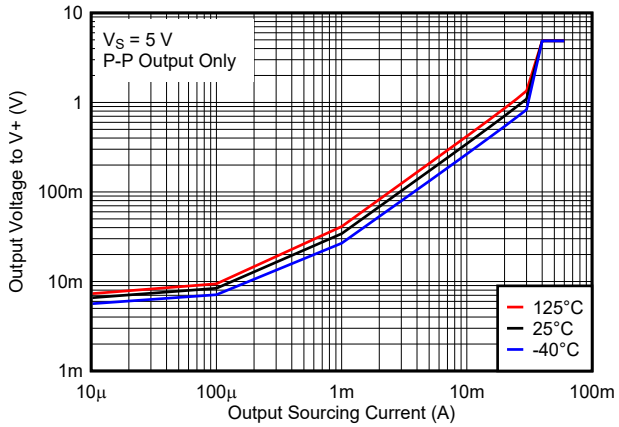

Figure 5-6. Output Voltage vs. Output Sourcing Current, 5V

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5 Typical Characteristics (continued)

T_A = 25°C, V_S = 12V, R_{PULLUP} = 2.5k, C_L = 20pF, V_{CM} = 0V, $V_{UNDERDRIVE}$ = 100mV, $V_{OVERDRIVE}$ = 100mV unless otherwise noted.

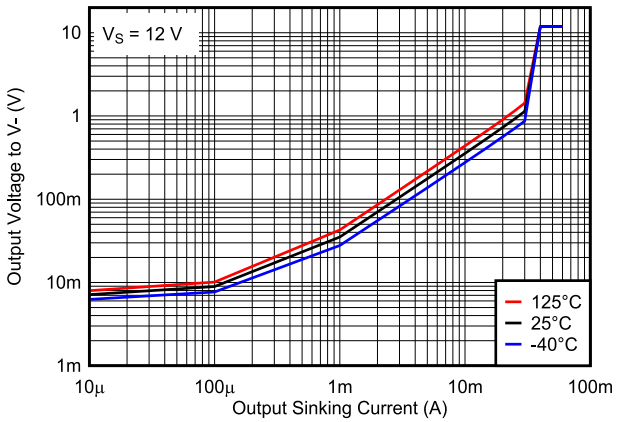

Figure 5-7. Output Voltage vs. Output Sinking Current, 12V

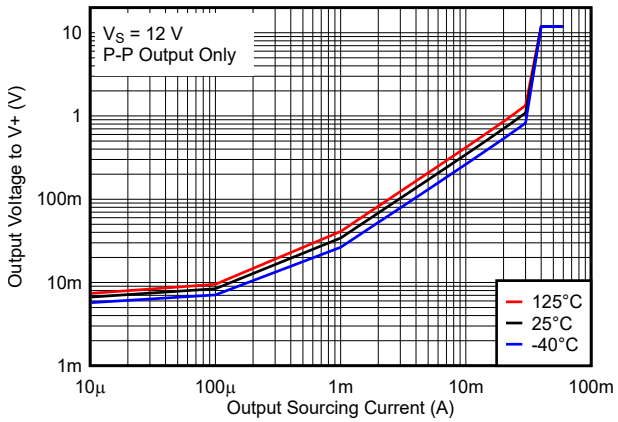

Figure 5-8. Output Voltage vs. Output Sourcing Current, 12V

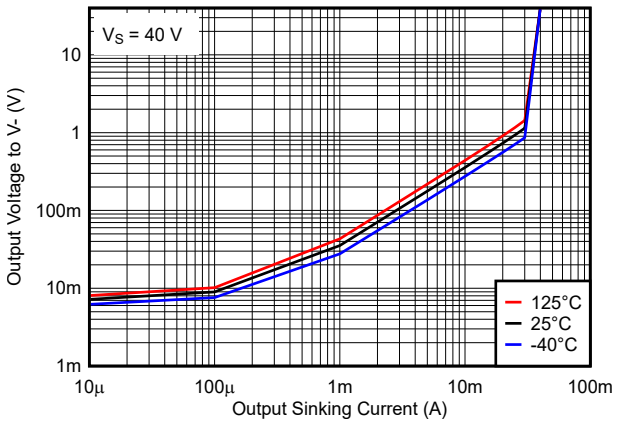

Figure 5-9. Output Voltage vs. Output Sinking Current, 40V

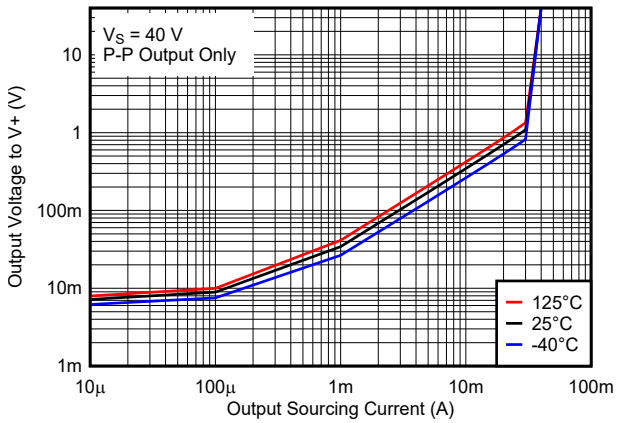

Figure 5-10. Output Voltage vs. Output Sourcing Current, 40V

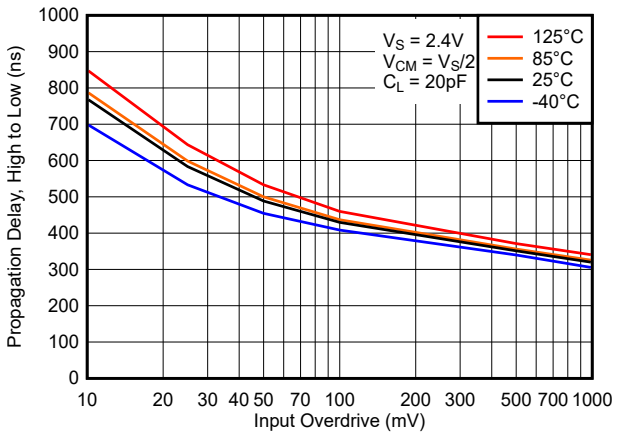

Figure 5-11. Propagation Delay, High to Low, 2.4V

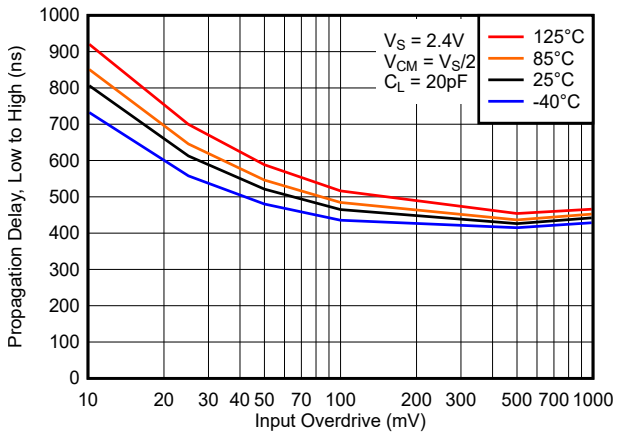

Figure 5-12. Propagation Delay, Low to High, 2.4V

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5 Typical Characteristics (continued)

T_A = 25°C, V_S = 12V, R_{PULLUP} = 2.5k, C_L = 20pF, V_{CM} = 0V, $V_{UNDERDRIVE}$ = 100mV, $V_{OVERDRIVE}$ = 100mV unless otherwise noted.

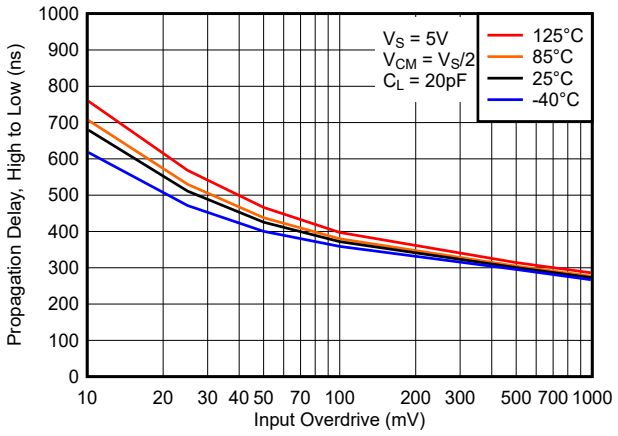

Figure 5-13. Propagation Delay, High to Low, 5V

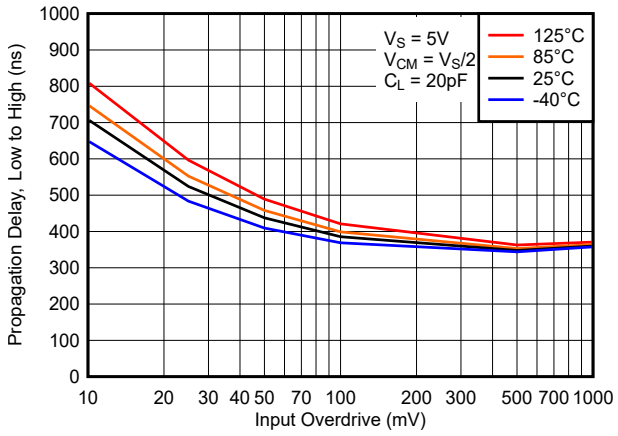

Figure 5-14. Propagation Delay, Low to High, 5V

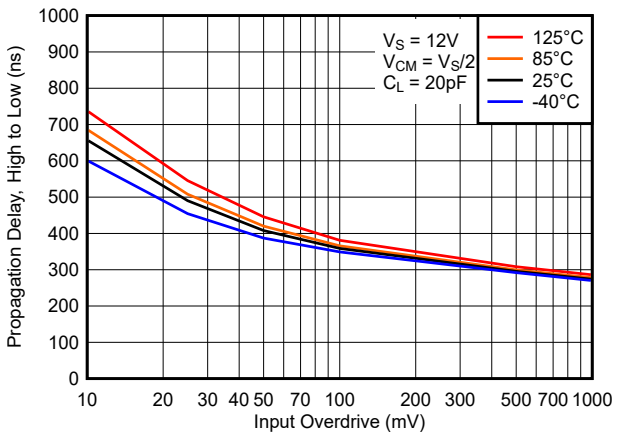

Figure 5-15. Propagation Delay, High to Low, 12V

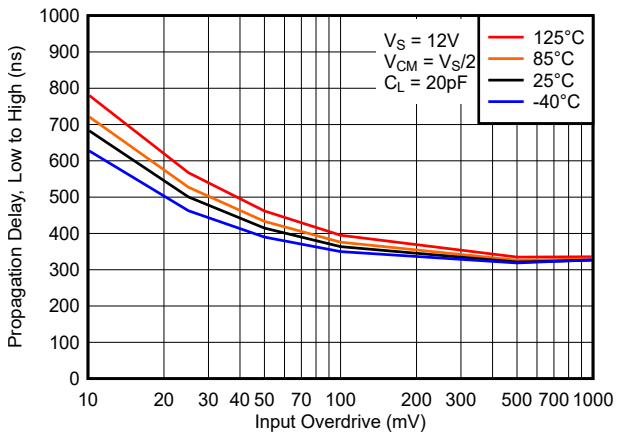

Figure 5-16. Propagation Delay, Low to High, 12V

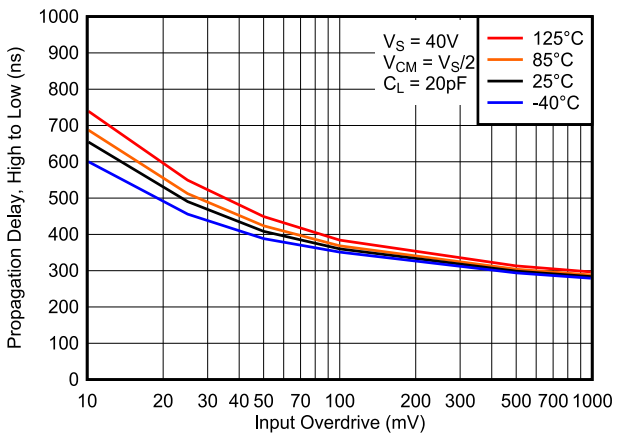

Figure 5-17. Propagation Delay, High to Low, 40V

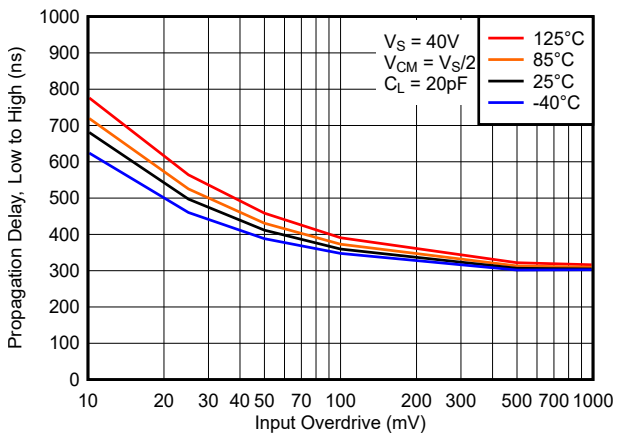

Figure 5-18. Propagation Delay, Low to High, 40V

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6 Detailed Description

6.1 Overview

The TLV181x-EP and TLV182x-EP devices are micro-power comparators with push-pull and open-drain output options. Operating down to –55°C while only consuming only 5µA per channel, the TLV181x-EP and TLV182x-EP are well suited for power conscious systems and supply monitoring applications. An internal power-on reset circuit places the output in a known state during power-up and power-down.

6.2 Functional Block Diagrams

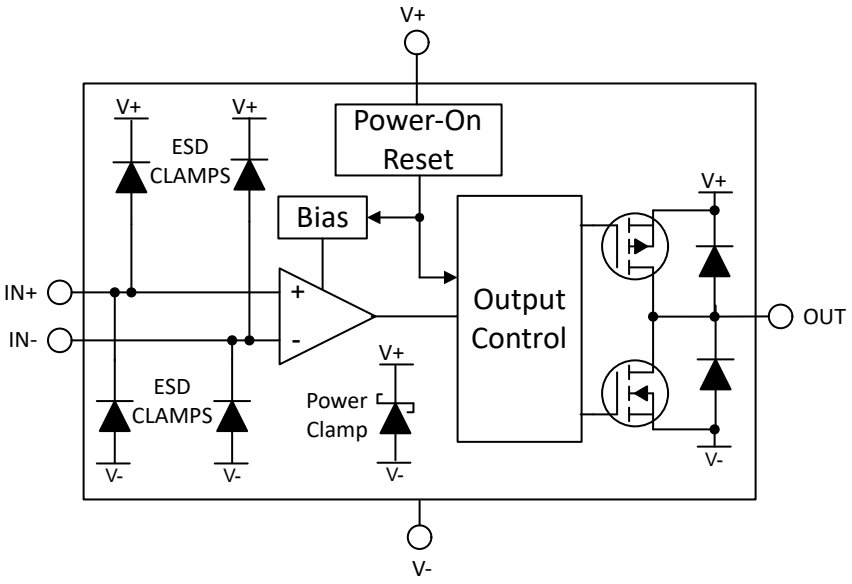

Figure 6-1. TLV1812-EP Block Diagram

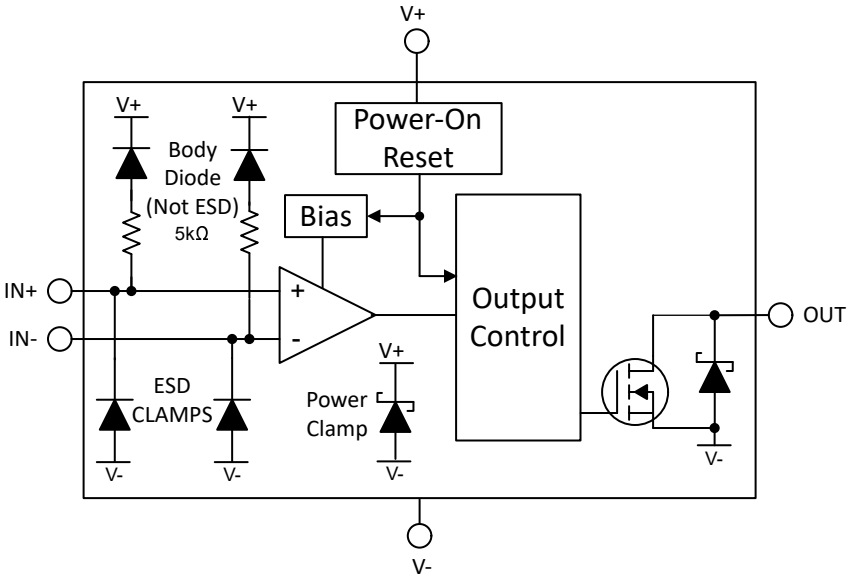

Figure 6-2. TLV1822-EP Block Diagram

6.3 Feature Description

TLV18x2-EP Family Options

The TLV18x2-EP family features 40V operation, micro-power 5µA supply currents, 420ns propagation delay, and a Power-On Reset (POR) function.

The TLV18**1**2-EP has a **push-pull** (sink-source) output.

The TLV18**2**2-EP has a **open-drain** (sink only) output, capable of being pulled-up to any voltage up to 40V, independent of comparator supply voltage.

6.4 Device Functional Modes

6.4.1 Inputs

6.4.1.1 TLV18x2-EP Rail-to-Rail Input

The TLV18x2-EP input voltage range extends from 200mV below V- to 200mV above V+. The differential input voltage (V_{ID}) can be any voltage within these limits. No phase-inversion of the comparator output occurs when the input voltages stay within the specified range.

For the TLV1812-EP (Push-Pull), the inputs have ESD clamps to the V+ supply line and therefore the input voltages must not exceed the supply voltages by more than 200mV. Do not apply signals to the rail to rail inputs with no supply voltage.

For the TLV1822-EP (Open-Drain), the inputs have weak clamps to the V+ supply line. Do not apply signals to the rail to rail inputs with no supply voltage.

6.4.1.2 ESD Protection

The TLV1822-EP open-drain output ESD protection consists of a snapback ESD clamp between the output and V- to allow the output to be pulled above V+ to a maximum of 40V. There is a "lower" ESD clamp between V- and the inputs. There are also a parasitic "upper" ESD soft-clamp diode between the input and V+ with a 5kΩ equivalent resistance (as shown in Figure 5-2). These clamps are not traditional ESD cells thus current must be limited to 1mA or less across the this upper diode and resistance. External diode clamping is recommended if the input voltage exceeds V+ during operation.

The TLV1812-EP push-pull output ESD protection contains a conventional diode-type "upper" ESD clamp between the output and V+, and a "lower" ESD clamp between the output and V-. The output must not exceed the supply rails by more than 200mV.

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 currents when the clamps conduct. The current must be limited 10mA or less, though TI recommends limiting the current to 1mA or less. This series resistance can be part of any resistive input dividers or networks.

6.4.1.3 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 chatter as the device triggers on it's own internal wideband noise. Instead, the inputs must 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+ (as long as the input is directly connected to the V+ pin to avoid transients).

6.4.2 Outputs

6.4.2.1 TLV1812-EP Push-Pull Output

The TLV1812-EP 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.

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

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

6.4.2.2 TLV1822-EP Open-Drain Output

The TLV1822-EP 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 0V up to 40V, independent of the comparator supply voltage (V+). The open-drain output allows logical OR'ing of multiple open drain outputs and logic level translation. TI recommends setting the pull-up resistor current to between 100uA and 1mA. Lower value pull-up resistor values help increase the rising edge rise-time, but at the expense of increasing V_{OL} and higher power dissipation. The rise-time is dependent on the time constant of the total pull-up resistance and total load capacitance. Large value pull-up resistors (>1MΩ) creates an exponential rising edge due to the output RC time constant and increase the rise-time.

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

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

6.4.3 Power-On Reset (POR)

The TLV18x2-EP family has 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 is activated for up to 200µs after the minimum supply voltage threshold of 2.4V is crossed, or immediately when the supply voltage drops below 2.4V. 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 TLV1812-EP push-pull output devices, the output is held low during the POR period (t_{on}).

For the TLV1822-EP open drain output option the POR circuit keeps the output high impedance (Hi-Z) during the POR period (t_{on}).

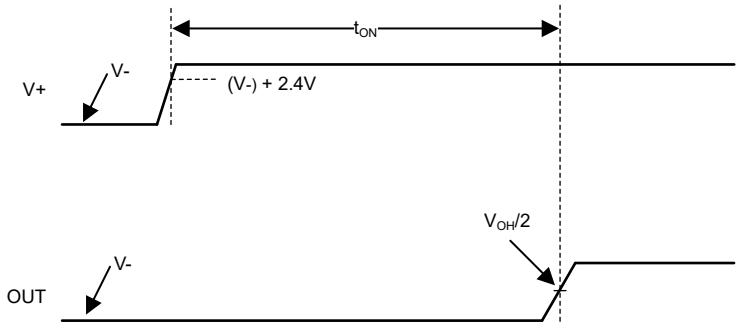

Figure 6-3. Power-On Reset Timing Diagram

Note: The output voltage rises with the pull-up voltage during the POR period.

6.4.4 Hysteresis

The TLV18x2-EP family does not have internal hysteresis. Due to the wide effective bandwidth and low input offset voltage, there is a possibility for the output to "chatter" when the absolute differential voltage is near zero as the comparator triggers on it's own internal wideband noise. This is normal comparator behavior and is expected. TI recommends that the user add external hysteresis if slow moving signals are expected. See Section 7.1.2 in the following section.

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7 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.

7.1 Application Information

7.1.1 Basic Comparator Definitions

7.1.1.1 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 7-1 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 7-1 summarizes the output conditions. The output logic can be inverted by simply swapping the input pins.

Table 7-1. Output Conditions

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

7.1.1.2 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 7-1 and is measured from the mid-point of the input to the midpoint of the output. Likewise, propagation varies with what is called Overdrive (VOD) and Underdrive (VUD) voltage levels (see section below).

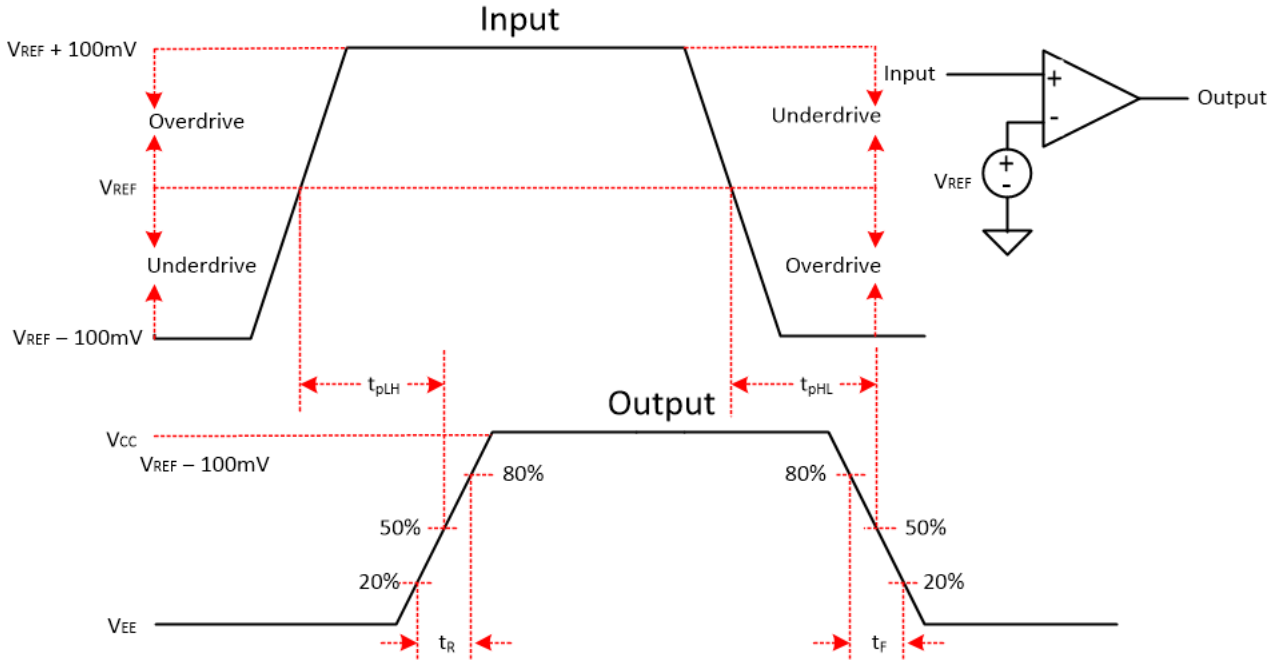

Figure 7-1. Comparator Timing Diagram

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7.1.1.3 Overdrive and Underdrive 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 100mV as shown in the Figure 7-1 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, apply the highest amount of overdrive possible. Contrary to overdrive voltage, larger underdrive voltage causes tp to increase. This is particulary important in applications where rail-to-rail input swings are present at the comparator inputs. The result can be skewed propagation delay (difference between tpLH and tpHL). As a low power comparator, use of this comparator family is not recommended if variation in propagation delay is critical.

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

7.1.2 Hysteresis

The basic comparator configuration can oscillate or produce a noisy "chatter" output if the applied differential input voltage is near the comparator's offset voltage. This typically occurs when the input signal is moving very slowly across the switching threshold of the comparator.

This problem can be prevented by the addition of hysteresis or positive feedback.

The 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 hysteresis (or trip window) that is designed to reduce comparator sensitivity to noise.

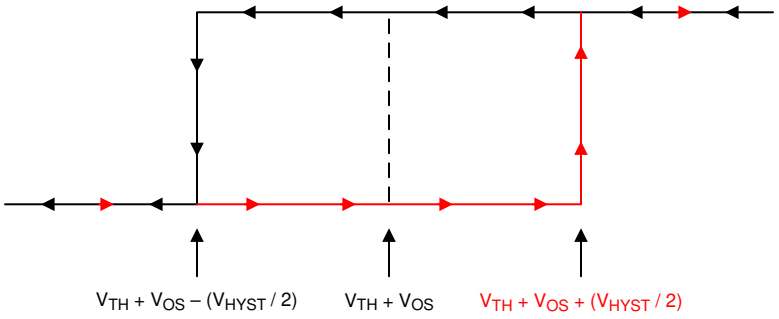

Figure 7-2. Hysteresis Transfer Curve

For more information, see the *Comparator with and without hysteresis circuit* application note.

7.1.2.1 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 7-3.

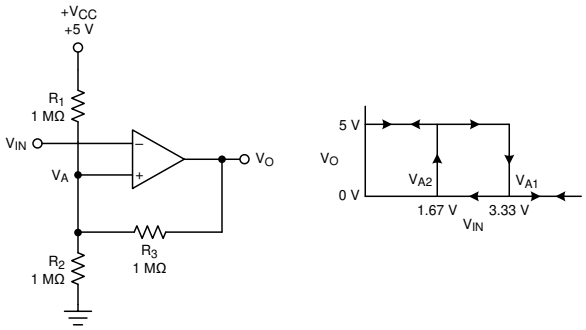

Figure 7-3. TLV1812-EP in an Inverting Configuration With Hysteresis

The equivalent resistor networks when the output is high and low are shown in Figure 7-3.

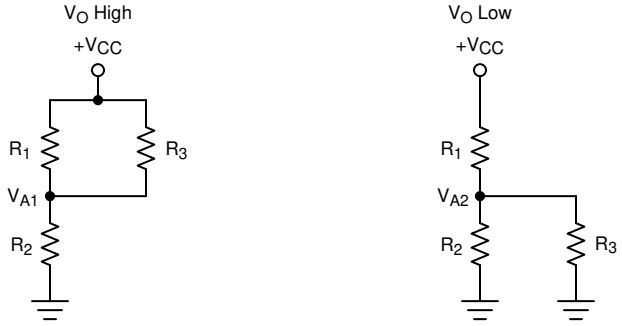

Figure 7-4. Inverting Configuration Resistor Equivalent Networks

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 7-4.

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

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

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}).

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

Equation 3 defines the total hysteresis provided by the network.

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

7.1.2.2 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 7-5.

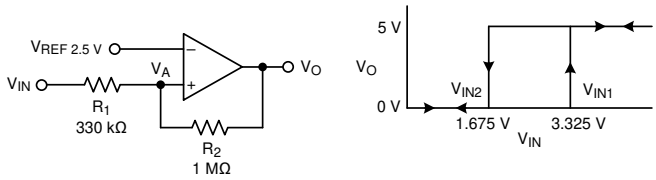

Figure 7-5. TLV1812-EP in a Non-Inverting Configuration With Hysteresis

The equivalent resistor networks when the output is high and low are shown in Figure 7-6.

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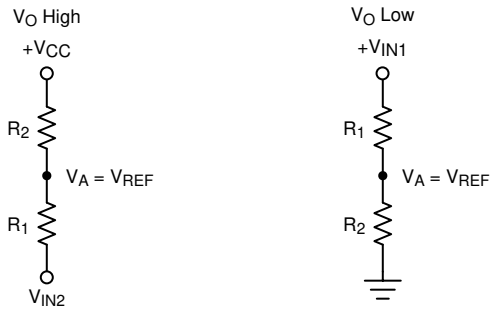

Figure 7-6. Non-Inverting Configuration Resistor Networks

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, see the *Inverting comparator with hysteresis circuit* application note and the *Non-Inverting Comparator With Hysteresis Circuit* application note.

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

Using an open drain output device, such as the TLV1822-EP, is also possible 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.

7.2 Typical Applications

7.2.1 Window Comparator

Window comparators are commonly used to detect undervoltage and overvoltage conditions. Figure 7-7 shows a simple window comparator circuit. Window comparators require open drain outputs (TLV1822-EP) if the outputs are directly connected together.

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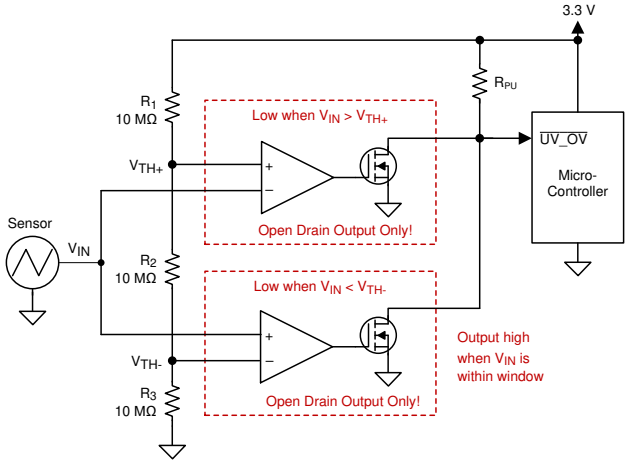

Figure 7-7. Window Comparator

7.2.1.1 Design Requirements

For this design, follow these design requirements:

- Alert (logic low output) when an input signal is less than 1.1V
- Alert (logic low output) when an input signal is greater than 2.2V
- Alert signal is active low
- Operate from a 3.3V power supply

7.2.1.2 Detailed Design Procedure

Configure the circuit as shown in Figure 7-7. Connect V_{CC} to a 3.3V power supply and V_{EE} to ground. Make R1, R2 and R3 each 10MΩ 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 2.2V and V_{TH-} is 1.1V. Large resistor values such as 10MΩ are used to minimize power consumption. The resistor values can 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 are low when the sensor is less than 1.1V or greater than 2.2V. The respective comparator outputs are high when the sensor is in the range of 1.1V to 2.2V (within the "window"), as shown in Figure 7-8.

7.2.1.3 Application Curve

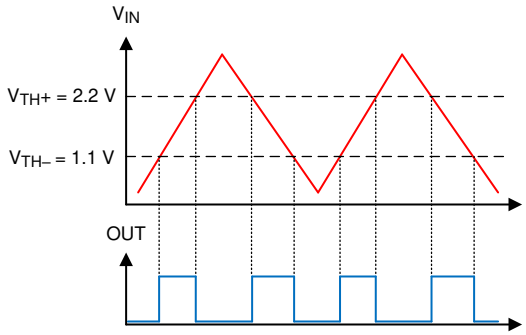

Figure 7-8. Window Comparator Results

For more information, see the *Window comparator circuit* application note.

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7.2.2 Square-Wave Oscillator

Square-wave oscillator can be used as low cost timing reference or system supervisory clock source. A push-pull output (TLV1812-EP) is recommended for best symmetry.

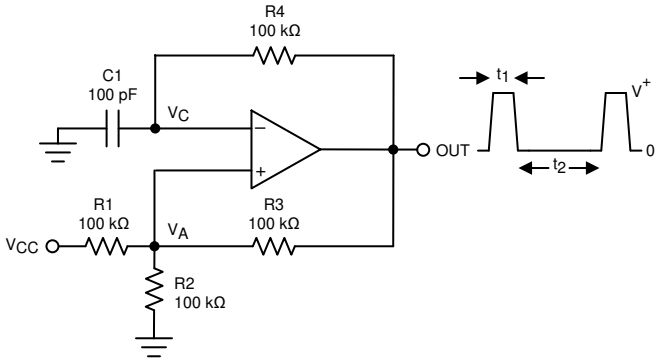

Figure 7-9. Square-Wave Oscillator

7.2.2.1 Design Requirements

The square-wave period is determined by the RC time constant of the capacitor C_1 and resistor R_4. The maximum frequency is limited by propagation delay of the device and the capacitance load at the output. The low input bias current allows a lower capacitor value and larger resistor value combination for a given oscillator frequency, which can help to reduce BOM cost and board space. TI recommends that R4 be over several kilo-ohms to minimize loading of the output.

7.2.2.2 Detailed Design Procedure

The oscillation frequency is determined by the resistor and capacitor values. The following calculation provides details of the steps.

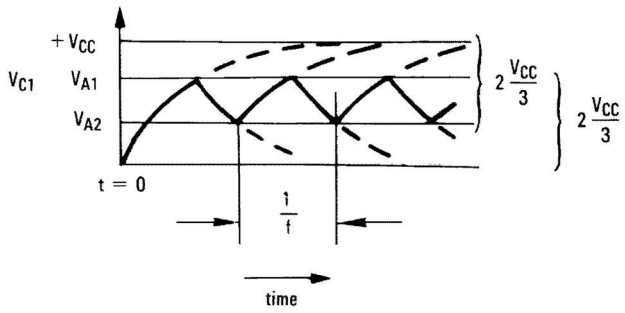

Figure 7-10. Square-Wave Oscillator Timing Thresholds

First consider the output of Figure Figure 7-9 as high, which indicates the inverted input V_C is lower than the noninverting input (V_A). This causes the C_1 to be charged through R_4, and the voltage V_C increases until equal to the noninverting input. The value of V_A at the point is calculated by Equation 7.

$$V_{A1} = \frac{V_{CC} \times R_2}{R_2 + R_1 \| R_3} \tag{7}$$

if $R_1 = R_2 = R_3$, then $V_{A1} = 2V_{CC}/3$

At this time the comparator output trips pulling down the output to the negative rail. The value of $V_A$at this point is calculated by Equation 8.

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$$V_{A2} = \frac{V_{CC}(R_2 \| R_3)}{R_1 + R_2 \| R_3} \quad (8)$$

if $R_1 = R_2 = R_3$, then $V_{A2} = V_{CC}/3$

The C_1 now discharges though the R_4, and the voltage V_{CC} decreases until reaching V_{A2}. At this point, the output switches back to the starting state. The oscillation period equals to the time duration from for C_1 from $2V_{CC}/3$ to V_{CC} / 3 then back to $2V_{CC}/3$, which is given by $R_4C_1 \times \ln 2$ for each trip. Therefore, the total time duration is calculated as $2\ R_4C_1 \times \ln 2$.

The oscillation frequency can be obtained by Equation 9:

$$f = 1/(2\ R4 \times C1 \times In2) \quad (9)$$

7.2.2.3 Application Curve

Figure 7-11 shows the simulated results of an oscillator using the following component values:

- $R_1 = R_2 = R_3 = R_4 = 100k\Omega$
- $C_1 = 100pF$, $C_L = 20pF$
- V+ = 5V, V– = GND
- C_{stray} (not shown) from V_A TO GND = 10pF

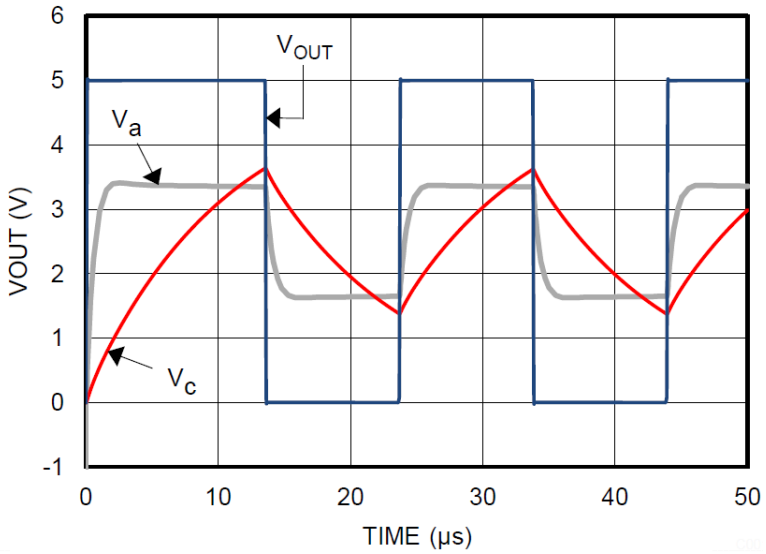

Figure 7-11. Square-Wave Oscillator Output Waveform

7.2.3 Adjustable Pulse Width Generator

Figure 7-12 is a variation of the square wave oscillator (see Figure 7-9) that allows adjusting the pulse widths.

R_4 and R_5 provide separate charge and discharge paths for the capacitor C depending on the output state.

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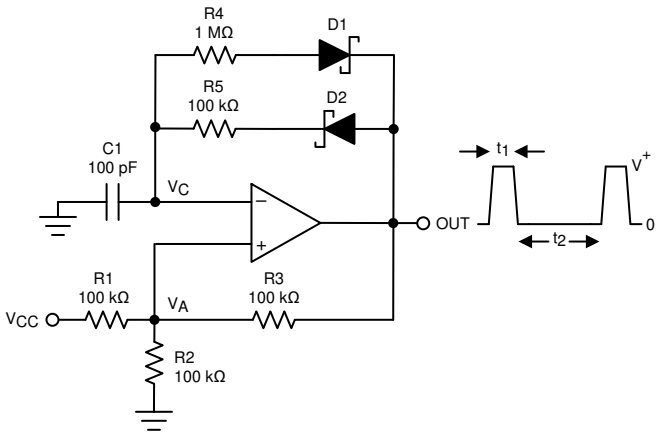

Figure 7-12. Adjustable Pulse Width Generator

The charge path is set through R_5 and D_2 when the output is high. Similarly, the discharge path for the capacitor is set by R_4 and D_1 when the output is low.

The pulse width t_1 is determined by the RC time constant of R_5 and C. Thus, the time t_2 between the pulses can be changed by varying R_4, and the pulse width can be altered by R_5. The frequency of the output can be changed by varying both R_4 and R_5. At low voltages, the effects of the diode forward drop (0.8V, or 0.15V for Shottky) must be taken into account by altering output high and low voltages in the calculations.

7.2.4 Time Delay Generator

The circuit shown in Figure 7-13 provides output signals at a prescribed time interval from a time reference and automatically resets the output low when the input returns to 0V. This is useful for sequencing a "power on" signal to trigger a controlled start-up of power supplies.

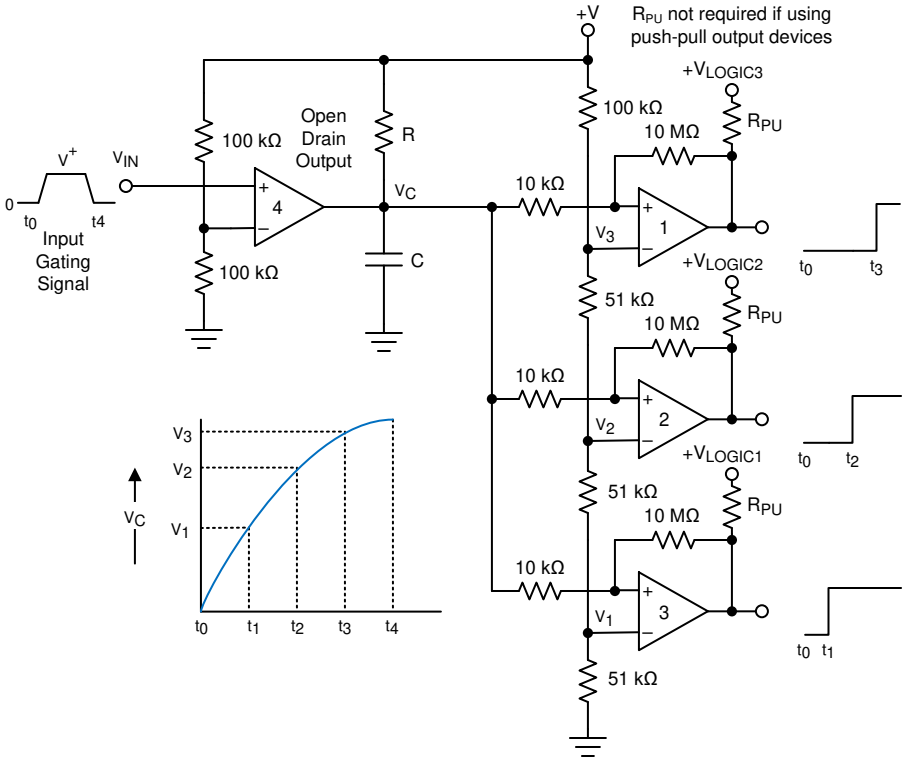

Figure 7-13. Time Delay Generator

Consider the case of V_{IN} = 0. The output of comparator 4 is also at ground, "shorting" the capacitor and holding the capacitor at 0V. This implies that the outputs of comparators 1, 2, and 3 are also at 0V. When an input signal is applied, the output of open drain comparator 4 goes High-Z and C charges exponentially through R. This is indicated in the graph. The output voltages of comparators 1, 2, and 3 switch to the high state in sequence when V_C rises above the reference voltages V_1, V_2 and V_3. A small amount of hysteresis has been provided by the 10kΩ and 10MΩ resistors to insure fast switching when the RC time constant is chosen to give long delay times. A good starting point is R = 100kΩ and C = 0.01µF to 1µF.

All outputs immediately go low when V_{IN} falls to 0V, due to the comparator output going low and immediately discharging the capacitor.

Comparator 4 must be a open-drain type output (TLV1822-EP), whereas comparators 1 though 3 can be either open drain or push-pull output, depending on system requirements. R_{PU} is not required for push-pull output devices.

7.2.5 Logic Level Shifter

The output of the TLV1822-EP is the uncommitted drain of the output transistor. Many open-drain outputs can be tied together to provide an output OR'ing function if desired.

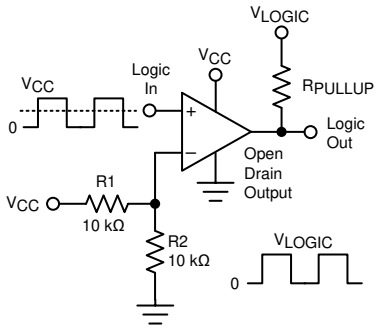

Figure 7-14. Universal Logic Level Shifter

The two 10kΩ resistors bias the input to half of the input logic supply level to set the threshold in the mid-point of the input logic levels. Only one shared output pull-up resistor is needed and can be connected to any pull-up voltage between 0V and 5.5V. The pullup voltage must match the driven logic input "high" level.

7.2.6 One-Shot Multivibrator

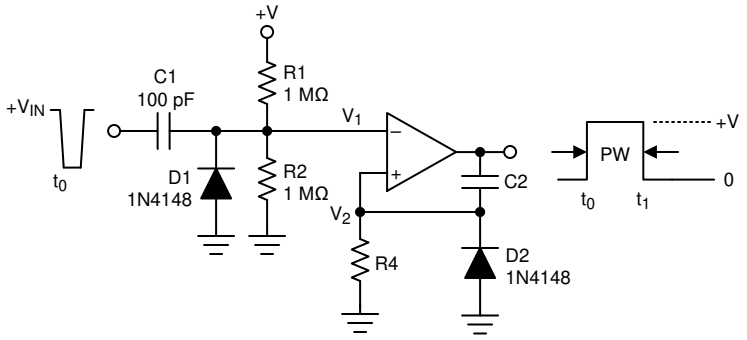

Figure 7-15. One-Shot Multivibrator

A monostable multivibrator has one stable state and can remain in that state indefinitely. The monostable multivibrator can be triggered externally to another quasi-stable state. A monostable multivibrator can thus be used to generate a pulse of desired width.

The desired pulse width is set by adjusting the values of C_2 and R_4. The resistor divider of R_1 and R_2 can be used to determine the magnitude of the input trigger pulse. The output changes state when $V_1 < V_2$. Diode D_2

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provides a rapid discharge path for capacitor C_2 to reset at the end of the pulse. The diode also prevents the non-inverting input from being driven below ground.

7.2.7 Bi-Stable Multivibrator

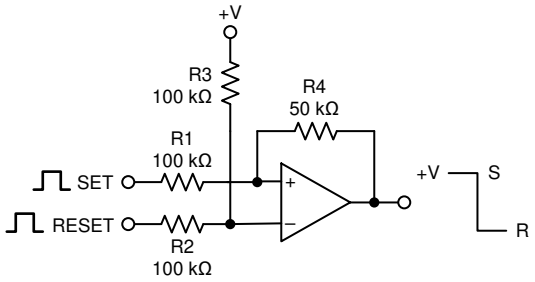

Figure 7-16. Bi-Stable Multivibrator

A bi-stable multivibrator has two stable states. The reference voltage is set up by the voltage divider of R_2 and R_3. A pulse applied to the SET terminal sets the output of the comparator high. The resistor divider of R_1 and R4 now sets the non-inverting input to a voltage greater than the reference voltage. A pulse applied to RESET toggles the output low.

7.2.8 Zero Crossing Detector

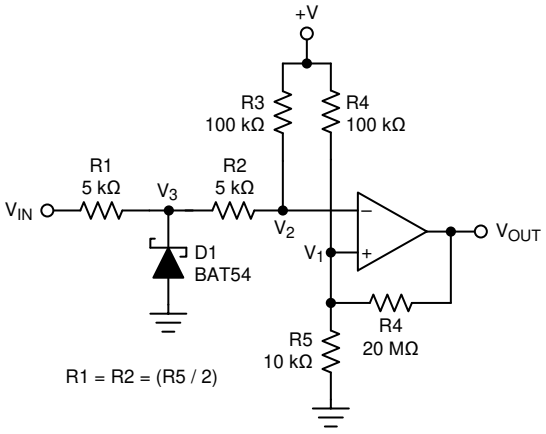

Figure 7-17. Zero Crossing Detector

A voltage divider of R_4 and R_5 establishes a reference voltage V_1 at the non-inverting input. By making the series resistance of R_1 and R_2 equal to R_5, the comparator switches when V_{IN} = 0. Diode D_1 insures that V_3 clamps near ground. The voltage divider of R_2 and R_3 then prevents V_2 from going below ground. A small amount of hysteresis is setup to facilitate rapid output voltage transitions.

7.2.9 Pulse Slicer

A Pulse Slicer is a variation of the Zero Crossing Detector and is used to detect the zero crossings on an input signal with a varying baseline level. This circuit works best with symmetrical waveforms. The RC network of R_1 and C_1 establishes an mean reference voltage V_{REF}, which tracks the mean amplitude of the V_{IN} signal. The non-inverting input is directly connected to V_{REF} through R2. R2 and R3 are used to produce hysteresis to keep transitions free of spurious toggles. The time constant is a tradeoff between long-term symmetry and response time to changes in amplitude.

The data is recommended to be encoded in NRZ (Non-Return to Zero) format to maintain proper average baseline. Asymmetrical inputs can suffer from timing distortions caused by the changing V_{REF} average voltage.

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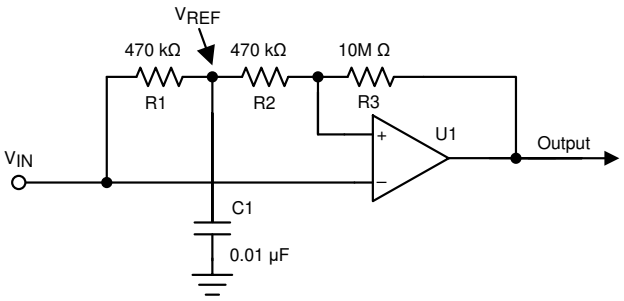

Figure 7-18. Pulse Slicer

For this design, follow these design requirements:

- The RC constant value (R_2 and C_1) must support the targeted data rate to maintain a valid tripping threshold.
- The hysteresis introduced with R_2 and R_{43} helps to avoid spurious output toggles.

The TLV1822-EP can also be used, but with the addition of a pull-up resistor on the output (not shown for clarity).

Figure 7-19 shows the results of a 9600 baud data signal riding on a varying baseline.

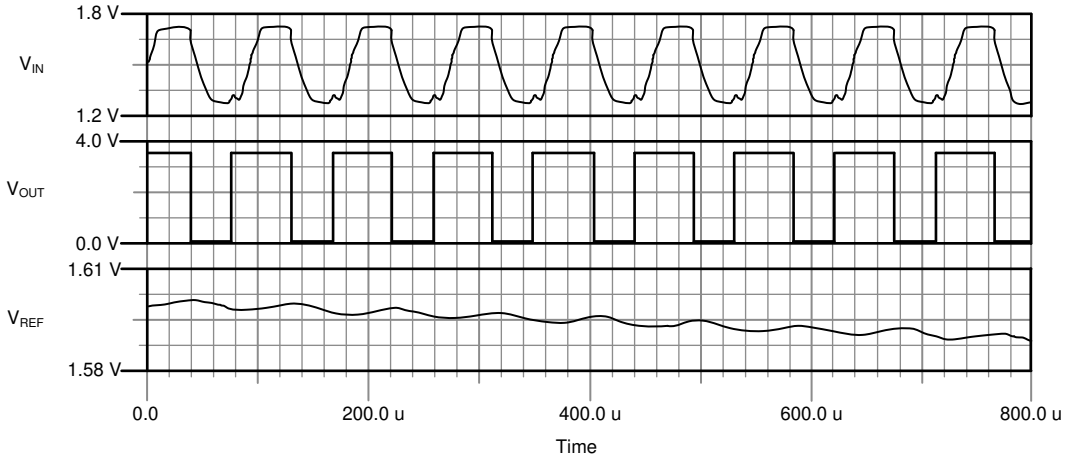

Figure 7-19. Pulse Slicer Waveforms

7.3 Power Supply Recommendations

Due to the fast output edges, bypass capacitors are critical on the supply pin to prevent supply ringing and false triggers and oscillations. Bypass the supply directly at *each* device with a low ESR 0.1µF ceramic bypass capacitor directly between V_{CC} pin and ground pins. Narrow, peak currents are 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 can be powered from both "split" supplies (V+ and V-), or "single" supplies (V+ and GND), with GND applied to the V- pin. Input signals must stay within the specified input range (between V+ and V-) for either type. Note that with a "split" supply the ouptut swings "low" (V_{OL}) to V- potential and not GND.

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7.4 Layout

7.4.1 Layout Guidelines

For accurate comparator applications, maintain a stable power supply with minimized noise and glitches. Output rise and fall times are in the tens of nanoseconds, and must be treated as high speed logic devices. The bypass capacitor must be as close to the supply pin as possible and connected to a solid ground plane, and preferably directly between the V_{CC} and GND pins.

Minimize coupling between outputs and inputs to prevent output oscillations. Do not run output and input traces in parallel to reduce coupling. When series resistance is added to inputs, place resistor close to the device. A low value (<100 ohms) resistor can 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 can be used when routing long distances.

7.4.2 Layout Example

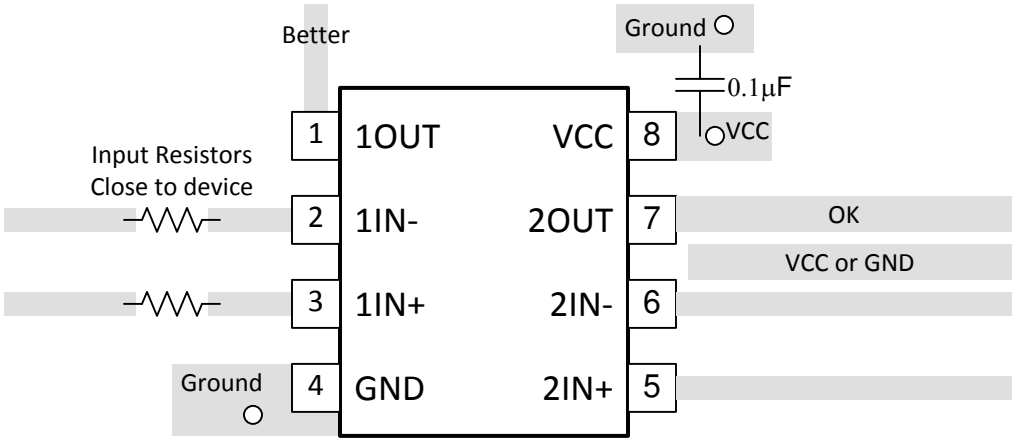

Figure 7-20. Dual Layout Example

8 Device and Documentation Support

8.1 Documentation Support

8.1.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *Analog Engineers Circuit Cookbook: Amplifiers* e-book
- Texas Instruments, *Precision Design, Comparator with Hysteresis* design guide
- Texas Instruments, *Window comparator circuit* application note
- Texas Instruments, *Reference Design, Window Comparator Reference Design* design guide
- Texas Instruments, *Comparator with and without hysteresis circuit* application note
- Texas Instruments, *Inverting comparator with hysteresis circuit* application note
- Texas Instruments, *Non-Inverting Comparator With Hysteresis Circuit* application note
- Texas Instruments, *Zero crossing detection using comparator circuit* application note
- Texas Instruments, *PWM generator circuit* application note
- Texas Instruments, *How to Implement Comparators for Improving Performance of Rotary Encoder in Industrial Drive Applications* application note
- Texas Instruments, *A Quad of Independently Func Comparators* application note

8.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* 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.

8.3 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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8.4 Trademarks

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8.5 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.

8.6 Glossary

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

9 Revision History

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

Changes from Revision * (May 2024) to Revision A (July 2025)	Page
• Added VID and Controlled Baseline information to *Features*	1
• Removed preview for TLV1812-EP/22 Dual SOIC Release	1

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10 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.

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TLV1812MDDFREP	Active	Production	SOT-23-THIN (DDF) | 8	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	T12EP
TLV1822MDDFREP	Active	Production	SOT-23-THIN (DDF) | 8	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	T22EP
V62/24628-01XE	Active	Production	SOT-23-THIN (DDF) | 8	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	T12EP
V62/24628-02XE	Active	Production	SOT-23-THIN (DDF) | 8	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	T22EP

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts 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.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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OTHER QUALIFIED VERSIONS OF TLV1812-EP, TLV1822-EP :

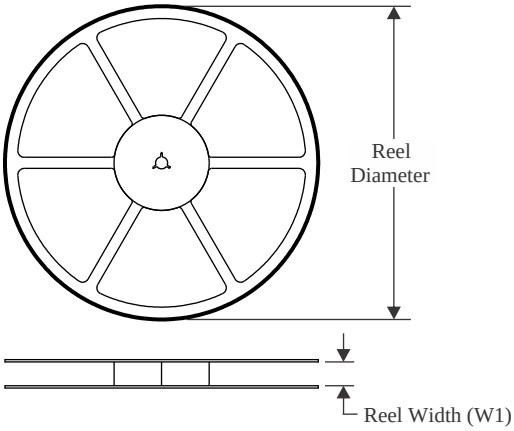
- Catalog : TLV1812, TLV1822
- Automotive : TLV1812-Q1, TLV1822-Q1

NOTE: Qualified Version Definitions:

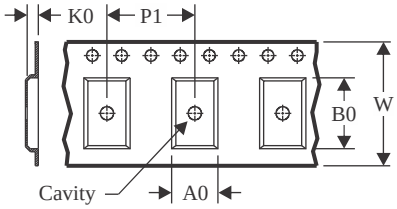
- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

REEL DIMENSIONS

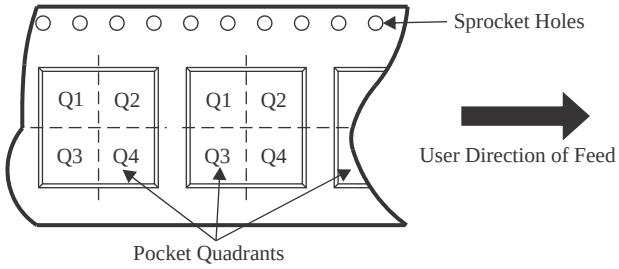


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

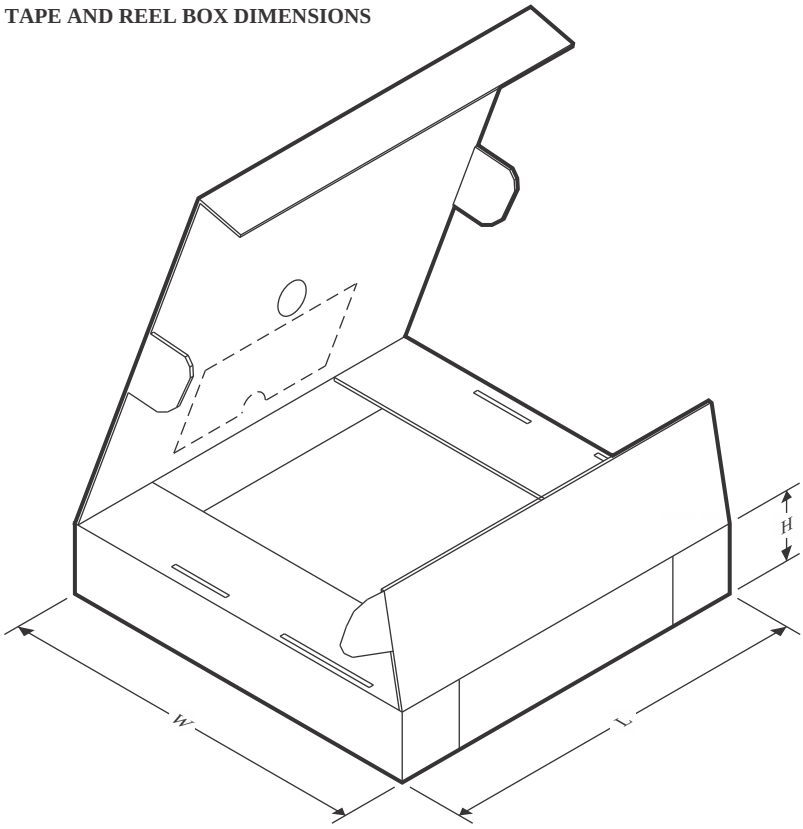
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV1812MDDFREP	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV1822MDDFREP	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

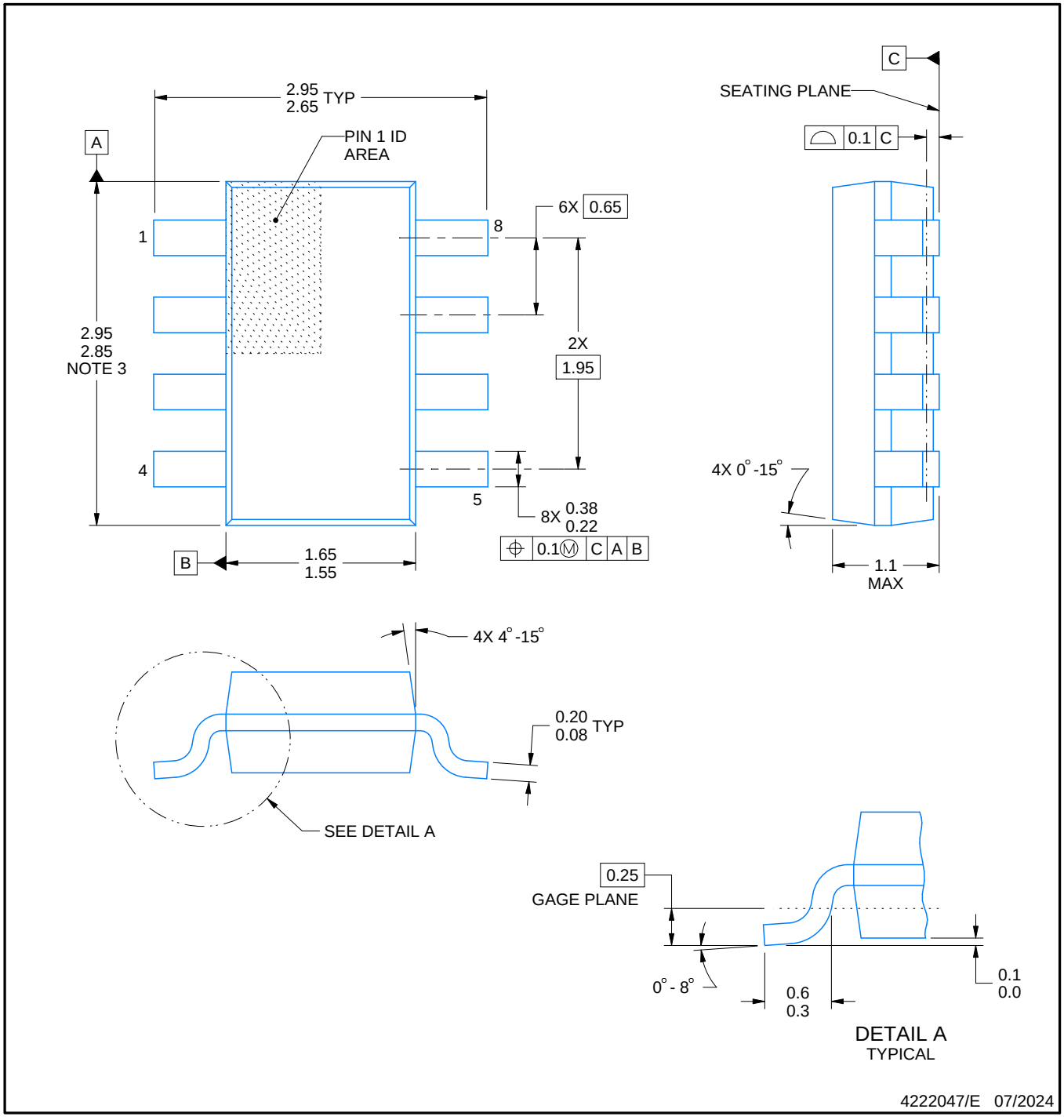
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV1812MDDFREP	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
TLV1822MDDFREP	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0

PACKAGE OUTLINE

DDF0008A

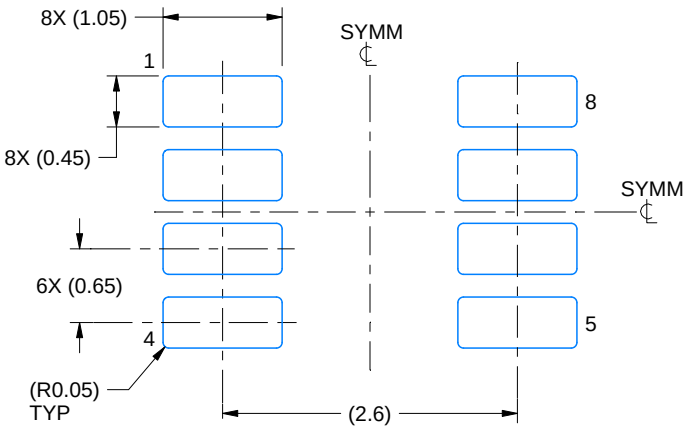
SOT-23-THIN - 1.1 mm max height

PLASTIC SMALL OUTLINE

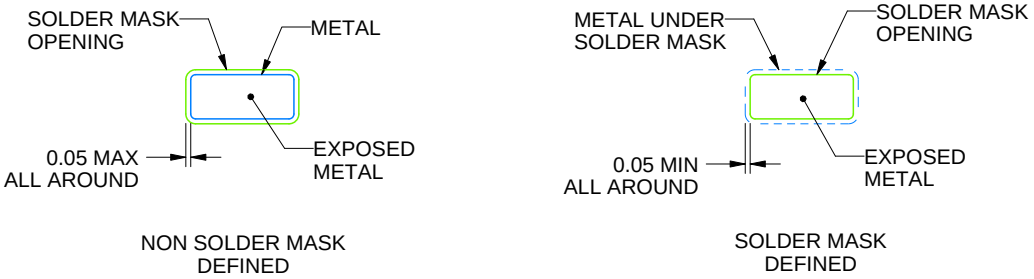


NOTES:

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. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

4222047/E 07/2024

NOTES: (continued)

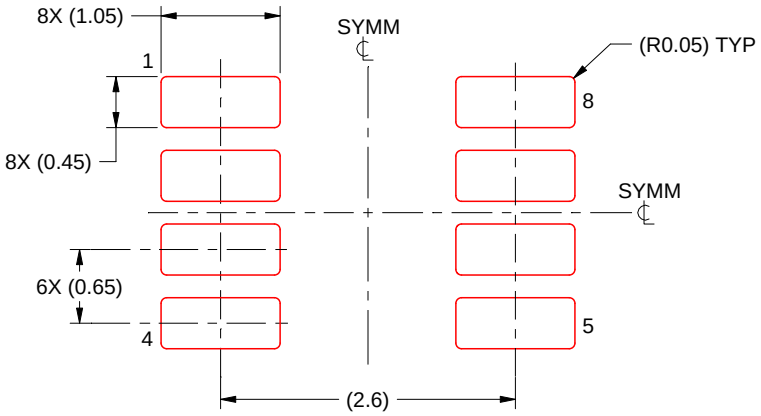
4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DDF0008A

SOT-23-THIN - 1.1 mm max height

PLASTIC SMALL OUTLINE



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

4222047/E 07/2024

NOTES: (continued)

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

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