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DATA SHEET

74HC04; 74HCT04 Hex inverter

Product specification
Supersedes data of 1993 Sep 01

2003 Jul 23

Hex inverter

74HC04; 74HCT04

FEATURES

- Complies with JEDEC standard no. 8-1A
- ESD protection:
HBM EIA/JESD22-A114-A exceeds 2000 V
MM EIA/JESD22-A115-A exceeds 200 V.
- Specified from -40 to $+85$ °C and -40 to $+125$ °C.

DESCRIPTION

The 74HC/HCT04 are high-speed Si-gate CMOS devices and are pin compatible with low power Schottky TTL (LSTTL). They are specified in compliance with JEDEC standard no. 7A. The 74HC/HCT04 provide six inverting buffers.

QUICK REFERENCE DATA

GND = 0 V; $T_{amb} = 25$ °C; $t_r = t_f \leq 6.0$ ns.

SYMBOL	PARAMETER	CONDITIONS	TYPICAL		UNIT
			HC04	HCT04	
t_{PHL}/t_{PLH}	propagation delay nA to nY	$C_L = 15$ pF; $V_{CC} = 5$ V	7	8	ns
C_I	input capacitance		3.5	3.5	pF
C_{PD}	power dissipation capacitance per gate	notes 1 and 2	21	24	pF

Notes

- C_{PD} is used to determine the dynamic power dissipation (P_D in μ W).

$$P_D = C_{PD} \times V_{CC}^2 \times f_i \times N + \Sigma(C_L \times V_{CC}^2 \times f_o) \text{ where:}$$

f_i = input frequency in MHz;

f_o = output frequency in MHz;

C_L = output load capacitance in pF;

V_{CC} = supply voltage in Volts;

N = total load switching outputs;

$\Sigma(C_L \times V_{CC}^2 \times f_o)$ = sum of the outputs.

- For 74HC04: the condition is $V_I = \text{GND to } V_{CC}$.

For 74HCT04: the condition is $V_I = \text{GND to } V_{CC} - 1.5$ V.

FUNCTION TABLE

See note 1.

INPUT	OUTPUT
nA	nY
L	H
H	L

Note

- H = HIGH voltage level;
L = LOW voltage level.

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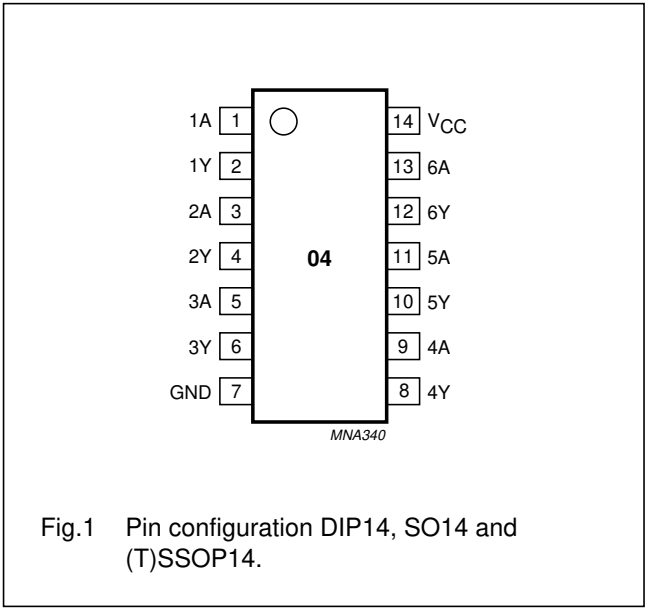
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ORDERING INFORMATION

TYPE NUMBER	PACKAGE				
	TEMPERATURE RANGE	PINS	PACKAGE	MATERIAL	CODE
74HC04N	−40 to +125 °C	14	DIP14	plastic	SOT27-1
74HCT04N	−40 to +125 °C	14	DIP14	plastic	SOT27-1
74HC04D	−40 to +125 °C	14	SO14	plastic	SOT108-1
74HCT04D	−40 to +125 °C	14	SO14	plastic	SOT108-1
74HC04DB	−40 to +125 °C	14	SSOP14	plastic	SOT337-1
74HCT04DB	−40 to +125 °C	14	SSOP14	plastic	SOT337-1
74HC04PW	−40 to +125 °C	14	TSSOP14	plastic	SOT402-1
74HCT04PW	−40 to +125 °C	14	TSSOP14	plastic	SOT402-1
74HC04BQ	−40 to +125 °C	14	DHVQFN14	plastic	SOT762-1
74HCT04BQ	−40 to +125 °C	14	DHVQFN14	plastic	SOT762-1

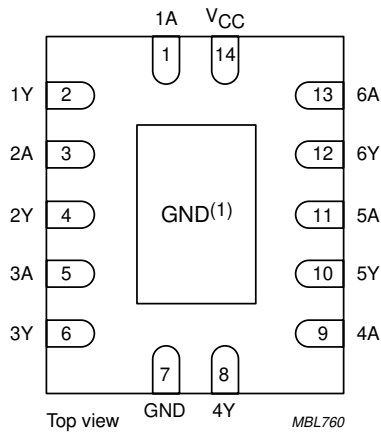
PINNING

PIN	SYMBOL	DESCRIPTION
1	1A	data input
2	1Y	data output
3	2A	data input
4	2Y	data output
5	3A	data input
6	3Y	data output
7	GND	ground (0 V)
8	4Y	data output
9	4A	data input
10	5Y	data output
11	5A	data input
12	6Y	data output
13	6A	data input
14	V _{CC}	supply voltage



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(1) The die substrate is attached to this pad using conductive die attach material. It can not be used as a supply pin or input.

Fig.2 Pin configuration DHVQFN14.

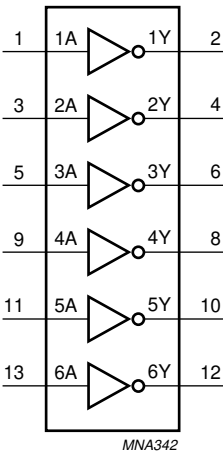


Fig.3 Logic symbol.

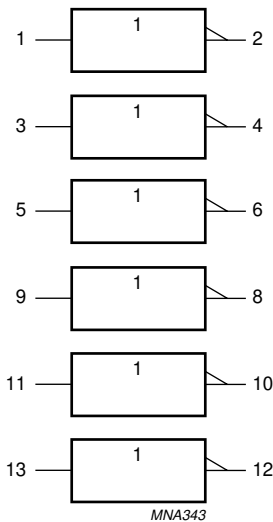


Fig.4 IEC logic symbol.

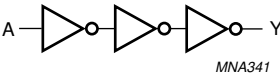


Fig.5 Logic diagram (one inverter).

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RECOMMENDED OPERATING CONDITIONS

SYMBOL	PARAMETER	CONDITIONS	74HC04			74HCT04			UNIT
			MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
V_{CC}	supply voltage		2.0	5.0	6.0	4.5	5.0	5.5	V
V_I	input voltage		0	–	V_{CC}	0	–	V_{CC}	V
V_O	output voltage		0	–	V_{CC}	0	–	V_{CC}	V
T_{amb}	ambient temperature	see DC and AC characteristics per device	–40	+25	+125	–40	+25	+125	°C
t_r, t_f	input rise and fall times	$V_{CC} = 2.0$ V	–	–	1 000	–	–	–	ns
		$V_{CC} = 4.5$ V	–	6.0	500	–	6.0	500	ns
		$V_{CC} = 6.0$ V	–	–	400	–	–	–	ns

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 60134); voltages are referenced to GND (ground = 0 V).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CC}	supply voltage		–0.5	+7.0	V
I_{IK}	input diode current	$V_I < -0.5$ V or $V_I > V_{CC} + 0.5$ V	–	±20	mA
I_{OK}	output diode current	$V_O < -0.5$ V or $V_O > V_{CC} + 0.5$ V	–	±20	mA
I_O	output source or sink current	-0.5 V < V_O < $V_{CC} + 0.5$ V	–	±25	mA
I_{CC}, I_{GND}	V_{CC} or GND current		–	±50	mA
T_{stg}	storage temperature		–65	+150	°C
P_{tot}	power dissipation				
	DIP14 package	$T_{amb} = -40$ to $+125$ °C; note 1	–	750	mW
	other packages	$T_{amb} = -40$ to $+125$ °C; note 2	–	500	mW

Notes

- For DIP14 packages: above 70 °C derate linearly with 12 mW/K.
- For SO14 packages: above 70 °C derate linearly with 8 mW/K.
For SSOP14 and TSSOP14 packages: above 60 °C derate linearly with 5.5 mW/K.
For DHVQFN14 packages: above 60 °C derate linearly with 4.5 mW/K.

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DC CHARACTERISTICS

Type 74HC04

At recommended operating conditions; voltages are referenced to GND (ground = 0 V).

SYMBOL	PARAMETER	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
		OTHER	V _{CC} (V)				
T _{amb} = 25 °C							
V _{IH}	HIGH-level input voltage		2.0	1.5	1.2	–	V
			4.5	3.15	2.4	–	V
			6.0	4.2	3.2	–	V
V _{IL}	LOW-level input voltage		2.0	–	0.8	0.5	V
			4.5	–	2.1	1.35	V
			6.0	–	2.8	1.8	V
V _{OH}	HIGH-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = –20 μA	2.0	1.9	2.0	–	V
		I _O = –20 μA	4.5	4.4	4.5	–	V
		I _O = –4.0 mA	4.5	3.98	4.32	–	V
		I _O = –20 μA	6.0	5.9	6.0	–	V
		I _O = –5.2 mA	6.0	5.48	5.81	–	V
V _{OL}	LOW-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = 20 μA	2.0	–	0	0.1	V
		I _O = 20 μA	4.5	–	0	0.1	V
		I _O = 4.0 mA	4.5	–	0.15	0.26	V
		I _O = 20 μA	6.0	–	0	0.1	V
		I _O = 5.2 mA	6.0	–	0.16	0.26	V
I _{LI}	input leakage current	V _I = V _{CC} or GND	6.0	–	0.1	±0.1	μA
I _{OZ}	3-state output OFF current	V _I = V _{IH} or V _{IL} ; V _O = V _{CC} or GND	6.0	–	–	±0.5	μA
I _{CC}	quiescent supply current	V _I = V _{CC} or GND; I _O = 0	6.0	–	–	2	μA

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SYMBOL	PARAMETER	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
		OTHER	V _{CC} (V)				
T _{amb} = −40 to +85 °C							
V _{IH}	HIGH-level input voltage		2.0	1.5	—	—	V
			4.5	3.15	—	—	V
			6.0	4.2	—	—	V
V _{IL}	LOW-level input voltage		2.0	—	—	0.5	V
			4.5	—	—	1.35	V
			6.0	—	—	1.8	V
V _{OH}	HIGH-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = −20 μA	2.0	1.9	—	—	V
		I _O = −20 μA	4.5	4.4	—	—	V
		I _O = −4.0 mA	4.5	3.84	—	—	V
		I _O = −20 μA	6.0	5.9	—	—	V
		I _O = −5.2 mA	6.0	5.34	—	—	V
V _{OL}	LOW-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = 20 μA	2.0	—	—	0.1	V
		I _O = 20 μA	4.5	—	—	0.1	V
		I _O = 4.0 mA	4.5	—	—	0.33	V
		I _O = 20 μA	6.0	—	—	0.1	V
		I _O = 5.2 mA	6.0	—	—	0.33	V
I _{LI}	input leakage current	V _I = V _{CC} or GND	6.0	—	—	±1.0	μA
I _{OZ}	3-state output OFF current	V _I = V _{IH} or V _{IL} ; V _O = V _{CC} or GND	6.0	—	—	±5.0	μA
I _{CC}	quiescent supply current	V _I = V _{CC} or GND; I _O = 0	6.0	—	—	20	μA

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SYMBOL	PARAMETER	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
		OTHER	V _{CC} (V)				
T _{amb} = −40 to +125 °C							
V _{IH}	HIGH-level input voltage		2.0	1.5	—	—	V
			4.5	3.15	—	—	V
			6.0	4.2	—	—	V
V _{IL}	LOW-level input voltage		2.0	—	—	0.5	V
			4.5	—	—	1.35	V
			6.0	—	—	1.8	V
V _{OH}	HIGH-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = −20 μA	2.0	1.9	—	—	V
		I _O = −20 μA	4.5	4.4	—	—	V
		I _O = −20 μA	6.0	5.9	—	—	V
		I _O = −4.0 mA	4.5	3.7	—	—	V
		I _O = −5.2 mA	6.0	5.2	—	—	V
V _{OL}	LOW-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = 20 μA	2.0	—	—	0.1	V
		I _O = 20 μA	4.5	—	—	0.1	V
		I _O = 20 μA	6.0	—	—	0.1	V
		I _O = 4.0 mA	4.5	—	—	0.4	V
		I _O = 5.2 mA	6.0	—	—	0.4	V
I _{LI}	input leakage current	V _I = V _{CC} or GND	6.0	—	—	±1.0	μA
I _{OZ}	3-state output OFF current	V _I = V _{IH} or V _{IL} ; V _O = V _{CC} or GND	6.0	—	—	±10.0	μA
I _{CC}	quiescent supply current	V _I = V _{CC} or GND; I _O = 0	6.0	—	—	40	μA

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Type 74HCT04

At recommended operating conditions; voltages are referenced to GND (ground = 0 V).

SYMBOL	PARAMETER	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
		OTHER	V _{CC} (V)				
T _{amb} = 25 °C							
V _{IH}	HIGH-level input voltage		4.5 to 5.5	2.0	1.6	–	V
V _{IL}	LOW-level input voltage		4.5 to 5.5	–	1.2	0.8	V
V _{OH}	HIGH-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = –20 μA	4.5	4.4	4.5	–	V
		I _O = –4.0 mA	4.5	3.84	4.32	–	V
V _{OL}	LOW-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = 20 μA	4.5	–	0	0.1	V
		I _O = 4.0 mA	4.5	–	0.15	0.26	V
I _{LI}	input leakage current	V _I = V _{CC} or GND	5.5	–	–	±0.1	μA
I _{OZ}	3-state output OFF current	V _I = V _{IH} or V _{IL} ; V _O = V _{CC} or GND; I _O = 0	5.5	–	–	±0.5	μA
I _{CC}	quiescent supply current	V _I = V _{CC} or GND; I _O = 0	5.5	–	–	2	μA
ΔI _{CC}	additional supply current per input	V _I = V _{CC} – 2.1 V; I _O = 0	4.5 to 5.5	–	120	432	μA
T _{amb} = –40 to +85 °C							
V _{IH}	HIGH-level input voltage		4.5 to 5.5	2.0	–	–	V
V _{IL}	LOW-level input voltage		4.5 to 5.5	–	–	0.8	V
V _{OH}	HIGH-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = –20 μA	4.5	4.4	–	–	V
		I _O = –4.0 mA	4.5	3.84	–	–	V
V _{OL}	LOW-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = 20 μA	4.5	–	–	0.1	V
		I _O = 4.0 mA	4.5	–	–	0.33	V
I _{LI}	input leakage current	V _I = V _{CC} or GND	5.5	–	–	±1.0	μA
I _{OZ}	3-state output OFF current	V _I = V _{IH} or V _{IL} ; V _O = V _{CC} or GND; I _O = 0	5.5	–	–	±5.0	μA
I _{CC}	quiescent supply current	V _I = V _{CC} or GND; I _O = 0	5.5	–	–	20	μA
ΔI _{CC}	additional supply current per input	V _I = V _{CC} – 2.1 V; I _O = 0	4.5 to 5.5	–	–	540	μA

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SYMBOL	PARAMETER	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
		OTHER	V _{CC} (V)				
T _{amb} = −40 to +125 °C							
V _{IH}	HIGH-level input voltage		4.5 to 5.5	2.0	—	—	V
V _{IL}	LOW-level input voltage		4.5 to 5.5	—	—	0.8	V
V _{OH}	HIGH-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = −20 μA	4.5	4.4	—	—	V
		I _O = −4.0 mA	4.5	3.7	—	—	V
V _{OL}	LOW-level output voltage	V _I = V _{IH} or V _{IL}					
		I _O = 20 μA	4.5	—	—	0.1	V
		I _O = 4.0 mA	4.5	—	—	0.4	V
I _{LI}	input leakage current	V _I = V _{CC} or GND	5.5	—	—	±1.0	μA
I _{OZ}	3-state output OFF current	V _I = V _{IH} or V _{IL} ; V _O = V _{CC} or GND; I _O = 0	5.5	—	—	±10	μA
I _{CC}	quiescent supply current	V _I = V _{CC} or GND; I _O = 0	5.5	—	—	40	μA
ΔI _{CC}	additional supply current per input	V _I = V _{CC} − 2.1 V; I _O = 0	4.5 to 5.5	—	—	590	μA

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AC CHARACTERISTICS

Family 74HC04

GND = 0 V; $t_r = t_f \leq 6.0$ ns; $C_L = 50$ pF.

SYMBOL	PARAMETER	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
		WAVEFORMS	V _{CC} (V)				
T _{amb} = 25 °C							
t _{PHL} /t _{PLH}	propagation delay nA to nY	see Figs 6 and 7	2.0	–	25	85	ns
			4.5	–	9	17	ns
			6.0	–	7	14	ns
t _{THL} /t _{TLH}	output transition time	see Figs 6 and 7	2.0	–	19	75	ns
			4.5	–	7	15	ns
			6.0	–	6	13	ns
T _{amb} = –40 to +85 °C							
t _{PHL} /t _{PLH}	propagation delay nA to nY	see Figs 6 and 7	2.0	–	–	105	ns
			4.5	–	–	21	ns
			6.0	–	–	18	ns
t _{THL} /t _{TLH}	output transition time	see Figs 6 and 7	2.0	–	–	95	ns
			4.5	–	–	19	ns
			6.0	–	–	16	ns
T _{amb} = –40 to +125 °C							
t _{PHL} /t _{PLH}	propagation delay nA to nY	see Figs 6 and 7	2.0	–	–	130	ns
			4.5	–	–	26	ns
			6.0	–	–	22	ns
t _{THL} /t _{TLH}	output transition time	see Figs 6 and 7	2.0	–	–	110	ns
			4.5	–	–	22	ns
			6.0	–	–	19	ns

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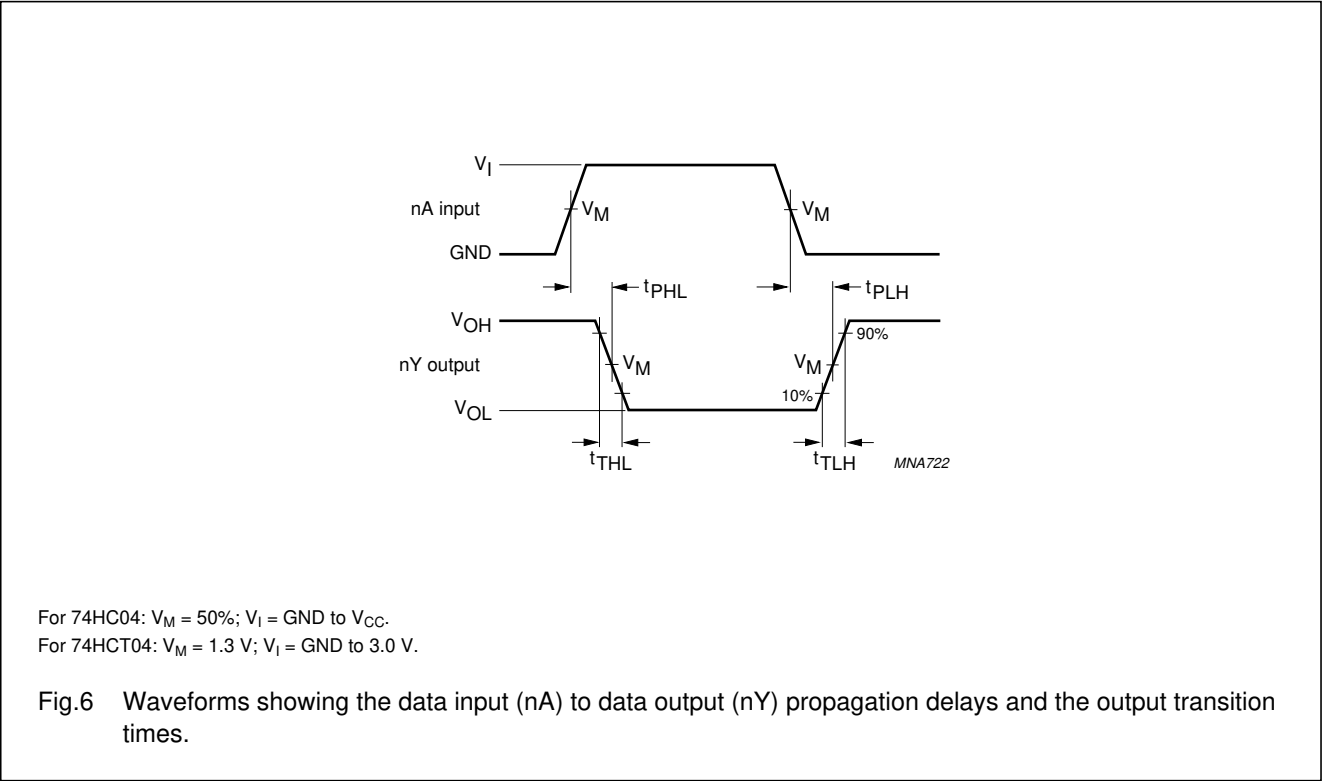
74HC04; 74HCT04

Family 74HCT04

GND = 0 V; $t_r = t_f \leq 6.0$ ns; $C_L = 50$ pF.

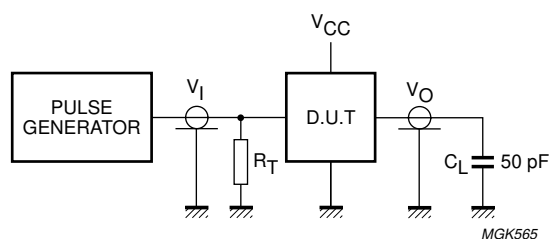
SYMBOL	PARAMETER	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
		WAVEFORMS	V _{CC} (V)				
T _{amb} = 25 °C							
t _{PHL} /t _{PLH}	propagation delay nA to nY	see Figs 6 and 7	4.5	–	10	19	ns
t _{THL} /t _{TLH}	output transition time	see Figs 6 and 7	4.5	–	7	15	ns
T _{amb} = –40 to +85 °C							
t _{PHL} /t _{PLH}	propagation delay nA to nY	see Figs 6 and 7	4.5	–	–	24	ns
t _{THL} /t _{TLH}	output transition time	see Figs 6 and 7	4.5	–	–	19	ns
T _{amb} = –40 to +125 °C							
t _{PHL} /t _{PLH}	propagation delay nA to nY	see Figs 6 and 7	4.5	–	–	29	ns
t _{THL} /t _{TLH}	output transition time	see Figs 6 and 7	4.5	–	–	22	ns

AC WAVEFORMS



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Definitions for test circuit:

C_L = Load capacitance including jig and probe capacitance.

R_T = Termination resistance should be equal to the output impedance Z_o of the pulse generator.

Fig.7 Load circuitry for switching times.

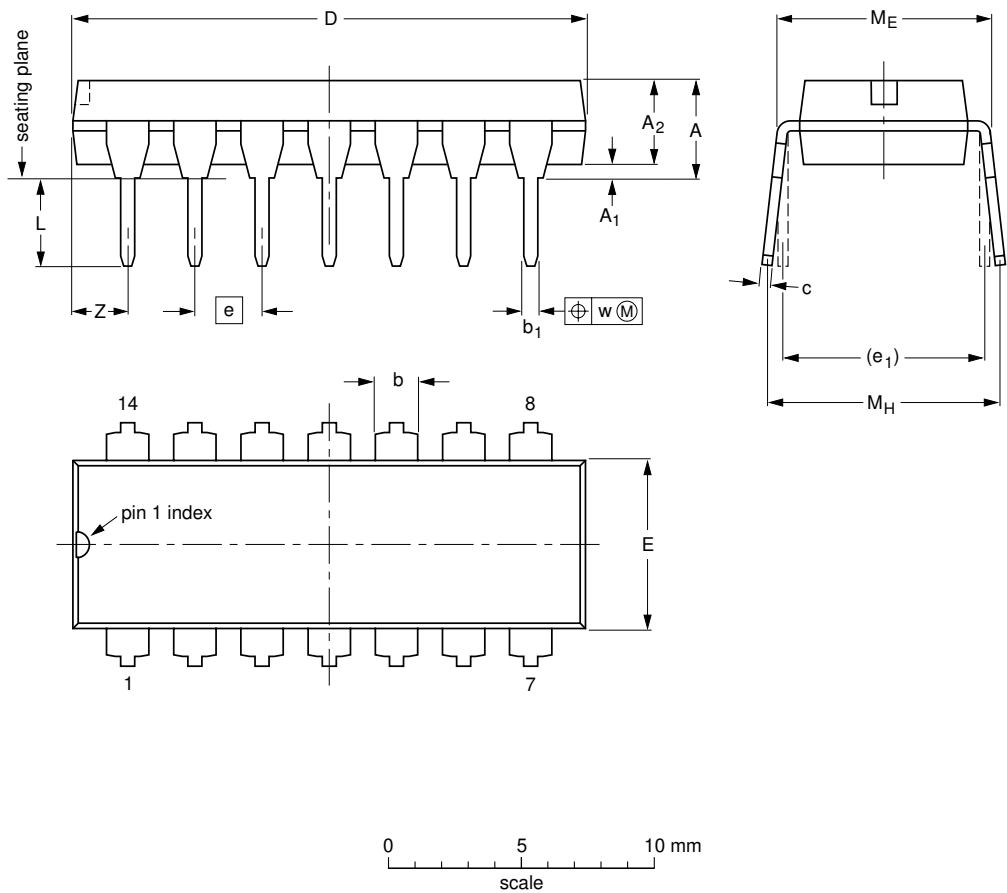
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PACKAGE OUTLINES

DIP14: plastic dual in-line package; 14 leads (300 mil)

SOT27-1

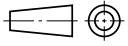


DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A ₁ min.	A ₂ max.	b	b ₁	c	D ⁽¹⁾	E ⁽¹⁾	e	e ₁	L	M _E	M _H	w	Z ⁽¹⁾ max.
mm	4.2	0.51	3.2	1.73 1.13	0.53 0.38	0.36 0.23	19.50 18.55	6.48 6.20	2.54	7.62	3.60 3.05	8.25 7.80	10.0 8.3	0.254	2.2
inches	0.17	0.02	0.13	0.068 0.044	0.021 0.015	0.014 0.009	0.77 0.73	0.26 0.24	0.1	0.3	0.14 0.12	0.32 0.31	0.39 0.33	0.01	0.087

Note

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

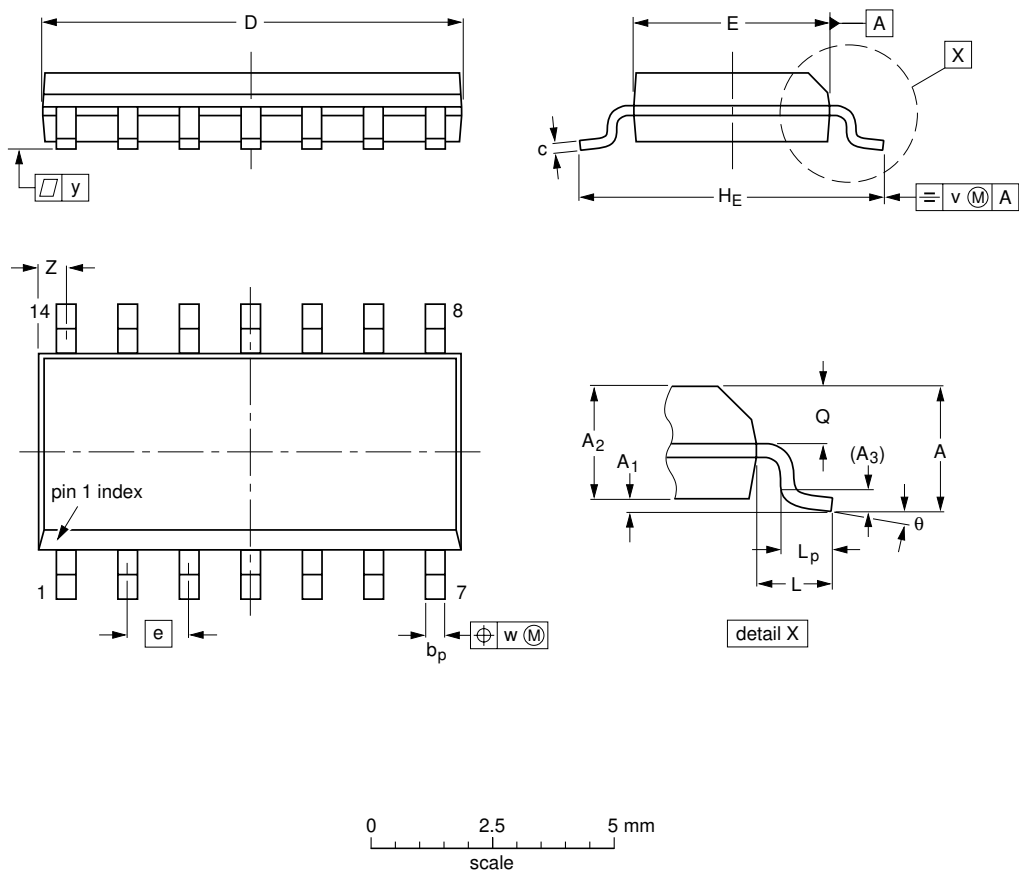
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT27-1	050G04	MO-001	SC-501-14			99-12-27- 03-02-13

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SO14: plastic small outline package; 14 leads; body width 3.9 mm

SOT108-1



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

UNIT	A max.	A ₁	A ₂	A ₃	b _p	c	D ⁽¹⁾	E ⁽¹⁾	e	H _E	L	L _p	Q	v	w	y	Z ⁽¹⁾	θ
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	8.75 8.55	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	0.35 0.34	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	

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

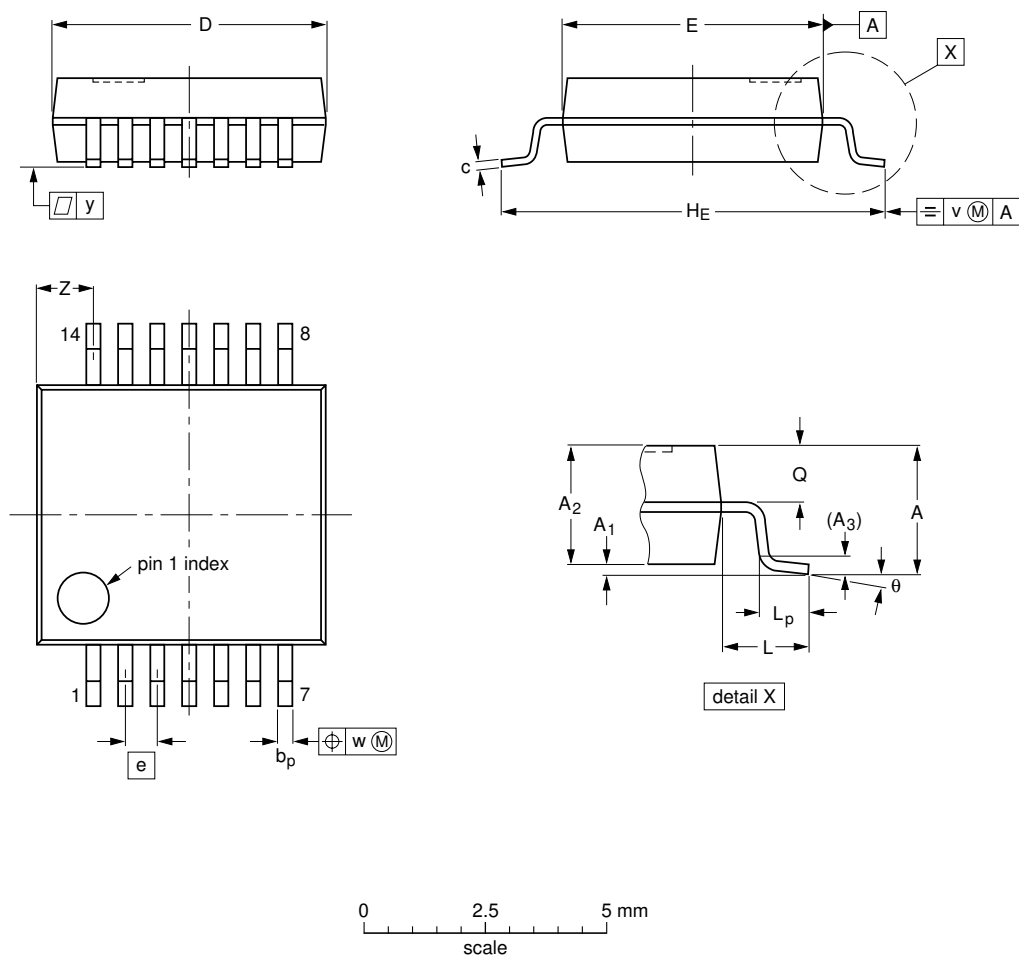
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT108-1	076E06	MS-012				99-12-27 03-02-19

Hex inverter

74HC04; 74HCT04

SSOP14: plastic shrink small outline package; 14 leads; body width 5.3 mm

SOT337-1



DIMENSIONS (mm are the original dimensions)

UNIT	A max.	A ₁	A ₂	A ₃	b _P	c	D ⁽¹⁾	E ⁽¹⁾	e	H _E	L	L _P	Q	v	w	y	Z ⁽¹⁾	θ
mm	2	0.21 0.05	1.80 1.65	0.25	0.38 0.25	0.20 0.09	6.4 6.0	5.4 5.2	0.65	7.9 7.6	1.25	1.03 0.63	0.9 0.7	0.2	0.13	0.1	1.4 0.9	8° 0°

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

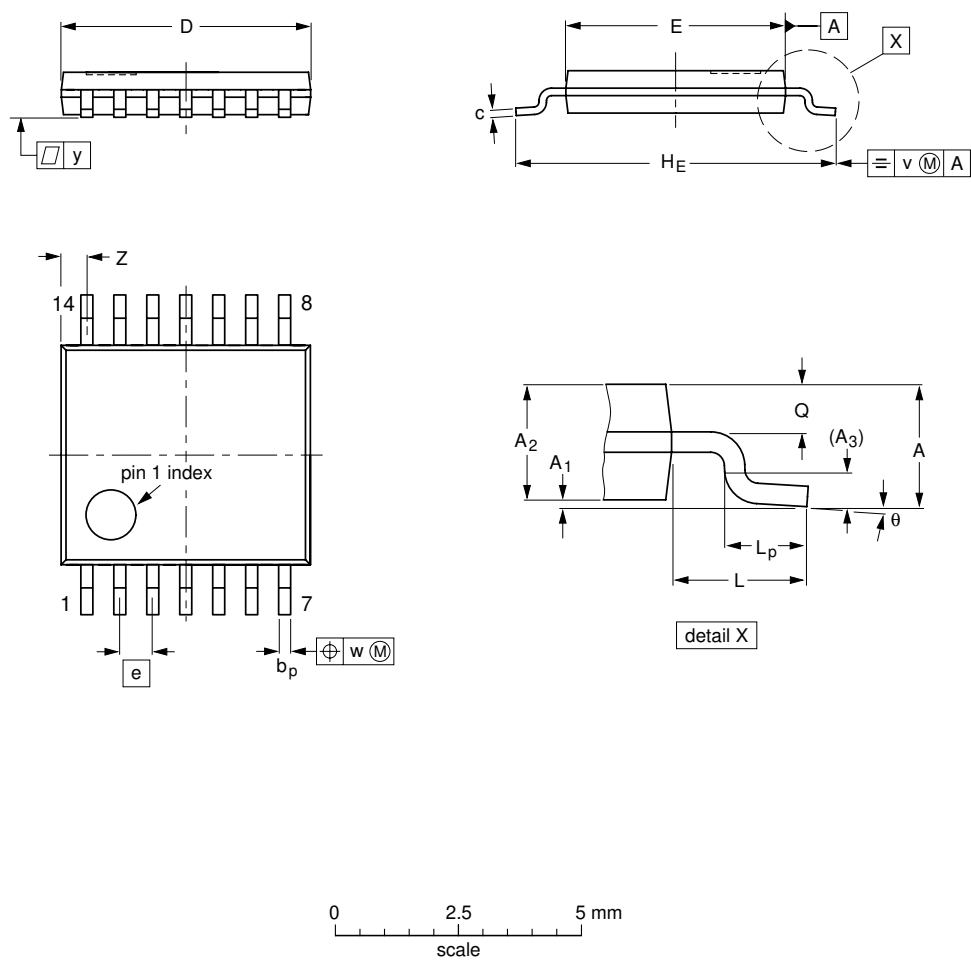
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT337-1		MO-150				99-12-27 03-02-19

Hex inverter

74HC04; 74HCT04

TSSOP14: plastic thin shrink small outline package; 14 leads; body width 4.4 mm

SOT402-1



DIMENSIONS (mm are the original dimensions)

UNIT	A max.	A ₁	A ₂	A ₃	b _p	c	D ⁽¹⁾	E ⁽²⁾	e	H _E	L	L _p	Q	v	w	y	Z ⁽¹⁾	θ
mm	1.1	0.15 0.05	0.95 0.80	0.25	0.30 0.19	0.2 0.1	5.1 4.9	4.5 4.3	0.65	6.6 6.2	1	0.75 0.50	0.4 0.3	0.2	0.13	0.1	0.72 0.38	8° 0°

Notes

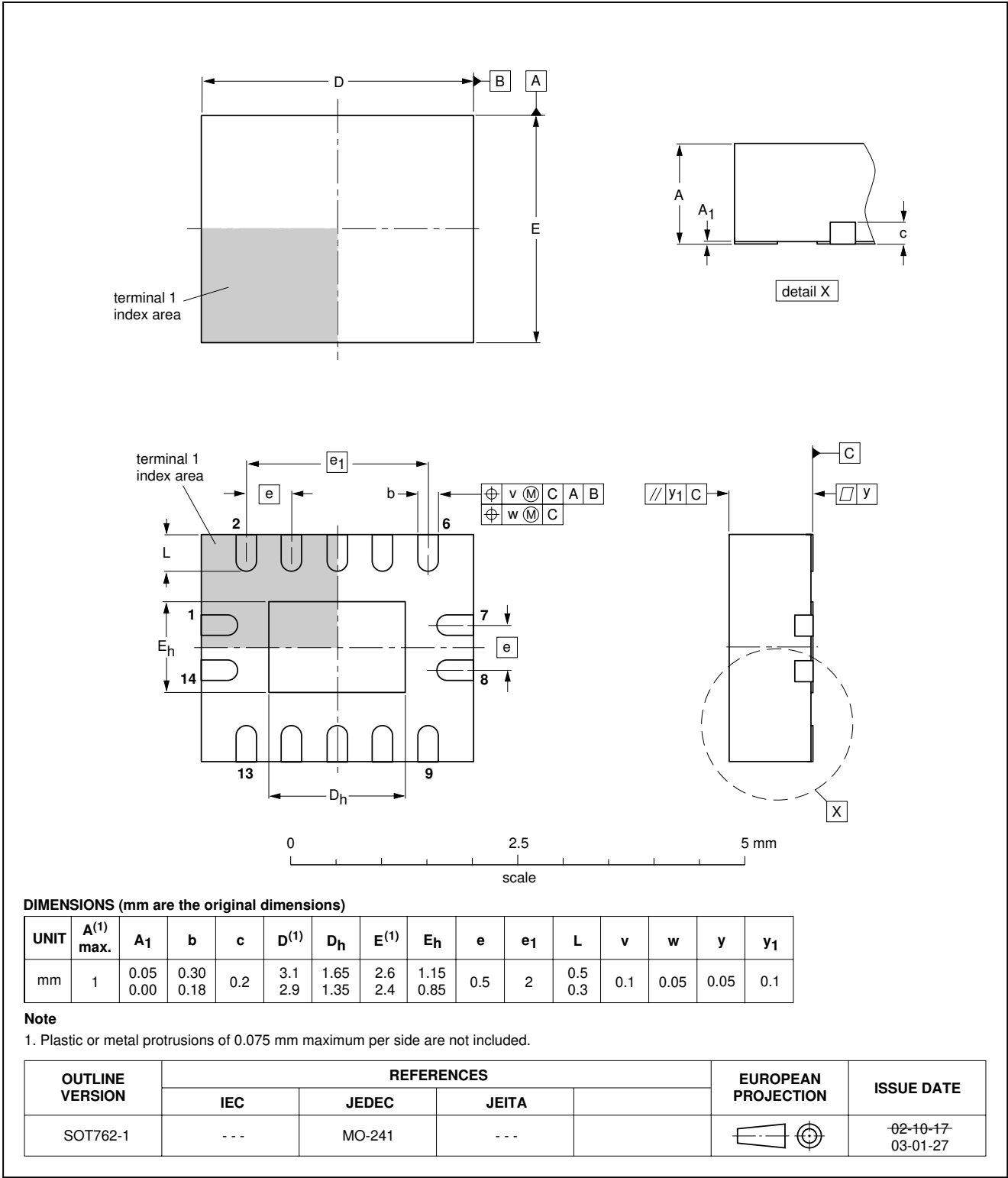
- 1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
- 2. Plastic interlead protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT402-1		MO-153				99-12-27- 03-02-18

Hex inverter

74HC04; 74HCT04

DHVQFN14: plastic dual in-line compatible thermal enhanced very thin quad flat package; no leads; 14 terminals; body 2.5 x 3 x 0.85 mm SOT762-1



Hex inverter

74HC04; 74HCT04

DATA SHEET STATUS

LEVEL	DATA SHEET STATUS ⁽¹⁾	PRODUCT STATUS ⁽²⁾⁽³⁾	DEFINITION
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).

Notes

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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