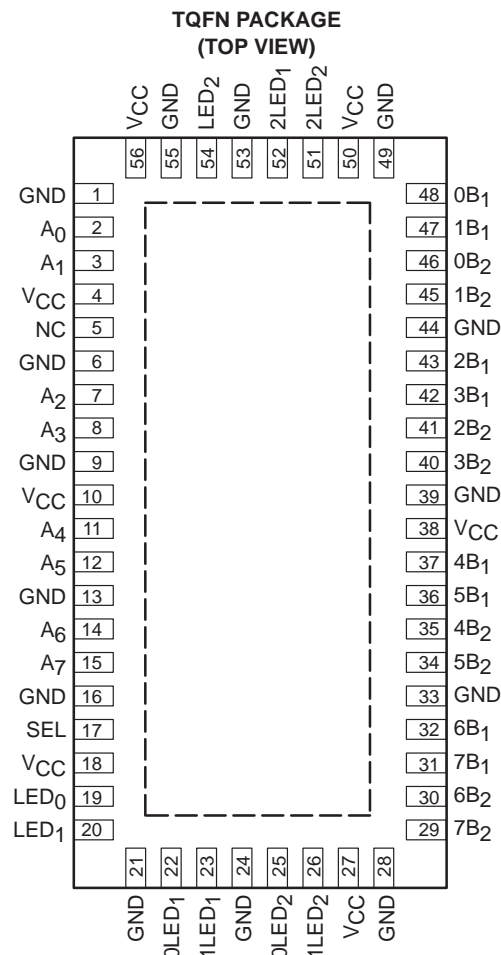


# TS3L500

## 16-BIT TO 8-BIT SPDT GIGABIT LAN SWITCH WITH LED SWITCH

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- **Wide Bandwidth (BW > 1100 MHz Typ)**
- **Low Crosstalk ( $X_{TALK} = -37$  dB Typ)**
- **Low Bit-to-Bit Skew ( $t_{sk(o)} = 100$  ps Max)**
- **Low and Flat ON-State Resistance ( $r_{on} = 4 \Omega$  Typ,  $r_{on(Flat)} = 0.5 \Omega$  Typ)**
- **Low Input/Output Capacitance ( $C_{ON} = 8$  pF Typ)**
- **Rail-to-Rail Switching on Data I/O Ports (0 to 5 V)**
- **V<sub>CC</sub> Operating Range From 3 V to 3.6 V**
- **Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II**
- **ESD Performance Tested Per JESD 22**
  - 2000-V Human-Body Model (A114-B, Class II)
  - 1000-V Charged-Device Model (C101)
- **Applications**
  - 10/100/1000 Base-T Signal Switching
  - Differential (LVDS, LVPECL) Signal Switching
  - Audio/Video Switching
  - Hub and Router Signal Switching



### description/ordering information

The TS3L500 is a 16-bit to 8-bit multiplexer/demultiplexer LAN switch with a single select (SEL) input. SEL controls the data path of the multiplexer/demultiplexer. The device provides additional I/Os for switching status indicating LED signals.

The device provides a low and flat ON-state resistance ( $r_{on}$ ) and an excellent ON-state resistance match. Low input/output capacitance, high bandwidth, low skew, and low crosstalk among channels make this device suitable for various LAN applications, such as 10/100/1000 Base-T.

This device can be used to replace mechanical relays in LAN applications. It also can be used to route signals from a 10/100 Base-T ethernet transceiver to the RJ-45 LAN connectors in laptops or in docking stations.

### ORDERING INFORMATION

T <sub>A</sub>	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	TQFN	Tape and reel	TS3L500RHUR	TK500

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/sc/package](http://www.ti.com/sc/package).



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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# TS3L500

## 16-BIT TO 8-BIT SPDT GIGABIT LAN SWITCH WITH LED SWITCH

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FUNCTION TABLE

INPUT SEL	INPUT/OUTPUT $A_n$	FUNCTION
L	$nB_1$	$A_n = nB_1, LED_x = XLED_1$
H	$nB_2$	$A_n = nB_2, LED_x = XLED_2$

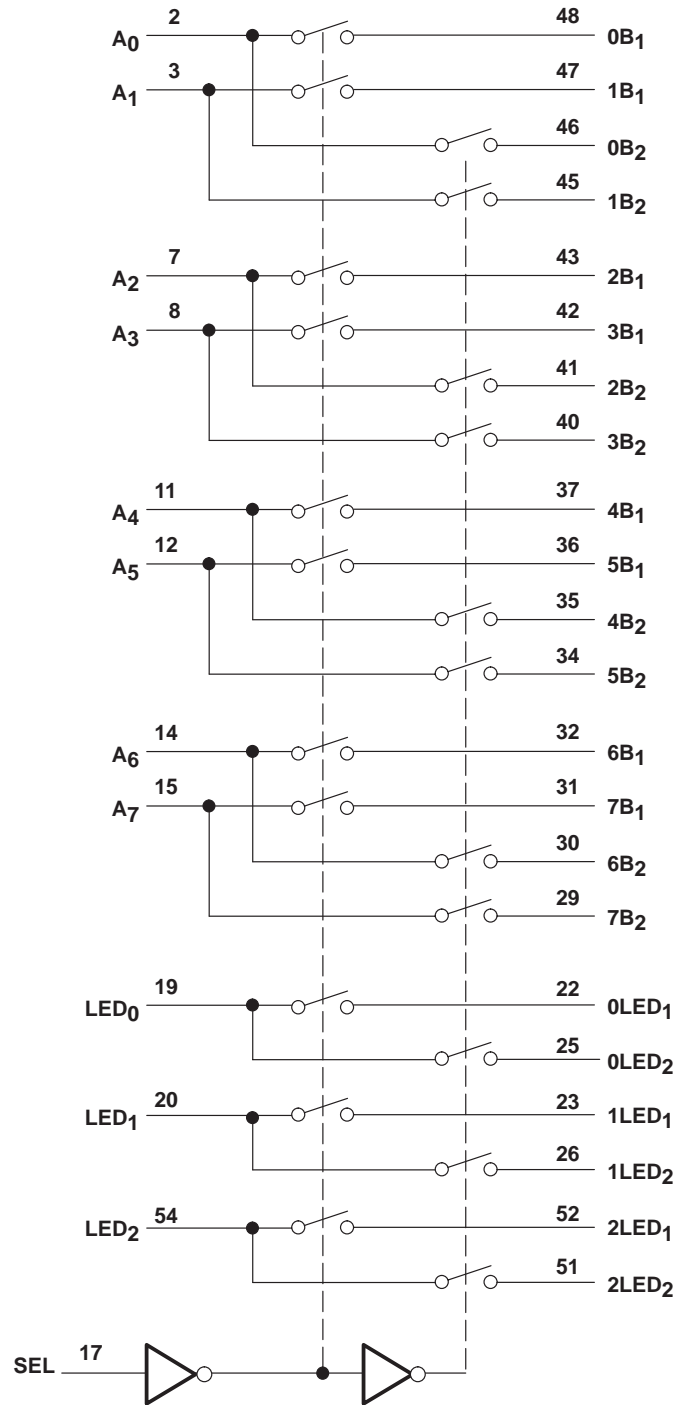
PIN DESCRIPTION

NAME	DESCRIPTION
$A_n$	Data I/O
$nB_m$	Data I/O
SEL	Select input
$LED_x$	LED I/O port
$XLED_m$	LED I/O port

# TS3L500 16-BIT TO 8-BIT SPDT GIGABIT LAN SWITCH WITH LED SWITCH

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logic diagram (positive logic)



# TS3L500

## 16-BIT TO 8-BIT SPDT GIGABIT LAN SWITCH WITH LED SWITCH

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

Supply voltage range, $V_{CC}$	-0.5 V to 4.6 V
Control input voltage range, $V_{IN}$ (see Notes 1 and 2)	-0.5 V to 7 V
Switch I/O voltage range, $V_{I/O}$ (see Notes 1, 2, and 3)	-0.5 V to 7 V
Control input clamp current, $I_{IK}$ ( $V_{IN} < 0$ )	-50 mA
I/O port clamp current, $I_{I/OK}$ ( $V_{I/O} < 0$ )	-50 mA
ON-state switch current, $I_{I/O}$ (see Note 4)	$\pm 128$ mA
Continuous current through $V_{CC}$ or GND terminals	$\pm 100$ mA
Package thermal impedance, $\theta_{JA}$ (see Note 5)	31.8°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. All voltages are with respect to ground, unless otherwise specified.
  2. The input and output voltage ratings may be exceeded if the input and output clamp-current ratings are observed.
  3.  $V_I$  and  $V_O$  are used to denote specific conditions for  $V_{I/O}$ .
  4.  $I_I$  and  $I_O$  are used to denote specific conditions for  $I_{I/O}$ .
  5. The package thermal impedance is calculated in accordance with JESD 51-7.

### recommended operating conditions (see Note 6)

		MIN	MAX	UNIT
$V_{CC}$	Supply voltage	3	3.6	V
$V_{IH}$	High-level control input voltage (SEL)	2	5.5	V
$V_{IL}$	Low-level control input voltage (SEL)	0	0.8	V
$V_{I/O}$	Input/output voltage	0	5.5	V
$T_A$	Operating free-air temperature	-40	85	°C

NOTE 6: 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.



# TS3L500

## 16-BIT TO 8-BIT SPDT GIGABIT LAN SWITCH WITH LED SWITCH

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**electrical characteristics for 1000 Base-T ethernet switching over recommended operating free-air temperature range,  $V_{CC} = 3.3\text{ V} \pm 0.3\text{ V}$  (unless otherwise noted)<sup>†</sup>**

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
$V_{IK}$	SEL	$V_{CC} = 3.6\text{ V}$ , $I_{IN} = -18\text{ mA}$	-0.7	-1.2		V
$I_{IH}$	SEL	$V_{CC} = 3.6\text{ V}$ , $V_{IN} = V_{CC}$			$\pm 1$	$\mu\text{A}$
$I_{IL}$	SEL	$V_{CC} = 3.6\text{ V}$ , $V_{IN} = \text{GND}$			$\pm 1$	$\mu\text{A}$
$I_{CC}$		$V_{CC} = 3.6\text{ V}$ , $I_{I/O} = 0$ , Switch ON or OFF		250	500	$\mu\text{A}$
$C_{IN}$	SEL	$f = 1\text{ MHz}$ , $V_{IN} = 0$		2	2.5	pF
$C_{OFF}$	B port	$V_I = 0$ , $f = 1\text{ MHz}$ , Outputs open, Switch OFF		2.5	4	pF
$C_{ON}$		$V_I = 0$ , $f = 1\text{ MHz}$ , Outputs open, Switch ON		8	9	pF
$r_{on}$		$V_{CC} = 3\text{ V}$ , $1.5\text{ V} \leq V_I \leq V_{CC}$ , $I_O = -40\text{ mA}$		4	6	$\Omega$
$r_{on(\text{flat})}$ <sup>§</sup>		$V_{CC} = 3\text{ V}$ , $V_I = 1.5\text{ V}$ and $V_{CC}$ , $I_O = -40\text{ mA}$		0.5		$\Omega$
$\Delta r_{on}$ <sup>¶</sup>		$V_{CC} = 3\text{ V}$ , $1.5\text{ V} \leq V_I \leq V_{CC}$ , $I_O = -40\text{ mA}$		0.4	1	$\Omega$

<sup>†</sup>  $V_I$ ,  $V_O$ ,  $I_I$ , and  $I_O$  refer to I/O pins.  $V_{IN}$  refers to the control inputs.

<sup>‡</sup> All typical values are at  $V_{CC} = 3.3\text{ V}$  (unless otherwise noted),  $T_A = 25^\circ\text{C}$ .

<sup>§</sup>  $r_{on(\text{flat})}$  is the difference of  $r_{on}$  in a given channel at specified voltages.

<sup>¶</sup>  $\Delta r_{on}$  is the difference of  $r_{on}$  from center (A4, A5) ports to any other port.

**electrical characteristics for 10/100 Base-T ethernet switching over recommended operating free-air temperature range,  $V_{CC} = 3.3\text{ V} \pm 0.3\text{ V}$  (unless otherwise noted)<sup>†</sup>**

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>‡</sup>	MAX	UNIT
$V_{IK}$	SEL	$V_{CC} = 3.6\text{ V}$ , $I_{IN} = -18\text{ mA}$	-0.7	-1.2		V
$I_{IH}$	SEL	$V_{CC} = 3.6\text{ V}$ , $V_{IN} = V_{CC}$			$\pm 1$	$\mu\text{A}$
$I_{IL}$	SEL	$V_{CC} = 3.6\text{ V}$ , $V_{IN} = \text{GND}$			$\pm 1$	$\mu\text{A}$
$I_{CC}$		$V_{CC} = 3.6\text{ V}$ , $I_{I/O} = 0$ , Switch ON or OFF		250	500	$\mu\text{A}$
$C_{IN}$	SEL	$f = 1\text{ MHz}$ , $V_{IN} = 0$		2	2.5	pF
$C_{OFF}$	B port	$V_I = 0$ , $f = 1\text{ MHz}$ , Outputs open, Switch OFF		2.5	4	pF
$C_{ON}$		$V_I = 0$ , $f = 1\text{ MHz}$ , Outputs open, Switch ON		8		pF
$r_{on}$		$V_{CC} = 3\text{ V}$ , $1.25\text{ V} \leq V_I \leq V_{CC}$ , $I_O = -10\text{ mA}$ to $-30\text{ mA}$		4	6	$\Omega$
$r_{on(\text{flat})}$ <sup>§</sup>		$V_{CC} = 3\text{ V}$ , $V_I = 1.25\text{ V}$ and $V_{CC}$ , $I_O = -10\text{ mA}$ to $-30\text{ mA}$		0.5		$\Omega$
$\Delta r_{on}$ <sup>¶</sup>		$V_{CC} = 3\text{ V}$ , $1.25\text{ V} \leq V_I \leq V_{CC}$ , $I_O = -10\text{ mA}$ to $-30\text{ mA}$		0.4	1	$\Omega$

<sup>†</sup>  $V_I$ ,  $V_O$ ,  $I_I$ , and  $I_O$  refer to I/O pins.  $V_{IN}$  refers to the control inputs.

<sup>‡</sup> All typical values are at  $V_{CC} = 3.3\text{ V}$  (unless otherwise noted),  $T_A = 25^\circ\text{C}$ .

<sup>§</sup>  $r_{on(\text{flat})}$  is the difference of  $r_{on}$  in a given channel at specified voltages.

<sup>¶</sup>  $\Delta r_{on}$  is the difference of  $r_{on}$  from center (A4, A5) ports to any other port.



# TS3L500

## 16-BIT TO 8-BIT SPDT GIGABIT LAN SWITCH WITH LED SWITCH

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switching characteristics over recommended operating free-air temperature range,  
 $V_{CC} = 3.3\text{ V} \pm 0.3\text{ V}$ ,  $R_L = 200\ \Omega$ ,  $C_L = 10\text{ pF}$  (unless otherwise noted) (see Figures 4 and 5)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	MIN	TYP†	MAX	UNIT
$t_{pd}‡$	A or B	B or A		0.25		ns
$t_{PZH}$ , $t_{PZL}$	SEL	A or B	0.5		15	ns
$t_{PHZ}$ , $t_{PLZ}$	SEL	A or B	0.9		9	ns
$t_{sk(o)}§$	A or B	B or A		50	100	ps
$t_{sk(p)}¶$				50	150	ps

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

‡ The propagation delay is the calculated RC time constant of the typical ON-state resistance of the switch and the specified load capacitance when driven by an ideal voltage source (zero output impedance).

§ Output skew between center port (A<sub>4</sub> to A<sub>5</sub>) to any other port

¶ Skew between opposite transitions of the same output in a given device  $|t_{PHL} - t_{PLH}|$

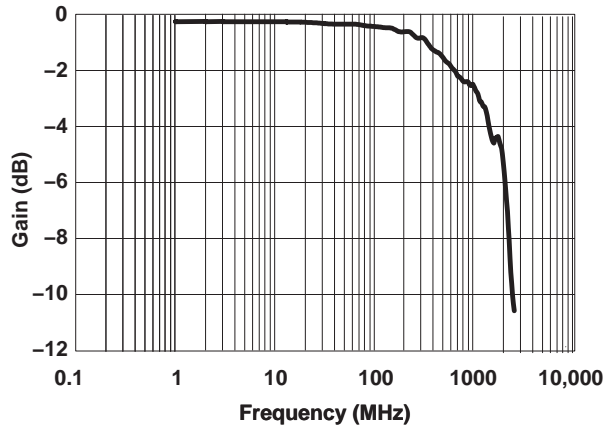
dynamic characteristics over recommended operating free-air temperature range,  
 $V_{CC} = 3.3\text{ V} \pm 0.3\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	TYP†	UNIT
X <sub>TALK</sub>	$R_L = 100\ \Omega$ , $f = 250\text{ MHz}$ , See Figure 8	-37	dB
O <sub>IRR</sub>	$R_L = 100\ \Omega$ , $f = 250\text{ MHz}$ , See Figure 9	-37	dB
BW	$R_L = 100\ \Omega$ , See Figure 7	1100	MHz

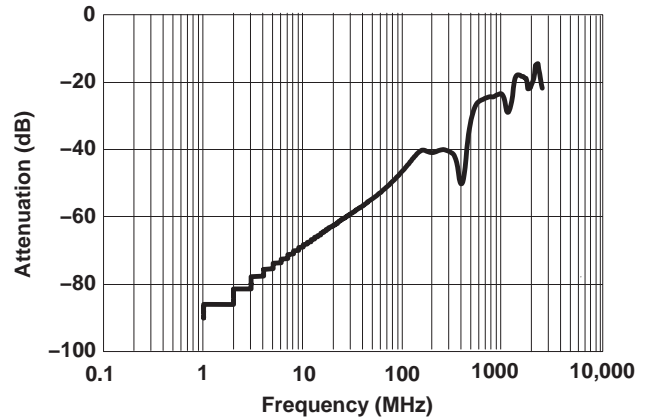
† All typical values are at  $V_{CC} = 3.3\text{ V}$  (unless otherwise noted),  $T_A = 25^\circ\text{C}$ .



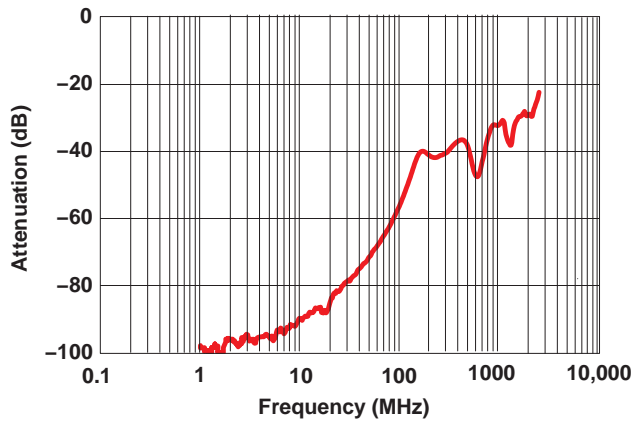
**OPERATING CHARACTERISTICS**



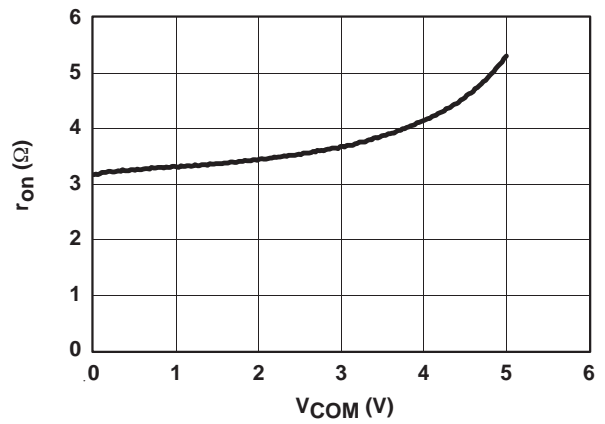
**Figure 1. Gain vs Frequency**



**Figure 2. OFF Isolation vs Frequency**



**Figure 3. Crosstalk vs Frequency**

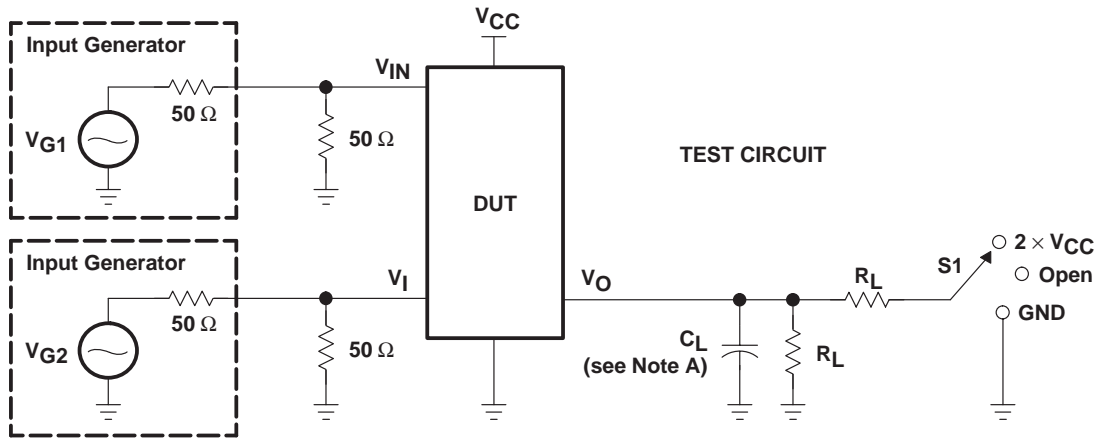


**Figure 4. r<sub>on</sub> (Ω) vs V<sub>com</sub> (V)**

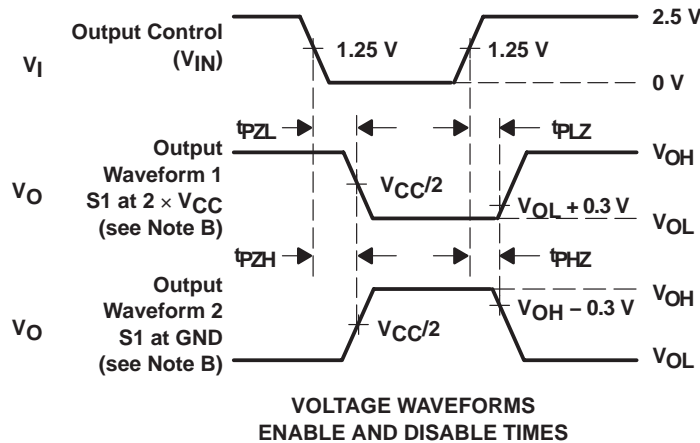
**TS3L500**  
**16-BIT TO 8-BIT SPDT GIGABIT LAN SWITCH**  
**WITH LED SWITCH**

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**PARAMETER MEASUREMENT INFORMATION**  
**Enable and Disable Times**



TEST	V <sub>CC</sub>	S1	R <sub>L</sub>	V <sub>in</sub>	C <sub>L</sub>	V <sub>Δ</sub>
t <sub>PLZ</sub> /t <sub>PZL</sub>	3.3 V ± 0.3 V	2 × V <sub>CC</sub>	200 Ω	GND	10 pF	0.3 V
t <sub>PHZ</sub> /t <sub>PZH</sub>	3.3 V ± 0.3 V	GND	200 Ω	V <sub>CC</sub>	10 pF	0.3 V

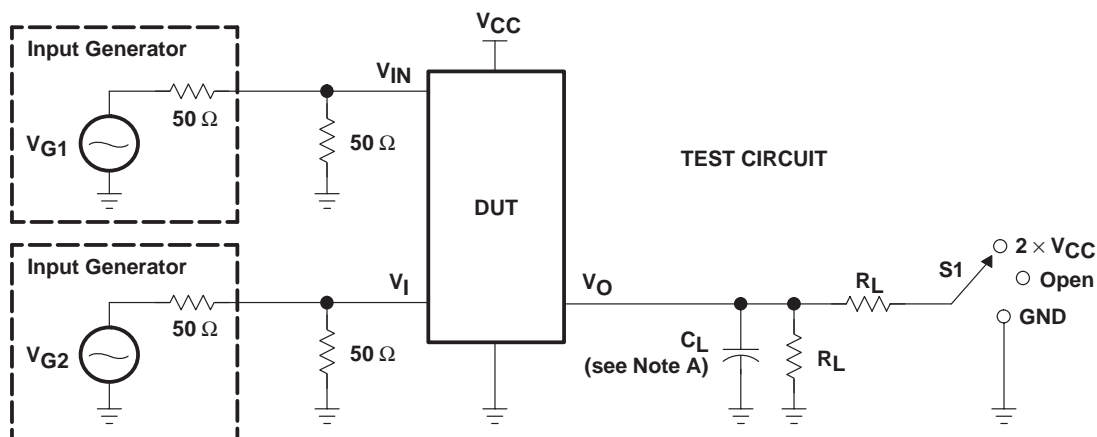


- NOTES: A. C<sub>L</sub> includes probe and jig capacitance.  
 B. Waveform 1 is for an output with internal conditions such that the output is low, except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high, except when disabled by the output control.  
 C. All input pulses are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z<sub>O</sub> = 50 Ω, t<sub>r</sub> ≤ 2.5 ns, t<sub>f</sub> ≤ 2.5 ns.  
 D. The outputs are measured one at a time, with one transition per measurement.  
 E. t<sub>PLZ</sub> and t<sub>PHZ</sub> are the same as t<sub>dis</sub>.  
 F. t<sub>PZL</sub> and t<sub>PZH</sub> are the same as t<sub>en</sub>.

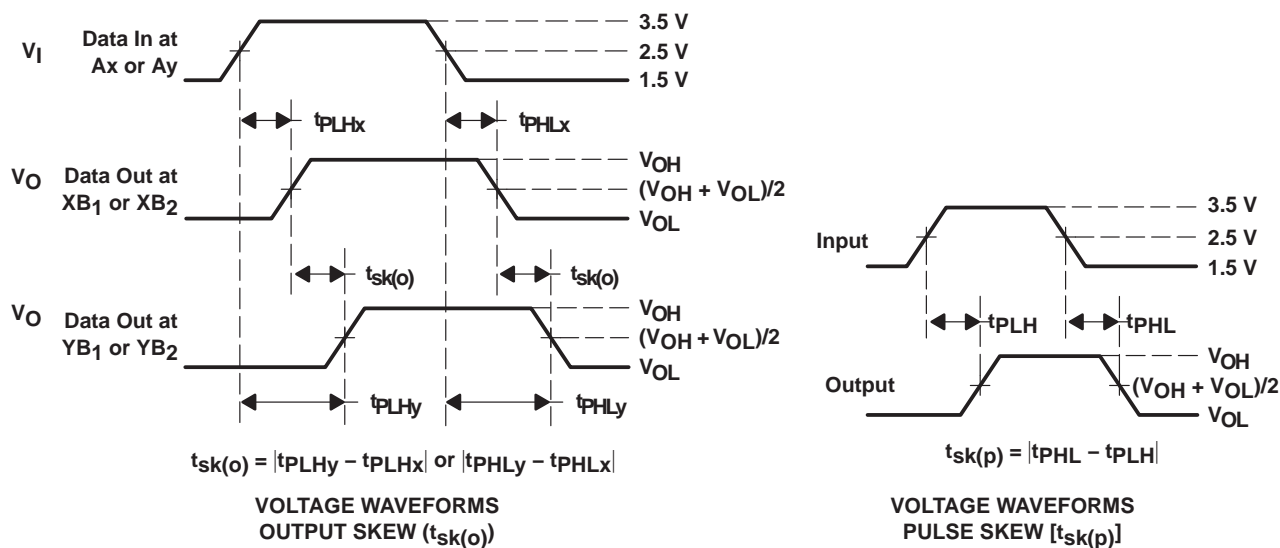
**Figure 5. Test Circuit and Voltage Waveforms**



**PARAMETER MEASUREMENT INFORMATION**  
**Skew**



TEST	V <sub>CC</sub>	S1	R <sub>L</sub>	V <sub>in</sub>	C <sub>L</sub>
t <sub>sk(o)</sub>	3.3 V ± 0.3 V	Open	200 Ω	V <sub>CC</sub> or GND	10 pF
t <sub>sk(p)</sub>	3.3 V ± 0.3 V	Open	200 Ω	V <sub>CC</sub> or GND	10 pF



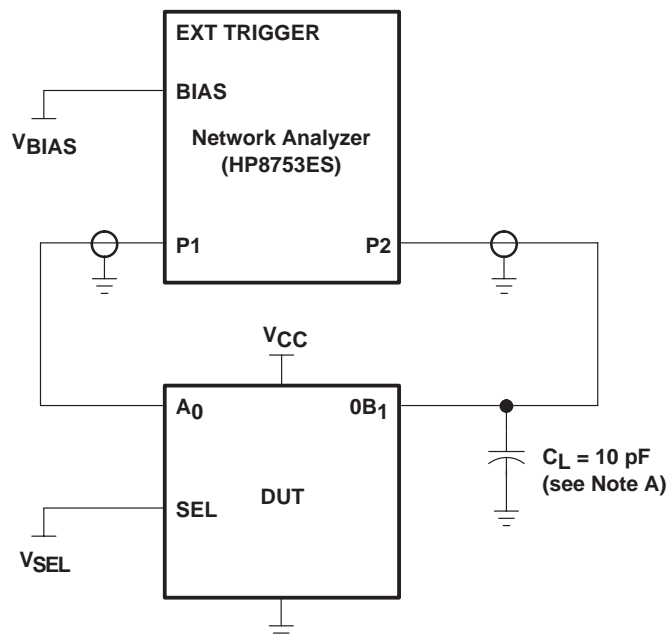
- NOTES: A. C<sub>L</sub> includes probe and jig capacitance.  
 B. Waveform 1 is for an output with internal conditions such that the output is low, except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high, except when disabled by the output control.  
 C. All input pulses are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z<sub>O</sub> = 50 Ω, t<sub>r</sub> ≤ 2.5 ns, t<sub>f</sub> ≤ 2.5 ns.  
 D. The outputs are measured one at a time, with one transition per measurement.

**Figure 6. Test Circuit and Voltage Waveforms**

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## PARAMETER MEASUREMENT INFORMATION



NOTE A:  $C_L$  includes probe and jig capacitance.

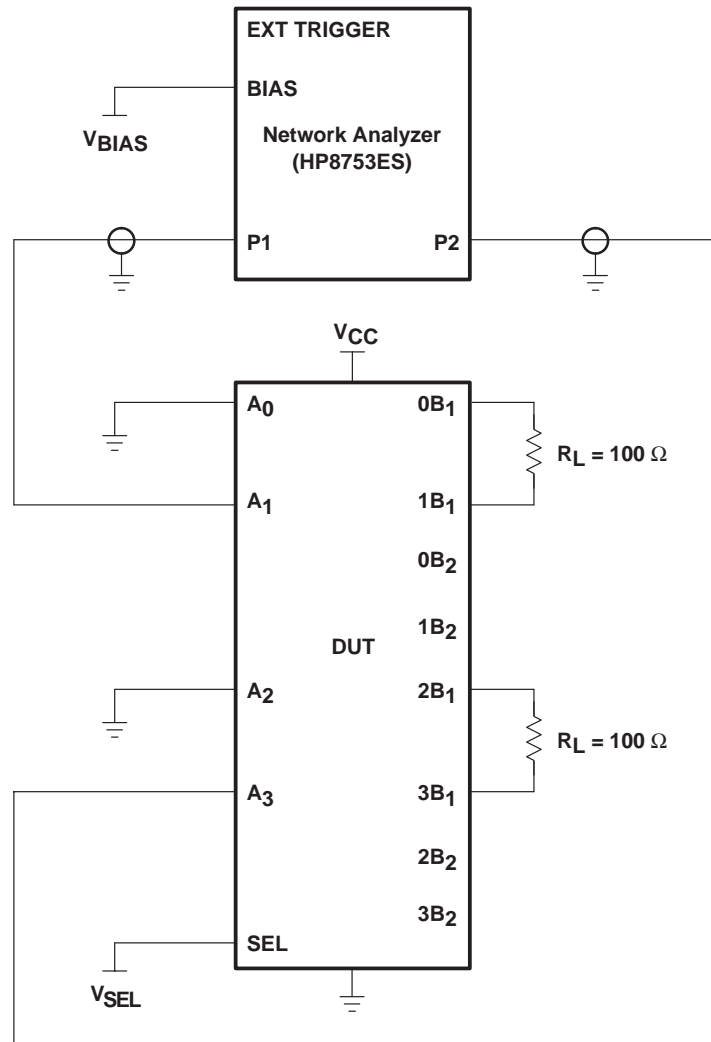
**Figure 7. Test Circuit for Frequency Response (BW)**

Frequency response is measured at the output of the ON channel. For example, when  $V_{SEL} = 0$  and  $A_0$  is the input, the output is measured at  $OB_1$ . All unused analog I/O ports are left open.

### HP8753ES setup

Average = 4  
RBW = 3 kHz  
 $V_{BIAS} = 0.35$  V  
ST = 2 s  
P1 = 0 dBm

**PARAMETER MEASUREMENT INFORMATION**



- NOTES: A.  $C_L$  includes probe and jig capacitance.  
 B. A 50- $\Omega$  termination resistor is needed to match the loading of the network analyzer.

**Figure 8. Test Circuit for Crosstalk ( $X_{TALK}$ )**

Crosstalk is measured at the output of the nonadjacent ON channel. For example, when  $V_{SEL} = 0$  and  $A_0$  is the input, the output is measured at  $1B_1$ . All unused analog input (A) ports are connected to GND, and output (B) ports are connected to GND through 50- $\Omega$  pulldown resistors.

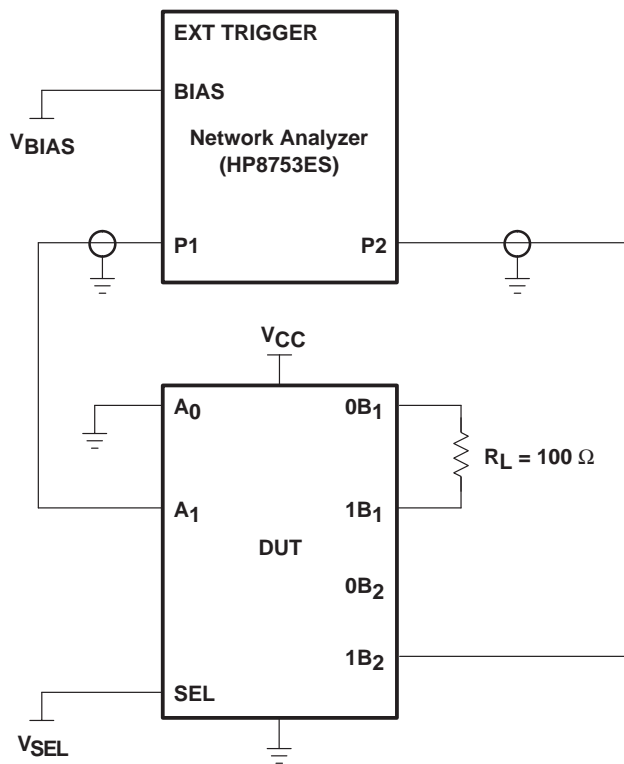
**HP8753ES setup**

- Average = 4
- RBW = 3 kHz
- $V_{BIAS} = 0.35$  V
- ST = 2 s
- P1 = 0 dBm

# TS3L500 16-BIT TO 8-BIT SPDT GIGABIT LAN SWITCH WITH LED SWITCH

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## PARAMETER MEASUREMENT INFORMATION



- NOTES: A.  $C_L$  includes probe and jig capacitance.  
B. A 50- $\Omega$  termination resistor is needed to match the loading of the network analyzer.

**Figure 9. Test Circuit for OFF Isolation ( $O_{IRR}$ )**

OFF isolation is measured at the output of the OFF channel. For example, when  $V_{SEL} = V_{CC}$  and  $A_0$  is the input, the output is measured at  $0B_2$ . All unused analog input (A) ports are left open, and output (B) ports are connected to GND through 50- $\Omega$  pull-down resistors.

### HP8753ES setup

Average = 4  
RBW = 3 kHz  
 $V_{BIAS} = 0.35$  V  
ST = 2 s  
P1 = 0 dBm

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TS3L500RHUR	ACTIVE	QFN	RHU	56	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TS3L500RHURG4	ACTIVE	QFN	RHU	56	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

<sup>(1)</sup> 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.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

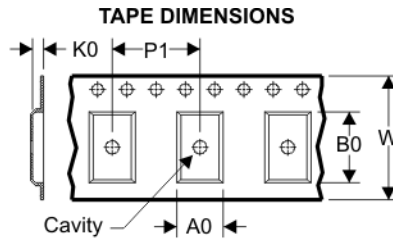
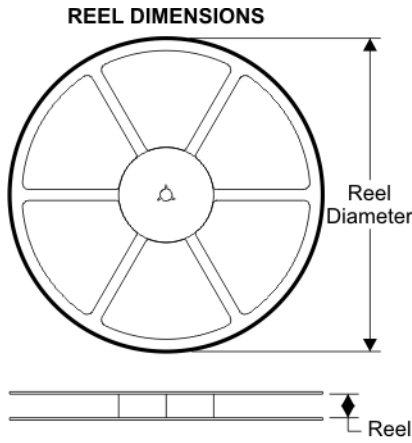
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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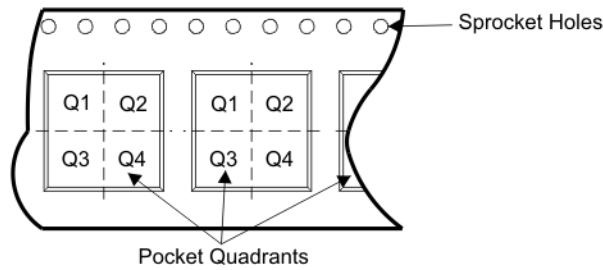
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**TAPE AND REEL BOX INFORMATION**



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**



Device	Package	Pins	Site	Reel Diameter (mm)	Reel Width (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TS3L500RHUR	RHU	56	SITE 48	329	24	5.3	11.3	1.3	12	24	Q1

**TAPE AND REEL BOX DIMENSIONS**

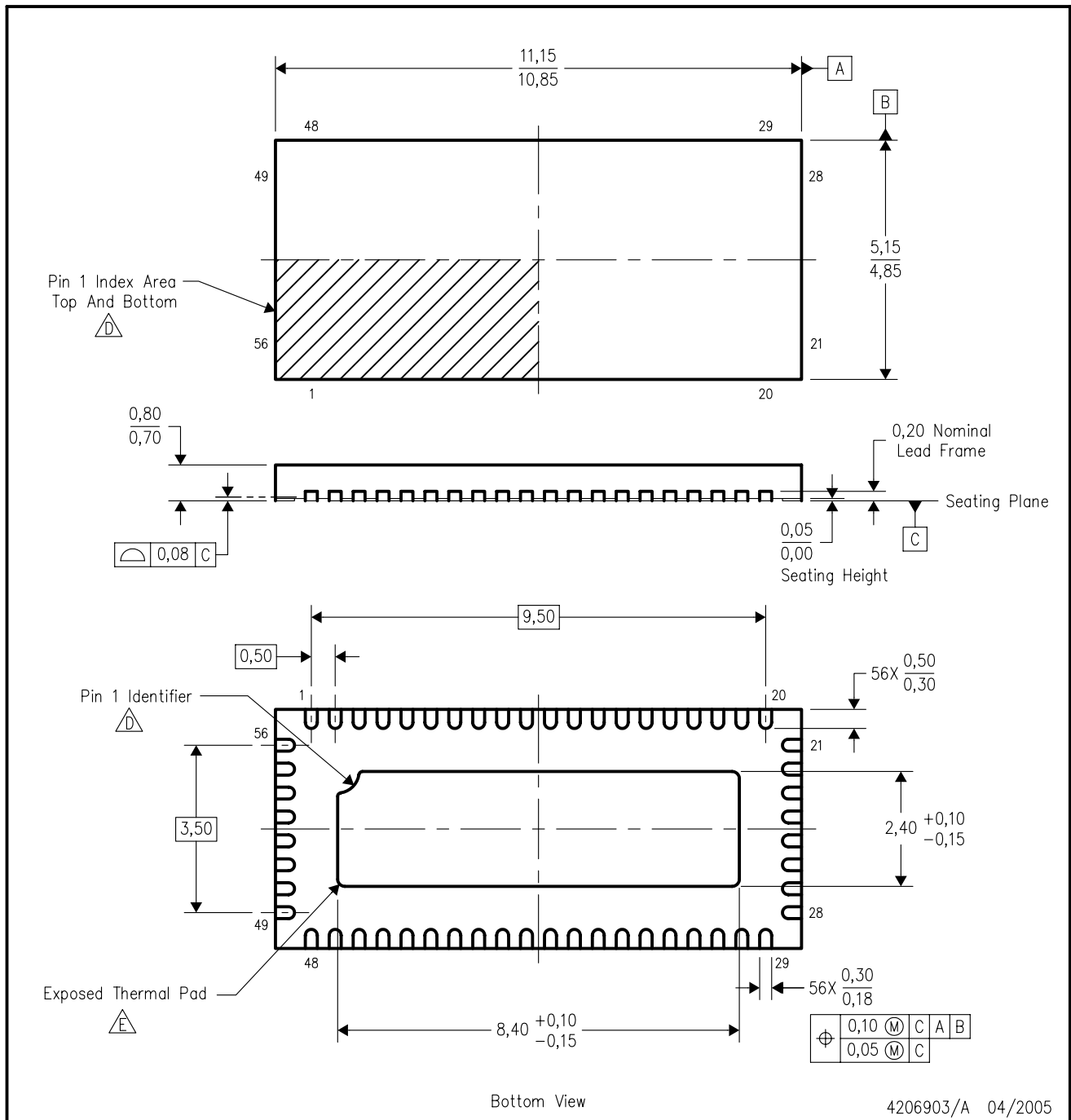


Device	Package	Pins	Site	Length (mm)	Width (mm)	Height (mm)
TS3L500RHUR	RHU	56	SITE 48	190.5	212.7	31.75

# MECHANICAL DATA

RHU (R-PQFP-N56)

PLASTIC QUAD FLATPACK



4206903/A 04/2005

- Notes:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. QFN (Quad Flatpack No-Lead) package configuration.
  - D. Pin 1 identifiers are located on both top and bottom of the package and within the zone indicated. The Pin 1 identifiers are either a molded, marked, or metal feature.
  - E. The package thermal pad must be soldered to the board for thermal and mechanical performance.
  - F. JEDEC MO-220 package registration is pending.

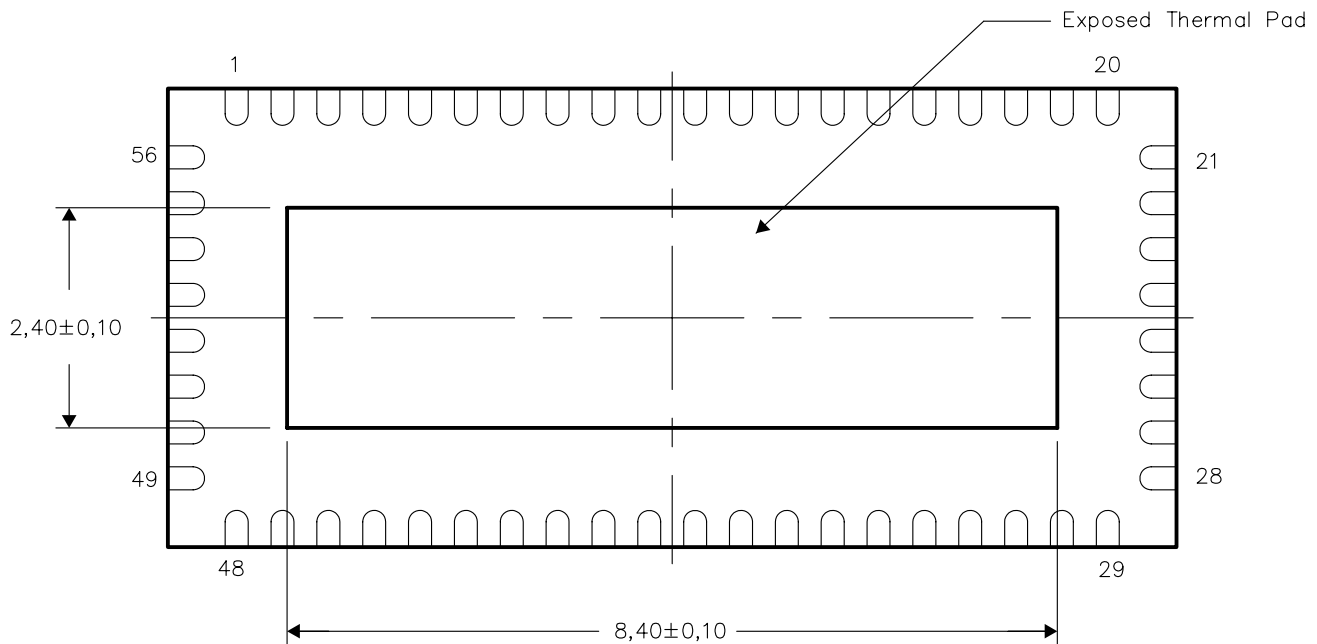


**THERMAL INFORMATION**

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, Quad Flatpack No-Lead Logic Packages, Texas Instruments Literature No. SCBA017. This document is available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.

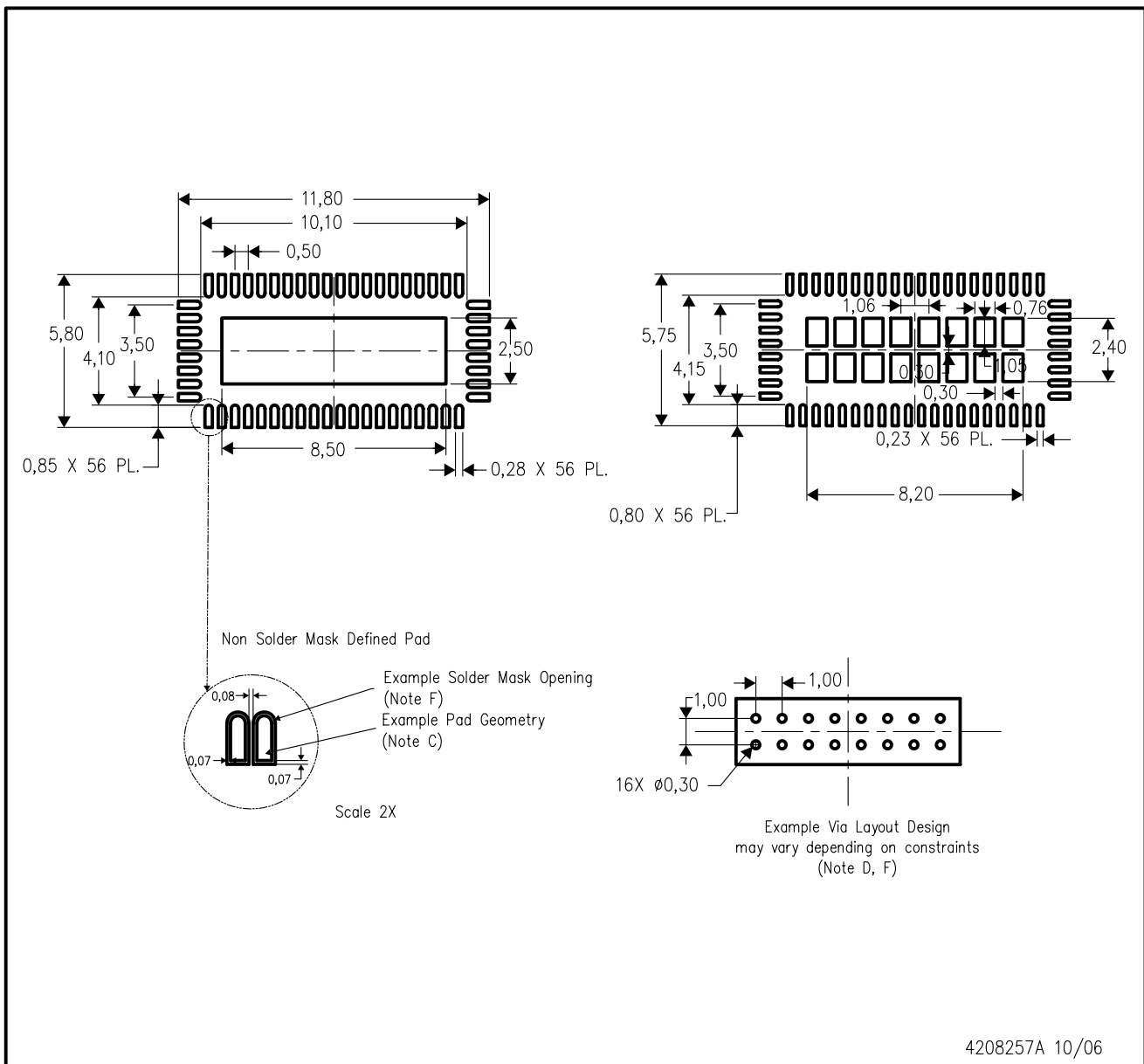


Bottom View

NOTE: All linear dimensions are in millimeters

Exposed Thermal Pad Dimensions

RHU (R-PQFP-N56)



4208257A 10/06

- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SCBA017, SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.

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