

# DATA SHEET

## **GTL2002**

2-bit bi-directional low voltage translator

Product data sheet  
Supersedes data of 2003 Apr 01

2004 Sep 29

## 2-bit bi-directional low voltage translator

## GTL2002

### FEATURES

- 2-bit bi-directional low voltage translator
- Allows voltage level translation between 1.0 V, 1.2 V, 1.5 V, 1.8 V, 2.5 V, 3.3 V, and 5 V buses which allows direct interface with GTL, GTL+, LVTTTL/TTL and 5 V CMOS levels
- Provides bi-directional voltage translation with no direction pin
- Low 6.5  $\Omega$  RDS<sub>ON</sub> resistance between input and output pins (Sn/Dn)
- Supports hot insertion
- No power supply required - Will not latch up
- 5 V tolerant inputs
- Low stand-by current
- Flow-through pinout for ease of printed circuit board trace routing
- ESD protection exceeds 2000 V HBM per JESD22-A114, 200 V MM per JESD22-A115, and 1000 V per JESD22-C101
- Packages offered: SO8, TSSOP8 (MSOP8), VSSOP8

### APPLICATIONS

- Any application that requires bi-directional or unidirectional voltage level translation from any voltage between 1.0 V and 5.0 V to any voltage between 1.0 V and 5.0 V
- The open drain construction with no direction pin is ideal for bi-directional low voltage (e.g., 1.0 V, 1.2 V, 1.5 V, or 1.8 V) processor I<sup>2</sup>C port translation to the normal 3.3 V or 5.0 V I<sup>2</sup>C-bus signal levels or GTL/GTL+ translation to LVTTTL/TTL signal levels.

### DESCRIPTION

The Gunning Transceiver Logic — Transceiver Voltage Clamps (GTL–TVC) provide high-speed voltage translation with low ON-state resistance and minimal propagation delay. The GTL2002 provides 2 NMOS pass transistors (Sn and Dn) with a common gate (G<sub>REF</sub>) and a reference transistor (S<sub>REF</sub> and D<sub>REF</sub>). The device allows bi-directional voltage translations between 1.0 V and 5.0 V without use of a direction pin.

When the Sn or Dn port is LOW the clamp is in the ON-state and a low resistance connection exists between the Sn and Dn ports. Assuming the higher voltage is on the Dn port, when the Dn port is high, the voltage on the Sn port is limited to the voltage set by the reference transistor (S<sub>REF</sub>). When the Sn port is high, the Dn port is pulled to V<sub>CC</sub> by the pull up resistors. This functionality allows a seamless translation between higher and lower voltages selected by the user, without the need for directional control.

All transistors have the same electrical characteristics and there is minimal deviation from one output to another in voltage or propagation delay. This is a benefit over discrete transistor voltage translation solutions, since the fabrication of the transistors is symmetrical. Because all transistors in the device are identical, S<sub>REF</sub> and D<sub>REF</sub> can be located on any of the other two matched Sn/Dn transistors, allowing for easier board layout. The translator's transistors provides excellent ESD protection to lower voltage devices and at the same time protect less ESD resistant devices.

### ORDERING INFORMATION

PACKAGES	TEMPERATURE RANGE	ORDER CODE	TOPSIDE MARK	DWG NUMBER
8-Pin Plastic SO	–40 °C to +85 °C	GTL2002D	GTL2002	SOT96–1
8-Pin Plastic TSSOP (MSOP)	–40 °C to +85 °C	GTL2002DP	2002	SOT505–1
8-Pin Plastic VSSOP	–40 °C to +85 °C	GTL2002DC	2002	SOT765–1

Standard packing quantities and other packaging data is available at [www.standardproducts.philips.com/packaging](http://www.standardproducts.philips.com/packaging).

# 2-bit bi-directional low voltage translator

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## PIN CONFIGURATION

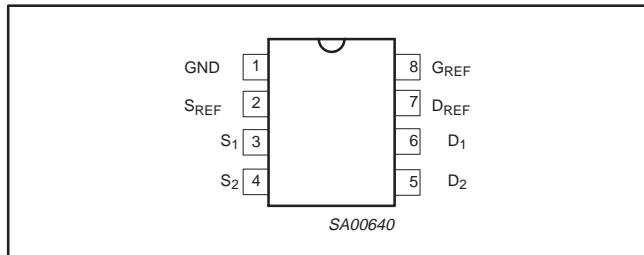


Figure 1. SO8 and TSSOP8 pinning

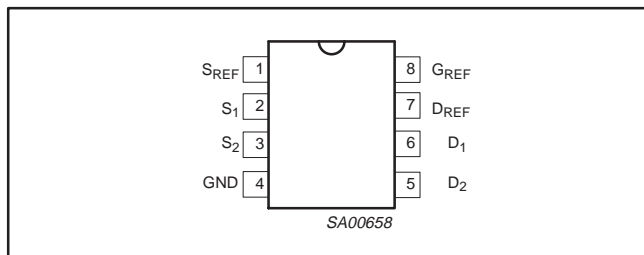


Figure 2. VSSOP8 pinning

## PIN DESCRIPTION

PIN NUMBER		SYMBOL	NAME AND FUNCTION
SO8 and TSSOP8	VSSOP8		
1	4	GND	Ground (0 V)
2	1	S <sub>REF</sub>	Source of reference transistor
3, 4	2, 3	S <sub>n</sub>	Port S <sub>1</sub> and Port S <sub>2</sub>
5, 6	5, 6	D <sub>n</sub>	Port D <sub>1</sub> and Port D <sub>2</sub>
7	7	D <sub>REF</sub>	Drain of reference transistor
8	8	G <sub>REF</sub>	Gate of reference transistor

## FUNCTION TABLE

HIGH-to-LOW translation assuming D<sub>n</sub> is at the higher voltage level

G <sub>REF</sub>	D <sub>REF</sub>	S <sub>REF</sub>	In-D <sub>n</sub>	Out-S <sub>n</sub>	Transistor
H	H	0 V	X	X	Off
H	H	V <sub>TT</sub>	H	V <sub>TT</sub> <sup>1</sup>	On
H	H	V <sub>TT</sub>	L	L <sup>2</sup>	On
L	L	0 - V <sub>TT</sub>	X	X	Off

H = HIGH voltage level  
 L = LOW voltage level  
 X = Don't Care

### NOTES:

1. S<sub>n</sub> is not pulled up or pulled down.
2. S<sub>n</sub> follows the D<sub>n</sub> input LOW.
3. G<sub>REF</sub> should be at least 1.5 V higher than S<sub>REF</sub> for best translator operation.
4. V<sub>TT</sub> is equal to the S<sub>REF</sub> voltage.

## FUNCTION TABLE

LOW-to-HIGH translation assuming D<sub>n</sub> is at the higher voltage level

G <sub>REF</sub>	D <sub>REF</sub>	S <sub>REF</sub>	In-S <sub>n</sub>	Out-D <sub>n</sub>	Transistor
H	H	0 V	X	X	Off
H	H	V <sub>TT</sub>	V <sub>TT</sub>	H <sup>1</sup>	nearly off
H	H	V <sub>TT</sub>	L	L <sup>2</sup>	On
L	L	0 - V <sub>TT</sub>	X	X	Off

H = HIGH voltage level  
 L = LOW voltage level  
 X = Don't Care

### NOTES:

1. D<sub>n</sub> is pulled up to V<sub>CC</sub> through an external resistor.
2. D<sub>n</sub> follows the S<sub>n</sub> input LOW.
3. G<sub>REF</sub> should be at least 1.5 V higher than S<sub>REF</sub> for best translator operation.
4. V<sub>TT</sub> is equal to the S<sub>REF</sub> voltage.

## CLAMP SCHEMATIC

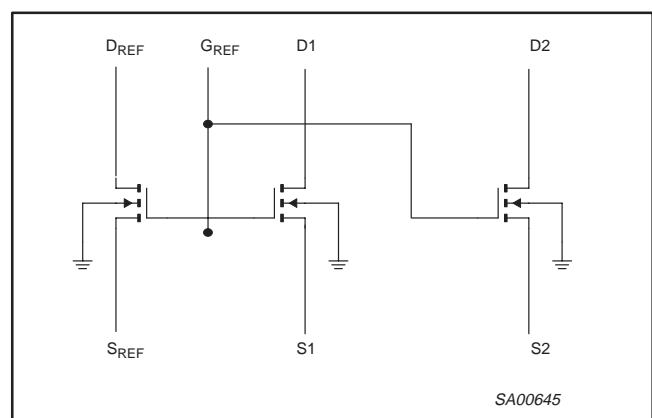


Figure 3. Clamp schematic

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## APPLICATIONS

### Bi-directional translation

For the bi-directional clamping configuration, higher voltage to lower voltage or lower voltage to higher voltage, the  $G_{REF}$  input must be connected to  $D_{REF}$  and both pins pulled to HIGH side  $V_{CC}$  through a pull-up resistor (typically 200 k $\Omega$ ). A filter capacitor on  $D_{REF}$  is recommended. The processor output can be totem pole or open drain (pull-up resistors may be required) and the chipset output can be totem pole or open drain (pull-up resistors are required to pull the  $D_n$  outputs to  $V_{CC}$ ). However, if either output is totem pole, data must be uni-directional or the outputs must be 3-statable and the outputs must be controlled by some direction control mechanism to prevent HIGH-to-LOW contentions in either direction. If both outputs are open drain, no direction control is needed. The opposite side of the reference transistor ( $S_{REF}$ ) is connected to the processor core power supply voltage. When  $D_{REF}$  is connected through a 200 k $\Omega$  resistor to a 3.3 V to 5.5 V  $V_{CC}$  supply and  $S_{REF}$  is set between 1.0 V to  $V_{CC} - 1.5$  V, the output of each  $S_n$  has a maximum output voltage equal to  $S_{REF}$  and the output of each  $D_n$  has a maximum output voltage equal to  $V_{CC}$ .

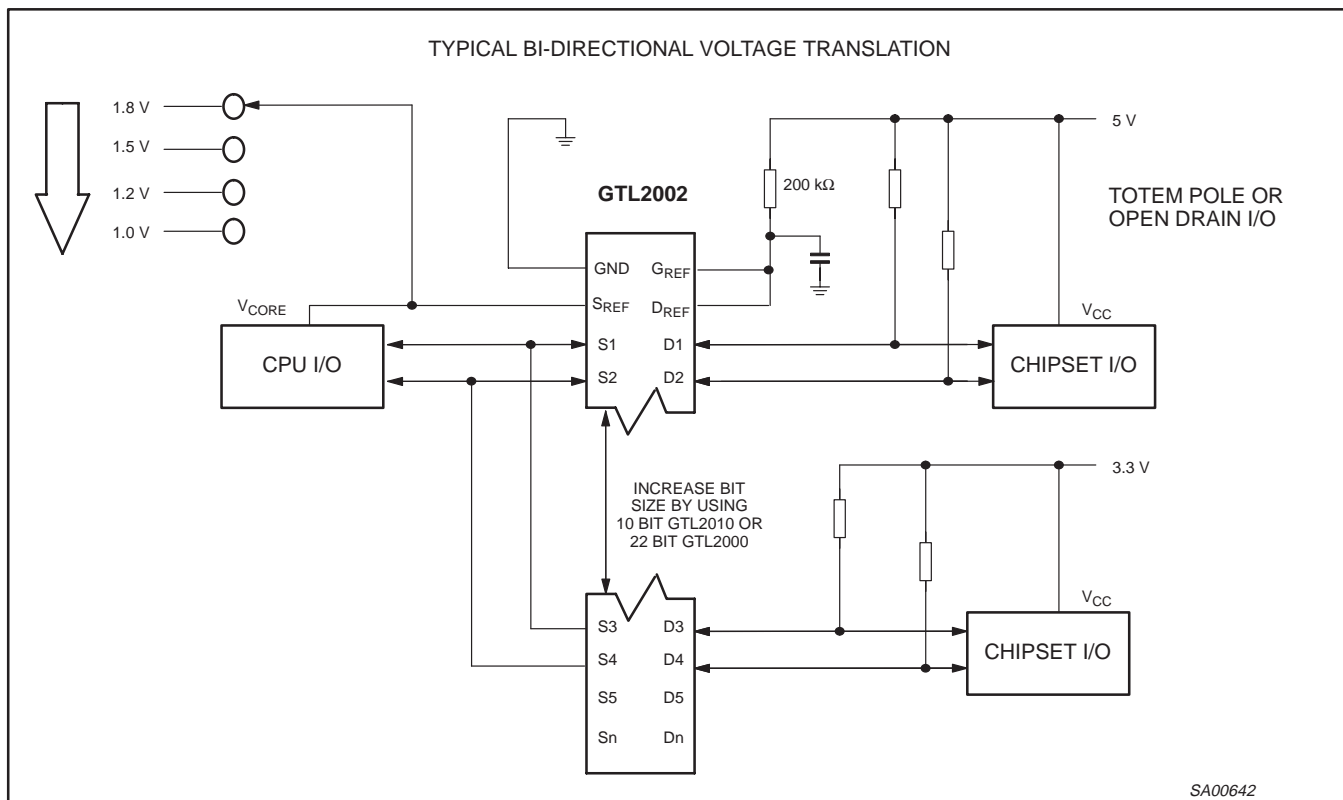


Figure 4. Bi-directional translation to multiple higher voltage levels such as an I<sup>2</sup>C-bus application

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## Uni-directional down translation

For uni-directional clamping, higher voltage to lower voltage, the  $G_{REF}$  input must be connected to  $D_{REF}$  and both pins pulled to the higher side  $V_{CC}$  through a pull-up resistor (typically 200 k $\Omega$ ). A filter capacitor on  $D_{REF}$  is recommended. Pull-up resistors are required if the chipset I/O are open drain. The opposite side of the reference transistor ( $S_{REF}$ ) is connected to the processor core supply voltage. When  $D_{REF}$  is connected through a 200 k $\Omega$  resistor to a 3.3 V to 5.5 V  $V_{CC}$  supply and  $S_{REF}$  is set between 1.0 V to  $V_{CC} - 1.5$  V, the output of each  $S_n$  has a maximum output voltage equal to  $S_{REF}$ .

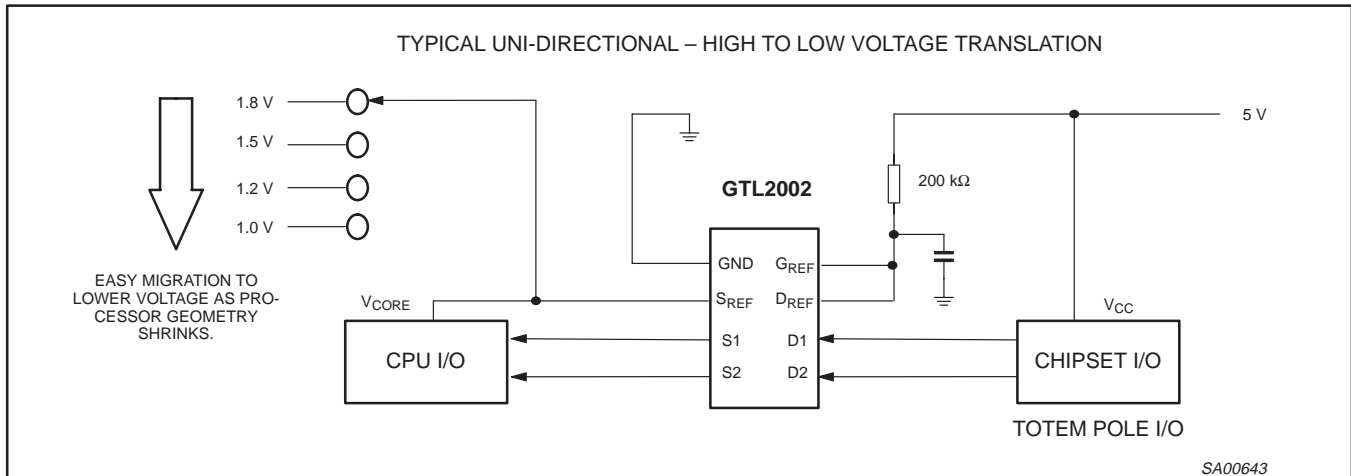


Figure 5. Uni-directional down translation, to protect low voltage processor pins

## Uni-directional up translation

For uni-directional up translation, lower voltage to higher voltage, the reference transistor is connected the same as for a down translation. A pull-up resistor is required on the higher voltage side ( $D_n$  or  $S_n$ ) to get the full HIGH level, since the GTL–TVC device will only pass the reference source ( $S_{REF}$ ) voltage as a HIGH when doing an up translation. The driver on the lower voltage side only needs pull-up resistors if it is open drain.

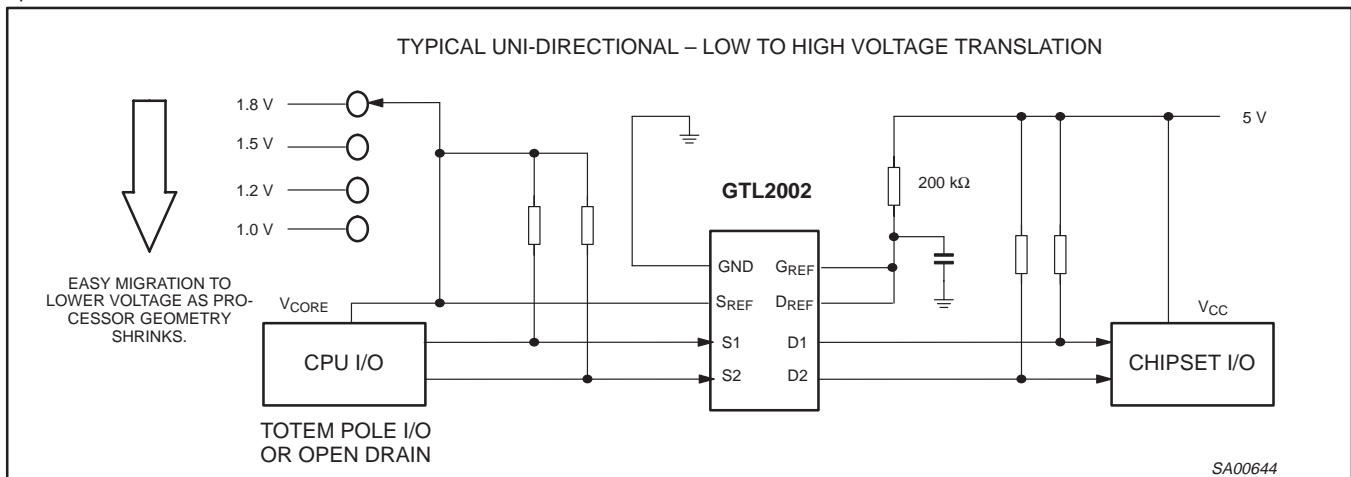


Figure 6. Uni-directional up translation, to higher voltage chip sets

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**Sizing pull-up resistor**

The pull-up resistor value needs to limit the current through the pass transistor when it is in the “on” state to about 15 mA. This will guarantee a pass voltage of 260 mV to 350 mV. If the current through the pass transistor is higher than 15 mA, the pass voltage will also be higher in the “on” state. To set the current through each pass transistor at 15 mA, the pull-up resistor value is calculated as follows:

$$\text{Resistor value } (\Omega) = \frac{\text{Pull-up voltage (V)} - 0.35 \text{ V}}{0.015 \text{ A}}$$

The table below summarizes resistor values for various reference voltages and currents at 15 mA and also at 10 mA and 3 mA. The resistor value shown in the +10 % column or a larger value should be used to ensure that the pass voltage of the transistor would be 350 mV or less. The external driver must be able to sink the total current from the resistors on both sides of the GTL–TVC device at 0.175 V, although the 15 mA only applies to current flowing through the GTL–TVC device. See Application Note *AN10145-01 Bi-Directional Voltage Translators* for more information.

**PULL-UP RESISTOR VALUES**

PULL-UP RESISTOR VALUE ( $\Omega$ )						
VOLTAGE	15 mA		10 mA		3 mA	
	NOMINAL	+ 10 %	NOMINAL	+ 10 %	NOMINAL	+ 10 %
5.0 V	310	341	465	512	1550	1705
3.3 V	197	217	295	325	983	1082
2.5 V	143	158	215	237	717	788
1.8 V	97	106	145	160	483	532
1.5 V	77	85	115	127	383	422
1.2 V	57	63	85	94	283	312

**NOTES:**

1. Calculated for  $V_{OL} = 0.35 \text{ V}$
2. Assumes output driver  $V_{OL} = 0.175 \text{ V}$  at stated current
3. +10 % to compensate for  $V_{DD}$  range and resistor tolerance.

**ABSOLUTE MAXIMUM RATINGS<sup>1, 2, 3</sup>**

SYMBOL	PARAMETER	CONDITIONS	RATING	UNIT
$V_{SREF}$	DC source reference voltage		–0.5 to +7.0	V
$V_{DREF}$	DC drain reference voltage		–0.5 to +7.0	V
$V_{GREF}$	DC gate reference voltage		–0.5 to +7.0	V
$V_{Sn}$	DC voltage Port $S_n$		–0.5 to +7.0	V
$V_{Dn}$	DC voltage Port $D_n$		–0.5 to +7.0	V
$I_{REFK}$	DC diode current on reference pins	$V_1 < 0 \text{ V}$	–50	mA
$I_{SK}$	DC diode current Port $S_n$	$V_1 < 0 \text{ V}$	–50	mA
$I_{DK}$	DC diode current Port $D_n$	$V_1 < 0 \text{ V}$	–50	mA
$I_{MAX}$	DC clamp current per channel	Channel in ON-state	$\pm 128$	mA
$T_{stg}$	Storage temperature range		–65 to +150	$^{\circ}\text{C}$

**NOTES:**

1. Stresses beyond those listed 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.
2. The performance capability of a high-performance integrated circuit in conjunction with its thermal environment can create junction temperatures which are detrimental to reliability. The maximum junction temperature of this integrated circuit should not exceed 150  $^{\circ}\text{C}$ .
3. The input and output negative voltage ratings may be exceeded if the input and output clamp current ratings are observed.

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## RECOMMENDED OPERATING CONDITIONS

SYMBOL	PARAMETER	CONDITIONS	LIMITS		UNIT
			Min	Max	
$V_{I/O}$	Input/output voltage (Sn, Dn)		0	5.5	V
$V_{SREF}$	DC source reference voltage <sup>1</sup>		0	5.5	V
$V_{DREF}$	DC drain reference voltage		0	5.5	V
$V_{GREF}$	DC gate reference voltage		0	5.5	V
$I_{PASS}$	Pass transistor current		—	64	mA
$T_{amb}$	Operating ambient temperature range	In free air	-40	+85	°C

## NOTE:

- $V_{SREF} \leq V_{DREF} - 1.5$  V for best results in level shifting applications.

## ELECTRICAL CHARACTERISTICS

Over recommended operating free-air temperature range (unless otherwise noted)

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNIT		
			MIN	TYP <sup>1</sup>	MAX			
$V_{OL}$	LOW-level output voltage	$V_{DD} = 3.0$ V; $V_{SREF} = 1.365$ V; $V_{Sn}$ or $V_{Dn} = 0.175$ V; $I_{clamp} = 15.2$ mA	—	260	350	mV		
$V_{IK}$	Input clamp voltage	$I_I = -18$ mA; $V_{GREF} = 0$ V	—	—	-1.2	V		
$I_{IH}$	Gate input leakage	$V_I = 5$ V; $V_{GREF} = 0$ V	—	—	5	μA		
$C_{I(GREF)}$	Gate capacitance	$V_I = 3$ V or 0 V	—	19.4	—	pF		
$C_{IO(OFF)}$	Off capacitance	$V_O = 3$ V or 0 V; $V_{GREF} = 0$ V	—	7.4	—	pF		
$C_{IO(ON)}$	On capacitance	$V_O = 3$ V or 0 V; $V_{GREF} = 3$ V	—	18.6	—	pF		
$r_{on}^2$	On-resistance	$V_I = 0$ V	$V_{GREF} = 4.5$ V	$I_O = 64$ mA	—	3.5	5	Ω
			$V_{GREF} = 3$ V		—	4.4	7	
			$V_{GREF} = 2.3$ V		—	5.5	9	
			$V_{GREF} = 1.5$ V		—	67	105	
		$V_I = 2.4$ V	$V_{GREF} = 4.5$ V	$I_O = 15$ mA	—	7	10	Ω
			$V_{GREF} = 3$ V		—	58	80	
$V_I = 1.7$ V	$V_{GREF} = 2.3$ V		—	50	70			

## NOTES:

- All typical values are measured at  $T_{amb} = 25$  °C
- Measured by the voltage drop between the Sn and the Dn terminals at the indicated current through the switch. On-state resistance is determined by the lowest voltage of the two (Sn or Dn) terminals.

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## AC CHARACTERISTICS FOR TRANSLATOR TYPE APPLICATIONS

$V_{REF} = 1.365\text{ V to }1.635\text{ V}$ ;  $V_{DD1} = 3.0\text{ V to }3.6\text{ V}$ ;  $V_{DD2} = 2.36\text{ V to }2.64\text{ V}$ ;  $GND = 0\text{ V}$ ;  $t_r = t_f \leq 3.0\text{ ns}$ . Refer to the Test Circuit diagram.

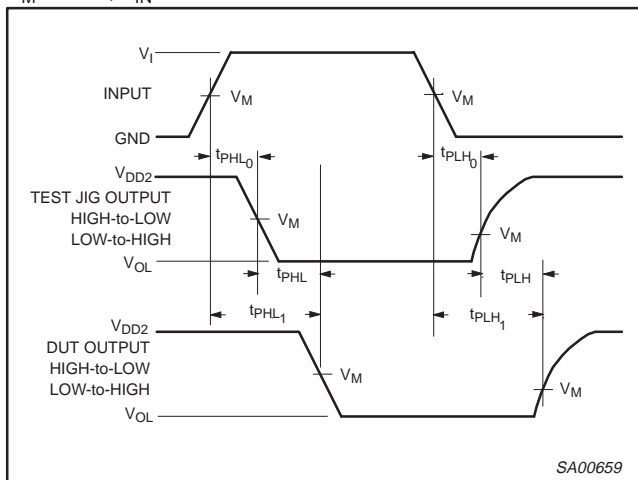
SYMBOL	PARAMETER	WAVEFORM	LIMITS			UNIT
			$T_{amb} = -40\text{ }^{\circ}\text{C to }+85\text{ }^{\circ}\text{C}$			
			MIN	TYP <sup>1</sup>	MAX	
$t_{PLH}^2$	Propagation delay Sn to Dn; Dn to Sn		0.5	1.5	5.5	ns

**NOTES:**

1. All typical values are measured at  $V_{DD1} = 3.3\text{ V}$ ,  $V_{DD2} = 2.5\text{ V}$ ,  $V_{REF} = 1.5\text{ V}$  and  $T_{amb} = 25\text{ }^{\circ}\text{C}$ .
2. Propagation delay guaranteed by characterization.
3.  $C_{ON(max)}$  of 30 pF and a  $C_{OFF(max)}$  of 15 pF is guaranteed by design.

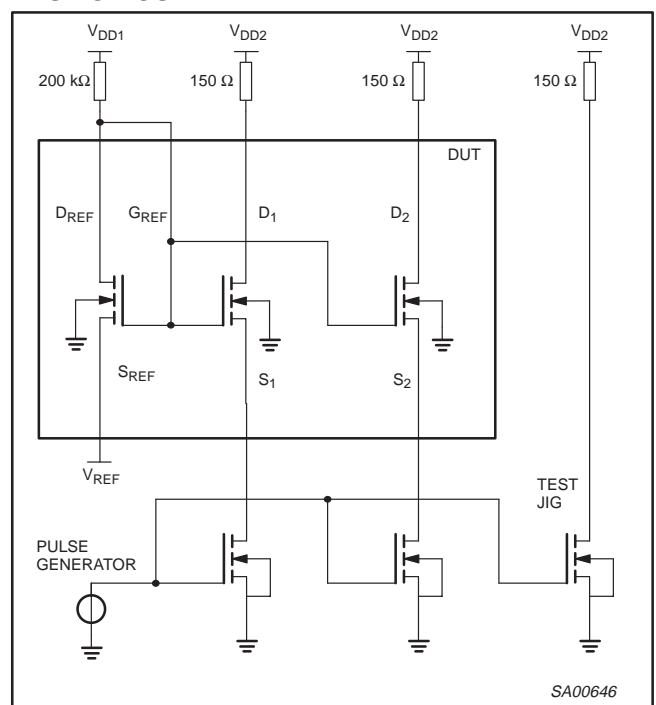
### AC WAVEFORMS

$V_M = 1.5\text{ V}$ ;  $V_{IN} = GND\text{ to }3.0\text{ V}$



Waveform 1. The Input ( $S_n$ ) to Output ( $D_n$ ) propagation delays

### TEST CIRCUIT



Waveform 2. Load circuit



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## AC CHARACTERISTICS FOR CBT TYPE APPLICATION

GND = 0 V;  $t_R$ ;  $C_L = 50$  pF

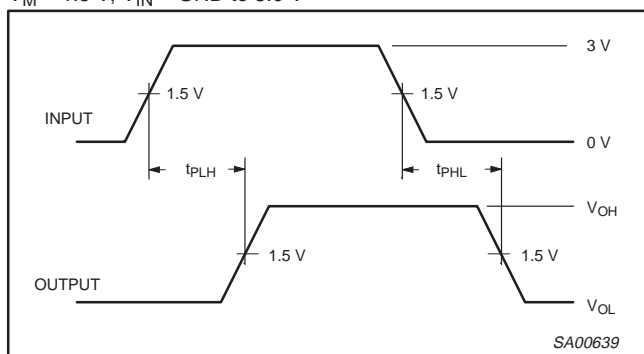
SYMBOL	PARAMETER DESCRIPTION	LIMITS $T_{amb} = -40\text{ }^\circ\text{C to } +85\text{ }^\circ\text{C}$ $G_{REF} = 5\text{ V} \pm 0.5\text{ V}$			UNITS
		Min	Mean	Max	
$t_{pd}$	Propagation delay <sup>1</sup>	—	—	250	ps

### NOTES:

1. This parameter is warranted but not production tested. The propagation delay is based on the RC time constant of the typical on-state resistance of the switch and a load capacitance of 50 pF, when driven by an ideal voltage source (zero output impedance).

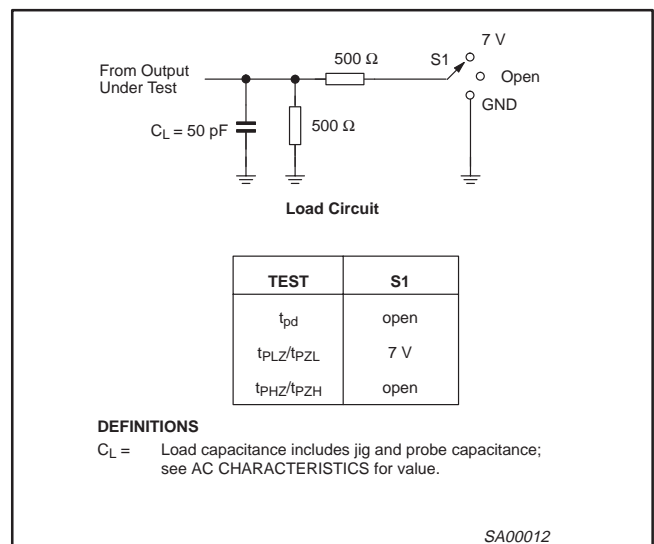
## AC WAVEFORMS

$V_M = 1.5$  V;  $V_{IN} = \text{GND to } 3.0$  V



Waveform 3. Input (Sn) to Output (Dn) Propagation Delays

## TEST CIRCUIT AND WAVEFORMS



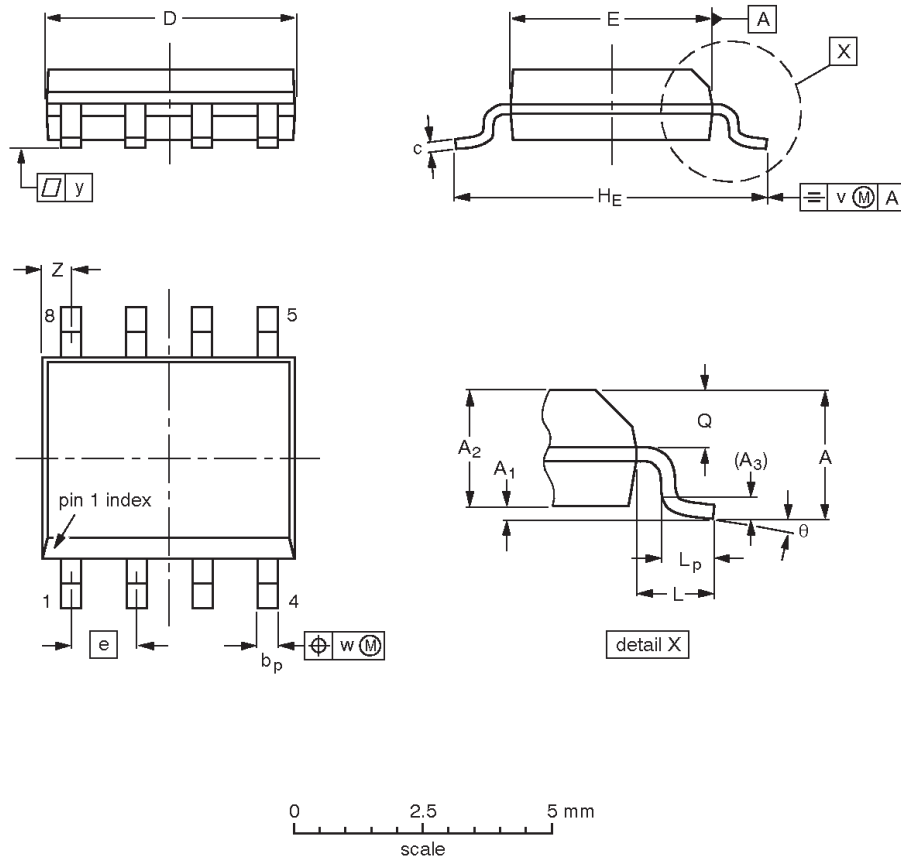
Waveform 4. Load circuit

# 2-bit bi-directional low voltage translator

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**SO8: plastic small outline package; 8 leads; body width 3.9 mm**

**SOT96-1**



**DIMENSIONS (inch dimensions are derived from the original mm dimensions)**

UNIT	A max.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(2)</sup>	e	H <sub>E</sub>	L	L <sub>p</sub>	Q	v	w	y	Z <sup>(1)</sup>	$\theta$
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	5.0 4.8	4.0 3.8	1.27	6.2 5.8	1.05	1.0 0.4	0.7 0.6	0.25	0.25	0.1	0.7 0.3	8° 0°
inches	0.069	0.010 0.004	0.057 0.049	0.01	0.019 0.014	0.0100 0.0075	0.20 0.19	0.16 0.15	0.05	0.244 0.228	0.041	0.039 0.016	0.028 0.024	0.01	0.01	0.004	0.028 0.012	

**Notes**

1. Plastic or metal protrusions of 0.15 mm (0.006 inch) maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm (0.01 inch) maximum per side are not included.

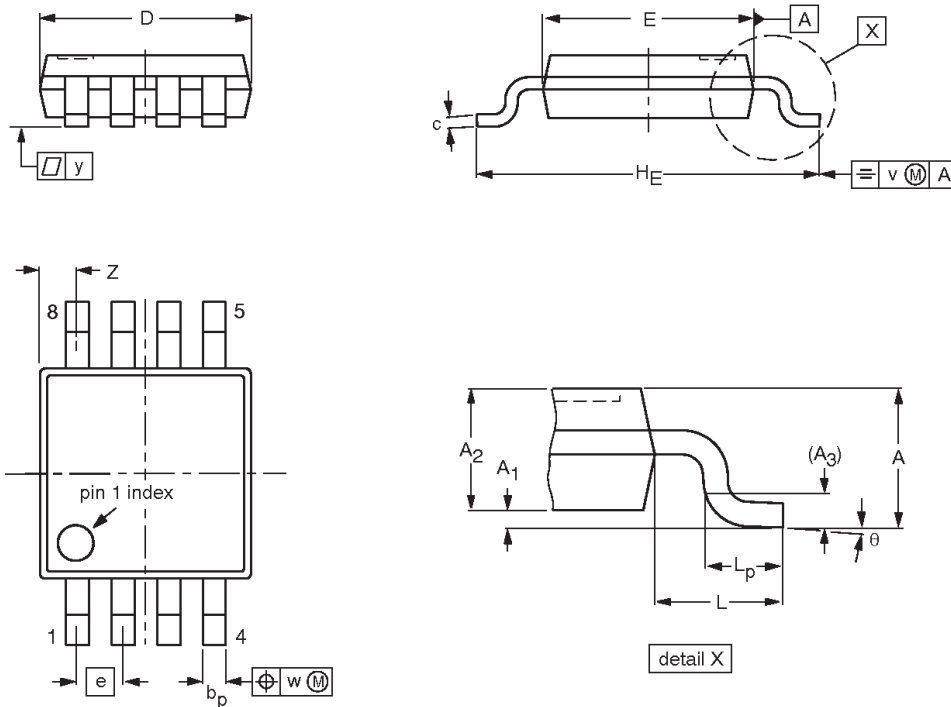
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT96-1	076E03	MS-012				99-12-27 03-02-18

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TSSOP8: plastic thin shrink small outline package; 8 leads; body width 3 mm

SOT505-1



**DIMENSIONS (mm are the original dimensions)**

UNIT	A max.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(2)</sup>	e	H <sub>E</sub>	L	L <sub>p</sub>	v	w	y	Z <sup>(1)</sup>	θ
mm	1.1	0.15 0.05	0.95 0.80	0.25	0.45 0.25	0.28 0.15	3.1 2.9	3.1 2.9	0.65	5.1 4.7	0.94	0.7 0.4	0.1	0.1	0.1	0.70 0.35	6° 0°

**Notes**

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

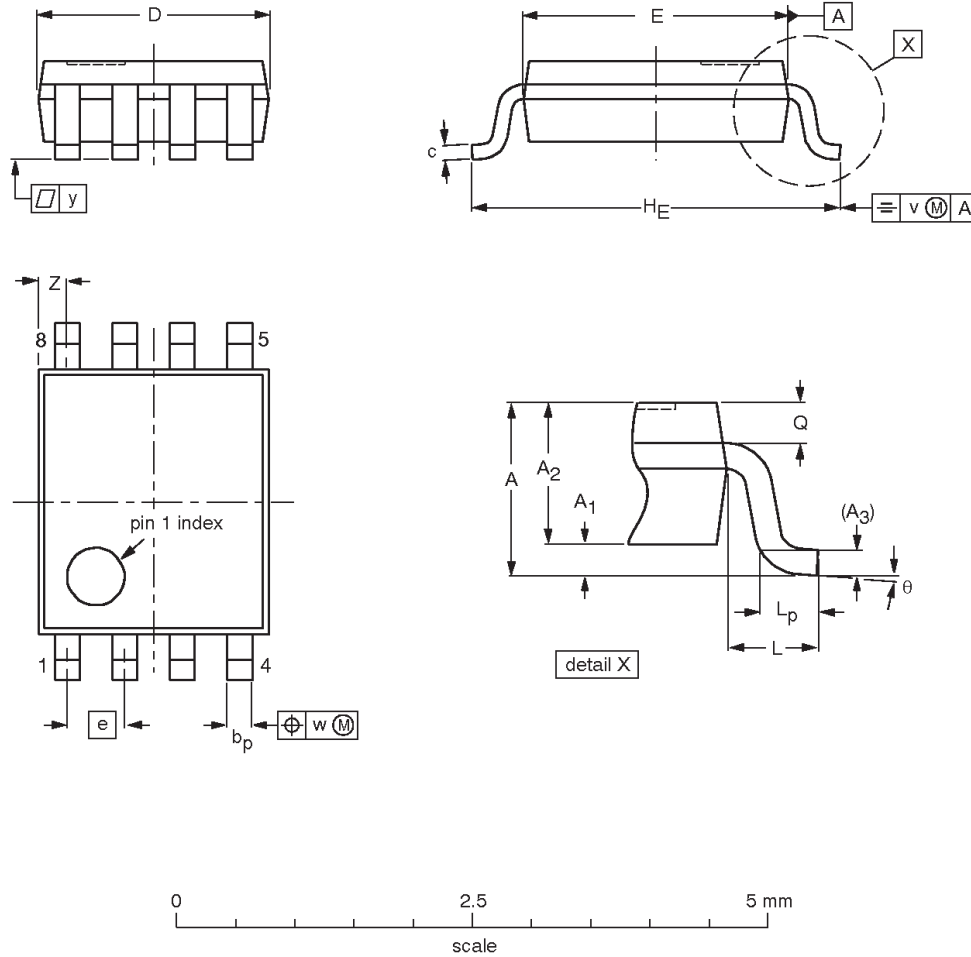
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT505-1						<del>99-04-09</del> 03-02-18

2-bit bi-directional low voltage translator

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VSSOP8: plastic very thin shrink small outline package; body width 2.3 mm

SOT765-1



DIMENSIONS (mm are the original dimensions)

UNIT	A max.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(2)</sup>	e	H <sub>E</sub>	L	L <sub>p</sub>	Q	v	w	y	Z <sup>(1)</sup>	θ
mm	1	0.15 0.00	0.85 0.60	0.12	0.27 0.17	0.23 0.08	2.1 1.9	2.4 2.2	0.5	3.2 3.0	0.4	0.40 0.15	0.21 0.19	0.2	0.13	0.1	0.4 0.1	8° 0°

Notes

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT765-1		MO-187				02-06-07

## 2-bit bi-directional low voltage translator

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**REVISION HISTORY**

Rev	Date	Description
_3	20040929	<b>Product data (9397 750 13058). Supersedes data of 2003 Apr 01 (9397 750 11349).</b> Modifications: <ul style="list-style-type: none"><li>• “Features” section on page 2, last bullet: add “(MSOP8)”</li><li>• “Ordering information” table on page 2: add “(MSOP)” to cell 8-Pin Plastic TSSOP in Packages column.</li><li>• Add VSSOP8 package offering.</li></ul>
_2	20030401	<b>Product data (9397 750 11349); ECN 853-2214 29603 Dated 28 February 2003.</b> <b>Supersedes data dated 2000 Aug 16 (9397 750 07417).</b>
_1	20000816	<b>Product data (9397 750 07417); ECN 853-2214 24367 dated 2000 Aug 16.</b>

## 2-bit bi-directional low voltage translator

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## Data sheet status

Level	Data sheet status <sup>[1]</sup>	Product status <sup>[2] [3]</sup>	Definitions
I	Objective data sheet	Development	This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice.
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[1] Please consult the most recently issued data sheet before initiating or completing a design.

[2] The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL <http://www.semiconductors.philips.com>.

[3] For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

## Definitions

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