DATA SHEET

PCA9540
2-channel I^{2}C multiplexer

Product data
Supersedes data of 2001 Feb 08

2002 May 13

Philips
Semiconductors

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2-channel I²C multiplexer PCA9540

FEATURES

- 1-of-2 bi-directional translating multiplexer
- I²C interface logic; compatible with SMBus standards
- Channel selection via I²C bus
- Power up with all multiplexer channels deselected
- Low Rds_{ON} switches
- Allows voltage level translation between 1.8 V, 2.5 V, 3.3 V and 5 V buses
- No glitch on power-up
- Supports hot insertion
- Low stand-by current
- Operating power supply voltage range of 2.3 V to 5.5 V
- 5 V tolerant Inputs
- 0 to 400 kHz clock frequency
- ESD protection exceeds 2000 V HBM per JESD22-A114, 100 V MM per JESD22-A115 and 1000 V per JESD22-C101
- Latch-up testing is done to JESDEC Standard JESD78 which exceeds 100 mA
- Package Offer: SO8, TSSOP8

DESCRIPTION

The PCA9540 is a 1-of-2 bi-directional translating multiplexer, controlled via the I²C bus. The SCL/SDA upstream pair fans out to two SCx/SDx downstream pairs, or channels. Only one SCx/SDx channel is selected at a time, determined by the contents of the programmable control register.

A power-on reset function puts the registers in their default state and initializes the I²C state machine with no channels selected.

The pass gates of the multiplexer are constructed such that the V_{DD} pin can be used to limit the maximum high voltage which will be passed by the PCA9540. This allows the use of different bus voltages on each SCx/SDx pair, so that 1.8 V, 2.5, or 3.3 V parts can communicate with 5 V parts without any additional protection. External pull-up resistors can pull the bus up to the desired voltage level for this channel. All I/O pins are 5 V tolerant.

PIN CONFIGURATION

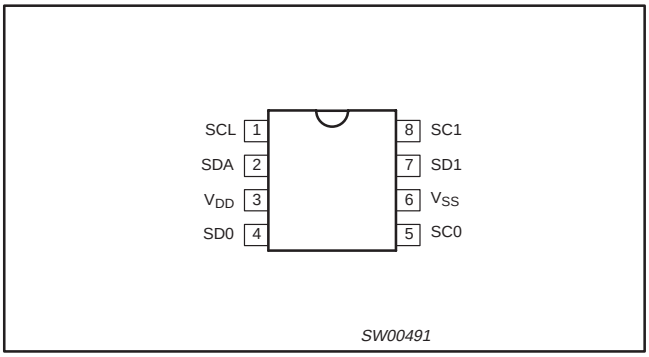


Figure 1. Pin configuration

PIN DESCRIPTION

PIN NUMBER	SYMBOL	FUNCTION
1	SCL	Serial clock line
2	SDA	Serial data line
3	V_{DD}	Supply voltage
4	SD0	Serial data 0
5	SC0	Serial clock 0
6	V_{SS}	Supply ground
7	SD1	Serial data 1
8	SC1	Serial clock 1

ORDERING INFORMATION

PACKAGES	TEMPERATURE RANGE	ORDER CODE	DRAWING NUMBER
8-Pin Plastic SO	–40 to +85 °C	PCA9540D	SOT96-1
8-Pin Plastic TSSOP	–40 to +85 °C	PCA9540DP	SOT505-1

Standard packing quantities and other packaging data is available at www.philipslogic.com/packaging.

BLOCK DIAGRAM

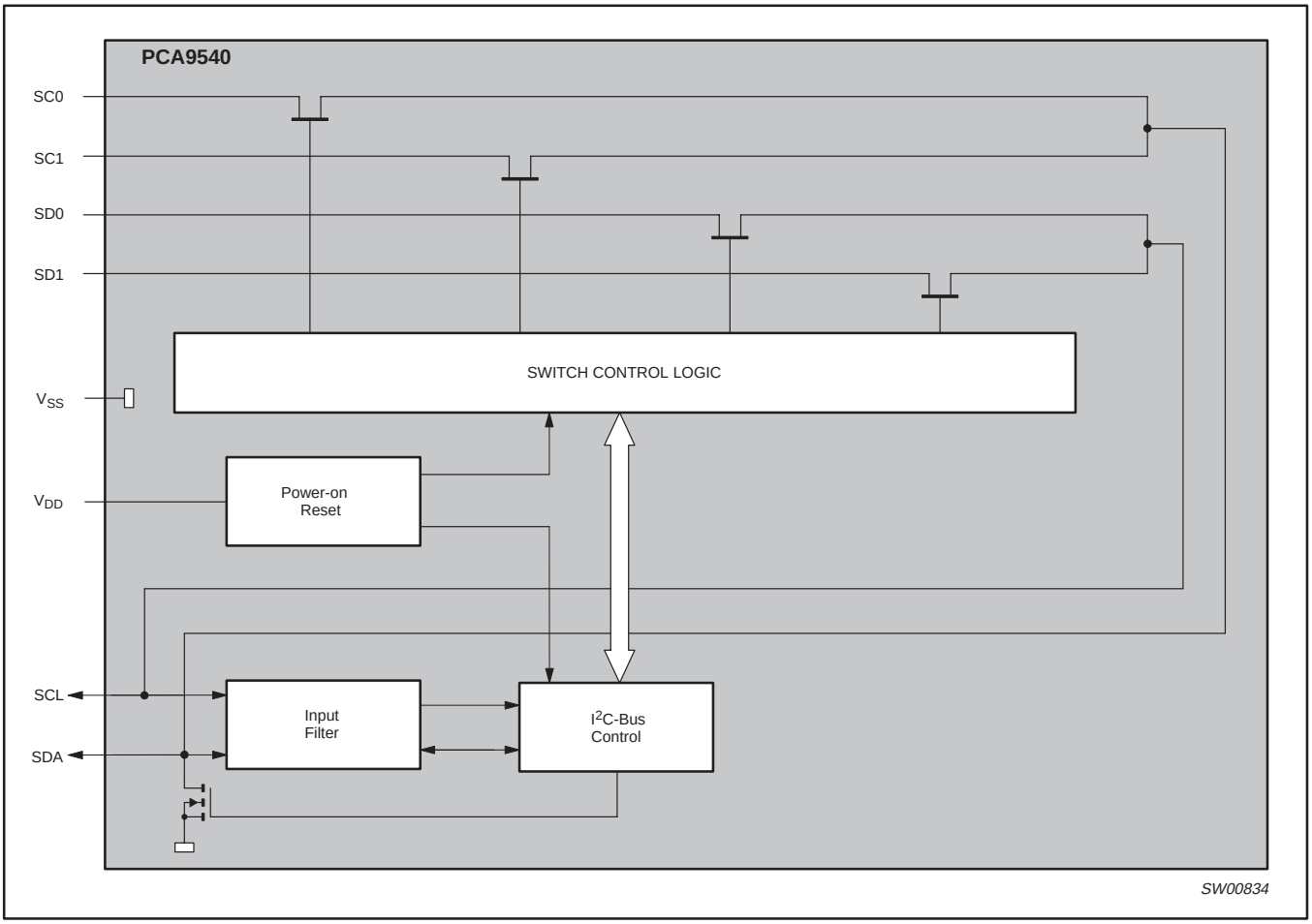


Figure 2. Block diagram

DEVICE ADDRESSING

Following a START condition the bus master must output the address of the slave it is accessing. The address of the PCA9540 is shown in Figure 3.

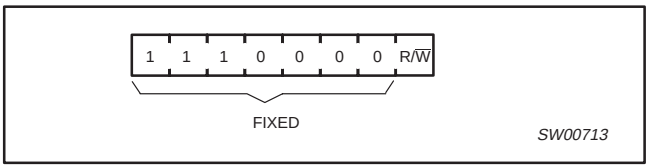


Figure 3. Slave address

The last bit of the slave address defines the operation to be performed. When set to logic 1, a read is selected while a logic 0 selects a write operation.

CONTROL REGISTER

Following the successful acknowledgement of the slave address, the bus master will send a byte to the PCA9540 which will be stored in the Control Register. If multiple bytes are received by the PCA9540, it will save the last byte received. This register can be written and read via the I²C bus.

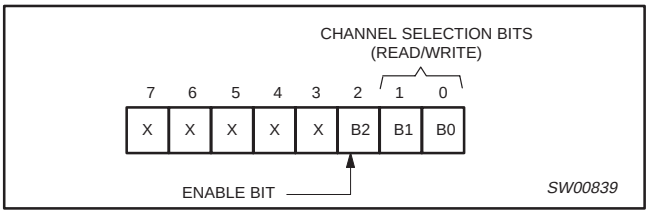


Figure 4. Control register

CONTROL REGISTER DEFINITION

A SCx/SDx downstream pair, or channel, is selected by the contents of the control register. This register is written after the PCA9540 has been addressed. The 2 LSBs of the control byte are used to determine which channel is to be selected. When a channel is selected, the channel will become active after a stop condition has been placed on the I²C bus. This ensures that all SCx/SDx lines will be in a HIGH state when the channel is made active, so that no false conditions are generated at the time of connection.

Table 1. Control Register; Write — Channel Selection/ Read — Channel Status

D7	D6	D5	D4	D3	B2	B1	B0	COMMAND
X	X	X	X	X	0	X	X	No channel selected
X	X	X	X	X	1	0	0	Channel 0 enabled
X	X	X	X	X	1	0	1	Channel 1 enabled
X	X	X	X	X	1	1	X	No channel selected

POWER-ON RESET

When power is applied to V_{DD}, an internal Power On Reset holds the PCA9540 in a reset state until V_{DD} has reached V_{POR}. At this point, the reset condition is released and the PCA9540 registers and I²C state machine are initialized to their default states, all zeroes causing all the channels to be deselected.

VOLTAGE TRANSLATION

The pass gate transistors of the PCA9540 are constructed such that the V_{DD} voltage can be used to limit the maximum voltage that will be passed from one I²C bus to another.

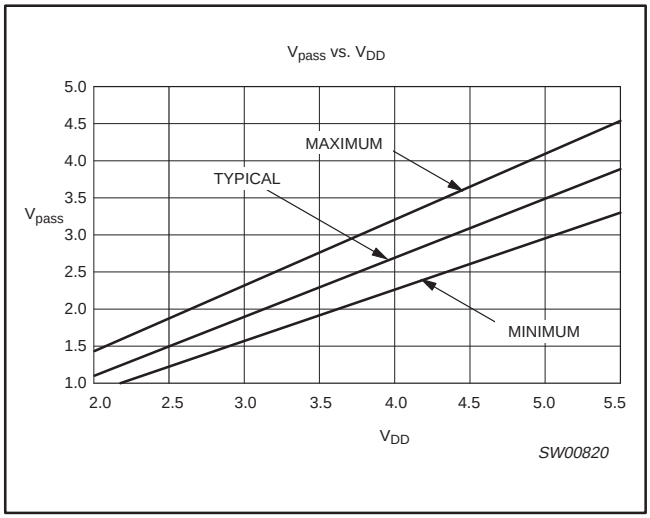


Figure 5. V_{pass} voltage

Figure 5 shows the voltage characteristics of the pass gate transistors (note that the graph was generated using the data specified in the DC Characteristics section of this datasheet). In order for the PCA9540 to act as a voltage translator, the V_{pass} voltage should be equal to, or lower than the lowest bus voltage. For example, if the main bus was running at 5 V, and the downstream buses were 3.3 V and 2.7 V, then V_{pass} should be equal to or below 2.7 V to effectively clamp the downstream bus voltages. Looking at Figure 5, we see that V_{pass} (max.) will be at 2.7 V when the PCA9540 supply voltage is 3.5 V or lower so the PCA9540 supply voltage could be set to 3.3 V. Pull-up resistors can then be used to bring the bus voltages to their appropriate levels (see Figure 12).

More Information can be found in Application Note AN262 *PCA954X family of I²C/SMBus multiplexers and switches.*

CHARACTERISTICS OF THE I²C-BUS

The I²C-bus is for 2-way, 2-line communication between different ICs or modules. The two lines are a serial data line (SDA) and a serial clock line (SCL). Both lines must be connected to a positive supply via a pull-up resistor when connected to the output stages of a device. Data transfer may be initiated only when the bus is not busy.

Bit transfer

One data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the HIGH period of the clock pulse as changes in the data line at this time will be interpreted as control signals (see FIgure 6).

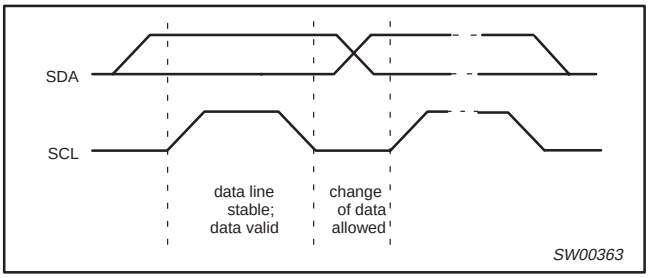


Figure 6. Bit transfer

Start and stop conditions

Both data and clock lines remain HIGH when the bus is not busy. A HIGH-to-LOW transition of the data line, while the clock is HIGH is defined as the start condition (S). A LOW-to-HIGH transition of the data line while the clock is HIGH is defined as the stop condition (P) (see Figure 7).

System configuration

A device generating a message is a ‘transmitter’, a device receiving is the ‘receiver’. The device that controls the message is the ‘master’ and the devices which are controlled by the master are the ‘slaves’ (see Figure 8).

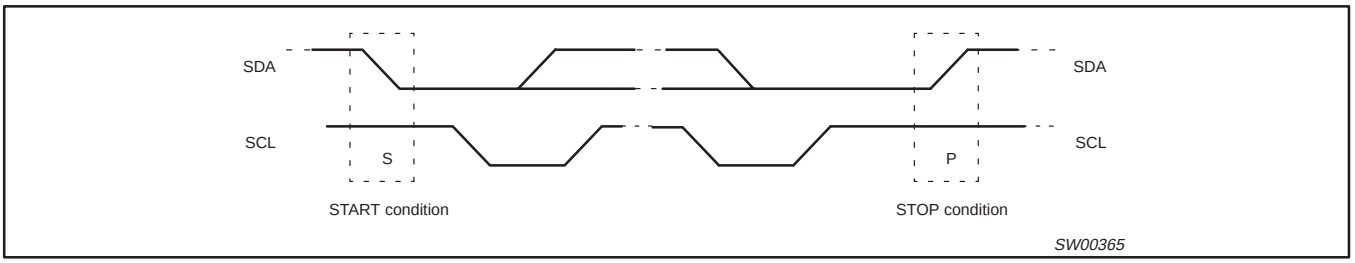


Figure 7. Definition of start and stop conditions

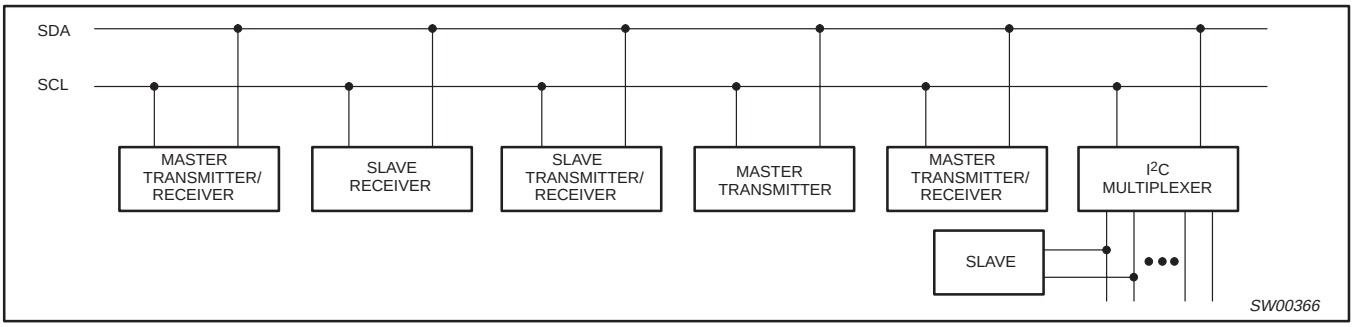


Figure 8. System configuration

Acknowledge

The number of data bytes transferred between the start and the stop conditions from transmitter to receiver is not limited. Each byte of eight bits is followed by one acknowledge bit. The acknowledge bit is a HIGH level put on the bus by the transmitter whereas the master generates an extra acknowledge related clock pulse.

A slave receiver which is addressed must generate an acknowledge after the reception of each byte. Also a master must generate an acknowledge after the reception of each byte that has been clocked out of the slave transmitter. The device that acknowledges has to pull down the SDA line during the acknowledge clock pulse, so that the SDA line is stable LOW during the HIGH period of the acknowledge related clock pulse, set-up and hold times must be taken into account.

A master receiver must signal an end of data to the transmitter by not generating an acknowledge on the last byte that has been clocked out of the slave. In this event, the transmitter must leave the data line HIGH to enable the master to generate a stop condition.

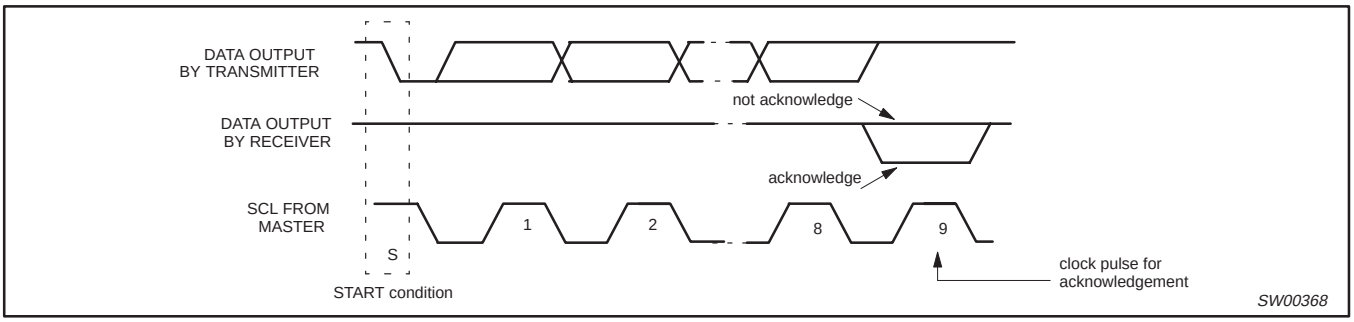


Figure 9. Acknowledgement on the I2C-bus

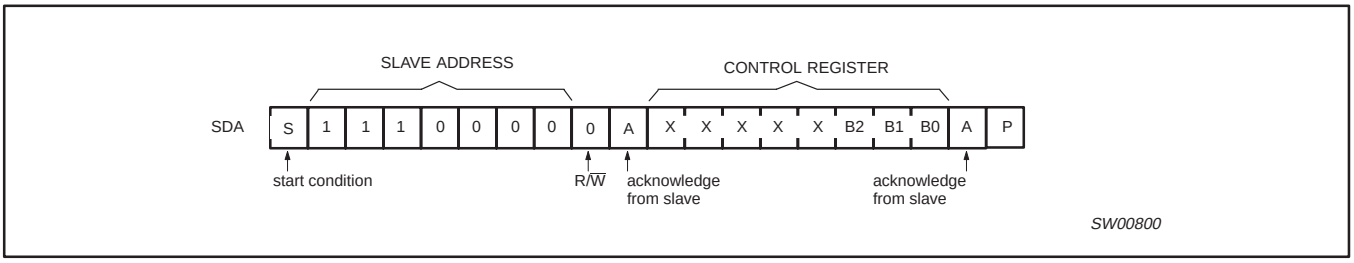


Figure 10. WRITE control register

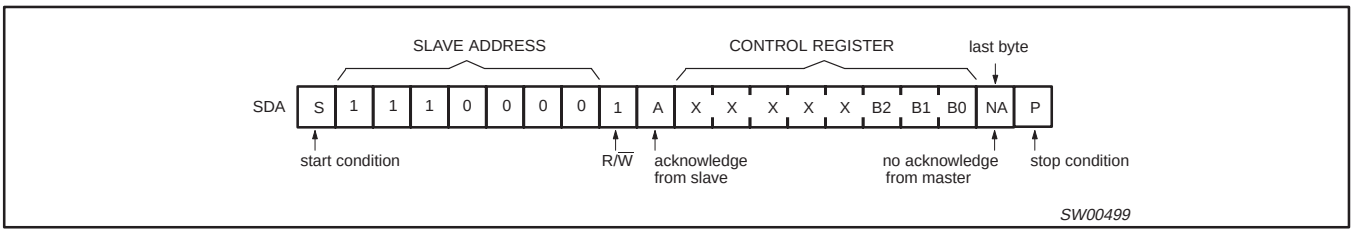


Figure 11. READ control register

TYPICAL APPLICATION

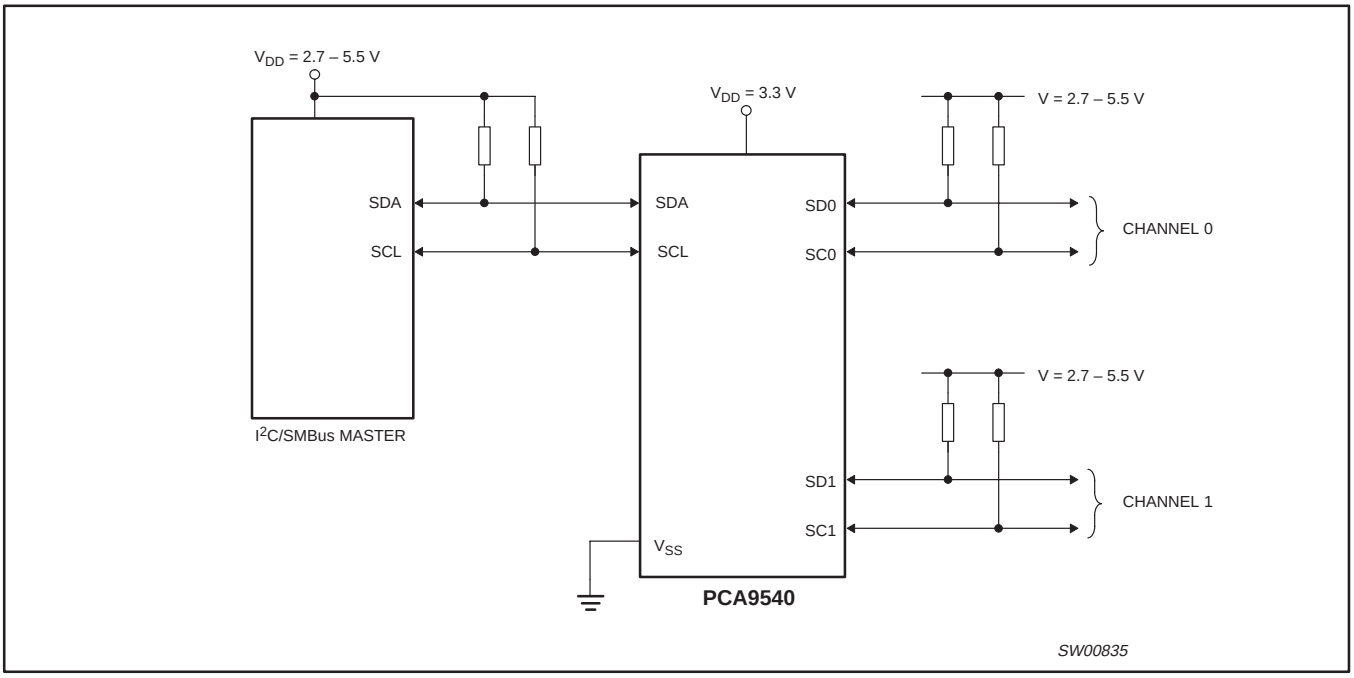


Figure 12. Typical application

ABSOLUTE MAXIMUM RATINGS[1, 2]

In accordance with the Absolute Maximum Rating System (IEC 134).Voltages are referenced to GND (ground = 0 V).

SYMBOL	PARAMETER	CONDITIONS	RATING	UNIT
V_{DD}	DC supply voltage		–0.5 to +7.0	V
V_I	DC input voltage		–0.5 to +7.0	V
I_I	DC input current		±20	mA
I_O	DC output current		±25	mA
I_{DD}	Supply current		±100	mA
I_{SS}	Supply current		±100	mA
P_{tot}	total power dissipation		400	mW
T_{stg}	Storage temperature range		–60 to +150	°C
T_{amb}	Operating ambient temperature		–40 to +85	°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.

DC CHARACTERISTICS

V_{DD} = 2.3 to 3.6 V; V_{SS} = 0 V; T_{amb} = –40 to +85 °C; unless otherwise specified. (See page 9 for V_{DD} = 3.6 to 5.5 V)

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNIT
			MIN	TYP	MAX	
Supply						
V_{DD}	Supply voltage		2.3	—	3.6	V
I_{DD}	Supply current	Operating mode; V_{DD} = 3.6 V; no load; $V_I = V_{DD}$ or V_{SS}; f_{SCL} = 100 kHz	—	50	100	µA
I_{stb}	Standby current	Standby mode; V_{DD} = 3.6 V; no load; $V_I = V_{DD}$ or V_{SS}; f_{SLC} = 0 kHz	—	20	100	µA
V_{POR}	Power-on reset voltage	no load; $V_I = V_{DD}$ or V_{SS}	—	1.6	2.1	V
Input SCL; input/output SDA						
V_{IL}	LOW level input voltage		–0.5	—	0.3 V_{DD}	V
V_{IH}	HIGH level input voltage		0.7 V_{DD}	—	6	V
I_{OL}	LOW level output current	V_{OL} = 0.4 V	3	—	—	mA
		V_{OL} = 0.6 V	6	—	—	mA
I_L	Leakage current	$V_I = V_{DD}$ or V_{SS}	–1	—	+1	µA
C_i	Input capacitance	$V_I = V_{SS}$	—	7	8	pF
Pass Gate						
R_{ON}	Switch resistance	V_{CC} = 3.0 to 3.6 V, V_O = 0.4 V, I_O = 15 mA	5	20	31	Ω
		V_{CC} = 2.3 to 2.7 V, V_O = 0.4 V, I_O = 10 mA	7	26	55	
V_{Pass}	Switch output voltage	$V_{swin} = V_{DD}$ = 3.3 V; I_{swout} = –100 µA	—	2.2	—	V
		$V_{swin} = V_{DD}$ = 3.0 to 3.6 V; I_{swout} = –100 µA	1.6	—	2.8	
		$V_{swin} = V_{DD}$ = 2.5 V; I_{swout} = –100 µA	—	1.5	—	
		$V_{swin} = V_{DD}$ = 2.3 to 2.7 V; I_{swout} = –100 µA	1.1	—	2.0	
I_L	Leakage current	$V_I = V_{DD}$ or V_{SS}	–1	—	+1	µA
C_{io}	Input/output capacitance	$V_I = V_{SS}$	—	2.5	5	pF

DC CHARACTERISTICS

V_{DD} = 3.6 to 5.5 V; V_{SS} = 0 V; T_{amb} = –40 to +85 °C; unless otherwise specified. (See page 8 for V_{DD} = 2.3 to 3.6 V)

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNIT
			MIN	TYP	MAX	
Supply						
V_{DD}	Supply voltage		3.6	—	5.5	V
I_{DD}	Supply current	Operating mode; V_{DD} = 5.5 V; no load; V_I = V_{DD} or V_{SS}; f_{SCL} = 100 kHz	—	580	700	µA
I_{stb}	Standby current	Standby mode; V_{DD} = 5.5 V; no load; V_I = V_{DD} or V_{SS}	—	100	200	µA
V_{POR}	Power-on reset voltage	no load; V_I = V_{DD} or V_{SS}	—	1.6	2.1	V
Input SCL; input/output SDA						
V_{IL}	LOW level input voltage		–0.5	—	0.3 V_{DD}	V
V_{IH}	HIGH level input voltage		0.7 V_{DD}	—	6	V
I_{OL}	LOW level output current	V_{OL} = 0.4 V	3	—	—	mA
		V_{OL} = 0.6 V	6	—	—	µA
I_{IL}	LOW level input current	V_I = V_{SS}	–10	—	10	mA
I_{IH}	HIGH level input current	V_I = V_{DD}	—	—	500	µA
C_i	Input capacitance	V_I = V_{SS}	—	6	8	pF
Pass Gate						
R_{ON}	Switch resistance	V_{CC} = 4.5 to 5.5 V, V_O = 0.4 V, I_O = 15 mA	4	11	24	Ω
V_{Pass}	Switch output voltage	V_{swin} = V_{DD} = 5.0 V; I_{swout} = –100 µA	—	3.5	—	V
		V_{swin} = V_{DD} = 4.5 to 5.5 V; I_{swout} = –100 µA	2.6	—	4.5	V
I_L	Leakage current	V_I = V_{DD} or V_{SS}	–1	—	+1	µA
C_{io}	Input/output capacitance	V_I = V_{SS}	—	2.5	5	pF

AC CHARACTERISTICS

SYMBOL	PARAMETER	STANDARD-MODE I²C-BUS		FAST-MODE I²C-BUS		UNIT
		MIN	MAX	MIN	MAX	
t_{pd}	Propagation delay from SDA to SD_n or SCL to SC_n	—	0.3[1]	—	0.3[1]	ns
f_{SCL}	SCL clock frequency	0	100	0	400	kHz
t_{BUF}	Bus free time between a STOP and START condition	4.7	—	1.3	—	µs
$t_{HD;STA}$	Hold time (repeated) START condition After this period, the first clock pulse is generated	4.0	—	0.6	—	µs
t_{LOW}	LOW period of the SCL clock	4.7	—	1.3	—	µs
t_{HIGH}	HIGH period of the SCL clock	4.0	—	0.6	—	µs
$t_{SU;STA}$	Set-up time for a repeated START condition	4.7	—	0.6	—	µs
$t_{SU;STO}$	Set-up time for STOP condition	4.0	—	0.6	—	µs
$t_{HD;DAT}$	Data hold time	0[2]	3.45	0[2]	0.9	µs
$t_{SU;DAT}$	Data set-up time	250	—	100	—	ns
t_R	Rise time of both SDA and SCL signals	—	1000	$20 + 0.1C_b$[3]	300	ns
t_F	Fall time of both SDA and SCL signals	—	300	$20 + 0.1C_b$[3]	300	µs
C_b	Capacitive load for each bus line	—	400	—	400	µs
t_{SP}	Pulse width of spikes which must be suppressed by the input filter	—	50	—	50	ns
$t_{VD:DATL}$	Data valid (HL)	—	1	—	1	µs
$t_{VD:DATH}$	Data valid (LH)	—	0.6	—	0.6	µs
$t_{VD:ACK}$	Data valid Acknowledge	—	1	—	1	µs

NOTES:
1. Pass gate propagation delay is calculated from the 20 Ω typical R_{ON} and and the 15 pF load capacitance.
2. A device must internally provide a hold time of at least 300 ns for the SDA signal (referred to the VIH_{min} of the SCL signal) in order to bridge the undefined region of the falling edge of SCL.
3. C_b = total capacitance of one bus line in pF.

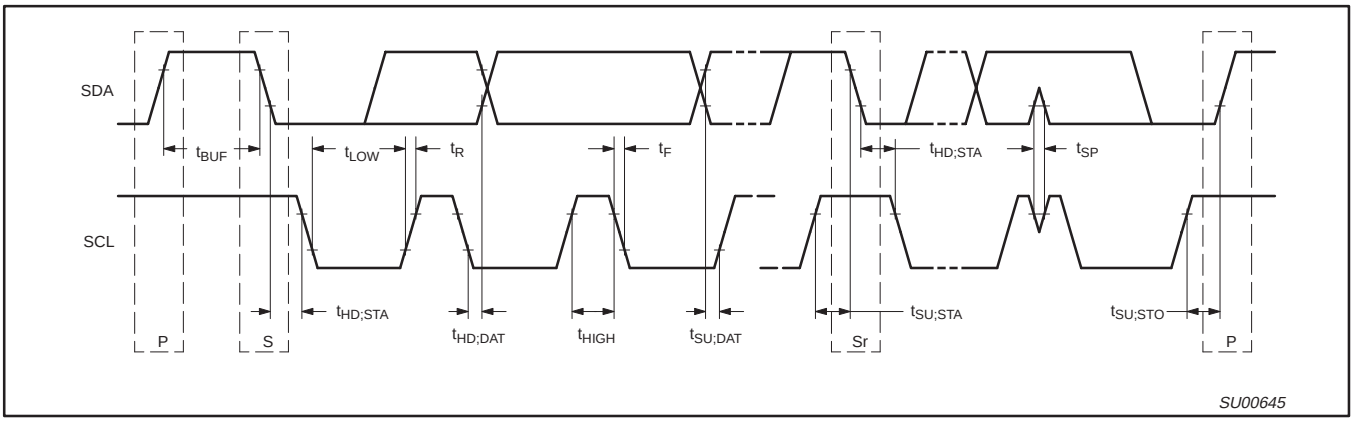
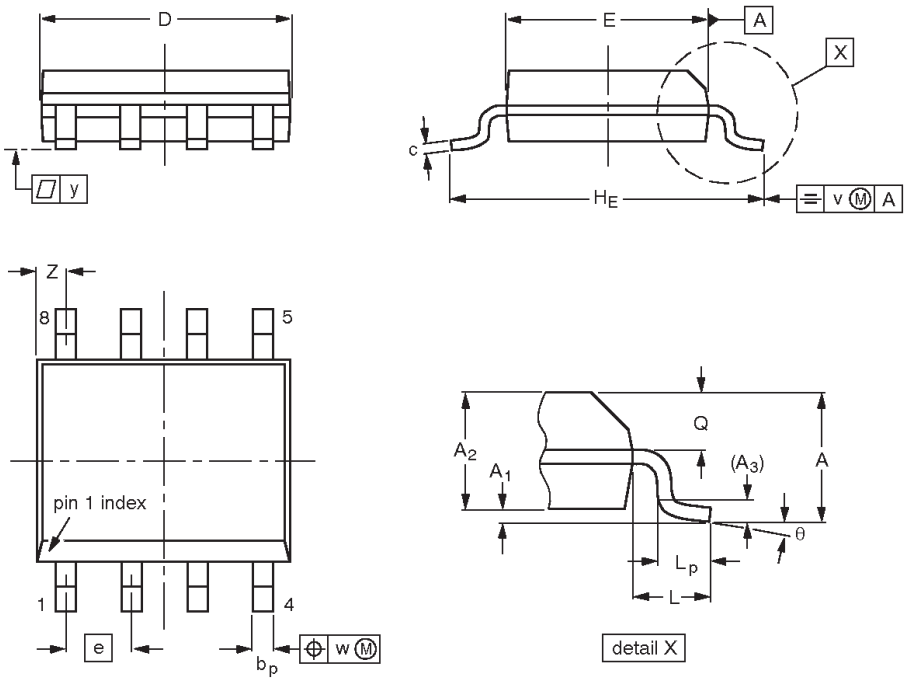
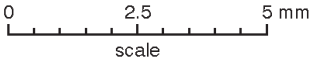


Figure 13. Definition of timing on the I²C-bus

SO8: plastic small outline package; 8 leads; body width 3.9 mm **SOT96-1**





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

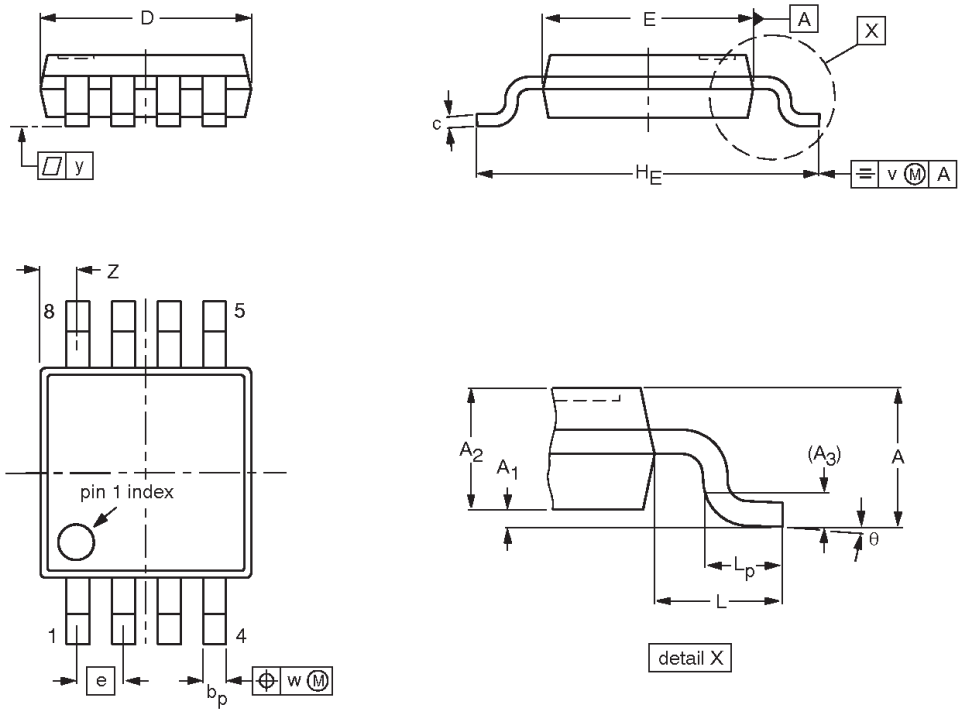
UNIT	A max.	A_1	A_2	A_3	b_p	c	$D^{(1)}$	$E^{(2)}$	e	H_E	L	L_p	Q	v	w	y	$Z^{(1)}$	θ
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	5.0 4.8	4.0 3.8	1.27	6.2 5.8	1.05	1.0 0.4	0.7 0.6	0.25	0.25	0.1	0.7 0.3	8^o 0^o
inches	0.069	0.010 0.004	0.057 0.049	0.01	0.019 0.014	0.0100 0.0075	0.20 0.19	0.16 0.15	0.050	0.244 0.228	0.041	0.039 0.016	0.028 0.024	0.01	0.01	0.004	0.028 0.012	

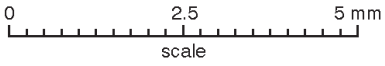
Notes

1. Plastic or metal protrusions of 0.15 mm 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	EIAJ			
SOT96-1	076E03	MS-012				~~97-05-22~~ 99-12-27

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_1	A_2	A_3	b_p	c	$D^{(1)}$	$E^{(2)}$	e	H_E	L	L_p	v	w	y	$Z^{(1)}$	θ
mm	1.10	0.15 0.05	0.95 0.80	0.25	0.45 0.25	0.28 0.15	3.10 2.90	3.10 2.90	0.65	5.10 4.70	0.94	0.70 0.40	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	EIAJ			
SOT505-1						99-04-09

2-channel I²C multiplexer PCA9540

Purchase of Philips I²C components conveys a license under the Philips' I²C patent to use the components in the I²C system provided the system conforms to the I²C specifications defined by Philips. This specification can be ordered using the code 9398 393 40011.

Data sheet status

Data sheet status[1]	Product status[2]	Definitions
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.
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.
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. Changes will be communicated according to the Customer Product/Process Change Notification (CPCN) procedure SNW-SQ-650A.

[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.

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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Date of release: 05-02

Document order number: 9397 750 09816

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