DATA SHEET

PDIUSBD11
USB device with serial interface

Product specification
Supersedes data of 1998 Feb 19
File under Integrated Circuits, IC22

1998 Nov 19

Philips
Semiconductors

PHILIPS

USB device with serial interface PDIUSBD11

FEATURES

- Complies with the Universal Serial Bus specification Rev. 1.1
- Complies with the ACPI, OnNOW, and USB power management requirements
- Compliant with USB Human Interface Devices and Monitor Control Class
- Compliant with System Management Bus Specification Rev. 1.0
- Integrated SIE (Serial Interface Engine), FIFO memory and transceivers
- Automatic USB protocol handling
- High speed I^2C Interface (up to 1 Mbit/s)
- Compatible with the PDIUSBH11 software
- Software controllable connection to USB bus (SoftConnect™)
- Low frequency 12 MHz crystal oscillator eases EMI design issues
- Programmable output clock frequency
- Bus powered capability with very low suspend current
- Controllable LazyClock output during suspend
- Single 3.3V supply with 5V tolerant I/O
- Available in 16-pin DIP and SO packages
- Full-scan design with high fault coverage (>99%) insures high quality
- Higher than 8 KV in-circuit ESD protection lowers cost of extra components

DESCRIPTION

The Universal Serial Bus hub PDIUSBD11 is a cost and feature-optimized USB interface device. It is used in microcontroller-based systems and communicates with the system microcontroller over the high speed I^2C serial bus. This modular approach to implementing USB functions allows the designer to choose the optimum system microcontroller from the available wide variety. This flexibility cuts down the development time, risks, and costs by allowing the use of the existing architecture and the firmware investments. This results in the fastest way to develop the most cost-effective USB peripheral solutions. The PDIUSBD11 is ideally suited for computer monitors, docking stations, keyboards, and many other applications that use the I^2C or the SMBus-based architecture.

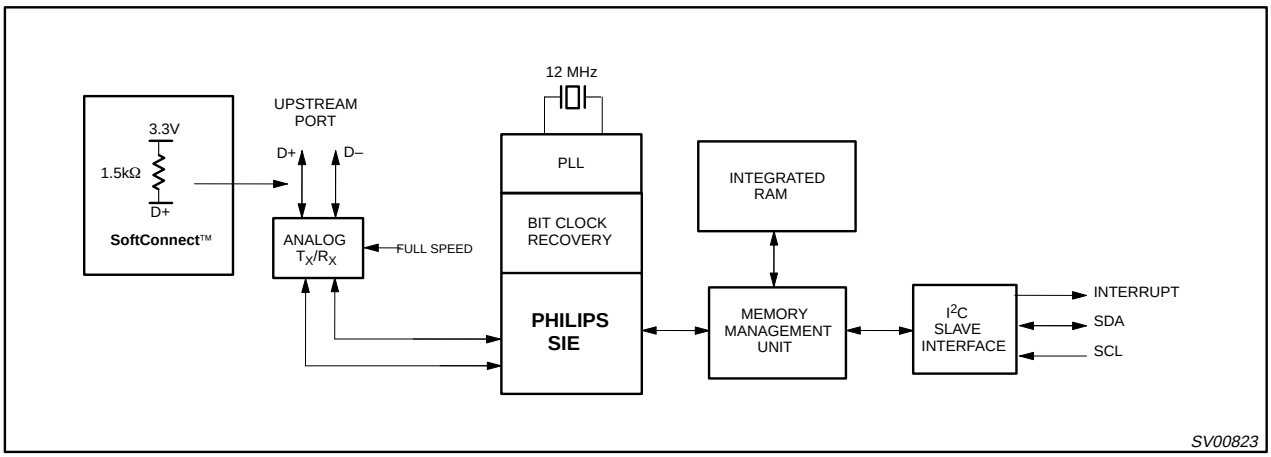
The PDIUSB11 conforms to the USB specification Rev. 1.1, I^2C serial interface and the SMBus specifications. It is fully compliant with the Human Interface Device Class and Monitor Control Class specifications. Its low suspend power consumption along with the programmable LazyClock output allows for easy implementation of equipment that is compliant to the ACPI, OnNOW, and USB power management requirements. The low operating power allows the implementation of bus-powered function.

The PDIUSBD11 is fully backward compatible to the PDIUSBH11/PDIUSBH11A software. In addition, it also incorporates the feature enhancements like SoftConnect™, LazyClock, programmable clock output, lower frequency crystal oscillator, multiple function endpoints and integration of termination resistors. All of these feature enhancements contribute to significant cost savings in the system implementation and at the same time ease the implementation of advanced USB functionality into the peripherals.

ORDERING INFORMATION

PACKAGES	TEMPERATURE RANGE	OUTSIDE NORTH AMERICA	NORTH AMERICA	PKG. DWG. #
16-pin plastic SO	–40°C to +85°C	PDIUSBD11 D	PDIUSBD11 D	SOT162-1
16-pin plastic DIP	–40°C to +85°C	PDIUSBD11 N	PDIUSBD11 N	SOT38-4

BLOCK DIAGRAM



NOTE:
1. This is a conceptual block diagram and does not include each individual signal.

Analog Transceiver
The transceiver interfaces directly to the USB cables through some termination resistors. They are capable of transmitting and receiving serial data at “full speed” (12 Mbit/s) only.

PLL
A 12 MHz to 48 MHz clock multiplier PLL (Phase-Locked Loop) is integrated on-chip. This allows for the use of low-cost 12 MHz crystal. EMI is also minimized due to lower frequency crystal. No external components are needed for the operation of the PLL.

Bit Clock Recovery
The bit clock recovery circuit recovers the clock from the incoming USB data stream using 4X over-sampling principle. It is able to track jitter and frequency drift specified by the USB specification.

Philips Serial Interface Engine (PSIE)
The Philips SIE implements the full USB protocol layer. It is completely hardwired for speed and needs no firmware intervention. The functions of this block include: synchronization pattern recognition, parallel/serial conversion, bit stuffing/de-stuffing, CRC checking/generation, PID verification/generation, address recognition, handshake evaluation/generation.

Memory Management Unit (MMU) and Integrated RAM
The MMU and the integrated RAM is used to handle the large difference in data rate between USB, running in bursts of 12 Mbit/s and the I^2C interface to the microcontroller, running at up to 1 Mbit/s. This allows the microcontroller to read and write USB packets at its own speed through I^2C.

I^2C Slave Interface
This block implements the necessary I^2C interface protocol. A slave I^2C allows for simple micro-coding. An interrupt is used to alert the microcontroller whenever the PDIUSBD11 needs attention. As a slave I^2C device, the PDIUSBD11 I^2C clock: SCL is an input and is controlled by the microcontroller. The I^2C interface can run up to 1 Mbit/s.

SoftConnect™
The connection to the USB is accomplished by bringing D+ (for high-speed USB device) high through a 1.5 kΩ pull-up resistor. In the PDIUSBD11, the 1.5 kΩ pull-up resistor is integrated on-chip and is not connected to V_{CC} by default. The connection of the internal resistor to Vcc is established through a command sent by the external/system microcontroller. This allows the system microcontroller to complete its initialization sequence before deciding to establish connection to the USB. Re-initialization of the USB bus connection can also be affected without requiring the pull out of the cable.

The PDIUSBD11 will check for USB VBUS availability before the connection can be established. VBUS sensing is provided through VBUS pin.

It should be noted that the tolerance of the internal resistors is higher (30%) than that specified by the USB specification (5%). However, the overall V_{SE} voltage specification for the connection can still be met with good margin. The decision to make sure of this feature lies with the users.

SoftConnect™ is a patent pending technology from Philips Semiconductors.

ENDPOINT DESCRIPTIONS

ENDPOINT#	ENDPOINT INDEX	TRANSFER TYPE	DIRECTION	MAX PACKET SIZE (BYTES)
0	2 3	Control	OUT IN	8 8
1	5 4	Generic	OUT IN	8 8
2	6 7	Generic	OUT IN	8 8
3	8 9	Generic	OUT IN	8 8

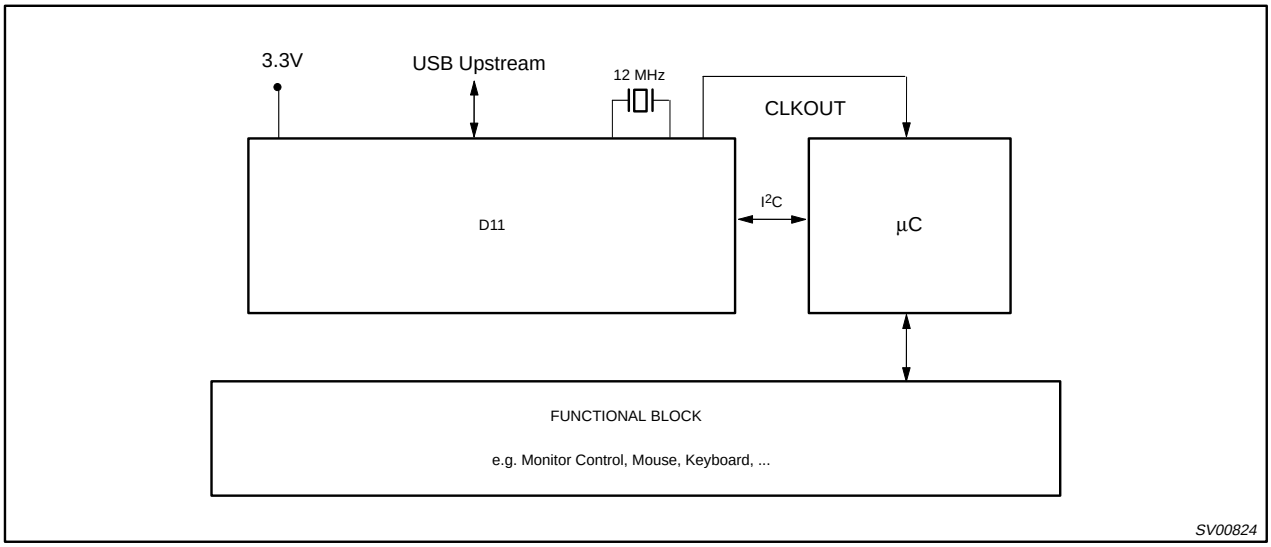
NOTE:
1. Generic endpoint can be used for Interrupt or Bulk endpoint.

PIN DESCRIPTION

PIN NO	PIN SYMBOL	TYPE	DRIVE	DESCRIPTION
1	TEST	Input		Connect to GND for normal operation
2	RESET_N	Input	ST	Power-on reset
3	XTAL1	Input		Crystal connection 1 (12MHz)
4	XTAL2	Output		Crystal connection 2 (12MHz)
5	CLKOUT	Output	3 mA	Programmable output clock for external devices
6	V_{CC}	Power		Voltage supply 3.3V±0.3V
7	SUSPEND	Output	OD6	Device is in suspended state
8	INT_N	Output	OD6	Connect to microcontroller interrupt
9	SDA	I/O	OD6	I^2C bi-directional data
10	SCL	I/O	OD6	I^2C bit-clock
11	GND	Power		Ground reference
12	DP	AI/O		USB D+ connection
13	DM	AI/O		USB D– connection
14	AGND	Power		Analog ground reference
15	AV_{CC}	Power		Analog voltage supply 3.3V±0.3V
16	VBUS	Input		USB VBUS sensing pin

NOTES:
1. Signals ending in _N indicate active LOW signals.
   ST: Schmitt Trigger
   OD6: Open Drain with 6 mA drive
   AI/O: Analog I/O

APPLICATION DIAGRAM



I²C Interface

The I²C bus is used to interface to an external microcontroller needed to control the operation of the USB device. For cost consideration, the target system microcontroller can be shared and utilized for both the functional part as well as the USB protocol interfacing. The PDIUSBD11 implements a slave I²C interface. When the PDIUSBD11 needs to communicate with the microcontroller it asserts an interrupt signal. The microcontroller services this interrupt by reading the appropriate status register on the PDIUSBD11 through the I²C bus. (For more information about the I²C serial bus, refer to the *I²C Handbook*, Philips order number 9397 750 00013).

The I²C interface on the PDIUSBD11 defines two types of transactions :

- **command transaction** – A command transaction is used to define which data (e.g., status byte, buffer data, ...) will be read from/written to the USB interface in the next data transaction. A data transaction usually follows a command transaction.
- **data transaction** – A data transaction reads data from/writes data to the USB interface. The meaning of the data is dependent on the command transaction which was sent before the data transaction.

Two addresses are used to differentiate between command and data transactions. Writing to the command address is interpreted as a command, while reading from/writing to the data address is used to transfer data between the PDIUSBH11A and the controller.

ADDRESS TABLE

Type of Address	Physical Address MSB to LSB (Binary)
Command	0011 011
Data	0011 010

Protocol

An I²C transaction starts with a Start Condition, followed by an address. When the address matches either the command or data address the transaction starts and runs until a Stop Condition or another Start Condition (repeated start) occurs.

The command address is write-only and is unable to do a read. The next bytes in the message are interpreted as commands. Several command bytes can be sent after one command address. Each of the command bytes is acknowledged and passed on to the Memory Management Unit inside the PDIUSBD11.

When the Start Condition address matches the data address, the next bytes are interpreted as data. When the RW bit in the address indicates a *master writes data to slave* (='0') the bytes are received, acknowledged and passed on to the Memory Management Unit. If the RW bit in the address indicates a *master reads data from slave* (='1') the PDIUSBD11 will send data to the master. The I²C-master must acknowledge all data bytes except the last one. In this way the I²C interface knows when the last byte has been transmitted and it then releases the SDA line so that the master controller can generate the Stop Condition.

Repeated start support allows another packet to be sent without generating a Stop Condition.

Timing

The I²C interface in the PDIUSBD11 can support clock speeds up to 1 MHz .

COMMAND SUMMARY

Some commands have the same command code (e.g., Read Buffer and Write Buffer). In these cases, the direction of the Data Phase (read or write) indicates which command is executed.

COMMAND NAME	RECIPIENT	CODING	DATA PHASE
Initialization Commands			
Set Address/Enable	Function	D1h	Write 1 byte
Set Endpoint Enable	Function	D8h	Write 1 byte
Set Mode	Function	F3h	Write 2 byte
Data Flow Commands			
Read Interrupt Register		F4h	Read 2 bytes
Select Endpoint	Control OUT Endpoint	00h	Read 1 byte (optional)
	Control IN Endpoint	01h	Read 1 byte (optional)
	Other Endpoints	00h+ Endpoint Index	Read 1 byte (optional)
Read Last Transaction Status	Control OUT Endpoint	40h	Read 1 byte
	Control IN Endpoint	41h	Read 1 byte
	Other Endpoints	40h+ Endpoint Index	Read 1 byte
Read Endpoint Status	Control OUT Endpoint	80h	Read 1 byte
	Control IN Endpoint	81h	Read 1 byte
	Other Endpoints	80h+ Endpoint Index	Read 1 byte
Read Buffer	Selected Endpoint	F0h	Read n bytes
Write Buffer	Selected Endpoint	F0h	Write n bytes
Set Endpoint Status	Control OUT Endpoint	40h	Write 1 byte
Set Endpoint Status	Control IN Endpoint	41h	Write 1 byte
	Other Endpoints	40h+ Endpoint Index	Write 1 byte
Acknowledge Setup	Selected Endpoint	F1h	None
Clear Buffer	Selected Endpoint	F2h	None
Validate Buffer	Selected Endpoint	FAh	None
General Commands			
Send Resume		F6h	None
Read Current Frame Number		F5h	Read 1 or 2 bytes

COMMAND DESCRIPTIONS

Command Procedure

There are three basic types of commands: Initialization , Data Flow, and General commands. Respectively, these are used to initialize the function; for data flow between the function and the host; and some general commands.

Initialization Commands

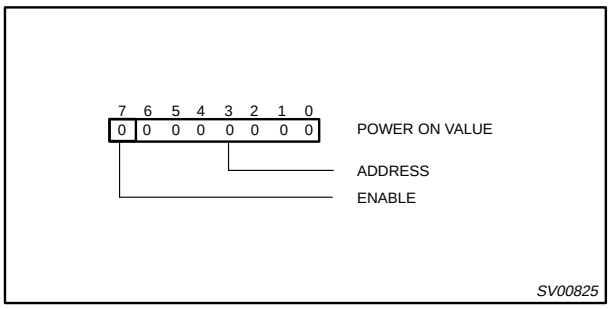
Initialization commands are used during the enumeration process of the USB network. These commands are used to enable the function endpoints. They are also used to set the USB assigned address.

Set Address / Enable

Command : D1h, (Function)

Data : Write 1 byte

This command is used to set the USB assigned address and enable the function.



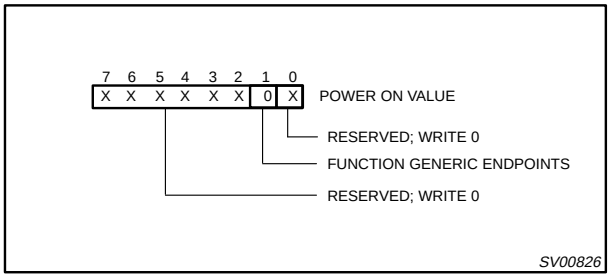
Address	The value written becomes the address.
Enable	A ‘1’ enables this function.

Set Endpoint Enable

Command : D8h

Data : Write 1 byte

The generic endpoints can only be enabled when the function is enabled via the Set Address/Enable command.



Function Generic Endpoint	A value of ‘1’ indicates the function generic endpoints are enabled.

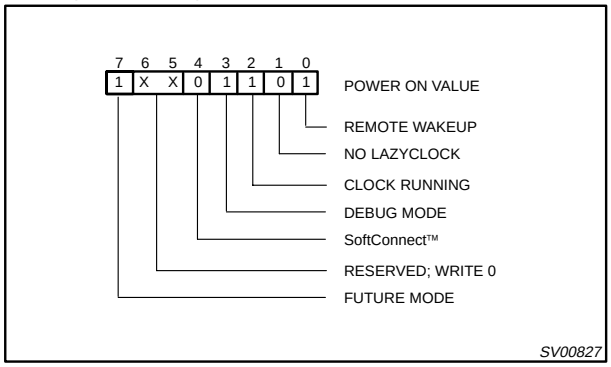
Set Mode

Command : F3h

Data : Write 2 bytes

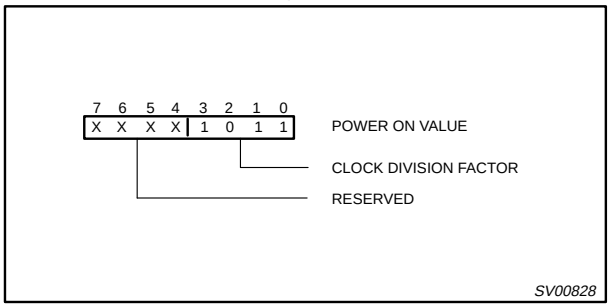
The Set Mode command is followed by two data writes. The first byte contains the configuration byte values. The second byte is the clock division factor byte.

Configuration Byte



Remote Wakeup	A ‘1’ indicates that a remote wakeup feature is ON. Bus reset will set this bit to ‘1’.
No LazyClock	A ‘1’ indicates that CLKOUT will not switch to LazyClock. A ‘0’ indicates that the CLKOUT switches to LazyClock 1ms after the Suspend pin goes high. LazyClock frequency is 30KHz ±40%. The programmed value will not be changed by a bus reset.
Clock Running	A ‘1’ indicates that the internal clocks and PLL are always running even during Suspend state. A ‘0’ indicates that the internal clock, crystal oscillator and PLL are stopped whenever not needed. To meet the strict Suspend current requirement, this bit needs to be set to ‘0’. The programmed value will not be changed by a bus reset.
Debug Mode	A ‘1’ indicates that all errors and “NAKing” are reported and a ‘0’ indicates that only OK and babbling are reported. The programmed value will not be changed by a bus reset.
SoftConnect™	A ‘1’ indicates that the upstream pull-up resistor will be connected if VBUS is available. A ‘0’ means that the upstream resistor will not be connected. The programmed value will not be changed by a bus reset.
FutureMode	Write a ‘1’.

Clock Division Factor Byte



Clock Division Factor — The value indicates clock division factor for CLKOUT. The output frequency is 48 MHz/(N+1) where N is the Clock Division Factor. The reset value is 11. This will produce the output frequency of 4 MHz which can then be programmed up (or down) by the user. The minimum value is one giving the range of frequency from 4 to 24 MHz. The PDIUSBD11 design ensures no glitching during frequency change. The programmed value will not be changed by a bus reset.

Data Flow Commands

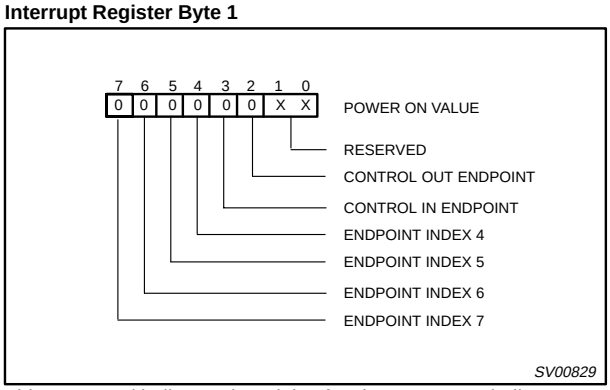
Data flow commands are used to manage the data transmission between the USB endpoints and the monitor. Much of the data flow is initiated via an interrupt to the microcontroller. The microcontroller utilizes these commands to access and determine whether the endpoint FIFOs have valid data.

Read Interrupt Register

Command : F4h

Data : Read 2 bytes

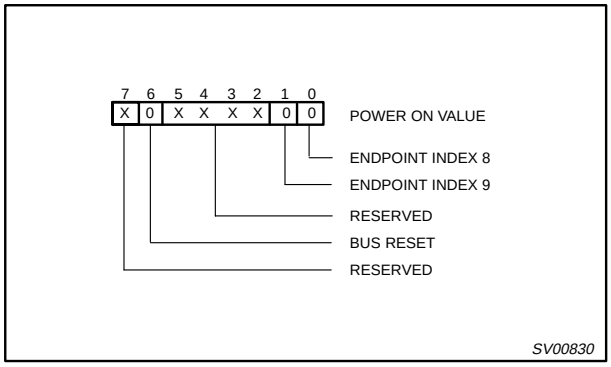
Interrupt Register Byte 1



This command indicates the origin of an interrupt. A ‘1’ indicates an interrupt occurred at this endpoint. The bits are cleared by reading the endpoint status register through the Read Endpoint Status command.

After a bus reset, an interrupt will be generated and bit 6 of the Interrupt Register Byte 2 will be ‘1’. The interrupt is internally cleared by reading the interrupt register. A bus reset is completely identical to the hardware reset through the RESET_N pin with the sole difference of interrupt notification.

Interrupt Register Byte 2

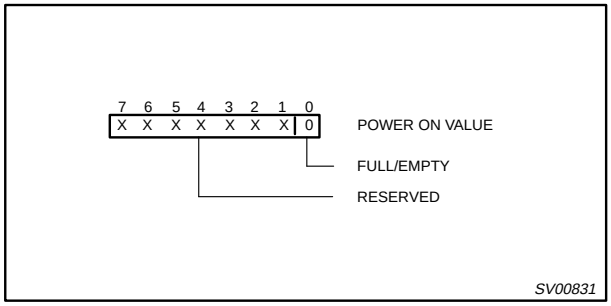


Select Endpoint

Command : 00-0Dh

Data : Optional Read 1 byte

The Select Endpoint command initializes an internal pointer to the start of the Selected buffer. Optionally, this command can be followed by a data read, which returns ‘0’ if the buffer is empty and ‘1’ if the buffer is full.



Full/Empty — A ‘1’ indicates the buffer is full, ‘0’ indicates an empty buffer.

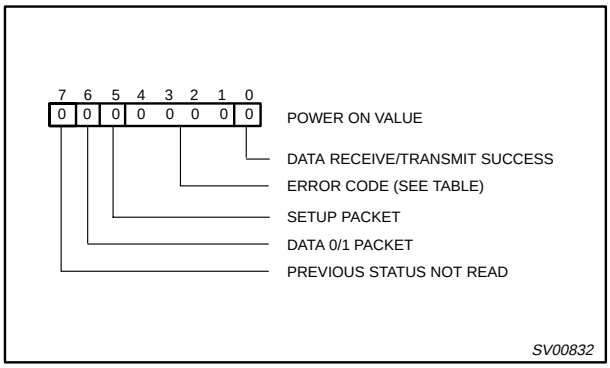
Read Last Transaction Status

Command : 40–4Dh

Data : Read 1 byte

The Read Last Transaction Status command is followed by one data read that returns the status of the last transaction of the endpoint. This command also resets the corresponding interrupt flag in the interrupt register, and clears the status, indicating that it was read.

This command is useful for debugging purposes. Since it keeps track of every transaction, the status information is overwritten for each new transaction.



Data Receive/Transmit Success	A ‘1’ indicates data has been received or transmitted successfully.
Error Code	See Table 1, Error Codes.
Setup Packet	A ‘1’ indicates the last successful received packet had a SETUP token (this will always read ‘0’ for IN buffers).
Data 0/1 Packet	A ‘1’ indicates the last successful received or sent packet had a DATA1 PID.
Previous Status not Read	A ‘1’ indicates a second event occurred before the previous status was read.

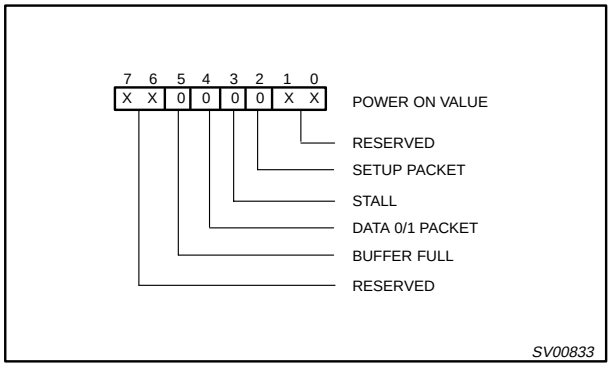
Table 1. ERROR CODES

ERROR CODE	RESULT
0000	No Error
0001	PID encoding Error; bits 7–4 are not the inversion of bits 3–0
0010	PID unknown; encoding is valid, but PID does not exist
0011	Unexpected packet; packet is not of the type expected (= token, data or acknowledge), or SETUP token to a non-control endpoint
0100	Token CRC Error
0101	Data CRC Error
0110	Time Out Error
0111	Babble Error
1000	Unexpected End-of-packet
1001	Sent or received NAK
1010	Sent Stall, a token was received, but the endpoint was stalled
1011	Overflow Error, the received packet was longer than the available buffer space
1101	Bitstuff Error
1111	Wrong DATA PID; the received DATA PID was not the expected one

Read Endpoint Status

Command : 80–8Dh

Data : Read 1 byte



Setup Packet	A ‘1’ indicates the last received packet had a SETUP token.
STALL	A ‘1’ indicates the endpoint is stalled.
Data 0/1 Packet	A ‘1’ indicates if the last received or sent packet had a DATA1 PID.
Buffer Full	A ‘1’ indicates that the buffer is full.

Read Buffer

Command : F0h

Data : Read multiple bytes (max 10)

The Read Buffer command is followed by a number of data reads, which return the contents of the selected endpoint data buffer. After each read, the internal buffer pointer is incremented by 1.

The buffer pointer is not reset to the buffer start by the Read Buffer command. This means that reading or writing a buffer can be interrupted by any other command (except for Select Endpoint), or can be done by more than one I^2C transaction (read the first 2 bytes to get the number of data bytes, then read the rest in other transactions).

The data in the buffer are organized as follows:

- byte 0: Reserved: can have any value
- byte 1: Number/length of data bytes
- byte 2: Data byte 1
- byte 3: Data byte 2

. . . . . .

Write Buffer

Command : F0h

Data : Write multiple bytes (max 10)

The Write Buffer command is followed by a number of data writes, which load the endpoints buffer. The data must be organized in the same way as described in the Read Buffer command. The first byte (reserved) should always be ‘0’. As in the Read Buffer command,

the data can be split up into different I^2C data transactions.

WARNING:
There is no protection against writing or reading over a buffer's boundary or against writing into an OUT buffer or reading from an IN buffer. Any of these actions could cause an incorrect operation. Data in an OUT buffer are only meaningful after a successful transaction.

Clear Buffer

Command : F2h

Data : None

When a packet is received completely, an internal endpoint buffer full flag is set. All subsequent packets will be refused by returning a NAK. When the microcontroller has read the data, it should free the buffer by the Clear Buffer command. When the buffer is cleared, new packets will be accepted.

Validate Buffer

Command : FAh

Data : None

When the microprocessor has written data into an IN buffer, it should set the buffer full flag by the Validate Buffer command. This indicates that the data in the buffer are valid and can be sent to the host when the next IN token is received.

Set Endpoint Status

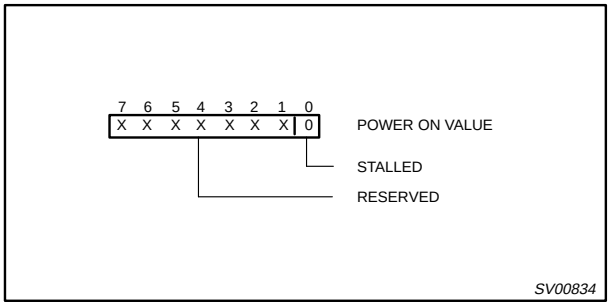
Command : 40–4Dh

Data : Write 1 byte

A stalled control endpoint is automatically unstalled when it receives a SETUP token, regardless of the content of the packet. If the endpoint should stay in its stalled state, the microcontroller can re-stall it.

When a stalled endpoint is unstalled (either by the Set Endpoint Status command or by receiving a SETUP token), it is also re-initialized. This flushes the buffer and if it is an OUT buffer it waits for a DATA 0 PID, if it is an IN buffer it writes a DATA 0 PID.

Even when unstalled, writing Set Endpoint Status to '0' initializes the endpoint.



Stalled A '1' indicates the endpoint is stalled.

Acknowledge Setup

Command : F1h

Data : None

The arrival of a SETUP packet flushes the IN buffer and disables the Validate Buffer and Clear Buffer commands for both IN and OUT endpoints.

The microcontroller needs to re-enable these commands by the Acknowledge Setup command. This ensures that the last SETUP packet stays in the buffer and no packet can be sent back to the host until the microcontroller has acknowledged explicitly that it has seen the SETUP packet.

The microcontroller must send the Acknowledge Setup command to both the IN and OUT endpoints.

GENERAL COMMANDS

Send Resume

Command : F6h

Data : None

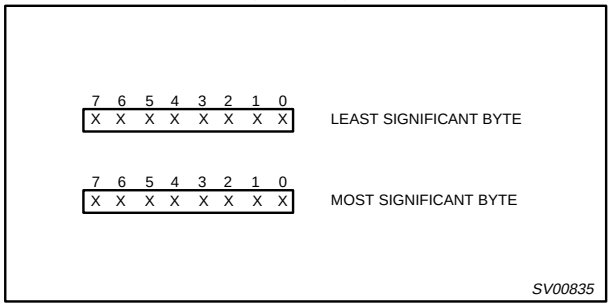
Sends an upstream resume signal for 10 ms. This command is normally issued when the device is in suspend. The RESUME command is not followed by a data read or write.

Read Current Frame Number

Command : F5h

Data : Read One or Two Bytes

This command is followed by one or two data reads and returns the frame number of the last successfully received SOF. The frame number is returned Least Significant Byte first.



RECOMMENDED OPERATING CONDITIONS

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
V_{CC}	DC supply voltage		3.0	3.6	V
V_I	DC input voltage range		0	5.5	V
$V_{I/O}$	DC input voltage range for I/O		0	5.5	V
$V_{AI/O}$	DC input voltage range for analog I/O		0	V_{CC}	V
V_O	DC output voltage range		0	V_{CC}	V
T_{amb}	Operating ambient temperature range in free air	See DC and AC characteristics per device	–40	85	°C

ABSOLUTE MAXIMUM RATINGS[1]

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
V_{CC}	DC supply voltage		–0.5	+4.6	V
I_{IK}	DC input diode current	$V_I < 0$		–50	mA
V_I	DC input voltage	Note 2	–0.5	+5.5	V
$V_{I/O}$	DC input voltage range for I/O		–0.5	V_{CC} + 0.5	V
I_{OK}	DC output diode current	$V_O > V_{CC}$ or $V_O < 0$		±50	mA
V_O	DC output voltage	Note 2	–0.5	V_{CC} + 0.5	V
I_O	DC output sink or source current for other pins	V_O = 0 to V_{CC}		±15	mA
I_O	DC output sink or source current for D+/D– pins	V_O = 0 to V_{CC}		±50	mA
I_{GND}, I_{CC}	DC V_{CC} or GND current			±100	mA
T_{STG}	Storage temperature range		–60	+150	°C
P_{TOT}	Power dissipation per package				

NOTES:
1. Stresses beyond those listed may cause damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those listed in the RECOMMENDED OPERATING CONDITIONS table is not implied. Exposure to absolute maximum rated conditions for extended periods may affect device reliability.
2. The input and output voltage ratings may be exceeded if the input and output current ratings are observed.

DC CHARACTERISTICS (Digital pins)

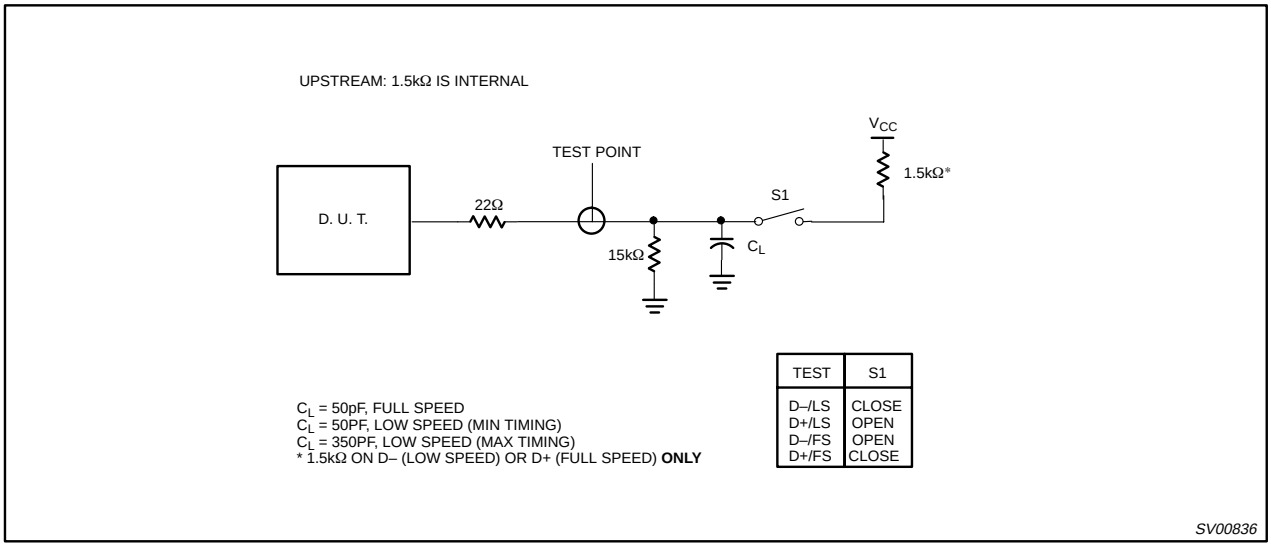
SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Input Levels:					
V_{IL}	LOW level input voltage				0.6	V
VIH	HIGH level input voltage		2.7			V
V_{TLH}	LOW to HIGH threshold voltage	ST (Schmitt Trigger) pins	1.4		1.9	V
V_{THL}	HIGH to LOW threshold voltage	ST pins	0.9		1.5	V
V_{HYS}	Hysteresis voltage	ST pins	0.4		0.7	V
	Output Levels:					
V_{OL}	LOW level output voltage	I_{OL} = rated drive I_{OL} = 20 µA			0.4 0.1	V
V_{OH}	HIGH level output voltage	I_{OH} = rated drive I_{OH} = 20 µA	2.4 V_{CC} – 0.1			V
	Leakage Current:					
I_{OZ}	OFF state current	OD (Open Drain) pins			±5	µA
I_L	Input leakage current				±5	µA

DC CHARACTERISTICS (AI/O pins)

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
	Leakage Current:				
I_{LO}	Hi-Z state data line leakage	$0V < V_{IN} < 3.3V$		±10	µA
	Input Levels:				
V_{DI}	Differential input sensitivity	$\|(D+) – (D–)\|$[1]	0.2		V
V_{CM}	Differential common mode range	Includes V_{DI} range	0.8	2.5	V
V_{SE}	Single-ended receiver threshold		0.8	2.0	V
	Output Levels:				
V_{OL}	Static output LOW	R_L of 1.5kΩ to 3.6V		0.3	V
V_{OH}	Static output HIGH	R_L of 15kΩ to GND	2.8	3.6	V
	Capacitance:				
C_{IN}	Transceiver capacitance	Pin to GND		20	pF
	Output Resistance:				
Z_{DRV}[2]	Driver output resistance	Steady state drive	29	44	Ω
	Integrated Resistance:				
Z_{PU}	Pull-up resistance	SoftConnect™ = ON	1.1	1.9	kΩ
Z_{PD}	Pull-down resistance	Pull-down = ON	11	19	kΩ

NOTES:
1. D+ is the symbol for the USB positive data pin: DP.
   D– is the symbol for the USB negative data pin: DM.
2. Includes external resistors of 22 Ω ± 1% each on D+ and D–.

LOAD FOR D+/D–



AC CHARACTERISTICS (AI/O pins, FULL speed)

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
	Driver characteristics:	C_L = 50pF; R_{pu} = 1.5kΩ on D+ to V_{CC}			
 T_r T_f	Transition Time: Rise time Fall time	Between 10% and 90%	 4 4	 20 20	ns
T_{RFM}	Rise/fall time matching	(T_r/T_f)	90	110	%
V_{CRS}	Output signal crossover voltage		1.3	2.0	V
	Driver Timings:				
T_{EOPT}	Source EOP width	Figure 1	160	175	ns
T_{DEOP}	Differential data to EOP transition skew	Figure 1	–2	5	ns
	Receiver Timings:				
 T_{JR1} T_{JR2}	Receiver Data Jitter Tolerance To next transition For paired transitions	 Characterized and not tested. Guaranteed by design.	 –18.5 –9	 18.5 9	ns
 T_{EOPR1} T_{EOPR2}	EOP Width at Receiver Must reject as EOP Must accept	Figure 1	 40 82		ns

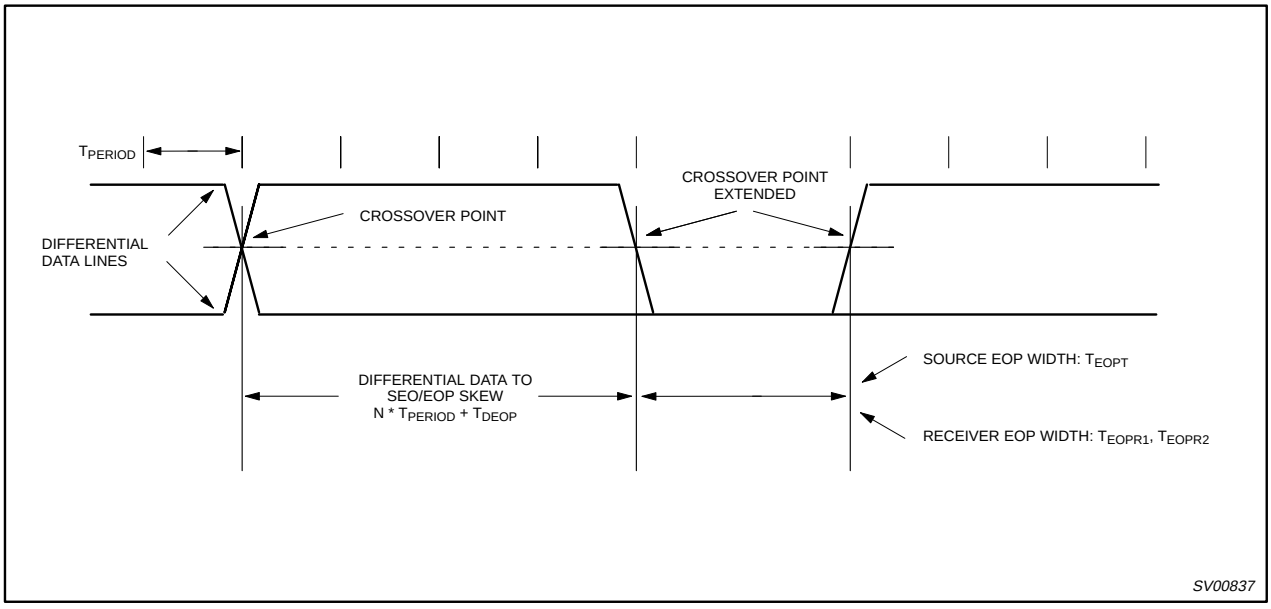


Figure 1. Differential data to EOP transition skew and EOP width

AC CHARACTERISTICS (I²C pins)

All timing values are valid within the operating supply voltage and ambient temperature range and reference to V_{IL} and V_{IH} with an input voltage swing of V_{SS} and V_{DD}.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
F_{SCL}	S_{CL} clock frequency			1000	kHz
T_{BUF}	Bus free time		0.5		µs
$T_{SU;STA}$	Start condition set-up time		0.25		µs
$T_{HD;STA}$	Start condition hold time		0.25		µs
T_{LOW}	S_{CL} LOW time		0.45		µs
T_{HIGH}	S_{CL} HIGH time		0.45		µs
T_r	S_{CL} and S_{DA} rise time			0.3	µs
T_f	S_{CL} and S_{DA} fall time			0.1	µs
$T_{SU;DAT}$	Data set-up time		100		ns
$T_{HD;DAT}$	Data hold time		0		ns
$T_{VD;DAT}$	S_{CL} LOW to data out valid			0.4	µs
$T_{SU;STO}$	Stop condition set-up time		0.25		µs

A detailed description of the I²C-bus specification, with applications, is given in the brochure "*The I²C-bus and how to use it*". This brochure may be ordered using the Philips order number 9398 393 40011.

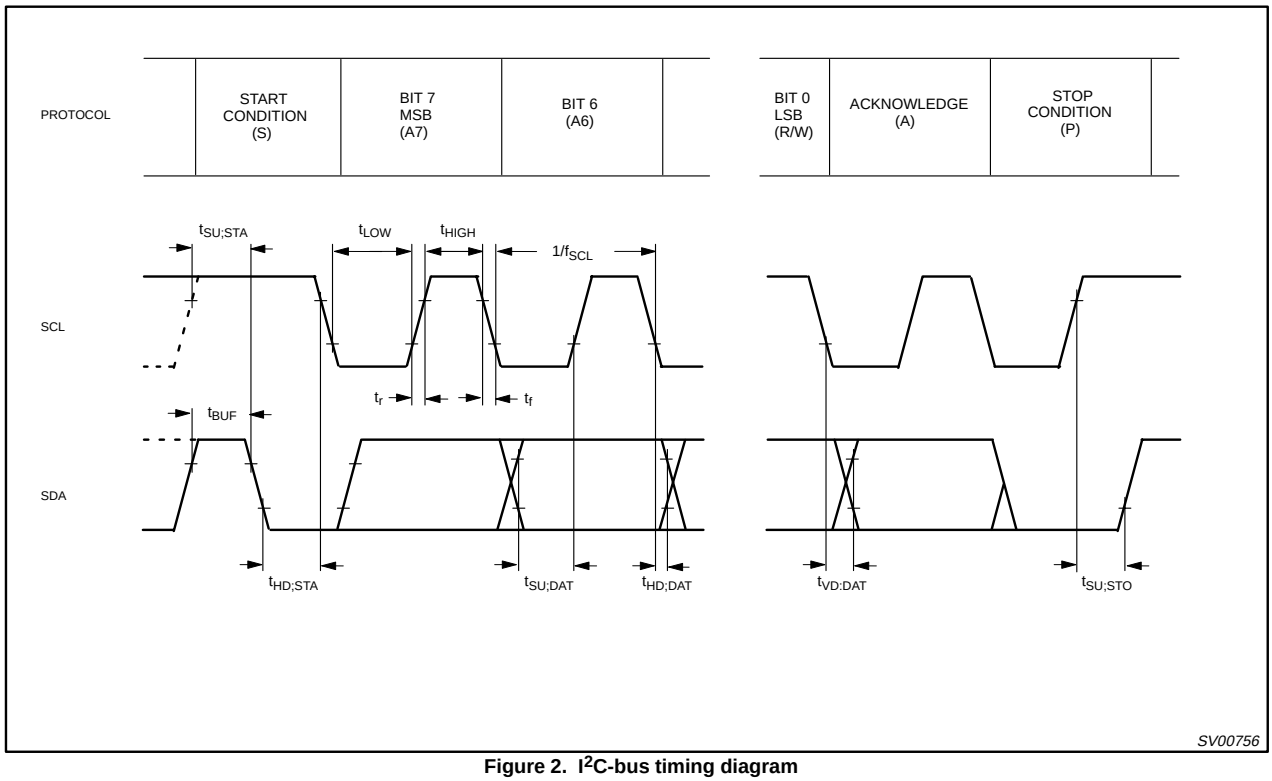
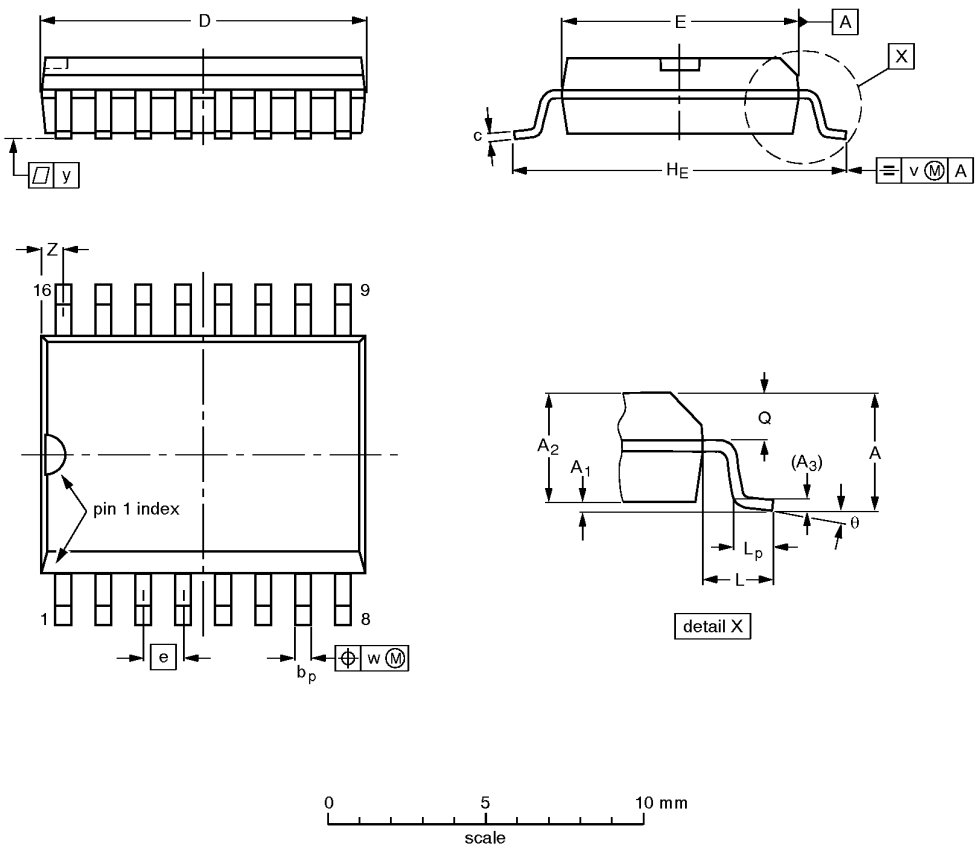


Figure 2. I²C-bus timing diagram

SO16: plastic small outline package; 16 leads; body width 7.5 mm **SOT162-1**



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

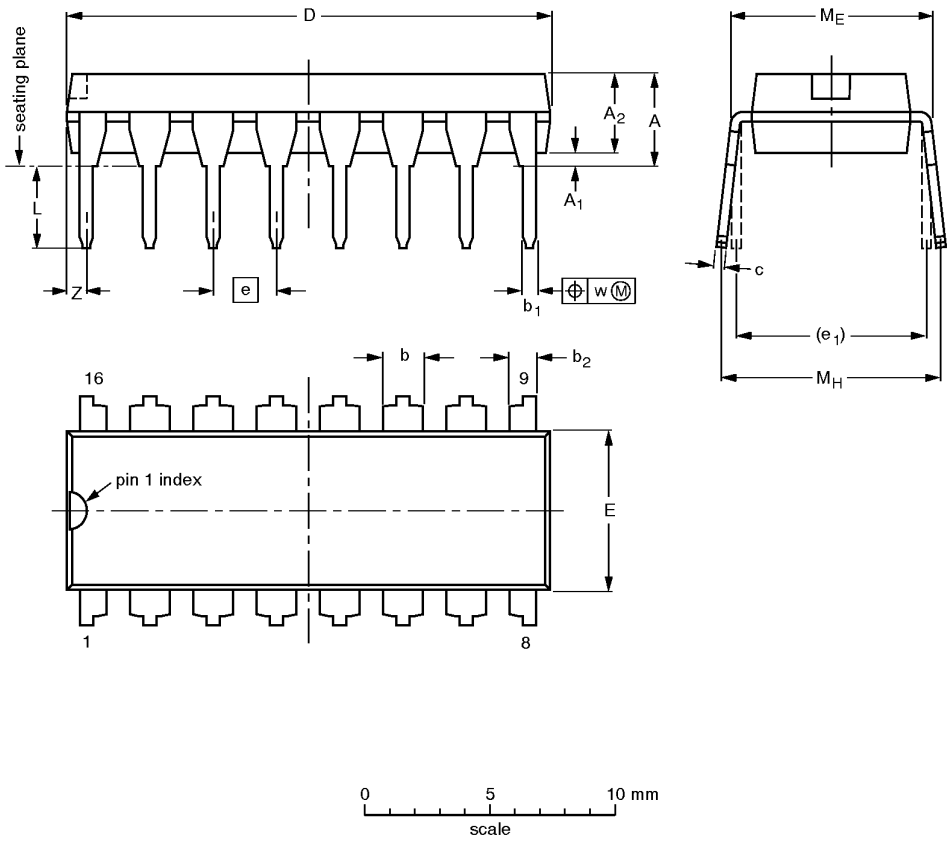
UNIT	A max.	A_1	A_2	A_3	b_p	c	D (1)	E (1)	e	H_E	L	L_p	Q	v	w	y	Z (1)	θ
mm	2.65	0.30 0.10	2.45 2.25	0.25	0.49 0.36	0.32 0.23	10.5 10.1	7.6 7.4	1.27	10.65 10.00	1.4	1.1 0.4	1.1 1.0	0.25	0.25	0.1	0.9 0.4	8° 0°
inches	0.10	0.012 0.004	0.096 0.089	0.01	0.019 0.014	0.013 0.009	0.41 0.40	0.30 0.29	0.050	0.42 0.39	0.055	0.043 0.016	0.043 0.039	0.01	0.01	0.004	0.035 0.016	

Note

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

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT162-1	075E03	MS-013AA				~~92-11-17~~ 95-01-24

DIP16: plastic dual in-line package; 16 leads (300 mil) **SOT38-4**



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

UNIT	A max.	A_1 min.	A_2 max.	b	b_1	b_2	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 1.30	0.53 0.38	1.25 0.85	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	0.76
inches	0.17	0.020	0.13	0.068 0.051	0.021 0.015	0.049 0.033	0.014 0.009	0.77 0.73	0.26 0.24	0.10	0.30	0.14 0.12	0.32 0.31	0.39 0.33	0.01	0.030

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			
SOT38-4						~~92-11-17~~ 95-01-14

SOLDERING

Introduction

This text gives a very brief insight to a complex technology. A more in-depth account of soldering ICs can be found in our *"Data Handbook IC26; Integrated Circuit Packages"* (document order number 9398 652 90011).

There is no soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and surface mount components are mixed on one printed-circuit board. However, wave soldering is not always suitable for surface mount ICs, or for printed-circuit boards with high population densities. In these situations reflow soldering is often used.

Through-hole mount packages

SOLDERING BY DIPPING OR BY SOLDER WAVE

The maximum permissible temperature of the solder is 260 °C; solder at this temperature must not be in contact with the joints for more than 5 seconds. The total contact time of successive solder waves must not exceed 5 seconds.

The device may be mounted up to the seating plane, but the temperature of the plastic body must not exceed the specified maximum storage temperature ($T_{stg(max)}$). If the printed-circuit board has been pre-heated, forced cooling may be necessary immediately after soldering to keep the temperature within the permissible limit.

MANUAL SOLDERING

Apply the soldering iron (24 V or less) to the lead(s) of the package, either below the seating plane or not more than 2 mm above it. If the temperature of the soldering iron bit is less than 300 °C it may remain in contact for up to 10 seconds. If the bit temperature is between 300 and 400 °C, contact may be up to 5 seconds.

Surface mount packages

REFLOW SOLDERING

Reflow soldering requires solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the printed-circuit board by screen printing, stencilling or pressure-syringe dispensing before package placement.

Several methods exist for reflowing; for example, infrared/convection heating in a conveyor type oven. Throughput times (preheating, soldering and cooling) vary between 100 and 200 seconds depending on heating method.

Typical reflow peak temperatures range from 215 to 250 °C. The top-surface temperature of the packages should preferable be kept below 230 °C.

WAVE SOLDERING

Conventional single wave soldering is not recommended for surface mount devices (SMDs) or printed-circuit boards with a high component density, as solder bridging and non-wetting can present major problems.

To overcome these problems the double-wave soldering method was specifically developed.

If wave soldering is used the following conditions must be observed for optimal results:

- Use a double-wave soldering method comprising a turbulent wave with high upward pressure followed by a smooth laminar wave.
- For packages with leads on two sides and a pitch (e):
  - larger than or equal to 1.27 mm, the footprint longitudinal axis is **preferred** to be parallel to the transport direction of the printed-circuit board;
  - smaller than 1.27 mm, the footprint longitudinal axis **must** be parallel to the transport direction of the printed-circuit board.

  The footprint must incorporate solder thieves at the downstream end.
- For packages with leads on four sides, the footprint must be placed at a 45° angle to the transport direction of the printed-circuit board. The footprint must incorporate solder thieves downstream and at the side corners.

During placement and before soldering, the package must be fixed with a droplet of adhesive. The adhesive can be applied by screen printing, pin transfer or syringe dispensing. The package can be soldered after the adhesive is cured.

Typical dwell time is 4 seconds at 250 °C.
A mildly-activated flux will eliminate the need for removal of corrosive residues in most applications.

MANUAL SOLDERING

Fix the component by first soldering two diagonally-opposite end leads. Use a low voltage (24 V or less) soldering iron applied to the flat part of the lead. Contact time must be limited to 10 seconds at up to 300 °C.

When using a dedicated tool, all other leads can be soldered in one operation within 2 to 5 seconds between 270 and 320 °C.

Suitability of IC packages for wave, reflow and dipping soldering methods

MOUNTING	PACKAGE	SOLDERING METHOD		
		WAVE	REFLOW(1)	DIPPING
Through-hole mount	DBS, DIP, HDIP, SDIP, SIL	suitable(2)	–	suitable
Surface mount	BGA, SQFP	not suitable	suitable	–
	HLQFP, HSQFP, HSOP, SMS	not suitable(3)	suitable	–
	PLCC(4), SO, SOJ	suitable	suitable	–
	LQFP, QFP, TQFP	not recommended(4)(5)	suitable	–
	SSOP, TSSOP, VSO	not recommended(6)	suitable	–

Notes

1. All surface mount (SMD) packages are moisture sensitive. Depending upon the moisture content, the maximum temperature (with respect to time) and body size of the package, there is a risk that internal or external package cracks may occur due to vaporization of the moisture in them (the so called popcorn effect). For details, refer to the Drypack information in the *"Data Handbook IC26; Integrated Circuit Packages; Section: Packing Methods"*.
2. For SDIP packages, the longitudinal axis must be parallel to the transport direction of the printed-circuit board.
3. These packages are not suitable for wave soldering as a solder joint between the printed-circuit board and heatsink (at bottom version) can not be achieved, and as solder may stick to the heatsink (on top version).
4. If wave soldering is considered, then the package must be placed at a 45° angle to the solder wave direction. The package footprint must incorporate solder thieves downstream and at the side corners.
5. Wave soldering is only suitable for LQFP, QFP and TQFP packages with a pitch (e) equal to or larger than 0.8 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.65 mm.
6. Wave soldering is only suitable for SSOP and TSSOP packages with a pitch (e) equal to or larger than 0.65 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.5 mm.

DEFINITIONS

Data sheet status	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). 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.	
Application information	
Where application information is given, it is advisory and does not form part of the specification.	

LIFE SUPPORT APPLICATIONS

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips for any damages resulting from such improper use or sale.

PURCHASE OF PHILIPS I²C COMPONENTS

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 specification defined by Philips. This specification can be ordered using the code 9398 393 40011.

Philips Semiconductors – a worldwide company

Argentina: see South America

Australia: 34 Waterloo Road, NORTH RYDE, NSW 2113,
Tel. +61 2 9805 4455, Fax. +61 2 9805 4466

Austria: Computerstr. 6, A-1101 WIEN, P.O. Box 213, Tel. +43 160 1010,
Fax. +43 160 101 1210

Belarus: Hotel Minsk Business Center, Bld. 3, r. 1211, Volodarski Str. 6,
220050 MINSK, Tel. +375 172 200 733, Fax. +375 172 200 773

Belgium: see The Netherlands

Brazil: see South America

Bulgaria: Philips Bulgaria Ltd., Energoproject, 15th floor,
51 James Bourchier Blvd., 1407 SOFIA,
Tel. +359 2 689 211, Fax. +359 2 689 102

Canada: PHILIPS SEMICONDUCTORS/COMPONENTS,
Tel. +1 800 234 7381

China/Hong Kong: 501 Hong Kong Industrial Technology Centre,
72 Tat Chee Avenue, Kowloon Tong, HONG KONG,
Tel. +852 2319 7888, Fax. +852 2319 7700

Colombia: see South America

Czech Republic: see Austria

Denmark: Prags Boulevard 80, PB 1919, DK-2300 COPENHAGEN S,
Tel. +45 32 88 2636, Fax. +45 31 57 0044

Finland: Sinikalliontie 3, FIN-02630 ESPOO,
Tel. +358 9 615800, Fax. +358 9 61580920

France: 51 Rue Carnot, BP317, 92156 SURESNES Cedex,
Tel. +33 1 40 99 6161, Fax. +33 1 40 99 6427

Germany: Hammerbrookstraße 69, D-20097 HAMBURG,
Tel. +49 40 23 53 60, Fax. +49 40 23 536 300

Greece: No. 15, 25th March Street, GR 17778 TAVROS/ATHENS,
Tel. +30 1 4894 339/239, Fax. +30 1 4814 240

Hungary: see Austria

India: Philips INDIA Ltd, Band Box Building, 2nd floor,
254-D, Dr. Annie Besant Road, Worli, MUMBAI 400 025,
Tel. +91 22 493 8541, Fax. +91 22 493 0966

Indonesia: PT Philips Development Corporation, Semiconductors Division,
Gedung Philips, Jl. Buncit Raya Kav.99-100, JAKARTA 12510,
Tel. +62 21 794 0040 ext. 2501, Fax. +62 21 794 0080

Ireland: Newstead, Clonskeagh, DUBLIN 14,
Tel. +353 1 7640 000, Fax. +353 1 7640 200

Israel: RAPAC Electronics, 7 Kehilat Saloniki St, PO Box 18053,
TEL AVIV 61180, Tel. +972 3 645 0444, Fax. +972 3 649 1007

Italy: PHILIPS SEMICONDUCTORS, Piazza IV Novembre 3,
20124 MILANO, Tel. +39 2 6752 2531, Fax. +39 2 6752 2557

Japan: Philips Bldg 13-37, Kohnan 2-chome, Minato-ku,
TOKYO 108-8507, Tel. +81 3 3740 5130, Fax. +81 3 3740 5077

Korea: Philips House, 260-199 Itaewon-dong, Yongsan-ku, SEOUL,
Tel. +82 2 709 1412, Fax. +82 2 709 1415

Malaysia: No. 76 Jalan Universiti, 46200 PETALING JAYA, SELANGOR,
Tel. +60 3 750 5214, Fax. +60 3 757 4880

Mexico: 5900 Gateway East, Suite 200, EL PASO, TEXAS 79905,
Tel. +9-5 800 234 7381

Middle East: see Italy

Netherlands: Postbus 90050, 5600 PB EINDHOVEN, Bldg. VB,
Tel. +31 40 27 82785, Fax. +31 40 27 88399

New Zealand: 2 Wagener Place, C.P.O. Box 1041, AUCKLAND,
Tel. +64 9 849 4160, Fax. +64 9 849 7811

Norway: Box 1, Manglerud 0612, OSLO,
Tel. +47 22 74 8000, Fax. +47 22 74 8341

Pakistan: see Singapore

Philippines: Philips Semiconductors Philippines Inc.,
106 Valero St. Salcedo Village, P.O. Box 2108 MCC, MAKATI,
Metro MANILA, Tel. +63 2 816 6380, Fax. +63 2 817 3474

Poland: Ul. Lukiska 10, PL 04-123 WARSZAWA,
Tel. +48 22 612 2831, Fax. +48 22 612 2327

Portugal: see Spain

Romania: see Italy

Russia: Philips Russia, Ul. Usatcheva 35A, 119048 MOSCOW,
Tel. +7 095 755 6918, Fax. +7 095 755 6919

Singapore: Lorong 1, Toa Payoh, SINGAPORE 319762,
Tel. +65 350 2538, Fax. +65 251 6500

Slovakia: see Austria

Slovenia: see Italy

South Africa: S.A. PHILIPS Pty Ltd., 195-215 Main Road Martindale,
2092 JOHANNESBURG, P.O. Box 7430 Johannesburg 2000,
Tel. +27 11 470 5911, Fax. +27 11 470 5494

South America: Al. Vicente Pinzon, 173, 6th floor,
04547-130 SÃO PAULO, SP, Brazil,
Tel. +55 11 821 2333, Fax. +55 11 821 2382

Spain: Balmes 22, 08007 BARCELONA,
Tel. +34 93 301 6312, Fax. +34 93 301 4107

Sweden: Kottbygatan 7, Akalla, S-16485 STOCKHOLM,
Tel. +46 8 5985 2000, Fax. +46 8 5985 2745

Switzerland: Allmendstrasse 140, CH-8027 ZÜRICH,
Tel. +41 1 488 2741 Fax. +41 1 488 3263

Taiwan: Philips Semiconductors, 6F, No. 96, Chien Kuo N. Rd., Sec. 1,
TAIPEI, Taiwan Tel. +886 2 2134 2865, Fax. +886 2 2134 2874

Thailand: PHILIPS ELECTRONICS (THAILAND) Ltd.,
209/2 Sanpavuth-Bangna Road Prakanong, BANGKOK 10260,
Tel. +66 2 745 4090, Fax. +66 2 398 0793

Turkey: Talatpasa Cad. No. 5, 80640 GÜLTEPE/ISTANBUL,
Tel. +90 212 279 2770, Fax. +90 212 282 6707

Ukraine: PHILIPS UKRAINE, 4 Patrice Lumumba str., Building B, Floor 7,
252042 KIEV, Tel. +380 44 264 2776, Fax. +380 44 268 0461

United Kingdom: Philips Semiconductors Ltd., 276 Bath Road, Hayes,
MIDDLESEX UB3 5BX, Tel. +44 181 730 5000, Fax. +44 181 754 8421

United States: 811 East Arques Avenue, SUNNYVALE, CA 94088-3409,
Tel. +1 800 234 7381

Uruguay: see South America

Vietnam: see Singapore

Yugoslavia: PHILIPS, Trg N. Pasica 5/v, 11000 BEOGRAD,
Tel. +381 11 625 344, Fax.+381 11 635 777

For all other countries apply to: Philips Semiconductors,
International Marketing & Sales Communications, Building BE-p, P.O. Box 218,
5600 MD EINDHOVEN, The Netherlands, Fax. +31 40 27 24825

Internet: http://www.semiconductors.philips.com

SCA60

Printed in The Netherlands 665102/00/02/pp20 Date of release: 1998 Nov 19 Document order number: 9397 750 04827

Let's make things better.

Philips Semiconductors

PHILIPS