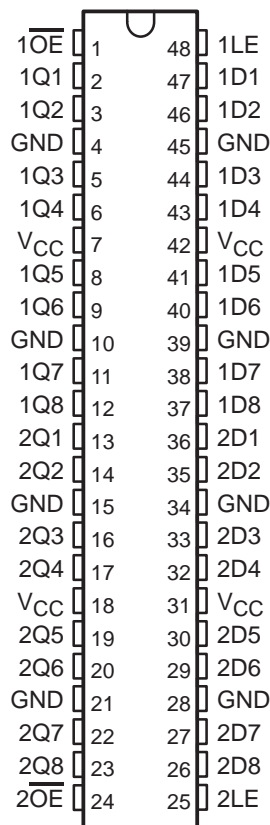


# SN54ALVTH16373, SN74ALVTH16373 2.5-V/3.3-V 16-BIT TRANSPARENT D-TYPE LATCHES WITH 3-STATE OUTPUTS

SCES067F – JUNE 1996 – REVISED JANUARY 1999

- State-of-the-Art Advanced BiCMOS Technology (ABT) *Widebus*™ Design for 2.5-V and 3.3-V Operation and Low Static Power Dissipation
- Support Mixed-Mode Signal Operation (5-V Input and Output Voltages With 2.3-V to 3.6-V  $V_{CC}$ )
- Typical  $V_{OLP}$  (Output Ground Bounce) < 0.8 V at  $V_{CC} = 3.3$  V,  $T_A = 25^\circ\text{C}$
- High Drive (–24/24 mA at 2.5-V and –32/64 mA at 3.3-V  $V_{CC}$ )
- Power Off Disables Outputs, Permitting Live Insertion
- High-Impedance State During Power Up and Power Down Prevents Driver Conflict
- Uses Bus Hold on Data Inputs in Place of External Pullup/Pulldown Resistors to Prevent the Bus From Floating
- Auto3-State Eliminates Bus Current Loading When Output Exceeds  $V_{CC} + 0.5$  V
- Latch-Up Performance Exceeds 250 mA Per JESD 17
- ESD Protection Exceeds 2000 V Per MIL-STD-883, Method 3015; Exceeds 200 V Using Machine Model; and Exceeds 1000 V Using Charged-Device Model, Robotic Method
- Flow-Through Architecture Facilitates Printed Circuit Board Layout
- Distributed  $V_{CC}$  and GND Pin Configuration Minimizes High-Speed Switching Noise
- Package Options Include Plastic Shrink Small-Outline (DL), Thin Shrink Small-Outline (DGG), Thin Very Small-Outline (DGV) Packages, and 380-mil Fine-Pitch Ceramic Flat (WD) Package

SN54ALVTH16373 . . . WD PACKAGE  
SN74ALVTH16373 . . . DGG, DGV, OR DL PACKAGE  
(TOP VIEW)



## description

The 'ALVTH16373 devices are 16-bit transparent D-type latches with 3-state outputs designed for 2.5-V or 3.3-V  $V_{CC}$  operation, but with the capability to provide a TTL interface to a 5-V system environment. These devices are particularly suitable for implementing buffer registers, I/O ports, bidirectional bus drivers, and working registers.

These devices can be used as two 8-bit latches or one 16-bit latch. When the latch-enable (LE) input is high, the Q outputs follow the data (D) inputs. When LE is taken low, the Q outputs are latched at the levels set up at the D inputs.



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# SN54ALVTH16373, SN74ALVTH16373

## 2.5-V/3.3-V 16-BIT TRANSPARENT D-TYPE LATCHES

### WITH 3-STATE OUTPUTS

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#### description (continued)

A buffered output-enable ( $\overline{OE}$ ) input can be used to place the eight outputs in either a normal logic state (high or low logic levels) or a high-impedance state. In the high-impedance state, the outputs neither load nor drive the bus lines significantly. The high-impedance state and the increased drive provide the capability to drive bus lines without interface or pullup components.

$\overline{OE}$  does not affect internal operations of the latch. Old data can be retained or new data can be entered while the outputs are in the high-impedance state.

Active bus-hold circuitry is provided to hold unused or floating data inputs at a valid logic level.

When  $V_{CC}$  is between 0 and 1.2 V, the device is in the high-impedance state during power up or power down. However, to ensure the high-impedance state above 1.2 V,  $\overline{OE}$  should be tied to  $V_{CC}$  through a pullup resistor; the minimum value of the resistor is determined by the current-sinking capability of the driver.

The SN54ALVTH16373 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The SN74ALVTH16373 is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

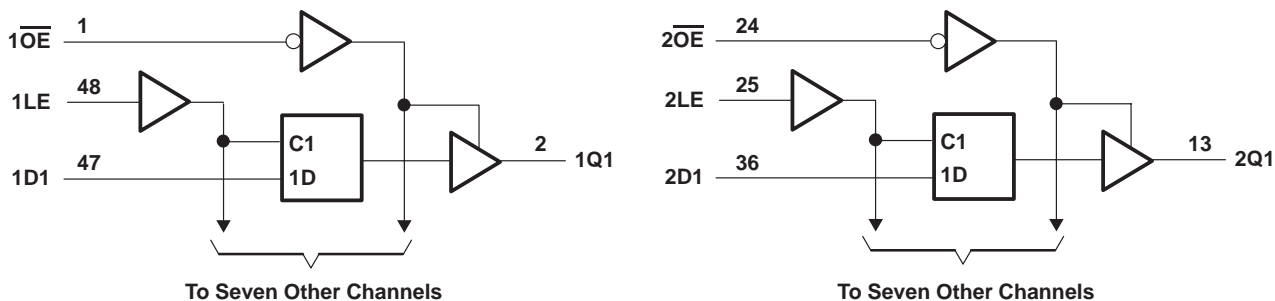
FUNCTION TABLE  
(each 8-bit section)

INPUTS			OUTPUT
$\overline{OE}$	LE	D	Q
L	H	H	H
L	H	L	L
L	L	X	$Q_0$
H	X	X	Z

# SN54ALVTH16373, SN74ALVTH16373 2.5-V/3.3-V 16-BIT TRANSPARENT D-TYPE LATCHES WITH 3-STATE OUTPUTS

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## logic diagram (positive logic)



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage range, $V_{CC}$ .....	-0.5 V to 4.6 V
Input voltage range, $V_I$ (see Note 1) .....	-0.5 V to 7 V
Voltage range applied to any output in the high-impedance or power-off state, $V_O$ (see Note 1) .....	-0.5 V to 7 V
Voltage range applied to any output in the high state, $V_O$ (see Note 1) .....	-0.5 V to 7 V
Output current in the low state, $I_{OL}$ : SN54ALVTH16373 .....	96 mA
SN74ALVTH16373 .....	128 mA
Output current in the high state, $I_{OH}$ : SN54ALVTH16373 .....	-48 mA
SN74ALVTH16373 .....	-64 mA
Input clamp current, $I_{IK}$ ( $V_I < 0$ ) .....	-50 mA
Output clamp current, $I_{OK}$ ( $V_O < 0$ ) .....	-50 mA
Package thermal impedance, $\theta_{JA}$ (see Note 2): DGG package .....	89°C/W
DGV package .....	93°C/W
DL package .....	94°C/W
Storage temperature range, $T_{stg}$ .....	-65°C to 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. The input and output negative-voltage ratings may be exceeded if the input and output clamp-current ratings are observed.  
2. The package thermal impedance is calculated in accordance with JESD 51.

## recommended operating conditions, $V_{CC} = 2.5\text{ V} \pm 0.2\text{ V}$ (see Note 3)

		SN54ALVTH16373			SN74ALVTH16373			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{CC}$	Supply voltage	2.3		2.7	2.3		2.7	V
$V_{IH}$	High-level input voltage	1.7			1.7			V
$V_{IL}$	Low-level input voltage			0.7			0.7	V
$V_I$	Input voltage	0	$V_{CC}$	5.5	0	$V_{CC}$	5.5	V
$I_{OH}$	High-level output current			-6			-8	mA
$I_{OL}$	Low-level output current			6			8	mA
	Low-level output current; current duty cycle $\leq 50\%$ ; $f \geq 1\text{ kHz}$			18			24	
$\Delta t/\Delta v$	Input transition rise or fall rate			10			10	ns/V
	Outputs enabled							
$\Delta t/\Delta V_{CC}$	Power-up ramp rate	200			200			$\mu\text{s}/\text{V}$
$T_A$	Operating free-air temperature	-55		125	-40		85	°C

NOTE 3: All unused control inputs of the device must be held at  $V_{CC}$  or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

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**WITH 3-STATE OUTPUTS**

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**recommended operating conditions,  $V_{CC} = 3.3\text{ V} \pm 0.3\text{ V}$  (see Note 3)**

		SN54ALVTH16373			SN74ALVTH16373			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
$V_{CC}$	Supply voltage	3		3.6	3		3.6	V
$V_{IH}$	High-level input voltage	2			2			V
$V_{IL}$	Low-level input voltage			0.8			0.8	V
$V_I$	Input voltage	0	$V_{CC}$	5.5	0	$V_{CC}$	5.5	V
$I_{OH}$	High-level output current			-24			-32	mA
$I_{OL}$	Low-level output current			24			32	mA
	Low-level output current; current duty cycle $\leq 50\%$ ; $f \geq 1\text{ kHz}$			48			64	
$\Delta t/\Delta v$	Input transition rise or fall rate	Outputs enabled		10			10	ns/V
$\Delta t/\Delta V_{CC}$	Power-up ramp rate			200			200	$\mu\text{s/V}$
$T_A$	Operating free-air temperature			-55			125	$^{\circ}\text{C}$

NOTE 3: All unused control inputs of the device must be held at  $V_{CC}$  or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

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**2.5-V/3.3-V 16-BIT TRANSPARENT D-TYPE LATCHES**  
**WITH 3-STATE OUTPUTS**

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**electrical characteristics over recommended operating free-air temperature range,  
 $V_{CC} = 2.5\text{ V} \pm 0.2\text{ V}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	SN54ALVTH16373		SN74ALVTH16373		UNIT
			MIN	TYP†	MAX	MIN	
$V_{IK}$		$V_{CC} = 2.3\text{ V}$ , $I_I = -18\text{ mA}$			-1.2		V
$V_{OH}$		$V_{CC} = 2.3\text{ V to } 2.7\text{ V}$ , $I_{OH} = -100\text{ }\mu\text{A}$	$V_{CC}-0.2$		$V_{CC}-0.2$		V
		$V_{CC} = 2.3\text{ V}$	1.8		1.8		
$V_{OL}$		$V_{CC} = 2.3\text{ V to } 2.7\text{ V}$ , $I_{OL} = 100\text{ }\mu\text{A}$	0.2		0.2		V
		$V_{CC} = 2.3\text{ V}$	0.4				
			0.4		0.4		
			0.5		0.5		
$I_I$	Control inputs	$V_{CC} = 2.7\text{ V}$ , $V_I = V_{CC}$ or GND	$\pm 1$		$\pm 1$		$\mu\text{A}$
		$V_{CC} = 0$ or $2.7\text{ V}$ , $V_I = 5.5\text{ V}$	10		10		
	Data inputs	$V_{CC} = 2.7\text{ V}$	10		10		
			-5		-5		
$I_{off}$		$V_{CC} = 0$ , $V_I$ or $V_O = 0$ to $4.5\text{ V}$			$\pm 100$		$\mu\text{A}$
$I_{BHL}^\ddagger$		$V_{CC} = 2.3\text{ V}$ , $V_I = 0.7\text{ V}$	115		115		$\mu\text{A}$
$I_{BHH}^\S$		$V_{CC} = 2.3\text{ V}$ , $V_I = 1.7\text{ V}$	-10		-10		$\mu\text{A}$
$I_{BHLO}^\P$		$V_{CC} = 2.7\text{ V}$ , $V_I = 0$ to $V_{CC}$	300		300		$\mu\text{A}$
$I_{BHHO}^\#$		$V_{CC} = 2.7\text{ V}$ , $V_I = 0$ to $V_{CC}$	-300		-300		$\mu\text{A}$
$I_{EX}^\parallel$		$V_{CC} = 2.3\text{ V}$ , $V_O = 5.5\text{ V}$	125		125		$\mu\text{A}$
$I_{OZ(PU/PD)}^\star$		$V_{CC} \leq 1.2\text{ V}$ , $V_O = 0.5\text{ V to } V_{CC}$ , $V_I = \text{GND or } V_{CC}$ , $\overline{OE} = \text{don't care}$	$\pm 100$		$\pm 100$		$\mu\text{A}$
$I_{OZH}$		$V_{CC} = 2.7\text{ V}$ $V_O = 2.3\text{ V}$ , $V_I = 0.7\text{ V or } 1.7\text{ V}$	5		5		$\mu\text{A}$
$I_{OZL}$		$V_{CC} = 2.7\text{ V}$ $V_O = 0.5\text{ V}$ , $V_I = 0.7\text{ V or } 1.7\text{ V}$	-5		-5		$\mu\text{A}$
$I_{CC}$		$V_{CC} = 2.7\text{ V}$ , $I_O = 0$ , $V_I = V_{CC}$ or GND	Outputs high		0.04 0.1		mA
			Outputs low		2.3 4.5		
			Outputs disabled		0.04 0.1		
$C_i$		$V_{CC} = 2.5\text{ V}$ , $V_I = 2.5\text{ V or } 0$	3.5		3.5		pF
$C_o$		$V_{CC} = 2.5\text{ V}$ , $V_O = 2.5\text{ V or } 0$	6		6		pF

† All typical values are at  $V_{CC} = 2.5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

‡ The bus-hold circuit can sink at least the minimum low sustaining current at  $V_{IL}$  max.  $I_{BHL}$  should be measured after lowering  $V_{IN}$  to GND and then raising it to  $V_{IL}$  max.

§ The bus-hold circuit can source at least the minimum high sustaining current at  $V_{IH}$  min.  $I_{BHH}$  should be measured after raising  $V_{IN}$  to  $V_{CC}$  and then lowering it to  $V_{IH}$  min.

¶ An external driver must source at least  $I_{BHLO}$  to switch this node from low to high.

# An external driver must sink at least  $I_{BHHO}$  to switch this node from high to low.

|| Current into an output in the high state when  $V_O > V_{CC}$

\* High-impedance state during power up or power down

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**WITH 3-STATE OUTPUTS**

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**electrical characteristics over recommended operating free-air temperature range,**  
 **$V_{CC} = 3.3\text{ V} \pm 0.3\text{ V}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		SN54ALVTH16373		SN74ALVTH16373		UNIT		
				MIN	TYP†	MAX	MIN		TYP†	MAX
$V_{IK}$		$V_{CC} = 3\text{ V}$ , $I_I = -18\text{ mA}$		-1.2		-1.2		V		
$V_{OH}$		$V_{CC} = 3\text{ V to } 3.6\text{ V}$ , $I_{OH} = -100\text{ }\mu\text{A}$		$V_{CC}-0.2$		$V_{CC}-0.2$		V		
		$V_{CC} = 3\text{ V}$		2		2				
$V_{OL}$		$V_{CC} = 3\text{ V to } 3.6\text{ V}$ , $I_{OL} = 100\text{ }\mu\text{A}$		0.2		0.2		V		
		$V_{CC} = 3\text{ V}$		$I_{OL} = 16\text{ mA}$		0.4				
				$I_{OL} = 24\text{ mA}$		0.5				
				$I_{OL} = 32\text{ mA}$		0.5				
				$I_{OL} = 48\text{ mA}$		0.55				
$I_{OL} = 64\text{ mA}$		0.55								
$I_I$		Control inputs $V_{CC} = 3.6\text{ V}$ , $V_I = V_{CC}$ or GND		$\pm 1$		$\pm 1$		$\mu\text{A}$		
				$V_{CC} = 0$ or $3.6\text{ V}$ , $V_I = 5.5\text{ V}$		10			10	
		Data inputs $V_{CC} = 3.6\text{ V}$		$V_I = 5.5\text{ V}$		10			10	
				$V_I = V_{CC}$		1			1	
		$V_I = 0$		-5		-5				
$I_{off}$		$V_{CC} = 0$ , $V_I$ or $V_O = 0$ to $4.5\text{ V}$				$\pm 100$		$\mu\text{A}$		
$I_{BHL}^\ddagger$		$V_{CC} = 3\text{ V}$ , $V_I = 0.8\text{ V}$		75		75		$\mu\text{A}$		
$I_{BHH}^\S$		$V_{CC} = 3\text{ V}$ , $V_I = 2\text{ V}$		-75		-75		$\mu\text{A}$		
$I_{BHLO}^\P$		$V_{CC} = 3.6\text{ V}$ , $V_I = 0$ to $V_{CC}$		500		500		$\mu\text{A}$		
$I_{BHHO}^\#$		$V_{CC} = 3.6\text{ V}$ , $V_I = 0$ to $V_{CC}$		-500		-500		$\mu\text{A}$		
$I_{EX}^\parallel$		$V_{CC} = 3\text{ V}$ , $V_O = 5.5\text{ V}$		125		125		$\mu\text{A}$		
$I_{OZ(PU/PD)}^\star$		$V_{CC} \leq 1.2\text{ V}$ , $V_O = 0.5\text{ V to } V_{CC}$ , $V_I = \text{GND or } V_{CC}$ , $\overline{OE} = \text{don't care}$		$\pm 100$		$\pm 100$		$\mu\text{A}$		
$I_{OZH}$		$V_{CC} = 3.6\text{ V}$ , $V_O = 3\text{ V}$ , $V_I = 0.8\text{ V or } 2\text{ V}$		5		5		$\mu\text{A}$		
$I_{OZL}$		$V_{CC} = 3.6\text{ V}$ , $V_O = 0.5\text{ V}$ , $V_I = 0.8\text{ V or } 2\text{ V}$		-5		-5		$\mu\text{A}$		
$I_{CC}$		$V_{CC} = 3.6\text{ V}$ , $I_O = 0$ , $V_I = V_{CC}$ or GND		Outputs high		0.07 0.1		mA		
				Outputs low		3.2 5.5				
				Outputs disabled		0.07 0.1				
$\Delta I_{CC}^\square$		$V_{CC} = 3\text{ V to } 3.6\text{ V}$ , One input at $V_{CC} - 0.6\text{ V}$ , Other inputs at $V_{CC}$ or GND		0.4		0.4		mA		
$C_i$		$V_{CC} = 3.3\text{ V}$ , $V_I = 3.3\text{ V or } 0$		3.5		3.5		pF		
$C_o$		$V_{CC} = 3.3\text{ V}$ , $V_O = 3.3\text{ V or } 0$		6		6		pF		

† All typical values are at  $V_{CC} = 3.3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

‡ The bus-hold circuit can sink at least the minimum low sustaining current at  $V_{IL}$  max.  $I_{BHL}$  should be measured after lowering  $V_{IN}$  to GND and then raising it to  $V_{IL}$  max.

§ The bus-hold circuit can source at least the minimum high sustaining current at  $V_{IH}$  min.  $I_{BHH}$  should be measured after raising  $V_{IN}$  to  $V_{CC}$  and then lowering it to  $V_{IH}$  min.

¶ An external driver must source at least  $I_{BHLO}$  to switch this node from low to high.

# An external driver must sink at least  $I_{BHHO}$  to switch this node from high to low.

|| Current into an output in the high state when  $V_O > V_{CC}$

\* High-impedance state during power up or power down

□ This is the increase in supply current for each input that is at the specified TTL voltage level rather than  $V_{CC}$  or GND.

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**timing requirements over recommended operating free-air temperature range,  $V_{CC} = 2.5\text{ V} \pm 0.2\text{ V}$  (unless otherwise noted) (see Figure 1)**

		SN54ALVTH16373		SN74ALVTH16373		UNIT
		MIN	MAX	MIN	MAX	
$t_w$	Pulse duration, LE high	1.5		1.5		ns
$t_{su}$	Setup time, data before LE↓	Data high	1.1	1		ns
		Data low	1.6	1.5		
$t_h$	Hold time, data after LE↓	Data high	1	0.9		ns
		Data low	1.6	1.5		

**timing requirements over recommended operating free-air temperature range,  $V_{CC} = 3.3\text{ V} \pm 0.3\text{ V}$  (unless otherwise noted) (see Figure 2)**

		SN54ALVTH16373		SN74ALVTH16373		UNIT
		MIN	MAX	MIN	MAX	
$t_w$	Pulse duration, LE high	1.5		1.5		ns
$t_{su}$	Setup time, data before LE↓	Data high	1.5	1.4		ns
		Data low		0.9		
$t_h$	Hold time, data after LE↓	Data high	1	0.9		ns
		Data low	1.5	1.4		

**switching characteristics over recommended operating free-air temperature range,  $C_L = 30\text{ pF}$ ,  $V_{CC} = 2.5\text{ V} \pm 0.2\text{ V}$  (unless otherwise noted) (see Figure 1)**

PARAMETER	FROM (INPUT)	TO (OUTPUT)	SN54ALVTH16373		SN74ALVTH16373		UNIT
			MIN	MAX	MIN	MAX	
$t_{PLH}$	D	Q	1	3.4	1	3.3	ns
$t_{PHL}$			1	4.3	1	4.2	
$t_{PLH}$	LE	Q	1.4	3.9	1.5	3.8	ns
$t_{PHL}$			1.4	4.6	1.5	4.5	
$t_{PZH}$	$\overline{OE}$	Q	1.7	4.4	1.8	4.3	ns
$t_{PZL}$			1.4	4.1	1.5	4	
$t_{PHZ}$	OE	Q	1.4	4.7	1.5	4.6	ns
$t_{PLZ}$			1	3.7	1	3.6	

**switching characteristics over recommended operating free-air temperature range,  $C_L = 50\text{ pF}$ ,  $V_{CC} = 3.3\text{ V} \pm 0.3\text{ V}$  (unless otherwise noted) (see Figure 2)**

PARAMETER	FROM (INPUT)	TO (OUTPUT)	SN54ALVTH16373		SN74ALVTH16373		UNIT
			MIN	MAX	MIN	MAX	
$t_{PLH}$	D	Q	1	3.2	1	3.1	ns
$t_{PHL}$			1	3.4	1	3.3	
$t_{PLH}$	LE	Q	1	3.4	1	3.3	ns
$t_{PHL}$			1	3.6	1	3.5	
$t_{PZH}$	$\overline{OE}$	Q	1.3	4.1	1.4	4	ns
$t_{PZL}$			1	3.5	1	3.4	
$t_{PHZ}$	$\overline{OE}$	Q	1.4	5	1.5	4.9	ns
$t_{PLZ}$			1.4	4.6	1.5	4.5	

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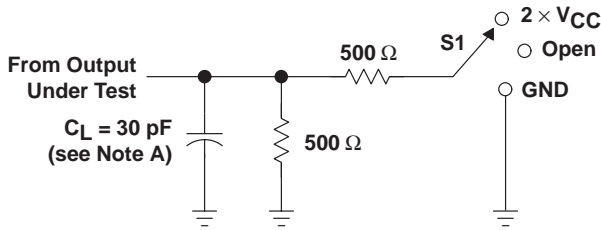


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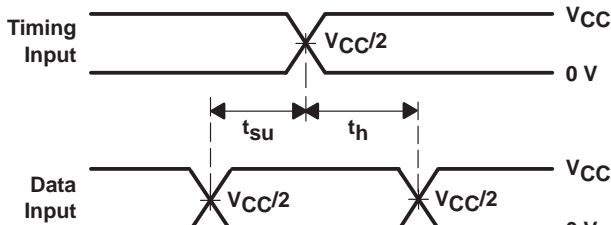
**PARAMETER MEASUREMENT INFORMATION**

$V_{CC} = 2.5\text{ V} \pm 0.2\text{ V}$

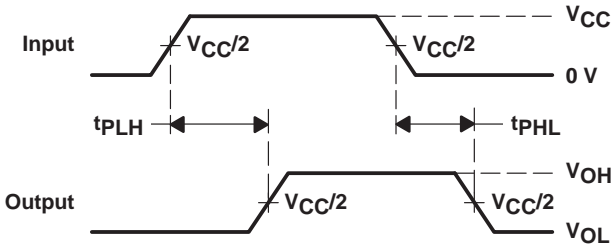


**LOAD CIRCUIT**

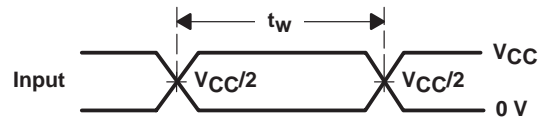
TEST	S1
$t_{PLH}/t_{PHL}$	Open
$t_{PLZ}/t_{PZL}$	2 $\times V_{CC}$
$t_{PHZ}/t_{PZH}$	GND



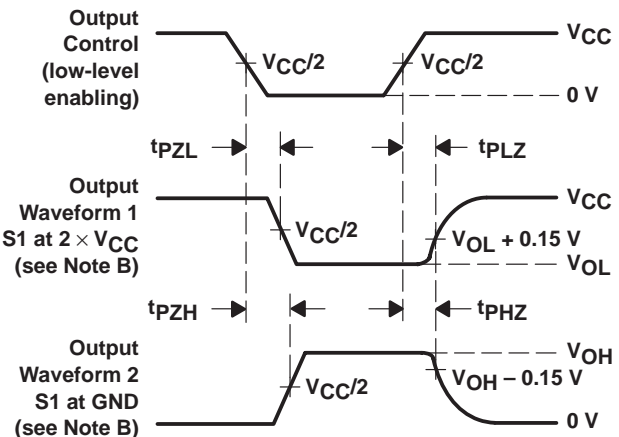
**VOLTAGE WAVEFORMS  
SETUP AND HOLD TIMES**



**VOLTAGE WAVEFORMS  
PROPAGATION DELAY TIMES**



**VOLTAGE WAVEFORMS  
PULSE DURATION**



**VOLTAGE WAVEFORMS  
ENABLE AND DISABLE TIMES**

- NOTES: A.  $C_L$  includes probe and jig capacitance.  
 B. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.  
 C. All input pulses are supplied by generators having the following characteristics: PRR  $\leq 10\text{ MHz}$ ,  $Z_O = 50\ \Omega$ ,  $t_r \leq 2\text{ ns}$ ,  $t_f \leq 2\text{ ns}$ .  
 D. The outputs are measured one at a time with one transition per measurement.

**Figure 1. Load Circuit and Voltage Waveforms**

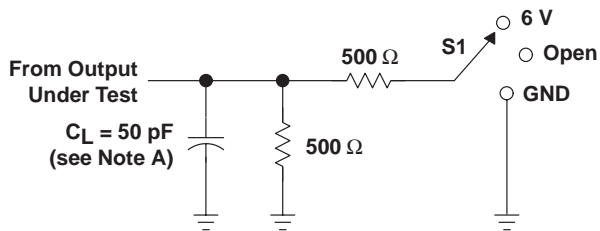


# SN54ALVTH16373, SN74ALVTH16373 2.5-V/3.3-V 16-BIT TRANSPARENT D-TYPE LATCHES WITH 3-STATE OUTPUTS

SCES067F – JUNE 1996 – REVISED JANUARY 1999

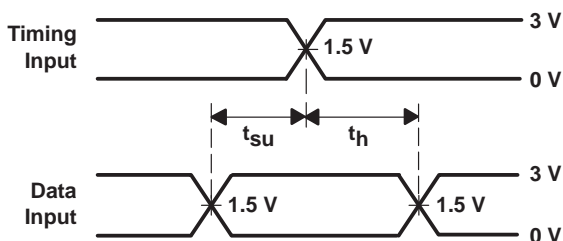
## PARAMETER MEASUREMENT INFORMATION

$V_{CC} = 3.3\text{ V} \pm 0.3\text{ V}$

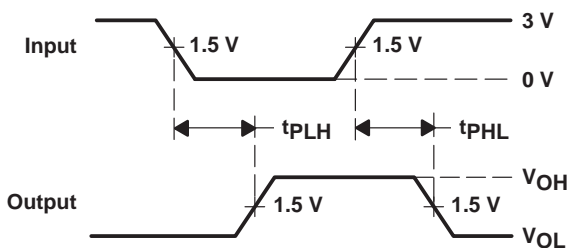


LOAD CIRCUIT

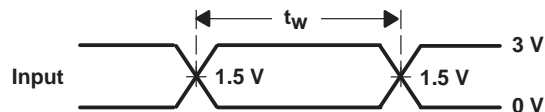
TEST	S1
$t_{PLH}/t_{PHL}$	Open
$t_{PLZ}/t_{PZL}$	6 V
$t_{PHZ}/t_{PZH}$	GND



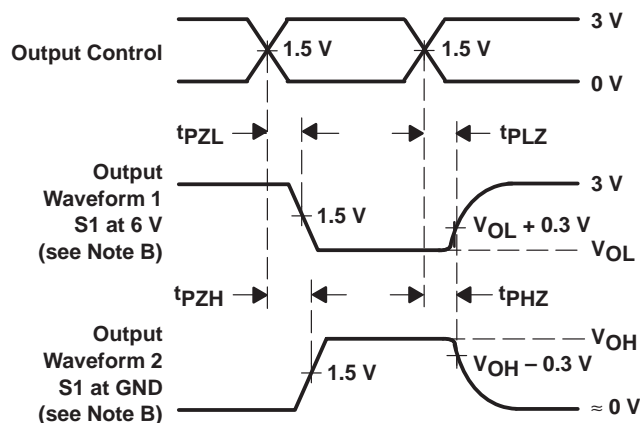
VOLTAGE WAVEFORMS  
SETUP AND HOLD TIMES



VOLTAGE WAVEFORMS  
PROPAGATION DELAY TIMES  
INVERTING AND NONINVERTING OUTPUTS



VOLTAGE WAVEFORMS  
PULSE DURATION



VOLTAGE WAVEFORMS  
ENABLE AND DISABLE TIMES  
LOW- AND HIGH-LEVEL ENABLING

- NOTES:
- $C_L$  includes probe and jig capacitance.
  - Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.
  - All input pulses are supplied by generators having the following characteristics:  $PRR \leq 10\text{ MHz}$ ,  $Z_O = 50\ \Omega$ ,  $t_r \leq 2.5\text{ ns}$ ,  $t_f \leq 2.5\text{ ns}$ .
  - The outputs are measured one at a time with one transition per measurement.

Figure 2. Load Circuit and Voltage Waveforms

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