

# DATA SHEET

## **GTL2000**

22-bit bi-directional low voltage translator

Product data  
Supersedes data of 2000 Jan 25

2003 Apr 01

## 22-bit bi-directional low voltage translator

## GTL2000

### FEATURES

- 22-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 busses 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  $\Omega$   $R_{DS(ON)}$  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
- Package offer: SSOP48, TSSOP48

### APPLICATIONS

- Any application that requires bi-directional or unidirectional voltage level translation from any voltage between 1.0 V & 5.0 V to any voltage between 1.0 V & 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 and/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 GTL2000 provides 22 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 twenty-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

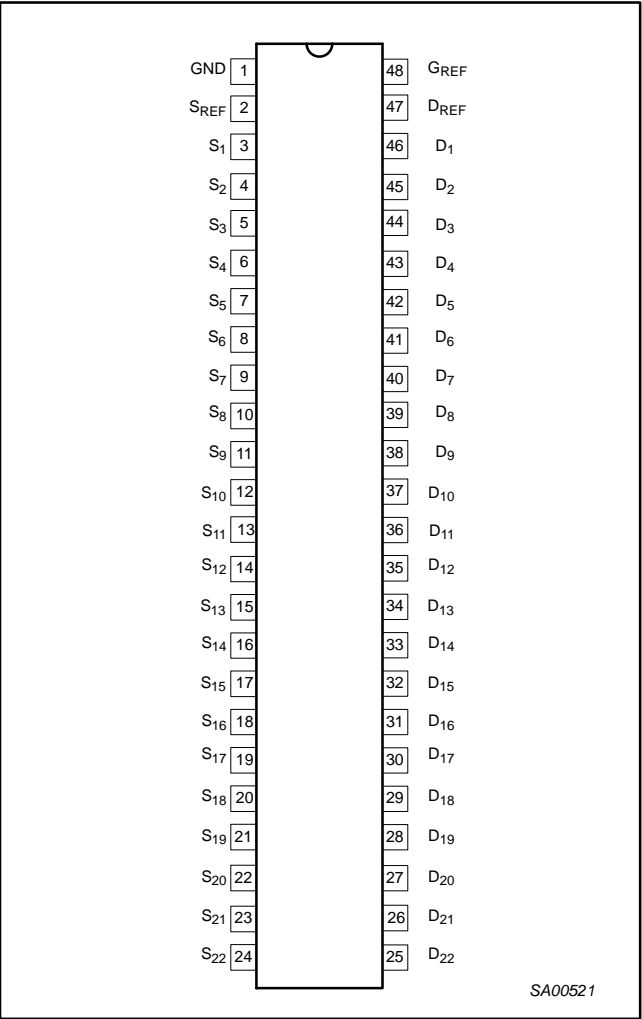
PACKAGES	TEMPERATURE RANGE	ORDER CODE	TOPSIDE MARK	DWG NUMBER
48-Pin Plastic SSOP	-40 to +85 °C	GTL2000DL	GTL2000DL	SOT370-1
48-Pin Plastic TSSOP	-40 to +85 °C	GTL2000DGG	GTL2000DGG	SOT362-1

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

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PIN CONFIGURATION



PIN DESCRIPTION

PIN NUMBER	SYMBOL	NAME AND FUNCTION
1	GND	Ground (0 V)
2	S <sub>REF</sub>	Source of reference transistor
3 - 24	S <sub>n</sub>	Port S <sub>1</sub> to Port S <sub>22</sub>
25 - 46	D <sub>n</sub>	Port D <sub>1</sub> to Port D <sub>22</sub>
47	D <sub>REF</sub>	Drain of reference transistor
48	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.

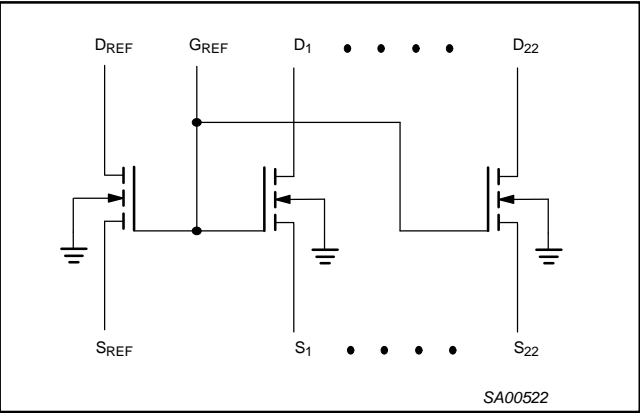
FUNCTION TABLE

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



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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  $V_{CC}$ .

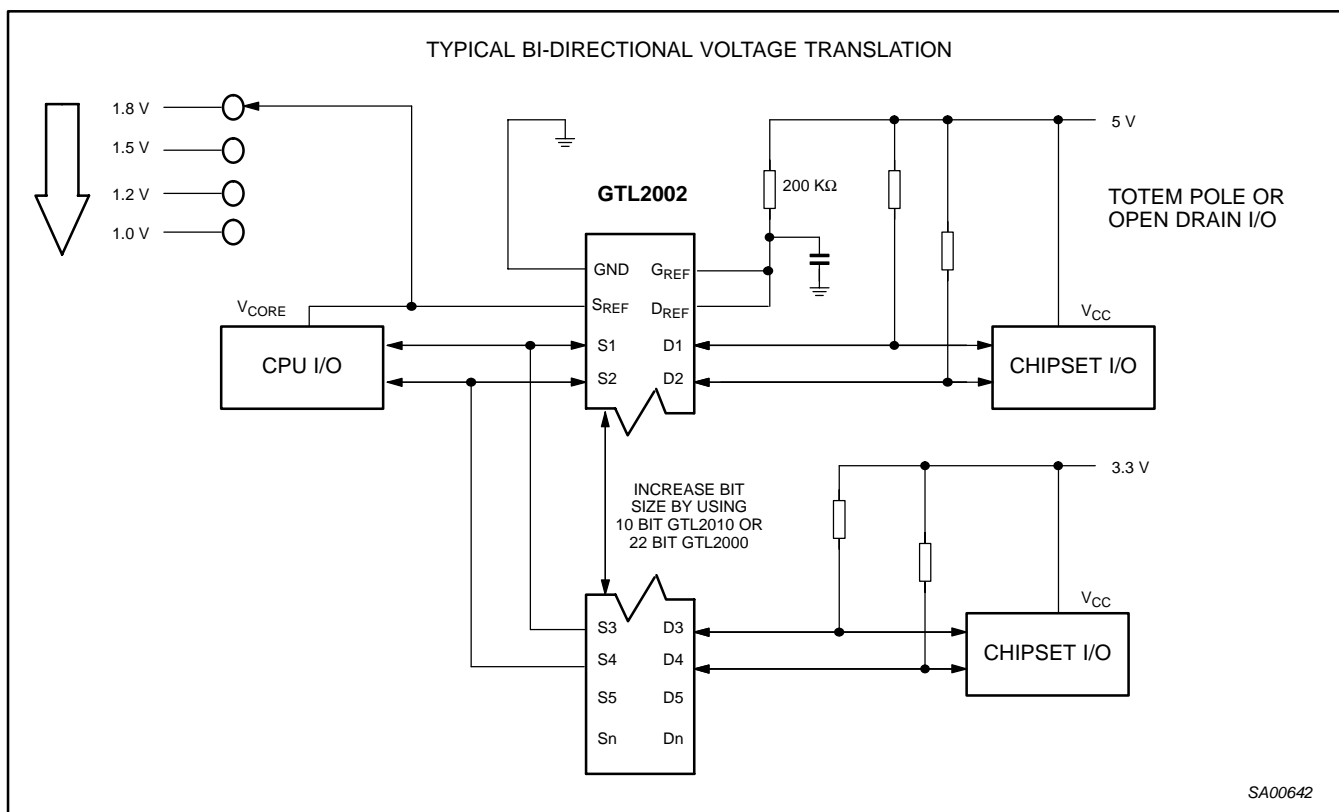


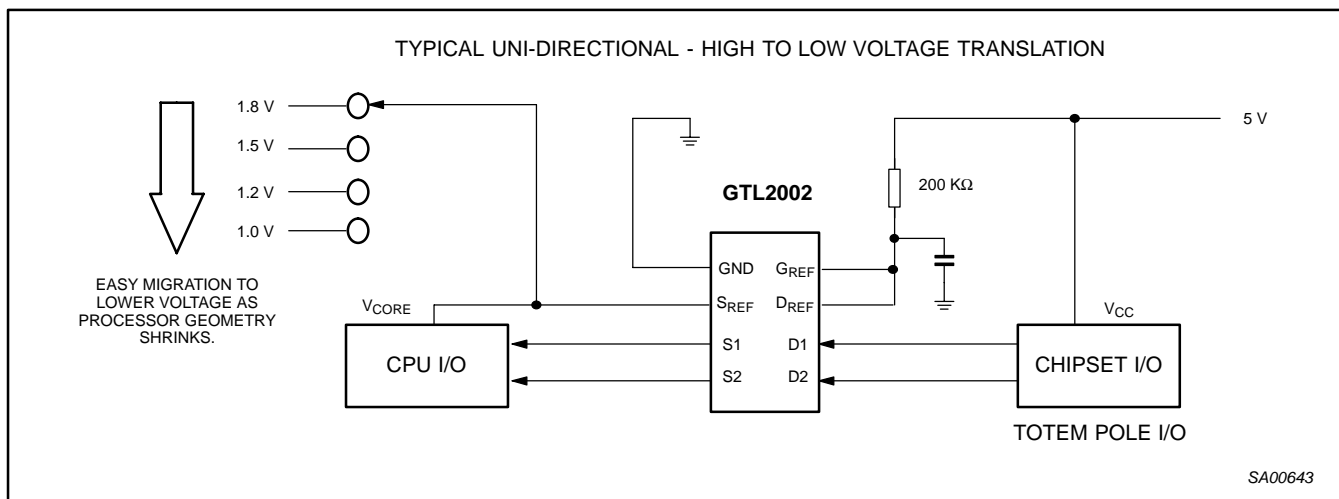
Figure 1. Bi-directional translation to multiple higher voltage levels such as an I<sup>2</sup>C bus application

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## Uni-directional down translation

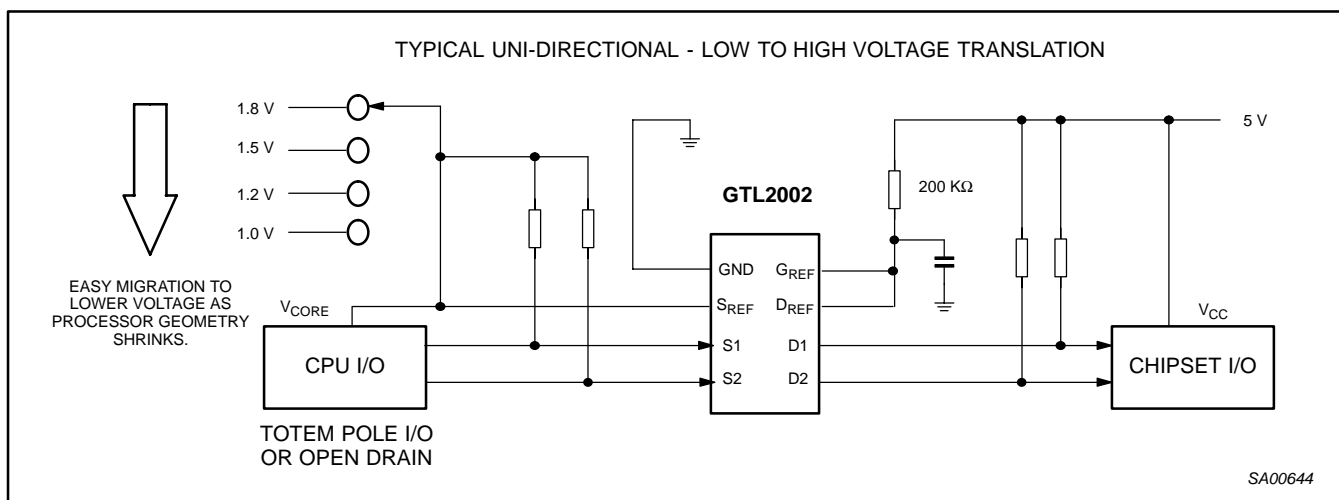
For uni-directional clamping, higher voltage to lower voltage, the  $G_{REF}$  input must be connected to  $D_{REF}$  and both pins pulled to the higher side  $V_{CC}$  through a pull-up resistor (typically 200 k $\Omega$ ). A filter capacitor on  $D_{REF}$  is recommended. Pull up resistors are required 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 2. 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 (Dn or Sn) 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 3. 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 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 (OHMS)						
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	$V_I < 0$	-50	mA
$I_{SK}$	DC diode current Port $S_n$	$V_I < 0$	-50	mA
$I_{DK}$	DC diode current Port $D_n$	$V_I < 0$	-50	mA
$I_{MAX}$	DC clamp current per channel	Channel in ON-state	$\pm 128$	mA
$T_{stg}$	Storage temperature range		-65 to +150	°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 °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:

1.  $V_{SREF} \leq V_{DREF} - 1.5$  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 <sub>OL</sub>	Low level output voltage	V <sub>DD</sub> = 3.0 V; V <sub>SREF</sub> = 1.365 V; V <sub>Sn</sub> or V <sub>Dn</sub> = 0.175 V; I <sub>clamp</sub> = 15.2 mA		—	260	350	mV	
V <sub>IK</sub>	Input clamp voltage	I <sub>I</sub> = -18 mA	V <sub>GREF</sub> = 0	—	—	-1.2	V	
I <sub>IH</sub>	Gate input leakage	V <sub>I</sub> = 5 V	V <sub>GREF</sub> = 0	—	—	5	μA	
C <sub>I(GREF)</sub>	Gate capacitance	V <sub>I</sub> = 3 V or 0		—	97.4	—	pF	
C <sub>IO(OFF)</sub>	Off capacitance	V <sub>O</sub> = 3 V or 0	V <sub>GREF</sub> = 0	—	7.4	—	pF	
C <sub>IO(ON)</sub>	On capacitance	V <sub>O</sub> = 3 V or 0	V <sub>GREF</sub> = 3 V	—	18.6	—	pF	
r <sub>on</sub> <sup>2</sup>	On-resistance	V <sub>I</sub> = 0	V <sub>GREF</sub> = 4.5 V	I <sub>O</sub> = 64 mA	—	3.5	5	Ω
			V <sub>GREF</sub> = 3 V		—	4.4	7	
			V <sub>GREF</sub> = 2.3 V		—	5.5	9	
			V <sub>GREF</sub> = 1.5 V		—	67	105	
			V <sub>GREF</sub> = 1.5 V	I <sub>O</sub> = 30 mA	—	9	15	Ω
		V <sub>I</sub> = 2.4 V	V <sub>GREF</sub> = 4.5 V	I <sub>O</sub> = 15 mA	—	7	10	Ω
			V <sub>GREF</sub> = 3 V		—	58	80	
			V <sub>I</sub> = 1.7 V		V <sub>GREF</sub> = 2.3 V	—	50	

## NOTES:

1. All typical values are measured at  $T_{amb} = 25$  °C
2. 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

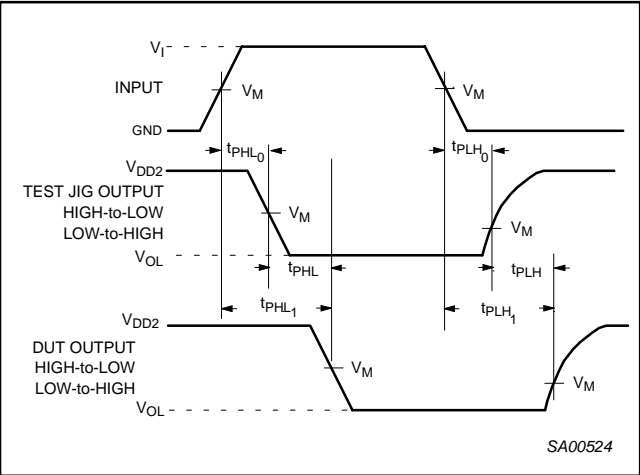
$V_{REF} = 1.365$  to  $1.635$  V;  $V_{DD1} = 3.0$  to  $3.6$  V;  $V_{DD2} = 2.36$  to  $2.64$  V;  $GND = 0$  V;  $t_r = t_f \leq 3.0$  ns. Refer to the Test Circuit diagram.

SYMBOL	PARAMETER	WAVEFORM	LIMITS			UNIT
			T <sub>amb</sub> = -40 to +85°C			
			MIN	TYP <sup>1</sup>	MAX	
t <sub>PLH</sub> <sup>2</sup>	Propagation delay Sn to Dn; Dn to Sn		0.5	1.5	5.5	ns

- NOTES:
1. All typical values are measured at  $V_{DD1} = 3.3$  V,  $V_{DD2} = 2.5$  V,  $V_{REF} = 1.5$  V and  $T_{amb} = 25^{\circ}C$ .
  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.

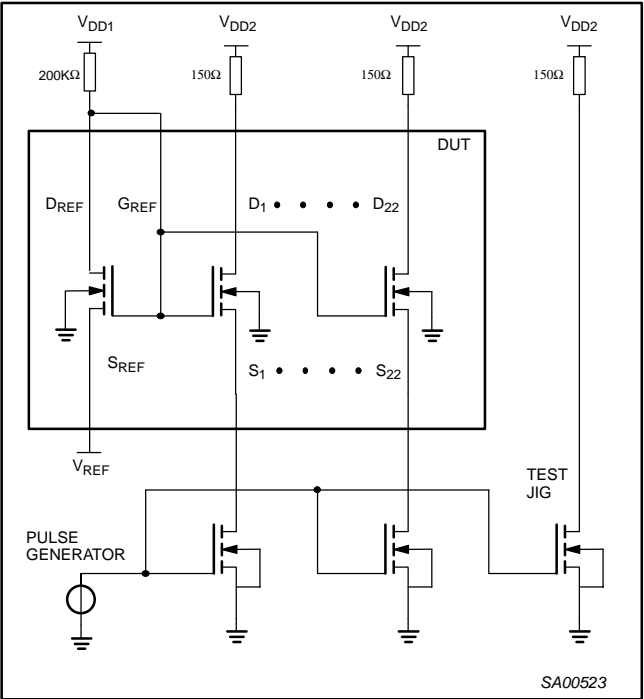
AC WAVEFORMS

$V_m = 1.5$  V;  $V_{IN} = GND$  to  $3.0$  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;  $t_R$ ;  $C_L = 50\text{ pF}$

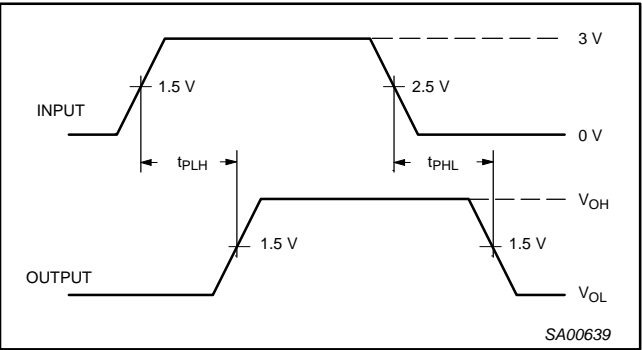
SYMBOL	PARAMETER DESCRIPTION	LIMITS -40 °C to +85 °C $G_{REF} = 5\text{ V} \pm 0.5\text{ V}$			UNITS
		Min	Mean	Max	
$t_{pd}$	Propagation delay <sup>1</sup>	—	—	250	ps

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).

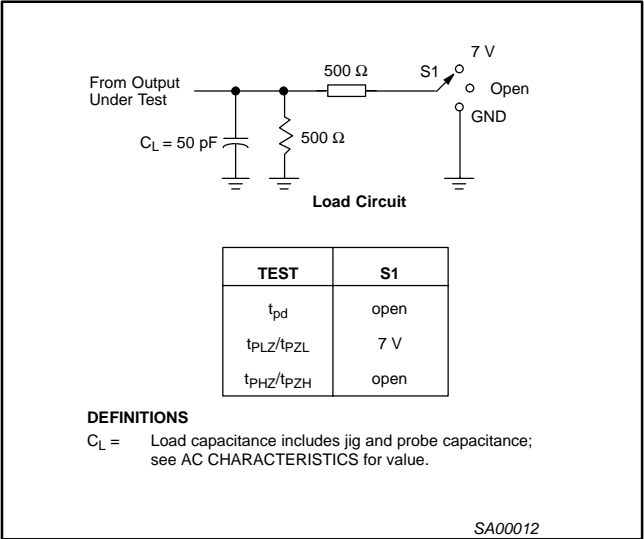
AC WAVEFORMS

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



Waveform 1. Input (Sn) to Output (Dn) Propagation Delays

TEST CIRCUIT AND WAVEFORMS



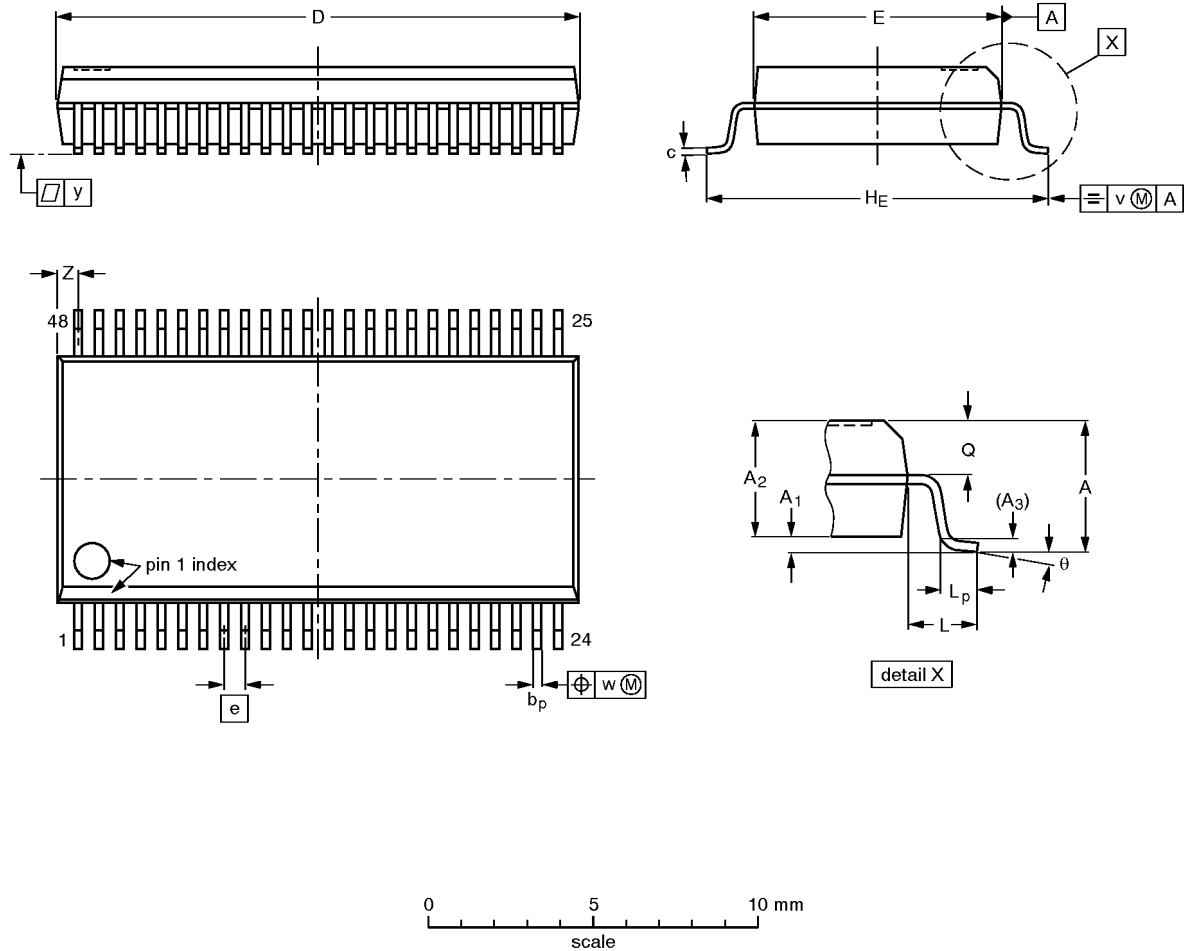
Waveform 2. Load circuit

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SSOP48: plastic shrink small outline package; 48 leads; body width 7.5 mm


SOT370-1



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>(1)</sup>	e	H <sub>E</sub>	L	L <sub>p</sub>	Q	v	w	y	Z <sup>(1)</sup>	θ
mm	2.8	0.4 0.2	2.35 2.20	0.25	0.3 0.2	0.22 0.13	16.00 15.75	7.6 7.4	0.635	10.4 10.1	1.4	1.0 0.6	1.2 1.0	0.25	0.18	0.1	0.85 0.40	8° 0°

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

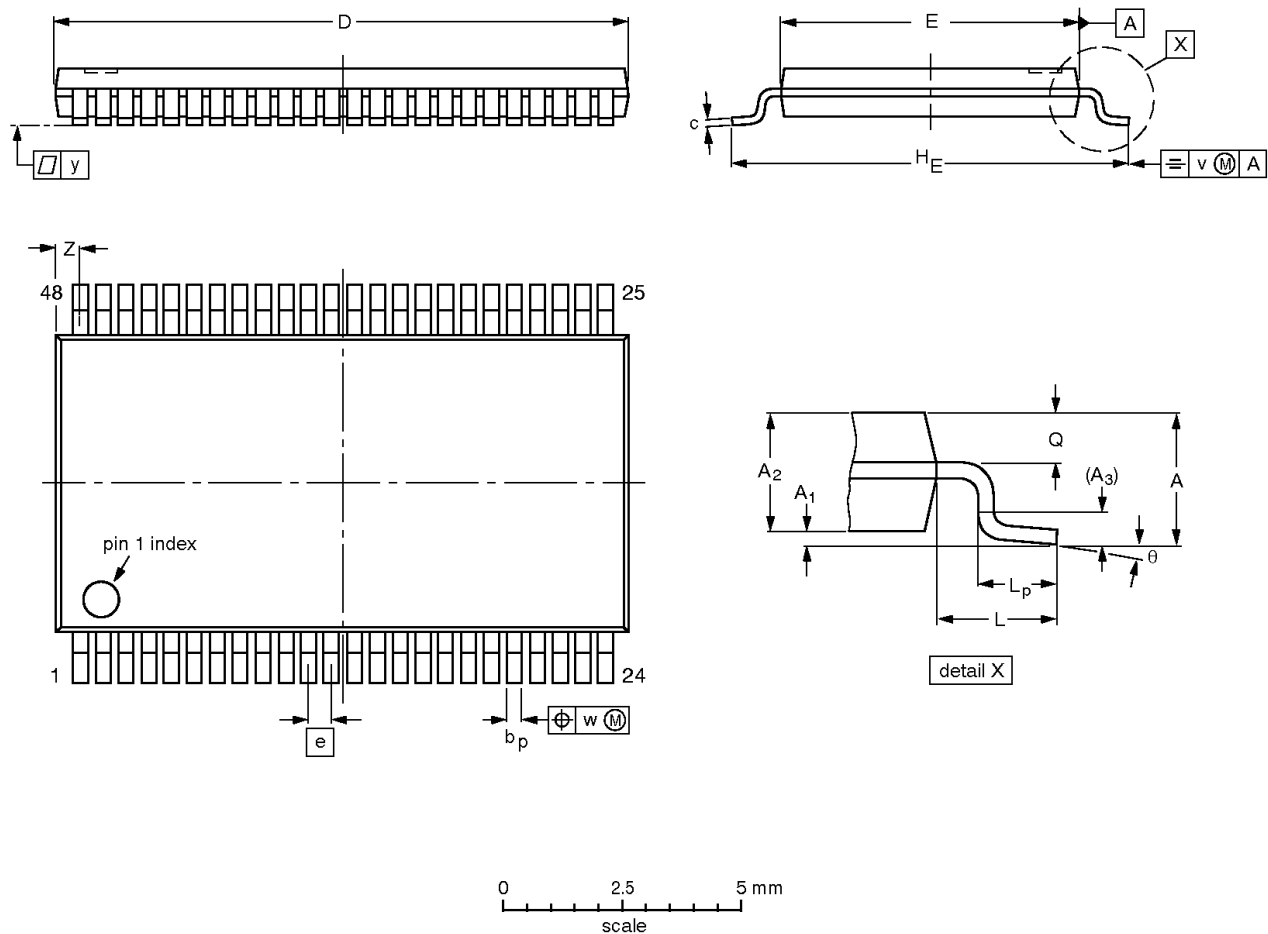
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT370-1		MO-118AA				93-11-02 95-02-04

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TSSOP48: plastic thin shrink small outline package; 48 leads; body width 6.1 mm

SOT362-1



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	θ
mm	1.2	0.15 0.05	1.05 0.85	0.25	0.28 0.17	0.2 0.1	12.6 12.4	6.2 6.0	0.5	8.3 7.9	1	0.8 0.4	0.50 0.35	0.25	0.08	0.1	0.8 0.4	8° 0°

Notes

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

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT362-1		MO-153				95-02-10 99-12-27

## 22-bit bi-directional low voltage translator

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## REVISION HISTORY

Rev	Date	Description
_3	20030401	<b>Product data (9397 750 11347); ECN 853-2154 29441 Dated 30 January 2003. Supersedes data dated 2000 Jan 25 (9397 750 06818).</b> Modifications: <ul style="list-style-type: none"><li>• New package release (TSSOP). The die was not changed.</li><li>• Added and modified specifications as data sheet was updated.</li></ul>
_2	20000125	Product data (9397 750 06818); ECN 853-2153 23030 dated 2000 Jan 25.

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## Data sheet status

Level	Data sheet status <sup>[1]</sup>	Product status <sup>[2] [3]</sup>	Definitions
I	Objective data	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.
II	Preliminary data	Qualification	This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product.
III	Product data	Production	This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Relevant changes will be communicated via a Customer Product/Process Change Notification (CPCN).

[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

**Short-form specification** — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

**Limiting values definition** — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.

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